# Carry and Trend Following Returns
# in the Foreign Exchange Market

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**Abstract**

Recent research has confirmed the behaviour of traders that significant excess returns can be achieved from following the predictions of the carry trade which involves buying currencies with relatively high short-term interest rates, or equivalently a high forward premium, and selling those with relatively low interest rates. This paper shows that similar-sized excess returns can be achieved by following a trend-following strategy which buys long positions in currencies that have achieved positive returns and otherwise holds cash. We demonstrate that market risk is an important determinant of carry returns but that the standard unconditional CAPM is inadequate in explaining the cross-section of forward premium ordered portfolio returns. We also show that the downside risk CAPM fails to explain this cross-section, in contrast to recent literature. A conditional CAPM which makes the impact of the market return as a risk factor depend on a measure of financial market stress performs very well in explaining more than 90% of the variation in portfolio returns and more than 90% of the average returns to the carry trade. Trend following is found to provide a significant hedge against these risks. The performance of the trend following factor is more surprising given that it does not have the negative skewness or maximum drawdown characteristic which is shown by the carry trade factor.

**Keywords:** Forward exchange rate returns, trend following, carry trade, financial market stress and exchange risk.

**JEL Classification:** F31, G12, G11, G15.

## 1. Introduction

Much of the recent analysis of the carry trade in the foreign exchange market has focused on the apparent impact of exposure to downside risk. The observation of significant negative skewness in carry returns has underpinned these developments. In parallel, recent research has demonstrated the strength of trend following strategies in providing significant positive excess returns in a number of financial markets without substantial or significant negative skewness. Indeed, the results for commodity futures presented in Clare, Seaton, Smith and Thomas (2014) show positive skewness for trend following strategies suggesting that these might offer a useful hedge against downside risk. At the same time, the importance of financial stress as a source of risk in a number of financial markets has been established. The recent financial crisis demonstrated the importance of financial stress in one market being transmitted across a wider range of markets. In this paper we draw together these approaches in order to assess the significance of episodes of financial stress as a driver of carry returns and the properties of trend following strategies in the forward foreign exchange market. Stress events appear to be episodic in nature. As the results of Hubrich and Tetlow (2015) show, the relationship between these episodes and the wider economy is essentially non-linear. We show that market betas conditional on financial stress can price a cross-section of currency returns and provide an explanation for the excess return on the carry trade whilst linear effects of financial stress have limited impact. We also show that trend following can provide a successful hedge against these risks.

Recent research has confirmed the behaviour of traders that significant excess returns can be achieved from following the predictions of the carry trade. As Burnside, Eichenbaum and Rebelo (2011) point out, the success of the strategy of buying high interest rate currencies and selling low interest rate currencies follows directly from the long-standing failure of uncovered interest parity demonstrated since Bilson (1981), see also Koijen et al (2018). Trend following, by contrast has received relatively little attention, despite being widely used in futures markets, particularly commodities, for many decades (see Ostgaard, 2008 and Moskowitz, Ooi and Pedersen, 2012). Trading signals can be generated by a variety of methods such as moving average crossovers and breakouts with the aim to determine the trend in the currency return. Long positions are adopted when the trend is positive and short positions, or cash, are taken when the trend is negative. Because trend following is generally rules-based it can aid investors because losses are mechanically cut short and winners are left to run. This is frequently the reverse of investors' natural instincts. The return on cash is also an important factor either as the collateral in futures trades or as the 'risk-off' asset for long-only methods. Recent research (for example, Clare, Seaton, Smith and Thomas, 2016) has shown that, in comparison to other strategies that produce significant positive excess returns, trend following does so with reduced volatility and skewness in returns and significantly reduced maximum drawdown.

We examine a model which prices carry returns with a market factor model where market risk is conditional on measures of financial stress. The literature on the carry trade has examined a wide range of possible risk and non-risk based explanations for the size and time series behaviour of carry returns. The key features are a significant high and persistent average return but one which displays significant negative skewness. Estimates of standard models and risk factors have shown only a weak relationship between risk factors and carry returns. Small and insignificant betas have been coupled with even smaller and less significant prices of risk, see for example Burnside, Eichenbaum and Rebelo (2011). More empirical support has been found for models based more directly on trades in the foreign exchange market. Menkhoff, Sarno, Schmeling and Schrimpf (2012) explain carry trade returns with a global foreign exchange volatility factor while Lustig, Roussanov and Verdelhan (2011) focus on a carry factor to explain the cross-section of foreign exchange returns. The impact of bad times on carry returns and thereby their skewness is a focus of Jurek (2014) in his analysis of selling puts and of Dobrynskaya (2014) and Lettau, Maggiori and Weber (2014) who demonstrate a high return for high interest rate currencies due to increased sensitivity of carry returns to downside returns in the market factor.

Financial stress has been identified as a potential source of risk in all financial markets. Early work by Brunnermeier, Nagel and Pedersen (2009) showed a negative relationship between carry returns and the Ted spread whilst Hu, Pan and Wang (2014) show that a US Treasury bond noise factor is significantly priced in interest rate ordered exchange rate return portfolios alongside the market factor. Here we show that the critical issue is the interaction of market stress and the market factor. We show that carry returns are high due to increased exposure to market risk due to increased financial market stress. In this sense the impact of financial market stress is episodic, in line with the effects on the wider economy identified by Hubrich and Telow (2015). This result could also be viewed as a more nuanced version of the downside CAPM model of Lettau, Maggiori and Weber (2014) and Dobrynskaya (2014) which focus only on the 'down market state'. We find, in common with Daniel, Hodrick and Lu (2017), that the key parameters of the downside CAPM model are small and insignificant and cannot generate a positive risk premium for the carry trade. In contrast, we show that the financial market stress CAPM model can explain a great deal of the variation in both the level of carry trade returns and the cross-section of interest rate ordered currency returns and that this does not depend on the precise definition of financial market stress.

From an investor's point of view, the heavily negatively skewed returns offered by the carry trade are mostly explained as compensation for exposure to the risk factors we identify. Alternative strategies offer the opportunity to hedge these risks. We show that trend following offers a simple hedge for the risks that are priced by the carry trade whilst generating a significant unexplained average return of a similar order of magnitude to that offered by carry. Thus, when combined with a trend following overlay, the combined strategy generates an average return well above that of the individual components. This increased average return also has desirable characteristics in terms of higher moments; it offers a higher Sharpe ratio and positive skewness as well as a smaller maximum drawdown than the components or alternative strategies.

The rest of this paper is organised as follows: in Section 2 we present the exchange rate data and we assess the returns from the two investment strategies and the methodologies used to produce them; in Section 3 we present the models of time varying market risk that we assess in Section 5 once we present the various measures of financial market stress in Section 4. Section 6 concludes the paper.

## 2. Exchange Rate Strategy Returns

### 2.1 Data

The returns that we examine are for 39 currencies measured against the US dollar: Australia, Austria, Belgium, Canada, China Hong Kong, Czech Republic, Denmark, Euro Area, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, United Arab Emirates, United Kingdom. This set of currencies includes a broad range of developed and developing country exchange rates and has been used in a number of related studies (eg Verdelhan, 2013). For robustness we have also computed all of the results in the paper for a smaller set of 20 developed country currencies, namely: Australia, Austria, Belgium, Canada, Denmark, Euro, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, United Kingdom. This smaller set of currencies has also been used in some studies (eg Burnside, Eichenbaum and Rebelo (2011). The results of these additional computations are available in an on-line appendix.

For each currency the data are monthly, measured on the last trading day of the month for the period January 1981 – December 2012. There are periods where the currencies were not traded and one or two data errors and these data are excluded. The number of currencies included varies over time; for example, currencies that became part of the Euro system only appear in the earlier part of the sample. The spot and one-month forward rate data are collected via Datastream from BBI and Reuters. The BBI US dollar exchange rate data which starts from 1983 is supplemented by cross rates constructed from UK sterling exchange rate data from Reuters. In each case returns are computed from the spot and forward data for period t+1 and the implicit interest rate differential for the computation of carry trades computed using the forward premium in period t.

## 2.2 Carry Returns

The results of following a simple carry strategy are shown in Table 1. In each panel we provide a set of summary statistics for the performance of the various strategies. In Panel A we show the results of buying a proportion of the top performing currencies measured by the size of the forward premium or degree of carry. The smallest group are shown in the first column with wider groupings of the best performers in the neighbouring columns. It is apparent from these results that carry is associated with higher average returns and a positive and large Sharpe Ratio. However, these portfolio returns are highly volatile and show substantial negative skewness and a large maximum drawdown[1]. This performance extends across up to half of the currencies with the highest levels of carry. To be comparable with other zero net investment returns, we present results for portfolios formed from the currencies with the lowest levels of carry in Panel B and the zero net investment, high minus low portfolios in Panel C. Here it is apparent that the strategy that focuses on those currencies with the highest (and lowest) carry

[1] Maximum drawdown is defined as the largest single fall in return in the sample. This can be thought of as the largest peak to trough.

generates the highest average return and Sharpe Ratio. These results confirm the basic characteristics of the carry trade: high average returns accompanied by high volatility and significant negative skewness and large maximum drawdown.

We can also demonstrate other features of the carry trade in these data for currency returns against the US dollar. We can show that a strategy of buying any currency which shows positive carry against the US dollar also provides a positive average return, although somewhat smaller than that which can be achieved by concentrating on the relative size of the carry. The zero net investment strategy of buying those with positive carry and selling those showing negative carry provides a substantial positive average return of 4.73% in our data which is slightly less heavily negatively skewed than the classic relative carry strategy. This strategy is examined in more detail by Lustig, Roussanov and Verdelhan (2011). We can also show that these two strategies can be combined although the net outcome is somewhat similar to that for the relative carry strategy alone.

### 2.3 Trend Following Returns

We consider a trend following rule that is popular with investors which is based on simple monthly moving averages of returns. The buy signal occurs when the individual currency return moves above its average where we consider moving averages ranging from 4 to 12 months. The intuition behind the simple trend following approach is that while current market price is most certainly the most relevant data point, it is less certain whether the most appropriate comparison is a month or a year ago, (Ilmanen, 2011). Taking a moving average therefore dilutes the significance of any particular observation.

We apply the trend following rule in three different ways. In Panel A of Table 2 the results are produced by observing the end month value of each of the N currencies in our sample; if that value is above its X month moving average (where X is either 4, 6 8 10 or 12 months) we "invest" 1/N of notional capital in that currency. We then earn the return from that currency over the subsequent month. In the event that its end month value is below its X month moving average we invest 1/N in US T-Bills, and then earn the return on US T-Bills over the subsequent month. Returns can then be calculated from this strategy. In Panel B of Table 2 we present analogous results, but instead identify negative trends. As such, when the end month value of any of the N currencies in our sample is below its X month moving average we "short" that currency with 1/N of notional capital. We then earn the return from the short position in that currency over the subsequent month. In the event that its end month value is above its 6 month moving average we invest 1/N in US T-Bills, and then earn the return on US T-Bills over the subsequent month. Finally, Panel C in Table 2 combines those currencies displaying a positive trend and sells those with a negative trend and therefore involves no net investment in T-Bills.

Panel A in Table 2 shows that buying currencies that display a positive trend generates significant positive returns with relatively low volatility and consequently a large Sharpe Ratio value. These returns are obtained with a smaller maximum drawdown than is shown in Table 1 for the various carry strategies and also show a somewhat reduced level of skewness. By contrast the performance from the negative trend analysis produces negative returns and maximum drawdowns that are between two and three times higher than those. The most impressive results are found in Panel C. The zero net investment strategies that buy those currencies displaying a positive trend and sell those with a negative trend show high average returns and Sharpe Ratios with essentially no skewness and modest maximum drawdown.

Overall, the trend following strategies based on moving averages between 4 and 12 months generate rather similar outcomes, although those based on shorter reference periods produce slightly higher average returns at little cost in terms of higher volatility and consequently we will focus on those in our comparisons with the carry trade. The attractiveness of such strategies is common to a range of financial markets as we have shown in earlier work examining equity and commodity futures markets, see Moskowitz, Ooi and Pedersen (2012) and Clare, Seaton, Smith and Thomas (2014, 2016).

## 3. Financial Market Stress and Time Varying Market Risk

We explore an explanation for the high returns to investment strategies based on a market model with time-varying market risk. According to this model the conditional market beta and therefore risk of carry trade strategies is high when financial market stress is subject to a negative shock and is conversely low in more benign times. This approach generalises those of Brunnermeier, Nagel and Pedersen (2009) and Hu, Pan and Wang (2014) who concentrate on market liquidity as a risk factor and Lettau, Maggiori and Weber (2014) who employ a downside risk market model. The recent literature on the impact of liquidity and other systemic risk shocks on the rest of the economy has emphasised the nonlinear and asymmetric nature of the relationship, see Giglio et al (2015) and Hubrich and Telow (2015). This informs our choice of a conditional market framework.

We estimate asset pricing models of portfolios of returns by exploiting the implications of first-order Euler equations for investor optimisation in the absence of arbitrage opportunities. These ensure that the expected product of the risky return in excess of the risk-free rate for portfolio $i$, $R_{i,t+1}$ and the stochastic discount factor $M_{t+1}$ equals zero;

$$E_t\left(R_{it+1}.M_{t+1}\right)=0$$

where the discount factor is modelled as a linear function of the risk factors $f_{j,t+1}$ which have average values $\mu_j$ and loadings $b_j$.

$$M_{t+1}=\left[1-\left(f_{jt+1}-\mu_j\right)'b_j\right]$$

This also implies a relationship between the excess returns and the quantity of risk or beta for each portfolio and price of risk lambda for each factor $j$ such that:

$$E(R_{i,t+1})=\text{cov}(R_i\,,f_j)b_j=\text{cov}(R_i\,,f_j)\sum_f^{-1}\,.\sum_f.b_{\;j}=\beta_{ij}.\lambda_j$$

where $\sum_f$ is the variance-covariance matrix of the factors $f_j$. The estimation of the betas is straightforward and can be computed through a series of regressions for the portfolio returns and any candidate factors:

$$R_{i,t+1}=a_i+f_{t+1}^{'}\beta_{ij}+\varepsilon_{it+1}$$

and the price of risk is related to the factor loadings such that

$$\lambda_j=\sum_f.b$$

The estimation of the parameters is carried out by the two-step generalised method of moments where the first stage uses an identity weighting matrix and the second stage uses an optimal weighting matrix constructed from a heteroskedastic and autocorrelation consistent estimate of the long-run covariance matrix of moment conditions.

The model predicts that unconditional average expected returns are given by:

$$\overline{R}_i=\beta_m\overline{R}_m+\beta_S\lambda^S+\alpha_i \tag{1}$$

for any currency return i and where the price of market risk is assumed to be equal to the average excess return on the market ie $\lambda^M=\overline{R}_m$, where $\overline{R}_i$ and $\overline{R}_m$ are the average excess returns to currency $i$ and the market and $a_i$ are the pricing errors. We estimate the betas through a conditional market model following the approach of Ferson and Harvey (1999), where the market stress shock is treated as the conditioning variable in this conditional beta model. We expect that the market stress shock will be a more informative conditioning variable than whether the market return is positive or negative as in Lettau, Maggiori and Weber (2014). The state where market stress is high is one where we might expect the sensitivity of foreign exchange returns to be heightened. The price of risk of the interaction term has to be estimated as the interaction term is not itself a return. We also allow the constant, alpha, to differ due to the market stress variable $S_t$. We estimate the set of equations:

$$R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_m R_{m,t+1} + \beta_L \left(R_{m,t+1} \times S_t\right) + \varepsilon_{i,t+1}$$
$$\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i \tag{2}$$

This approach is related to one recently proposed by Lettau, Maggiori and Weber (2014) and Dobrynska (2014) of a downside risk CAPM (DR-CAPM) model to price risk in the forward foreign exchange market and therefore to explain the extent of carry returns. The higher average returns for high interest rate currencies are explained by higher market betas for these currencies conditional on bad market returns. They show that unconditional differences in market beta between high and low interest currencies, ie the traditional market beta on a carry trade, whilst positive, are not sufficient to explain the difference in average returns. Allowing the market beta to vary depending on the market return is argued to provide an explanation for the level of carry returns when combined with a high price of down market risk. The model therefore implies that expected returns are given by:

$$\overline{R}_i = \beta \overline{R}_m + \left(\beta^- - \beta\right)\lambda^- \tag{3}$$

where the price of market risk is the expected return on the market $\overline{R}_m$ and the price of downside market risk is $\lambda^-$. The sensitivities of foreign exchange returns to market and downside market risk are $\beta$ and $\beta^-$, respectively. Lettau, Maggiori and Weber (2014) identify downside market returns with an indicator variable that is one when market returns are less than one standard deviation below the mean. In our work we use a more intuitive indicator dummy variable $I^-$ which is equal to one if market returns are negative and zero otherwise.[2]

[2] Lettau, Maggiori and Weber (2014) claim that their results are robust to alternative definitions of the down market state such as the one that we use.

The sensitivities to market and downside market risk are estimated using the following equation:

$$R_{t+1} = \alpha_0 + \alpha_1 I^- + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times I^- \right) + \varepsilon_{t+1} \qquad (4)$$

where $\beta_2 = (\beta^- - \beta)$ and we also allow the constant, alpha, to differ due to the indicator variable.

## 4. Measures of Financial Market Stress

Since the financial crisis a number of measures of financial market stress have been developed. The first, which has also been used widely in popular discussion of the impact of the financial crisis, is the Ted spread, the difference between the London Interbank Offered Rate (LIBOR) and the risk-free Treasury bill rate. The model is that increases in the Ted spread are associated with tighter funding liquidity. Brunnermeier, Nagel and Pedersen (2008) find that innovations to the Ted spread are negatively associated with contemporaneous carry returns whilst having a positive relationship with forecasts of their future values. Here we expand the range of financial market stress measures across a much wider range than the liquidity measure examined by Brunnermeier, Nagel and Pedersen (2008). We examine the Ted spread for the United States, (USTed) as well as an unweighted average Ted spread of 20 developed countries enumerated in Cardelli, Elekdag and Lall (2011), (WTed). We also examine financial market stress shocks beyond the Libor market.

Recently the focus for measuring market-wide liquidity has moved away from differentials in rates of return to different assets to more nuanced measures of market dislocation. Hu, Pan and Wang (2014) propose a measure exploiting the connection between the amount of arbitrage capital in the market and observed noise in US Treasury bonds. They hypothesise that shortage of arbitrage capital allows yields to deviate from conventional measures of the yield curve resulting in noise in prices. They show that this noise measure captures several episodes of liquidity crises of a number of origins and across a range of financial markets. In common with Brunnermeier, Nagel and Pedersen (2008), Hu, Pang and Wang show a significant negative impact on contemporaneous carry returns. In particular, Hu, Pan and Wang construct their noise measure, henceforth, HPW as:

$$HPW_t = \sqrt{\frac{1}{N_t} \sum_{i=1}^{N_t} \left[ y_t^i - y^i\left(b_t\right) \right]^2}$$

where the noise measure is driven by the deviations between market yields $y_t^i$ and their model-implied equivalents $y^i\left(b_t\right)$ on $N_t$ US Treasury bonds with maturity between 1 and 10 years. The model-implied yields are those implied by the Svensson (1994) model of the yield curve with parameters $b_i$ which are obtained by minimizing the weighted sum of squared deviations between actual and model-implied bond prices. Hu, Pang and Wang observe substantial variation in their liquidity measure (here Hpwn) over time and especially during the financial crisis period.

Finally, the most general measures of market stress are those based on indices of financial instability constructed from a range of financial market indicators. We examine one of the most comprehensive of these indices, the IMF (International Monetary Fund) Financial Stress Index (FSI) described in Cardelli, Elekdag and Lall (2011). They describe the index as being constructed from the "Extreme values of a composite variable….built using market-based indicators in real time and high frequency", Cardelli, Elekdag and Lall (2011). The elements of the index are:

FSI = bank sector $\beta$ + TED spreads + Inverted term spreads + Corporate debt spreads + Stock market returns + Stock market volatility + Exchange market volatility

The disparate nature of the elements of the index potentially makes combining them in an equally-weighted linear index problematic but this approach is commonly followed by a number of international and national monetary authorities. The method of construction and properties of a number of alternative indices are compared by Kliesen, Owyang and Vermann (2012). This analysis shows that the IMF-FSI for the US (here USFSI) is quite highly correlated with other indices for the US economy (0.68 – 0.86) and forecasts industrial production 1-month ahead within 5% of the best of the alternative indices. We also examine an unweighted average of the measure for 20 developed countries enumerated in Cardelli, Elekdag and Lall (2011), (WFSI).

## 5. Understanding Carry Returns

### 5.1 Sensitivity to Standard Risk Factors

The statistics in Table 1 show that the returns to carry are substantial over a long period of time. In this section we ask whether the strategies discussed above can provide a convincing explanation for the size and behaviour of these excess returns. The first explanations to consider are those offered by exposure to standard risk factors. In Table 3 we show the results of exposing the returns from the three strategies to the 4-factor US equity Fama-French model in Panel A and to a wider group of world financial market return factors in Panel B. These results show that a small proportion of the average excess return to the carry trade is explained by both groups of risk factors. The alphas that remain in both cases are only a little more than 10% lower than the unconditional average returns. There is, however, a significant estimate of the market beta in both the Fama-French and broader models. We also find a significant beta on the bond return in the broader factor model.

### 5.2 The Impact of Financial Market Stress

We start our analysis of the impact of market stress by considering the direct impact of the various market stress measures on the returns from carry. We estimate the relationship between returns and the value of the market stress measure in the prior month. The market stress conditional market model that we examine below employs these measures known in period t. The simple regressions could be regarded as forecasting models of returns given market stress information. The estimates given in Table 4, panel A show that there is only weak evidence of the ability of the measures to forecast future returns; all of the measures are negatively related to carry but with small coefficients and at best, marginal statistical significance. This result is confirmed in a more general context by Linde et al (2014) who find that market stress measures do not provide significant predictive power for the structural innovations in a medium scale macroeconomic model of the US economy.

### 5.3 Financial Market Stress and Downside Risk

We examine the first stage of the DR-CAPM or downside risk market model in Table 5A. We estimate the model for the long minus short carry returns. The measure of the market return we use is the US market excess return from the Ken French database as used in Table 3. The estimates of the first part of the DR-CAPM show two important results. First, we find a positive marginally significant coefficient on the downside risk indicator variable –the estimate is that periods of equity market falls are periods of high carry returns, some 0.9% higher in annualised terms. The market beta is also positive and significant, as in the simple market model shown in the second line. However, the critical interaction term between the indicator variable and the market return is insignificant and negative. The fact that the downside beta is insignificant for the long minus short top 5 minus bottom 5 carry return guarantees that it will not be able to explain the cross section of carry returns. Thus the downside beta cannot explain any of the variation in the expected return to the carry trade, in contrast to the results presented by Lettau, Maggiori and Weber (2014). There is a relatively small difference between the dataset we use here and theirs but our result is consistent with that of Daniel, Hodrick and Lu (2017) who also find little support for the DR-CAPM.

Table 5B presents estimates of the first stage of the market stress market model for the Carry strategy. The estimates show that the market return beta is very significant and positive. The interaction term between the market stress variables and the market return is positive and very significant for four out of the five market stress measures, only the Treasury noise variable is insignificant. The direct effect of the market stress variables on carry returns are in general small and insignificant.

The significance of the betas on the market return and interaction term with market stress suggests that both may contribute to explaining the average excess return to the carry trade. As the interaction term is not a return, it is only possible to make this assessment by estimating the cross section model (1), above. We do this by constructing a set of five portfolios of currencies based on their carry return, ie forward premium. Each currency is placed in a portfolio based on the forward premium and these portfolios are rebalanced every month. The cross-section of average returns is shown in column 1 of Table 6, where the excess return of the quintile with the highest forward premium is significantly positive and larger than for any other quintile. The average for the lowest quintile is significantly negative. We use two-step GMM to estimate the two equations (1) and (2) simultaneously. We estimate the price of risk for the interaction term but follow Lettau, Maggiori and Weber (2014) in setting the price of risk for the market return equal to its average return. The estimates of the model for the four market stress measures that are significant in Table 3 are given in Tables 6 to 9. In the estimates of the model employing the USTed spread, the price of the conditional market beta risk is significant and substantial. The pricing errors of the five portfolios are all small and the fit of the model is 0.92. The J-test suggests that the model does not provide a complete explanation of the cross-section of forward premium-ordered returns. The estimates of the model for the remaining three measures of market stress suggest that the model is robust to the precise definition of market stress. In particular, the estimates of the US and World Ted spread models are rather similar. In both cases the price of risk of the conditional market beta or interaction term is very significant and large. Equally, the fit of the cross-section model is above 90%. In the case of the IMF financial stress indices, the estimates of the price of risk are again both significant although the overall fit of the model is somewhat more modest that for the Ted spreads. The fit of the cross section is higher than 60% but there is no rejection of the J test at the 5% level.

The estimates of these models show that conditional market beta risk explains a large part of the average carry trade excess return. If we measure the return to the carry trade by taking the average return from the highest forward premium quintile and subtract the average return of the lowest quintile, the average carry trade return is 0.623% per month. The proportion of this spread that each of the four models explain is given the final panel of Tables 6 - 9. The proportion explained is highest in the case of the US and World Ted spread models where more than 0.57% per month or 93% of the spread is explained by the conditional market beta with some 16% explained by the market return in the US case and a negative amount in the World case. In the case of the two Financial Stress Index models the proportion explained by the market stress conditional market beta model is 57% whilst the market return itself explains 18% of the average carry trade return.

## 6. Explaining Trend Following Returns

The summary statistics in Table 2 show that the trend following strategy can deliver significant positive average returns of a similar order of magnitude to carry but with reduced drawdown and negative skewness. In analysing these returns we begin by examining whether they can be priced by standard risk factors. In Panel B of Table 3 we present the results of a regression where the dependent variable is the returns generated by the Trend Following strategy shown in Panel C of Table 2, and where the moving average has been calculated using a 6 month window. The results show that the alpha is highly significant and that none of the conventional risk factors can explain the TF results. In Panel B of Table 4 we test the relationship between various measures of market stress and the trend following returns. First, the alpha in each regression is always positive and highly significant. Second, in most cases there is no relationship between these market stress proxies and the trend following returns. The exception is the WFSI variable which is positively related to the strategy's returns. However, in summary it would be difficult to argue that the trend following returns are simply proxying for financial market stress.

Panels B in Tables 5A and 5B show the first stage of the market stress market model for the trend following strategy. In all cases the simple market beta is estimated to be insignificantly different from zero. This result mirrors the results in Table 3 that show that the positive returns from trend following are not explained at all by standard market beta and the market return unlike carry returns. Likewise, the estimated direct effect of the market stress measures on trend following returns are also found to be insignificant although generally positive and marginally significantly so in the case of the US Ted spread. By contrast, the estimates show that the interaction term between market stress and the equity market return has a strongly significant negative relationship to trend following returns. The largest and most significant effect relates to the US and World Ted spreads. The evidence is that trend following offers a hedge against market risk at times of heightened financial market stress in contrast to the evidence for carry discussed above.

We discussed above whether the positive beta associated with the interaction of market stress with market returns estimated for carry returns could explain the cross-section of carry returns. In this section we ask whether the hedge that trend following provides according to the results in Table 5B also explains the cross-section of trend following returns. In order to provide a cross-section of trend following returns we construct a set of five portfolios of currencies ordered by the size of their trend following signal where the moving average has been calculated using a 6 month window. The properties of the average returns for these portfolios are shown in the second column of Table 10. These show large and significant excess return to the largest trend following signal in the top portfolio and a negative and borderline significant return to currencies with the lowest, and preponderantly negative, trend following signal in the bottom portfolio.

The estimates in Tables 10 – 13 show estimates of the model for all four measures of financial stress. The estimates for the US Ted spread in Table 10 are representative in that they show that the negative hedging effect of the interacted market stress and market return is largest and most significant amongst those currencies with the biggest positive trend following signal. The risk premium associated with this effect estimated across the cross-section of trend following portfolios is significantly negative in contrast to the positive risk premium estimated for carry returns. This is confirmed for all financial market stress measures in Tables 11 – 13. The beta on the interaction effect is larger and more significant in the cases of the Ted spread measures (Tables 10 and 11) and less so in the cases of the FSI measures (Tables 12 and 13). In none of these cases do the market beta or the conditional market beta explain any of the average spread of returns between the TFH and TFL portfolios. The negative prices of risk that are implied by our estimates lead us to conclude that the trend following strategy provides a significant hedge against the risks that we found priced in carry trades.

## 7. Combining Trend Following with Carry Strategies

Results presented in Tables 1 and 2 indicate that both Carry and Trend Following strategies can produce risk-adjusted returns that are potentially attractive to investors. We have shown that the cross-section of carry trade returns can be explained by the financial stress market model that we present in this paper. We also have shown that trend following offers a comprehensive hedge against the risks priced in the carry trade cross section.

We complete our characterisation of the basic properties of the returns from various strategies by examining the performance of carry trade strategies where a trend following overlay has been applied in a second stage of portfolio construction. The results of applying this process are shown in Table 14 and Figure 1. The "Positive/Negative" strategy involves 'investing' in those currencies where both the end month carry and trend are positive (using either a 6 month (Panel A) or ten month (Panel B) moving average signal). Conversely, if end month carry and trend are both negative then we take a short position in that currency, otherwise no position. Capital is then allocated equally across all the qualifying currencies for that month. For the "High/Low Carry 5" strategy, a long position in the currency is created if the currency is one of the top 5 highest carry currencies and is in a positive trend. Short positions are created in an analogous way, so that the currency has to be one of the bottom 5 lowest carry currencies and in a negative trend. The currency positions are equally-weighted amongst qualifying the currencies. The results in Table 14 show that very high average returns can be generated from these strategies with relatively low volatility and consequently very high Sharpe ratios approaching one. These returns are also achieved with low maximum drawdown and only very mild negative skewness. Once again, the results based on the six and ten month moving average windows differ very little. Figure 1 shows the cumulative return to the carry strategy with the addition of the trend following filter referred to as the "High/Low Carry 5" strategy in Table 14, with a 6 month moving average filter. The figure demonstrates the superior performance of this strategy over either the raw carry or trend following strategies. In particular, the benefits of the carry strategy in the 2001-2005 period and the robust performance of trend following strategies in the financial crisis period are clear to see.

### 7.1 Explaining Returns Generated by a Carry Strategy with a Trend Following Filter

Panel C of Table 3 presents the relationship between the returns generated by the carry strategy with the addition of the trend following filter referred to as the "High/Low Carry 5" strategy in Table 14, with a 6 month moving average filter. Once again the results indicate that there is no statistically significant relationship between the returns generated by this strategy and risk factors that are commonly employed in the academic literature to capture systematic risk. Panel C of Table 4 also shows that there is no significant relationship between the same carry returns with the trend following filter and proxies for market stress. Finally, Panel C in both Table 5A and Table 5B show, respectively that neither a downside equity risk model, nor a market stress risk model can explain the high average returns generated from this strategy. Combining carry with trend following produces returns with a significant component of alpha which requires explanation.

## 8. Conclusions

In this paper we have assessed a model which offers a risk-based explanation for the size of the return from the carry trade. We have shown that market risk is an important determinant of carry returns but that the standard unconditional CAPM is inadequate in explaining the cross-section of forward premium ordered portfolio returns. We have also shown that the downside risk CAPM also fails to explain this cross-section, in contrast to recent literature. We show that a conditional CAPM which makes the impact of the market return as a risk factor depend on a measure of financial market stress performs very well in explaining more than 90% of the variation in portfolio returns and more than 90% of the average returns to the carry trade. We also show that trend following offers a significant hedge against the risks that we find are significantly priced in the carry trade. This leaves open a number of important theoretical issues as to what might explain the large and significant average returns to trend following in the foreign exchange as well as other markets.

From an investing point of view it has been very difficult in practice to find foreign exchange investing strategies which offer consistent returns with attractive low correlations with conventional asset classes. However the trend following overlay on the conventional carry strategy would seem to achieve just that: among the four strategies plotted in Figure 1 not only does carry plus trend following dominate in terms of risk, return and drawdown, but its correlation with the MSCI is only 0.024 compared with 0.292 for carry with no trend following,

-0.098 for trend following alone, and a much larger 0.412 for the passive currency strategy. Similarly correlations with the Aggregate Barclays Bond Index are -0.093 for carry overlaid with trend following,-0.064 for carry itself,-0.046 for trend following alone and 0.194 for the passive currency strategy itself. Taken together with Figure 1 and the accompanying performance data these results would point to a suitably transformed carry trade portfolio as a potentially useful diversifying addition to conventional assets in a diversified portfolio.

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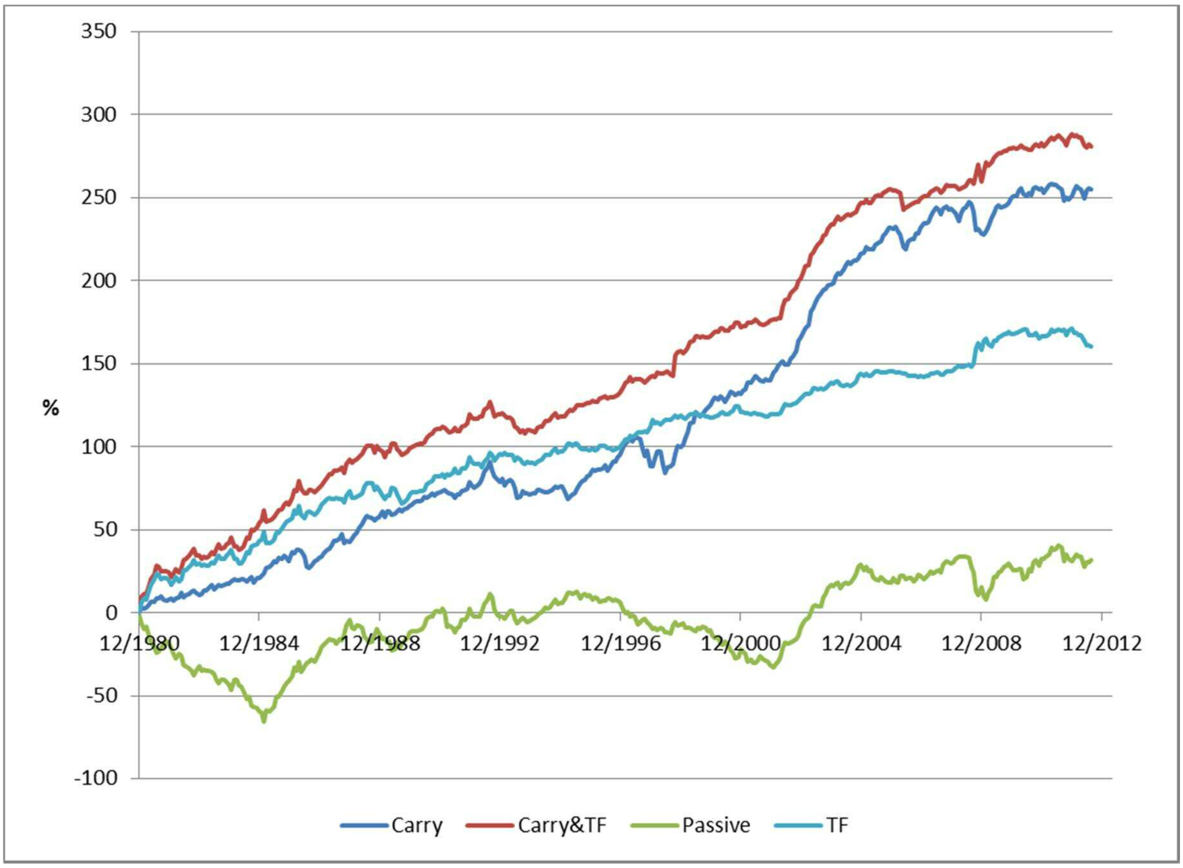
## Figure 1: Cumulative Returns from Foreign Exchange Strategies

The figure shows the cumulative returns in percent of investing in four strategies: Carry represents the returns on a portfolio of long positions in the five highest carry returns and short positions in the five lowest carry returns (Table 1, panel C, col 1); TF represents the returns generated by applying the 6-month trend following filter (Table 11, panel C, col 2); and Carry & TF the returns on the carry portfolio where a further trend following filter is applied to the individual currencies (Table 12, panel A, col 3), Passive represents the returns from buying all currencies, equally weighted, in December 1980 until December 2012.




| | Carry | Carry & TF | Passive | TF |
|---|---|---|---|---|
| Annualized Excess Return (%) | 7.82 | 8.30 | 0.74 | 4.69 |
| Annualized Volatility (%) | 8.01 | 7.95 | 9.20 | 6.71 |
| Sharpe Ratio | 0.98 | 1.04 | 0.08 | 0.70 |
| Max. Monthly Return (%) | 8.29 | 12.38 | 6.83 | 8.85 |
| Min. Monthly Return (%) | -10.66 | -10.36 | -10.68 | -8.48 |
| Maximum Drawdown | 20.72 | 17.71 | 55.30 | 12.67 |
| Skew | -0.90 | -0.21 | -0.42 | -0.03 |

## Table 1: Carry

This table presents the performance statistics of portfolios formed on the basis of the level of each currency's carry, or forward premium. The portfolios in Panel A are constructed by ranking the currencies using the level of carry and then by investing in the top 5, 25% or 50% of currencies, that is, the top 5, quarter or half of 'winners'. Panel B is constructed in the same way but where the portfolio comprises the bottom 5, 25% and 50% of currencies or 'losers'. Panel C shows the performance of the zero net investment portfolios constructed by buying the identified winners from Panel A and selling the relevant losers from Panel B. The performance statistics of all the portfolios are based on monthly rebalancing.

| Panel A | High 5 | High Quarter | High Half |
|---|---|---|---|
| Annualized Excess Return (%) | 4.74 | 3.93 | 2.95 |
| Annualized Volatility (%) | 10.32 | 10.45 | 9.04 |
| Sharpe Ratio | 0.46 | 0.38 | 0.33 |
| Max. Monthly Return (%) | 9.07 | 8.33 | 7.12 |
| Min. Monthly Return (%) | -16.00 | -16.16 | -11.82 |
| Maximum Drawdown | 43.28 | 45.35 | 45.78 |
| Skew | -0.93 | -1.07 | -0.76 |

| Panel B | Low 5 | Low Quarter | Low Half |
|---|---|---|---|
| Annualized Excess Return (%) | -3.01 | -3.27 | -1.89 |
| Annualized Volatility (%) | 8.48 | 8.55 | 8.08 |
| Sharpe Ratio | -0.36 | -0.38 | -0.23 |
| Max. Monthly Return (%) | 6.99 | 7.65 | 6.42 |
| Min. Monthly Return (%) | -12.15 | -13.26 | -11.84 |
| Maximum Drawdown | 74.43 | 77.99 | 64.12 |
| Skew | -0.28 | -0.35 | -0.58 |

| Panel C | H5 - L5 | HQ - LQ | HH - LH |
|---|---|---|---|
| Annualized Excess Return (%) | 7.82 | 7.26 | 4.86 |
| Annualized Volatility (%) | 8.01 | 8.22 | 5.27 |
| Sharpe Ratio | 0.98 | 0.88 | 0.92 |
| Max. Monthly Return (%) | 8.29 | 8.18 | 4.73 |
| Min. Monthly Return (%) | -10.66 | -11.55 | -5.83 |
| Maximum Drawdown | 20.72 | 25.70 | 21.28 |
| Skew | -0.90 | -1.03 | -0.84 |

## Table 2: Properties of Trend Following Currency Strategies

This Table presents the performance statistics of portfolios formed on the basis of the level of trend following rule based on monthly moving averages of returns. The buy signal occurs when the individual currency return moves above the average where we consider moving averages ranging from 4 to 12 months. The portfolios in Panel A are constructed by including all currencies which show a positive trend whilst those shown in Panel B had recent below trend performance. Panel C shows the performance of the zero net investment portfolios constructed by buying the identified winners from Panel A and selling the relevant losers from Panel B. The performance statistics of all the portfolios are based on monthly rebalancing.

| | Signal Length (months) | | | | |
|---|---|---|---|---|---|
| | 4 | 6 | 8 | 10 | 12 |
| *Panel A Positive Trend* | | | | | |
| Annualized Excess Return (%) | 3.26 | 3.38 | 2.48 | 3.23 | 2.82 |
| Annualized Volatility (%) | 7.11 | 6.99 | 7.16 | 6.94 | 7.31 |
| Sharpe Ratio | 0.46 | 0.48 | 0.35 | 0.46 | 0.39 |
| Max. Monthly Return (%) | 7.36 | 7.36 | 7.36 | 7.36 | 7.36 |
| Min. Monthly Return (%) | -9.32 | -9.11 | -9.61 | -9.11 | -11.90 |
| Maximum Drawdown | 27.70 | 22.92 | 28.06 | 30.49 | 30.62 |
| Skew | -0.56 | -0.50 | -0.84 | -0.72 | -0.98 |
| *Panel B Negative Trend* | | | | | |
| Annualized Excess Return (%) | -2.61 | -2.81 | -2.59 | -2.83 | -1.85 |
| Annualized Volatility (%) | 8.12 | 8.08 | 7.99 | 7.98 | 7.93 |
| Sharpe Ratio | -0.32 | -0.35 | -0.32 | -0.35 | -0.23 |
| Max. Monthly Return (%) | 6.91 | 6.91 | 7.03 | 6.91 | 7.48 |
| Min. Monthly Return (%) | -10.55 | -9.67 | -8.78 | -9.50 | -8.46 |
| Maximum Drawdown | 67.54 | 69.02 | 68.05 | 72.49 | 65.21 |
| Skew | -0.57 | -0.50 | -0.34 | -0.32 | -0.26 |
| *Panel C Long Positive and Short Negative* | | | | | |
| Annualized Excess Return (%) | 4.84 | 4.69 | 3.86 | 4.34 | 4.08 |
| Annualized Volatility (%) | 6.72 | 6.71 | 6.70 | 6.82 | 6.80 |
| Sharpe Ratio | 0.72 | 0.70 | 0.58 | 0.64 | 0.60 |
| Max. Monthly Return (%) | 9.32 | 8.85 | 7.42 | 8.76 | 6.78 |
| Min. Monthly Return (%) | -8.71 | -8.48 | -8.48 | -8.48 | -8.48 |
| Maximum Drawdown | 13.49 | 12.67 | 13.37 | 17.91 | 20.24 |
| Skew | 0.03 | -0.03 | -0.18 | -0.18 | -0.39 |

## Table 3: Carry and Trend Following Returns and Sensitivity to Standard Risk Factors

This table presents the unconditional mean excess returns (column 1) "Average", generated by different investment strategies: Carry represents the returns on a portfolio of long positions in the five highest carry returns and short positions in the five lowest carry returns; TF represents the returns generated by applying the 6-month trend following filter; and Carry & TF the returns on the carry portfolio where a further trend following filter is applied to the individual currencies. All portfolios are equally weighted. The table reports the results of regressing the returns from these strategies on the Fama and French (1992) three factors, MKT, SMB and HML, plus Carhart's (1997) momentum factor, UMD. Panel B reports the results of regressing the returns from these strategies against a set of wider risk factors the Goldman –Sachs Commodity Index (GSCI), the world equity market return index (MSCI), Barclays Bond Index (BAR). The returns and risk factors are measured in the same period, t+1. Newey and West (1997) t-statistics are shown in square brackets. Prob F is based upon a F-statistic for the test of the joint significance of the independent regressors. Estimation sample: January 1984 – December 2012. The performance statistics of all the portfolios are based on monthly rebalancing.

| | Average | Alpha | MKT | SMB | HML | UMD | Prob F |
|---|---|---|---|---|---|---|---|
| Panel A: Carry | 0.670 | 0.587 | 0.154 | 0.0501 | 0.0499 | -0.0384 | 0.0 |
| | [4.68] | [4.08] | [4.76] | [1.30] | [1.15] | [1.59] | |
| | | Alpha | GSCI | MSCI | BAR | | |
| | | 0.532 | 0.00366 | 0.0128 | -0.0148 | | 0.0 |
| | | [3.85] | [1.80] | [4.95] | [2.56] | | |
| | Average | Alpha | MKT | SMB | HML | UMD | Prob F |
| Panel B: TF | 0.421 | 0.479 | -0.0534 | -0.0177 | -0.0630 | 0.00157 | 0.577 |
| | [4.44] | [4.54] | [1.54] | [0.52] | [1.34] | [0.08] | |
| | | Alpha | GSCI | MSCI | BAR | | |
| | | 0.428 | -0.00204 | -0.00266 | -0.00381 | | 0.621 |
| | | [4.50] | [1.18] | [1.05] | [0.54] | | |
| | Average | Alpha | MKT | SMB | HML | UMD | Prob F |
| Panel C: Carry & TF | 0.738 | 0.777 | -0.00524 | -0.00628 | -0.0535 | -0.0184 | 0.669 |
| | [5.99] | [5.68] | [0.13] | [0.14] | [0.85] | [0.69] | |
| | | Alpha | GSCI | MSCI | BAR | | |
| | | 0.681 | -0.00201 | 0.00240 | -0.0136 | | 0.254 |
| | | [5.38] | [1.18] | [0.73] | [1.74] | | |

## Table 4: Carry and Sensitivity to Financial Market Stress

This table presents the response of returns generated by different investment strategies to market stress. These are measured by changes in the Ted spread for the US and for an equally weighted world measure, the IMF financial stability index for the US and equally weighted world measure and the treasury bond noise measure proposed by Hu, Pang and Wang (2014). In each case increases in these variables are associated with tightening of market liquidity and stress. Carry represents the returns on a portfolio of long positions in the five highest carry returns and short positions in the five lowest carry returns; TF represents the returns generated by applying the 6-month trend following filter; and Carry & TF the returns on the carry portfolio where a further trend following filter is applied to the individual currencies. All portfolios are equally weighted. The portfolio returns are measured in period t+1 and the market stress factors in period t. Newey and West (1997) t-statistics are shown in square brackets. Estimation sample: January 1984 – December 2012. The performance statistics of all the portfolios are based on monthly rebalancing.

| | Alpha | USTed | WTed | USFSI | WFSI | HPWN | | Alpha | USTed | WTed | USFSI | WFSI | HPWN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Carry** | 0.688 | -0.801 | | | | | **Panel B: TF** | 0.364 | 0.637 | | | | |
| | [4.38] | [1.03] | | | | | | [3.96] | [1.15] | | | | |
| | 0.689 | | -0.520 | | | | | 0.362 | | 0.238 | | | |
| | [4.38] | | [0.32] | | | | | [3.93] | | [0.16] | | | |
| | 0.692 | | | -0.113 | | | | 0.362 | | | 0.0509 | | |
| | [4.67] | | | [1.67] | | | | [3.95] | | | [0.56] | | |
| | 0.690 | | | | -0.268 | | | 0.362 | | | | 0.262 | |
| | [4.50] | | | | [1.80] | | | [3.94] | | | | [2.13] | |
| | 0.713 | | | | | -0.0985 | | 0.309 | | | | | 0.204 |
| | [4.20] | | | | | [0.59] | | [3.46] | | | | | [1.57] |
| **Panel C: Carry & TF** | 0.695 | 0.359 | | | | | | | | | | | |
| | [5.58] | [0.90] | | | | | | | | | | | |
| | 0.693 | | 0.162 | | | | | | | | | | |
| | [5.56] | | [0.12] | | | | | | | | | | |
| | 0.693 | | | 0.124 | | | | | | | | | |
| | [5.56] | | | [1.22] | | | | | | | | | |
| | 0.693 | | | | 0.156 | | | | | | | | |
| | [5.54] | | | | [0.83] | | | | | | | | |
| | 0.662 | | | | | 0.222 | | | | | | | |
| | [5.01] | | | | | [1.32] | | | | | | | |

## Table 5A: Estimation of Downside Betas

This table presents estimates of the downside betas for different investment strategies. The downside equity risk model estimated is equation (4) in the text: $R_{t+1} = \alpha_0 + \alpha_1 I^- + \beta_1 R_{m,t+1} + \beta_2 \left(R_{m,t+1} \times I^-\right) + \varepsilon_{t+1}$, where $R_{t+1}$ is the strategy return, $R_{m,t+1}$ is the return on the US stock market and $I^-$ is dummy variable indicating that the market return is negative. Carry represents the returns on a portfolio of long positions in the five highest carry returns and short positions in the five lowest carry returns; TF represents the returns generated by applying the 6-month trend following filter and Carry & TF the returns on the carry portfolio where a further trend following filter is applied to the individual currencies. All portfolios are equally weighted. Newey and West (1997) t-statistics are shown in square brackets. Estimation sample: January 1984 – December 2012. The performance statistics of all the portfolios are based on monthly rebalancing.

| | $\alpha_0$ | $I_t^-$ | $R_{m,t+1}$ | $R_{m,t+1} \times I^-$ |
|---|---|---|---|---|
| **Panel A: $R_{t+1}$ Carry** | | | | |
| | 0.162 | 0.856 | 0.252 | -0.00954 |
| | [0.50] | [1.99] | [3.37] | [0.09] |
| | 0.588 | | 0.176 | |
| | [3.82] | | [5.26] | |
| **Panel B: $R_{t+1}$ TF** | | | | |
| | 0.214 | 0.0386 | 0.0107 | -0.0845 |
| | [0.89] | [0.10] | [0.17] | [0.80] |
| | 0.384 | | -0.0382 | |
| | [3.94] | | [1.07] | |
| **Panel C: $R_{t+1}$ Carry & TF** | | | | |
| | 0.321 | 0.404 | 0.106 | -0.0923 |
| | [1.01] | [0.96] | [1.39] | [0.84] |
| | 0.680 | | 0.0230 | |
| | [5.31] | | [0.59] | |

## Table 5B: Estimation of Financial Market Stress Betas

This table presents estimates of the market stress betas for different investment strategies. The market stress risk model is: $R_{t+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left(R_{m,t+1} \times S_t\right) + \varepsilon_{t+1}$ where $R_{t+1}$ is the strategy return, $R_{m,t+1}$ is the return on the US stock market and $S_t$ is the stress measure. The market stress measures are changes in the Ted spread for the US, the financial stability index for the US and the HPW treasury market noise measure. Carry represents the returns on a portfolio of long positions in the five highest carry returns and short positions in the five lowest carry returns; TF represents the returns generated by applying the 6-month trend following filter and Carry & TF the returns on the carry portfolio where a further trend following filter is applied to the individual currencies. All portfolios are equally weighted. All portfolios are equally weighted. Newey and West (1997) t-statistics are shown in square brackets. Estimation sample: January 1984 – December 2012. The performance statistics of all the portfolios are based on monthly rebalancing.

| Panel A | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|
| $R_{t+1}$ **Carry** | | | | |
| Stress Measure | | | | |
| | 0.574 | -0.429 | 0.158 | 0.187 |
| USTed | [3.96] | [1.13] | [6.00] | [6.40] |
| | 0.616 | 0.852 | 0.162 | 0.473 |
| WTed | [4.10] | [1.05] | [6.06] | [4.98] |
| | 0.618 | -0.0784 | 0.165 | 0.0463 |
| USFSI | [4.20] | [1.21] | [6.11] | [1.94] |
| | 0.620 | -0.168 | 0.162 | 0.0471 |
| WFSI | [4.21] | [1.34] | [5.98] | [2.05] |
| | 0.627 | 0.0655 | 0.195 | 0.0167 |
| HPWNoise | [3.78] | [0.43] | [5.36] | [0.60] |

| Panel B | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|
| $R_{t+1}$ **TF** | | | | |
| Stress Measure | | | | |
| | 0.413 | 0.472 | -0.0271 | -0.106 |
| USTed | [4.24] | [1.62] | [0.93] | [3.02] |
| | 0.366 | -0.522 | -0.0289 | -0.313 |
| WTed | [3.99] | [0.57] | [1.04] | [2.53] |
| | 0.353 | 0.0347 | -0.0277 | -0.0485 |
| USFSI | [3.87] | [0.57] | [1.02] | [2.52] |
| | 0.352 | 0.0626 | -0.0267 | -0.0488 |
| WFSI | [3.85] | [0.53] | [0.97] | [2.54] |
| | 0.304 | 0.125 | -0.0418 | -0.0393 |
| HPWNoise | [3.44] | [1.46] | [1.32] | [1.78] |

| Panel C | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|
| $R_{t+1}$ **Carry & TF** | | | | |
| Stress Measure | | | | |
| | 0.694 | 0.220 | 0.0276 | -0.0434 |
| USTed | [5.90] | [0.62] | [0.73] | [1.06] |
| | 0.672 | -0.0669 | 0.0269 | -0.124 |
| WTed | [5.26] | [0.06] | [0.72] | [0.94] |
| | 0.657 | 0.120 | 0.0321 | -0.0335 |
| USFSI | [5.20] | [1.38] | [0.98] | [2.08] |
| | 0.655 | 0.166 | 0.0342 | -0.0349 |
| WFSI | [5.16] | [1.08] | [1.01] | [2.11] |
| | 0.613 | 0.181 | 0.0298 | -0.0522 |
| HPWNoise | [4.61] | [1.89] | [0.80] | [3.19] |

## Table 6: Carry and Estimates of Market Stress Risk Premia: US Ted Spread

The market stress risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_t$ is the stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$, the price of market stress risk is $\lambda_S$ and the pricing error is $a_i$. The stress measure is the change in the Ted spread for the US. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing.

| **Panel A** | **Average** | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| CarryH | 0.484 | 0.248 | -1.779 | 0.202 | 0.135 |
| | [2.07] | [1.18] | [2.92] | [4.55] | [2.89] |
| Carry4 | 0.302 | 0.246 | 0.196 | 0.121 | 0.0544 |
| | [1.44] | [1.79] | [0.52] | [2.74] | [1.66] |
| Carry3 | 0.226 | 0.0628 | -0.566 | 0.100 | 0.0473 |
| | [0.59] | [0.15] | [1.28] | [2.53] | [1.45] |
| Carry2 | 0.0384 | -0.0347 | -0.702 | 0.0646 | 0.0174 |
| | [0.61] | [0.26] | [1.87] | [2.05] | [0.61] |
| CarryL | -0.139 | -0.185 | -0.654 | 0.0309 | -0.0245 |
| | [1.83] | [1.35] | [1.71] | [0.87] | [0.85] |
| **Panel B** | | | | $\lambda^M$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | 3.854 |
| | | | | [-] | [3.20] |
| Pricing errors $a_i$ | | -0.154 | Spread | H-L | 0.623 |
| | | -0.0664 | Explained | $R_{m,t+1}$ | 0.102 |
| | | | | $R_{m,t+1} \times S_t$ | |
| | | -0.0144 | | | 0.578 |
| | | 0.0224 | | | |
| | | -0.0624 | | | |
| $R^2$ | 0.918 | | | | |
| J-test $\chi^2(4)$ | 10.12 | (0.0385) | | | |

## Table 7: Carry and Estimates of Market Stress Risk Premia: World Ted Spread

The market stress risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_{t-1}$ is the stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$, the price of market stress risk is $\lambda_S$ and the pricing error is $a_i$. The market stress measure is the change in the world Ted spread. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing.

| **Panel A** | **Average** | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| CarryH | 0.484 | 0.492 | -0.394 | 0.223 | 0.395 |
| | [2.07] | [2.79] | [0.26] | [4.59] | [3.49] |
| Carry4 | 0.302 | 0.197 | 1.112 | 0.143 | 0.141 |
| | [1.44] | [1.91] | [0.98] | [3.04] | [1.88] |
| Carry3 | 0.226 | 0.192 | 0.0544 | 0.109 | 0.150 |
| | [0.59] | [1.87] | [0.05] | [2.57] | [2.13] |
| Carry2 | 0.0384 | -1.566 | -0.982 | 0.122 | -0.0103 |
| | [0.61] | [0.76] | [0.83] | [1.70] | [0.10] |
| CarryL | -0.139 | -0.144 | -1.852 | 0.450 | -0.0994 |
| | [1.83] | [1.33] | [1.32] | [1.11] | [1.19] |
| **Panel B** | | | | $\lambda_m$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | 1.170 |
| | | | | [-] | [3.54] |
| Pricing errors $a_i$ | | -0.111 | Spread | H-L | 0.623 |
| | | -0.0219 | Explained | $R_{m,t+1}$ | -0.135 |
| | | -0.0144 | | $R_{m,t+1} \times S_t$ | 0.578 |
| | | 0.0525 | | | |
| | | -0.0492 | | | |
| $R^2$ | 0.954 | | | | |
| J-test $\chi^2(4)$ | 8.20 | (0.0847) | | | |

## Table 8: Carry and Estimates of Market Stress Risk Premia: US Financial Stress Index

The market stress risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_t$ is the market stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$ , the price of market stress risk is $\lambda_S$ and the pricing error is $a_i$. The stress measure is the change in the US financial stress index. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing.

| **Panel A** | **Average** | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| CarryH | 0.484 | 0.496 | -0.0311 | 0.193 | 0.0555 |
| | [2.07] | [2.65] | [0.34] | [3.98] | [2.31] |
| Carry4 | 0.302 | 2.761 | -0.0245 | 0.0241 | 0.0530 |
| | [1.44] | [2.23] | [0.24] | [0.36] | [2.46] |
| Carry3 | 0.226 | 0.365 | 0.0503 | 0.0804 | 0.0433 |
| | [0.59] | [3.04] | [0.69] | [1.96] | [2.71] |
| Carry2 | 0.0384 | 0.182 | 0.00739 | 0.0508 | 0.0235 |
| | [0.61] | [1.86] | [0.09] | [1.48] | [1.83] |
| CarryL | -0.139 | 0.124 | -0.0242 | 0.00153 | 0.0195 |
| | [1.83] | [1.28] | [0.25] | [0.04] | [1.56] |
| **Panel B** | | | | $\lambda_m$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | 7.472 |
| | | | | [-] | [1.97] |
| Pricing errors $a_i$ | | -0.0422 | Spread | H-L | 0.623 |
| | | -0.167 | Explained | $R_{m,t+1}$ | 0.114 |
| | | -0.144 | | $R_{m,t+1} \times S_t$ | 0.354 |
| | | -0.107 | | | |
| | | -0.285 | | | |
| $R^2$ | 0.640 | | | | |
| J-test $\chi^2(4)$ | 8.69 | (0.0694) | | | |

## Table 9: Carry and Estimates of Market Stress Risk Premia: Developed World Financial Stress Index

The market stress risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_{t-1}$ is the market stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$, the price of stress risk is $\lambda_S$ and the pricing error is $a_i$. The stress measure is the change in the developed world financial stress index. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing.

| **Panel A** | **Average** | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| CarryH | 0.484 | 0.511 | -0.0796 | 0.187 | 0.0563 |
| | [2.07] | [2.73] | [0.42] | [4.01] | [2.39] |
| Carry4 | 0.302 | 2.699 | -0.0841 | 0.0204 | 0.0531 |
| | [1.44] | [2.17] | [0.50] | [0.31] | [2.55] |
| Carry3 | 0.226 | 0.373 | -0.0125 | 0.0740 | 0.0436 |
| | [0.59] | [3.12] | [0.09] | [1.90] | [2.85] |
| Carry2 | 0.0384 | 0.195 | 0.00221 | 0.0476 | 0.0247 |
| | [0.61] | [2.01] | [0.01] | [1.45] | [2.00] |
| CarryL | -0.139 | 0.131 | -0.0937 | -0.00490 | 0.0200 |
| | [1.83] | [1.37] | [0.60] | [0.14] | [1.65] |
| **Panel B** | | | | $\lambda_m$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | 7.528 |
| | | | | [-] | [2.04] |
| Pricing errors $a_i$ | | -0.0484 | Spread | H-L | 0.623 |
| | | -0.1754 | Explained | $R_{m,t+1}$` | 0.114 |
| | | | | $R_{m,t+1} \times S_t$ | |
| | | -0.1454 | | | 0.350 |
| | | -0.1096 | | | |
| | | -0.2864 | | | |
| $R^2$ | 0.627 | | | | |
| J-test $\chi^2(4)$ | 8.53 | (0.0740) | | | |

## Table 10: Trend Following and Estimates of Market Stress Hedging Premia: US Ted Spread

The market risk risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_t$ is the stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$, the price of market stress risk is $\lambda_S$ and the pricing error is $a_i$. The stress measure is the change in the Ted spread for the US. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing.

| **Panel A** | **Average** | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| TFH | 0.570 | 0.446 | -0.828 | 0.0957 | -0.172 |
| | [2.98] | [2.62] | [1.68] | [3.12] | [4.63] |
| TF4 | 0.268 | -0.0169 | -1.563 | 0.0868 | -0.0631 |
| | [0.95] | [0.08] | [2.83] | [2.18] | [1.22] |
| TF3 | 0.231 | 0.0639 | -0.994 | 0.0680 | -0.105 |
| | [0.77] | [0.33] | [2.12] | [1.70] | [2.10] |
| TF2 | 0.0504 | -0.00250 | -0.767 | 0.0611 | -0.0383 |
| | [0.33] | [0.01] | [1.36] | [1.20] | [0.73] |
| TFL | -0.131 | -0.193 | -1.287 | 0.0933 | 0.00119 |
| | [1.46] | [0.90] | [1.98] | [1.44] | [0.02] |
| **Panel B** | | | | $\lambda^M$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | -3.187 |
| | | | | [-] | [3.04] |
| Pricing errors $a_i$ | | -0.0324 | Spread | H-L | 0.702 |
| | | 0.01668 | Explained | $R_{m,t+1}$ | 0.00143 |
| | | -0.143 | | $R_{m,t+1} \times S_t$ | -0.619 |
| | | -0.107 | | | |
| | | -0.182 | | | |
| $R^2$ | 0.859 | | | | |
| J-test $\chi^2(4)$ | 9.26 | (0.026) | | | |

## Table 11: Trend Following and Estimates of Market Stress Hedging Premia: World Ted Spread

The market stress risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_{t-1}$ is the stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$, the price of market stress risk is $\lambda_S$ and the pricing error is $a_i$. The stress measure is the change in the world Ted spread. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing.

| **Panel A** | **Average** | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| TFH | 0.570 | 0.375 | -1.221 | 0.121 | -0.338 |
| | [2.98] | [2.59] | [1.08] | [3.78] | [4.26] |
| TF4 | 0.268 | -0.0186 | -2.280 | 0.138 | 0.0145 |
| | [0.95] | [0.12] | [1.31] | [3.08] | [3.41] |
| TF3 | 0.231 | 0.0107 | -0.943 | 0.125 | -0.0140 |
| | [0.77] | [0.08] | [0.66] | [2.74] | [0.10] |
| TF2 | 0.0504 | -0.151 | -0.637 | 0.142 | 0.137 |
| | [0.33] | [0.98] | [0.41] | [2.40] | [0.79] |
| TFL | -0.131 | -0.268 | -0.519 | 0.183 | 0.244 |
| | [1.46] | [1.57] | [0.22] | [2.55] | [1.20] |
| **Panel B** | | | | $\lambda^M$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | -1.141 |
| | | | | [-] | [2.88] |
| Pricing errors $a_i$ | | 0.112 | Spread | H-L | 0.702 |
| | | 0.203 | Explained | $R_{m,t+1}$ | -0.0369 |
| | | | | $R_{m,t+1} \times S_t$ | |
| | | 0.141 | | | -0.680 |
| | | 0.122 | | | |
| | | 0.0382 | | | |
| $R^2$ | 0.809 | | | | |
| J-test $\chi^2(4)$ | 9.52 | (0.0232) | | | |

## Table 12: Trend Following and Estimates of Market Stress Hedging Premia: US Financial Stress Index

The market stress risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_t$ is the market stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_L \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$ , the price of stress risk is $\lambda_S$ and the pricing error is $a_i$. The stress measure is the change in the US financial stress index. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing.

| Panel A | Average | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| TFH | 0.570 | 0.184 | 0.00395 | 0.112 | -0.0328 |
| | [2.98] | [2.61] | [0.05] | [3.51] | [1.67] |
| TF4 | 0.268 | -0.0675 | -0.0510 | 0.123 | 0.0530 |
| | [0.95] | [0.79] | [0.51] | [3.03] | [1.72] |
| TF3 | 0.231 | -0.0541 | 0.0587 | 0.119 | 0.0444 |
| | [0.77] | [0.73] | [0.65] | [2.76] | [1.74] |
| TF2 | 0.0504 | 0.539 | 0.0245 | 0.114 | 0.0787 |
| | [0.33] | [0.43] | [0.23] | [2.15] | [2.03] |
| TFL | -0.131 | -0.240 | 0.0116 | 0.179 | 0.0953 |
| | [1.46] | [1.83] | [0.10] | [2.72] | [2.45] |
| **Panel B** | | | | $\lambda^M$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | -3.065 |
| | | | | [-] | [2.42] |
| Pricing errors $a_i$ | | 0.405 | Spread | H-L | 0.702 |
| | | 0.359 | Explained | $R_{m,t+1}$ | -0.0399 |
| | | | | $R_{m,t+1} \times S_t$ | |
| | | 0.298 | | | -1.260 |
| | | 0.225 | | | |
| | | 0.0567 | | | |
| $R^2$ | 0.074 | | | | |
| J-test $\chi^2(4)$ | 10.4 | (0.0152) | | | |

## Table 13: Trend Following and Estimates of Market Stress Hedging Premia: Developed World Financial Stress Index

The market stress risk model in Panel A is: $R_{it+1} = \alpha_0 + \alpha_1 S_t + \beta_1 R_{m,t+1} + \beta_2 \left( R_{m,t+1} \times S_t \right) + \varepsilon_{it+1}$ where $R_{it+1}$ is the excess return of portfolio $i$, $R_{m,t+1}$ is the market return and $S_{t-1}$ is the market stress measure. The estimation of the price of risk in Panel B is: $\overline{R}_i = \beta_m \overline{R}_m + \beta_S \lambda^S + a_i$ where the price of market risk $\lambda^M$ is equal to the market risk premium $\overline{R}_m$, the price of market stress risk is $\lambda_S$ and the pricing error is $a_i$. The stress measure is the change in the developed world financial stress index. Newey and West (1997) t-statistics are shown in square brackets. The performance statistics of all the portfolios are based on monthly rebalancing

| **Panel A** | **Average** | $\alpha_0$ | $S_t$ | $R_{m,t+1}$ | $R_{m,t+1} \times S_t$ |
|---|---|---|---|---|---|
| TFH | 0.570 | 0.179 | 0.0675 | 0.111 | -0.0310 |
| | [2.98] | [2.68] | [0.39] | [3.05] | [1.57] |
| TF4 | 0.268 | -0.0667 | -0.116 | 0.117 | 0.0578 |
| | [0.95] | [0.78] | [0.58] | [3.02] | [1.93] |
| TF3 | 0.231 | -0.0520 | -0.00328 | 0.114 | 0.0473 |
| | [0.77] | [0.72] | [0.02] | [2.77] | [1.99] |
| TF2 | 0.0504 | 0.546 | -0.0161 | 0.109 | 0.0834 |
| | [0.33] | [0.42] | [0.09] | [2.09] | [2.23] |
| TFL | -0.131 | -0.234 | -0.0101 | 0.173 | 0.100 |
| | [1.46] | [1.80] | [0.05] | [2.69] | [2.63] |
| **Panel B** | | | | $\lambda^M$ | $\lambda_S$ |
| Price of risk | | | | 0.595 | -2.907 |
| | | | | [-] | [2.40] |
| Pricing errors $a_i$ | | 0.416 | Spread | H-L | 0.702 |
| | | 0.368 | Explained | $R_{m,t+1}$ | -0.0369 |
| | | | | $R_{m,t+1} \times S_t$ | |
| | | 0.303 | | | -1.260 |
| | | 0.229 | | | |
| | | 0.0590 | | | |
| $R^2$ | 0.031 | | | | |
| J-test $\chi^2(4)$ | 10.5 | (0.0147) | | | |

## Table 14: Properties of Carry and Trend Following Strategies Combined

This table presents the performance statistics of portfolios formed on the basis of three different zero net investment carry strategies from previous tables. Each currency in each portfolio is then subject to a trend following analysis. The portfolio whose performance is summarised in column 1 is based on the absolute carry strategy shown in column 3 of Table 2, that in column 2 is column 1, panel C of Table 1. The two panels in this table show results from applying the trend following filter which buys those currencies showing a positive trend and sells those currencies which show a negative trend to the carry portfolio currencies. The performance statistics of all the portfolios are based on monthly rebalancing.

| | Positive/Negative | High/Low Carry 5 |
|---|---|---|
| *6-Month Trend Following* | | |
| Annualized Excess Return (%) | 6.51 | 8.30 |
| Annualized Volatility (%) | 6.75 | 7.95 |
| Sharpe Ratio | 0.96 | 1.04 |
| Max. Monthly Return (%) | 7.79 | 12.38 |
| Min. Monthly Return (%) | -7.11 | -10.36 |
| Maximum Drawdown | 11.94 | 17.71 |
| Skew | -0.20 | -0.21 |
| *10-Month Trend Following* | | |
| Annualized Excess Return (%) | 6.60 | 8.11 |
| Annualized Volatility (%) | 6.94 | 7.97 |
| Sharpe Ratio | 0.95 | 1.02 |
| Max. Monthly Return (%) | 7.79 | 9.64 |
| Min. Monthly Return (%) | -8.81 | -10.08 |
| Maximum Drawdown | 11.15 | 12.05 |
| Skew | -0.48 | -0.45 |