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CURRENCY MOMENTUM STRATEGIES

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Currency Momentum Strategies*

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Abstract

We provide a broad empirical investigation of momentum strategies in foreign exchange markets. We find a significant cross-sectional spread in excess returns of up to 10% p.a. between past winner and loser currencies. This spread in excess returns is not explained by traditional risk factors and shows behavior consistent with investor over- and underreaction. Moreover, currency momentum is mostly driven by return continuation in spot rates and has very different properties from the widely studied carry trade. However, there seem to be very effective limits to arbitrage which prevent momentum returns from being easily exploitable in foreign exchange markets.

JEL Classification: F31, G12, G15.

Keywords: Momentum returns, Limits to Arbitrage, Idiosyncratic Volatility, Carry Trades.

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1. Introduction

Momentum returns in stock markets provide a strong challenge to standard finance theory. Simply buying assets with high recent returns and selling assets with low recent returns results in a very profitable investment strategy whose returns are difficult to understand by means of standard risk factors (Jegadeesh and Titman, 1993, 2001). Consequently, researchers have proposed various explanations which focus not only on conventional risk-based models (e.g. Harvey and Siddique, 2000; Chordia and Shivakumar, 2002; Johnson, 2002; Pastor and Stambaugh, 2003; Liu and Zhang, 2011), but also on characteristics such as credit risk (Avramov, Chordia, Jostova, and Philipov, 2007) or bankruptcy risk (Eisdorfer, 2008), limits to arbitrage (e.g. Chabot and Jagannathan, 2009), behavioral explanations such as investor under-reaction (e.g. Chui, Titman, and Wei, 2010), or high transaction costs (Korajczyk and Sadka, 2004). Despite this progress, the literature does not seem to have settled on a generally accepted explanation for momentum returns yet.

In this paper, we study foreign exchange (FX) markets as a natural laboratory for the analysis of momentum returns. Compared to stock markets, FX markets are more liquid and feature huge transaction volumes and low transaction costs, they are populated largely by sophisticated professional investors, and there are no natural short-selling constraints that prevent the shorting of past loser assets to fully implement momentum strategies. Hence, considering FX markets raises the hurdle for generating significant excess returns from momentum strategies considerably.

Surprisingly, there is little evidence on the existence of momentum profits in FX markets. Large cross-country data sets were rare in the past so that the literature has generally focused on momentum strategies where single currencies are bought and sold over time (Menkhoff and Taylor, 2007). However, some evidence on the existence of momentum profits in the FX market is provided by Okunev and White (2003), Asness, Moskowitz, and Pedersen (2009) and Burnside, Eichenbaum, and Rebelo (2011) in the context of small cross sections of major currencies.

The main contribution of this paper is to study the economic anatomy of momentum profits in FX markets. We start by forming currency portfolios where an investor is long in currencies with high past excess returns and short in currencies with low past excess returns. We take the viewpoint of a U.S. investor and consider exchange rates against the U.S. dollar (USD). Our data covers the period from January 1976 to January 2010, and we study a cross-section of 48 currencies.

We find large and significant excess returns to these momentum strategies of up to 10% per annum (p.a). As in Jegadeesh and Titman (2001) we find some evidence of return continuation and subsequent reversals over longer horizons of up to 36 months, which is consistent with behavioral biases, such as investor under- and over-reaction. Importantly, currency momentum is very different from the popular carry trade in FX markets, providing high returns which are largely unrelated to carry trade returns.[1]

In order to rationalize these high excess returns of currency momentum strategies, we investigate whether currency momentum is significantly affected by (i) transaction costs, (ii) business cycle risk and other traditional risk factors, and (iii) different forms of limits to arbitrage. We find that momentum returns are sensitive to transaction costs. Adjusting returns for bid-ask spreads lowers the profitability of momentum strategies significantly since momentum portfolios are skewed towards currencies with high transaction costs. However, transaction costs are unable to completely account for currency momentum returns.

Also, momentum returns in FX markets are not systematically related to standard proxies for business cycle risk, liquidity risk (Brunnermeier, Nagel, and Pedersen, 2009), the carry trade risk factor proposed by Lustig, Roussanov, and Verdelhan (2011), FX volatility (Menkhoff, Sarno, Schmeling, and Schrimpf, 2011), the three Fama-French factors (Fama and French,

[1] The carry trade is a popular trading strategy that borrows in currencies with low interest rates and invests in currencies with high interest rates. According to uncovered interest parity, if investors are risk neutral and form expectations rationally, exchange rate changes will eliminate any gain arising from the differential in interest rates across countries. However, a number of empirical studies show that high interest rate currencies tend to appreciate while low interest rate currencies tend to depreciate. As a consequence, carry trades form a profitable investment strategy, giving rise to the "forward premium puzzle" (Fama, 1984). See Lustig, Roussanov, and Verdelhan (2011), Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) and Menkhoff, Sarno, Schmeling, and Schrimpf (2011).

1992) or a four factor model including a U.S. stock momentum return factor (Carhart, 1997). In short, there does not seem to be a systematic risk factor which would explain (net) momentum returns, a result which is akin to the corresponding findings based on U.S. equity momentum.

However, the profitability of currency momentum strategies varies significantly over time, which may induce limits to arbitrage for the major market participants in FX markets (e.g. proprietary traders and hedge funds), who usually have rather short investment horizons and may thus act myopically. Also, momentum returns are clearly related to currency characteristics. Returns are much higher in currencies with high (lagged) idiosyncratic volatility (about 8% p.a.) compared to currencies with low idiosyncratic volatility (about 4% p.a.). Returns are also related to measures of country risk, i.e. momentum strategies in countries with a high risk rating tend to yield significantly positive excess returns, whereas momentum strategies in countries with low risk ratings do not. Finally, a similar effect is found for a measure of exchange rate stability risk (i.e. the expected risk of observing large currency movements in the future).

In summary, we provide evidence that, despite FX markets' differences relative to stock markets, the properties of momentum strategies seem to be somewhat similar, which suggests that momentum profits in different asset classes may share a common root. Similar to stock markets, the high excess returns of currency momentum strategies can be (only) partially explained by their sensitivity to high transaction costs. Another piece of explanation is provided by the exposure of currency momentum strategies to limits of arbitrage. These strategies are risky in that their returns are quite unstable over short time periods and that their exposure is subject to fundamental investment risk, captured by idiosyncratic characteristics of the currencies involved.

The remainder of this paper proceeds as follows. We selectively discuss earlier literature in Section 2. Section 3 details our data and portfolio formation procedure. Section 4 describes momentum returns in FX markets and compares momentum strategies with the popular carry trade, while Section 5 provides evidence on our attempts to explain the high returns to currency momentum strategies. Section 6 concludes. Additional results can be found in an Appendix to this paper.

2. Related Literature

Academic studies about momentum strategies are mostly focused on stock markets with some recent extensions into bond and commodity markets. We shortly survey this literature before we refer to FX markets.

Stock market momentum. The empirical literature on momentum strategies is highly influenced by Jegadeesh and Titman (1993). They show in a thorough analysis of the U.S. stock market that the application of simple momentum strategies yields high returns, in the order of about 12% p.a., which cannot be explained by conventional risk factors, such as the Fama and French (1993) three factor model. Subsequent out-of-sample studies extend the original research into new domains, including other countries, other frequencies and other stock portfolios. Regarding other countries, Rouwenhorst (1998, 1999) confirms the momentum returns for European and emerging markets respectively; Jegadeesh and Titman (2001) extend their earlier examination for the U.S. to a longer period with very similar results, and Chui, Titman, and Wei (2010) still find momentum returns for most stock markets in the world with a further updated sample. Regarding other frequencies than the originally examined monthly returns, Gutierrez Jr. and Kelley (2008) show that momentum returns in U.S. stocks also exist for weekly rebalancing if one considers cumulative returns over the following 52 weeks. Chan, Hameed, and Tong (2000) apply a momentum strategy to (up to) 23 national stock market indices over the period 1980 to 1995. Based on a weekly formation period and up to 26 weeks holding period, they find an excess return of roughly 1% per month, i.e. excess returns in the same order of magnitude as Jegadeesh and Titman (1993) found for the U.S. stock market.

While stock momentum excess returns are very well documented, their explanation has been heavily disputed following four directions related to: (i) risk factors, (ii) behavioral influences, (iii) informational issues, and (iv) transaction costs. Starting with risk-based explanations (i), early studies show that momentum strategies are not related to conventional risk factors, as documented by e.g. Jegadeesh and Titman (2001) and Fama and French (1993). Further research has linked momentum returns to macroeconomic factors. Chordia and Shivakumar (2002) find support for time-varying risk factors explaining momentum returns, whereas Griffin and Martin (2003) and Cooper, Gutierrez, and Hameed (2004) do not. With respect to firm-specific risk factors, the following linkages have been established: momentum is stronger among smaller firms (Hong, Lim, and Stein, 2000), among firms with lower credit rating (Avramov, Chordia, Jostova, and Philipov, 2007), and among firms with high revenue growth volatility (Sagi and Seascholes, 2007). Also, momentum returns appear to a large extent generated by firms with a high likelihood to go bankrupt (Eisdorfer, 2008).

The suspicion of behavioral biases (ii) as a determinant of momentum returns has been raised since the beginning of the debate. Jegadeesh and Titman (1993, p. 90) state that: "... our results suggest that investor expectations are systematically biased". However, they cannot distinguish between possible explanations for this bias, i.e. between models of investor over-confidence (Daniel, Hirshleifer, and Subrahmanyam, 1998) or investor under-reaction (Barberis, Shleifer, and Vishny, 1998; Hong and Stein, 1999). As over-confidence is difficult to identify in time-series studies, empirical studies have focused on other indicators for not fully rational behavior. Grinblatt and Han (2005) hypothesize that behavioral biases lead investors to hold on to their losing stocks and to under-react to information. They introduce a variable to capture such behavior (unrealized capital gains), and find that controlling for this variable makes momentum disappear. Using a different approach, Hvidkjaer (2006) distinguishes the average trade size of U.S. stocks and finds that only small trades show the typical momentum behavior, whereas large trades do not. Chui, Titman, and Wei (2010) start with the observation that momentum is internationally widespread but does not occur in every single country. They show that "individualism" within a population is related to momentum, even after controlling for the other relations found before.

The informational explanation of momentum returns (iii) argues that the way analyst recommendations occur may cause momentum. Chan, Jegadeesh, and Lakonishok (1996) provide early evidence that analysts' earnings forecasts respond gradually to news and thus allow for under-reaction. Hong, Lim, and Stein (2000) demonstrate in detail the relation between weak analyst coverage and stronger momentum, which may be interpreted as a firm characteristic. Analyst behavior will lead, during the period of information incorporation, to information heterogeneity among investors, which is shown by Verardo (2009) to be related to momentum.

A final strand of studies explores the role of transaction costs (iv) in explaining momentum. Lesmond, Schill, and Zhou (2004) state that reasonably high transaction costs may wipe out momentum profits. Korajczyk and Sadka (2004) qualify this finding as they argue that momentum strategies may be designed in a way to limit transaction costs; this will lead to a more moderate cost level so that even very large momentum portfolios (with assets worth more than one billion U.S. dollars) are still highly profitable.

Momentum in bonds and commodities. Momentum returns have also been shown to exist in other asset classes. Regarding bond markets, momentum strategies do not work for investment-grade bonds (Gebhardt, Hvidkjaer, and Swaminathan, 2005) or bonds at the country level (Asness, Moskowitz, and Pedersen, 2009) but yield positive returns for non-investment grade *corporate* bonds (Jostova, Nikolova, Philipov, and Stahel, 2010). Further analysis shows that momentum returns are not related to liquidity but seem to reflect default risk in the winner and loser portfolios. Regarding commodity markets, the high returns to momentum strategies are shown to be related to market states with low level of inventories that indicate higher risk (Gorton, Hayashi, and Rouwenhorst, 2008). These findings suggest common sources of momentum profits which seem to be based on the risk characteristics of the underlying assets.

Currency momentum. In contrast to the extensive literature on momentum strategies in stock markets, the literature on currency momentum has developed a much narrower field. The most striking difference is the fact that currency momentum studies generally do not analyze momentum in a cross-section of currencies but in the time-series of single exchange rates, as surveyed by Menkhoff and Taylor (2007).[2] This time-series literature has extensively examined which kinds of momentum trading rules work best. However, there is little evidence on cross-sectional aspects of currency momentum.

One exception is Okunev and White (2003) which analyzes a universe of eight currencies over 20 years, from January 1980 to June 2000. At the end of each month, the investor goes long in the currency with the best last-month performance and goes short in the currency with the worst last-month performance. This yields a return of about 6% p.a., which is largely independent of the base currency chosen and of the specific trading rules chosen, i.e. how exactly the best and worst currencies are identified. Thus, there is clear indication that currency momentum strategies may be profitable and thus worthy of a thorough examination.[3] Burnside, Eichenbaum, and Rebelo (2011) investigate returns to an equally-weighted momentum portfolio that aggregates over momentum positions in individual currencies. They find (as we do in this paper) that standard risk factors cannot account for currency momentum returns.

In this paper, we go beyond earlier research in a number of directions. First, we analyze a much longer time span and, more important, a much larger cross-section of currencies which includes currencies of developed and emerging countries. This extended sample across time and currencies is crucial for our analysis of returns to currency momentum strategies since it allows us to better identify return variation over time (and, hence, states of the business cycle) as well as across currencies that are structurally different and should have different exposure to global risk factors. Second, we can take explicit account of transaction costs, which is crucial since momentum returns are only relevant as long as they survive realistic transaction costs. Third, we take a close look at possible limits to arbitrage (which are a key theme in the recent literature on stock momentum) and investigate the role of idiosyncratic return volatility, country risk, and the risk of exchange rate stability. In sum, we provide a detailed account of the anatomy of currency momentum strategies that is missing in the

[2]See, for example, Harris and Yilmaz (2009), Neely, Weller, and Ulrich (2009), and Serban (2010) in this respect.

[3]More recently, Asness, Moskowitz, and Pedersen (2009) have also investigated returns to a single currency momentum strategy based on ten currencies. The focus of their paper is very different from ours, however, and is more concerned with the commonality of momentum across asset classes.

literature until now.

3. Data and Currency Portfolios

This section describes our data, the computation of currency excess returns, and the construction of momentum portfolios.

Data source and sample currencies. The data for spot exchange rates and 1-month forward exchange rates cover the sample period from January 1976 to January 2010, and are obtained from BBI and Reuters (via Datastream). We denote the spot and forward rates in logs as s and f, respectively. Our total sample consists of the following 48 countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Euro area, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Iceland, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Ukraine, United Kingdom.

It is worth noting that, compared to e.g. Lustig, Roussanov, and Verdelhan (2011) or Menkhoff, Sarno, Schmeling, and Schrimpf (2011), whose samples start in 1983 and have seven currency pairs in the beginning of the sample (mainly) based on BBI data quoted against the U.S. dollar, we employ a longer time series that extends back to 1976. We do so by complementing BBI data (which only start in 1983) with Reuters data quoted against the British Pound as in Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011). We have a total of 16 currencies for this longer time span and convert these data to quotations against the U.S. dollar. These 16 countries are: Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. In addition to the larger cross-section and longer time series, we also have bid and ask quotes for spot and forward rates available so that we can adjust for transaction costs for the whole period from 1976 to 2010.

Currency excess returns. Excess returns to a U.S. investor for holding foreign currency k are given by

$$rx_{t+1}^{k} \equiv i_{t}^{k} - i_{t} - \triangle s_{t+1}^{k} \approx f_{t}^{k} - s_{t+1}^{k} \tag{1}$$

where s and f denote the (log) spot and 1-month forward rate (foreign currency unit per USD), respectively. Δs denotes the log spot rate change or return. Descriptive statistics for excess returns, forward discounts, and bid-ask spreads are reported in the Appendix (Table A.1).

For future reference, we also define net currency excess returns, i.e. currency excess returns after bid-ask spreads. These returns only apply when investigating dynamic investment strategies (momentum strategies in our case), where investors form portfolios of currencies. We detail the construction of portfolios below and simply define how we adjust for transaction costs here.

The net return for a currency that enters a portfolio at time t and exits the portfolio at the end of the month is computed as $rx_{t+1}^{l} = f_{t}^{b} - s_{t+1}^{a}$ for a long position and $rx_{t+1}^{s} = -f_{t}^{a} + s_{t+1}^{b}$ for a short position. An a (b) superscript indicates the ask (bid) quote. A currency that enters a portfolio but stays in the portfolio at the end of the month has a net excess return $rx_{t+1}^{l} = f_{t}^{b} - s_{t+1}$ for a long position and $rx_{t+1}^{s} = -f_{t}^{a} + s_{t+1}$ for a short position, whereas a currency that exits a portfolio at the end of month t but already was in the current portfolio the month before ($t-1$) has an excess return of $rx_{t+1}^{l} = f_{t}^{b} - s_{t+1}^{a}$ for a long position and $rx_{t+1}^{s} = -f_{t}^{a} + s_{t+1}^{b}$ for a short position. Hence, since forward contracts in our sample have a maturity of one month, the investor always incurs transaction costs in the forward leg of his position but does not always have to trade the spot market leg of his position if he stays invested in a foreign currency. In addition, we assume that the investor has to establish a new position in each single currency in the first month (January 1976) and that he has to sell all positions in the last month (at the end of January 2010).

However, one has to bear in mind that bid-ask spreads from BBI/Reuters are based on indicative quotes which are "too high" (see e.g. Lyons, 2001) relative to actual effective spreads in FX markets so that our results with net returns (after deducting the bid-ask spread) should be understood as undercutting the lower bound on the profitability of momentum strategies and not as the "exact" return. For this reason, we frequently provide results with and without transaction costs below in our empirical analysis. We denote returns or spot rate changes after deducting bid-ask spreads as "net returns" and "net spot rate changes", respectively.

Portfolio construction. At the end of each month, we form six portfolios based on lagged returns over the previous $f = 1, 3, 6, 12$ months (f denotes the formation period) and these portfolios are held for $h = 1, 3, 6, 12$ months (h denotes the holding period). The one sixth of all available currencies in a given month which have the lowest lagged returns are allocated to the first portfolio (denoted "Low"), the next sixth is allocated to portfolio 2, and so on, and the one sixth of all currencies with the highest lagged returns are allocated to the sixth portfolio (denoted "High"). Hence, this procedure yields a time-series of six currency momentum portfolios' excess returns and is analogous to the construction of momentum portfolios in the equity market literature.[4]

However, since interest rate differentials (forward discounts) contribute a significant share of the excess return of currency investments, we also track the pure spot rate changes of momentum portfolios themselves and report them separately in many tables. This way, we can check whether currency momentum is mainly driven by interest rate differentials or whether it occurs in spot rates, too.

Finally, in most analyses we work with the portfolio which is long in the winner currencies (portfolio "High") and short in the loser currencies (portfolio "Low"). These portfolios are denoted $MOM_{f,h}$ where f and h are the formation and holding period, respectively, as defined

[4] Lustig and Verdelhan (2007) were the first to form portfolios of currency excess returns to be able to study the cross-section of carry trade risk premia. This approach of forming currency portfolios has been followed by several other papers afterwards.

above. We also refer to these portfolios simply as "long-short" momentum portfolios or "high minus low" portfolios.

4. Characterizing Currency Momentum Returns

In this section, we present our main empirical results regarding the profitability and characteristics of currency momentum strategies (Section 4.1), the difference between currency momentum and currency carry trade strategies (Section 4.2), the exposure of momentum returns to traditional risk factors and business cycle state variables, and the long-run return behavior of momentum strategies (Section 4.3).

4.1. Returns to Momentum Strategies in Currency Markets

Table 1 shows average annualized excess returns (left panel) and spot rate changes (right panel) for a number of high minus low momentum portfolios with formation and holding periods each varying between one and twelve months: $f, h = 1, 3, 6, 9, 12$. Average excess returns in the left panel are based on sorting on lagged excess returns, and average spot rate changes in the right panel are based on sorting on lagged spot rate changes.

Turning to excess returns in the left panel first, we find that momentum strategies yield quite high (and statistically highly significant) excess returns of about $6 - 10\%$ for short holding periods of one month and their profits slowly fade out when increasing the holding period. The latter finding is quite pronounced since there is a monotone decline in average excess returns when moving from short holding periods to longer holding periods h for a given formation period f. However, we find many instances of significant momentum returns for strategies with higher holding periods as well, so that momentum is not confined to very short holding periods.

In the right panel of Table 1 we also report the average difference between spot rate changes for the high and low portfolio. For ease of exposition, we actually report the negative of the log spot rate change (in the notation of Section 3) so that higher values indicate a positive contribution of spot rate movements to a momentum strategy's total excess return. Interestingly, the profitability of currency momentum strategies is also clearly visible in spot rate changes themselves and is thus not completely driven by the interest rate differential as is the case for carry trades (see e.g. Lustig, Roussanov, and Verdelhan, 2011). In fact, the strategy with a twelve months formation period is completely driven by favorable spot rate changes and the interest rate differential reduces the excess return somewhat.

TABLE 1 ABOUT HERE

As noted above, results tend to be strongest for a holding period of $h = 1$ month. So we focus on these strategies in most of the following analysis as they seem to present the hardest challenge when trying to understand momentum returns in currency markets. Since the level of average excess returns is also clearly dependent on the formation period f, we provide results for the three strategies with $f = 1, 6$, and 12 months in our empirical analyses below. In sum, most of our analysis in the remainder of the paper focuses on the three benchmark strategies $MOM_{1,1}, MOM_{6,1}$, and $MOM_{12,1}$.[5]

As a first and simple means of investigating a possible link between momentum returns and the state of the business cycle, and to provide a graphical exposition of momentum returns accruing to investors, Figure 1 shows cumulative excess returns for the three benchmark momentum strategies $MOM_{1,1}, MOM_{6,1}$, and $MOM_{12,1}$ over the full sample period. Shaded areas correspond to NBER recessions. As evidenced by the figure, there is no obvious correlation of momentum returns with the state of the business cycle (as examined in later Section

[5]We have also limited the sample to currencies which have a positive score on the capital account openness index of Chinn and Ito (2006) both in the formation and holding period to control for the possibility that some currencies are not tradable or that are only traded in more opaque offshore markets which would not be adequately reflected in our data. We report results for this restricted subset in Table A.3 in the Appendix. As can be seen, the results are not affected by excluding these currencies. Moreover, countries with negative capital account openness index values do not account for a large share of the relevant corner portfolios (less than 20% on average).

5.2). However, the three benchmark momentum strategies show some co-movement but are not perfectly correlated.

FIGURE 1 ABOUT HERE

4.2. *Comparing Currency Momentum and the Carry Trade*

An important question is to what extent momentum strategies simply capture the same information as the popular carry trade strategy in FX markets, where investors go long in high interest rate currencies and short in low interest rate currencies. After all, interest rate differentials are strongly autocorrelated and spot rate changes do not seem to adjust to compensate for this interest rate differential, which is well-known in the literature as the "forward premium puzzle" (Fama, 1984). Hence, it may be the case that lagged high returns simply proxy for lagged high interest rate differentials and that, therefore, currency momentum returns are very similar to carry trade returns. In order to address this concern, we perform a comprehensive comparison between momentum returns and carry trade returns in this section. The results clearly show that carry trade and momentum strategies, as well as their associated returns, are in fact very different.

Comparing portfolio properties. We first investigate characteristics of momentum and carry trade portfolios, which are reported in Table 2. The table shows descriptive statistics for the six momentum portfolios with a formation and holding period of one month and six carry trade portfolios where currencies are sorted into portfolios depending on their lagged interest rate, as in e.g. Lustig, Roussanov, and Verdelhan (2011) or Menkhoff, Sarno, Schmeling, and Schrimpf (2011).[6]

[6]To conserve space in this table, we focus on the momentum strategy with $f = 1$ and $h = 1$. Results are similar for the other strategies.

As can be inferred from this table, there is a monotonically increasing pattern in average returns for both cross-sections but no clear pattern in higher moments of the return distribution. While the level of average returns and standard deviations of the high minus low momentum and carry trade portfolios is roughly similar, we find that the two long-short portfolios are clearly different in terms of their skewness. While the carry trade produces negatively skewed excess returns (also see Brunnermeier, Nagel, and Pedersen, 2009), we find a slightly positive skewness for the momentum strategy.

Table 2 about here

More interestingly, the last two rows of each panel show lagged average returns and lagged average forward discounts for each portfolio at the time of portfolio formation. Momentum portfolios do have a positive spread in forward discounts and carry trade portfolios have a positive spread in lagged returns, but these spreads are much lower in absolute value than the spread in the characteristic used for sorting currencies into portfolios. More specifically, the average cross-sectional spread in forward discounts at the time of portfolio formation is about 4.6% (5.13% versus 0.44%) for the momentum cross-section but averages more than 15% for the carry trade cross-section. Similarly, the average spread in lagged returns is almost 6% for the momentum portfolios (2.94% versus -2.93%) but only 0.84% for the carry trade cross-section. Hence, momentum and carry trade strategies may be somewhat related but are far from being identical.

Return correlations. Table 3, Panel A, shows correlation coefficients between returns to momentum portfolios and carry trade portfolios. We show results for the long-short momentum strategies $MOM_{1,1}$, $MOM_{6,1}$, and $MOM_{12,1}$ and always only show the correlation between corresponding portfolios; e.g. the correlation of momentum portfolio 2 and carry trade portfolio 2, or the correlation between the high minus low (H-L) carry trade and momentum portfolios. It can be seen that the correlations of excess returns for the six portfolios are rather high but that there is basically no correlation between the high minus low portfolios, and the latter represent the way carry trade and momentum strategies are typically implemented by market participants. Thus, the return to following a momentum strategy is basically uncorrelated with carry trade returns and this finding holds true regardless of the respective formation period underlying a momentum strategy.

TABLE 3 ABOUT HERE

In contrast, we show in Panel B that the high minus low portfolios of the three momentum strategies are much more highly correlated and reach correlations of more than 70% for $MOM_{6,1}$ and $MOM_{12,1}$. Hence, it seems fair to conclude that returns to different momentum strategies are likely to share a strong common component.

That excess returns to carry trades and momentum strategies are basically uncorrelated in FX markets seems in line with real-world strategies of many currency investors who combine momentum and carry trade positions in their portfolios to take advantage of an alleged diversification benefit from following the two strategies simultaneously.[7] For example, during the recent financial crisis from July 2007 to June 2009, the benchmark momentum strategy with $h = f = 1$ experienced an average monthly return of 0.80% whereas the carry trade yielded a negative average monthly return of -0.05%. The return correlation of these two strategies was as low as -31% over these two years. Hence, the two strategies showed a clearly different behavior during this period.

Double sorts. Next, we provide results based on double sorts. To this end, we first double-sort currencies into two portfolios depending on whether a currency has a lagged forward

[7] Patton and Ramadorai (2011) for example show in a general universe of hedge funds (not necessarily currency funds) that there is significant exposure to carry trade and momentum-type returns and that this exposure is time-varying. Pojarliev and Levich (2010) show via style regressions that currency fund managers engage in both carry trade and momentum-type strategies. Melvin and Shand (2011) show that currency managers follow momentum strategies but that their exposure to momentum and the way momentum strategies are implemented change over time.

discount above or below the median (of all available currencies), and then into three portfolios depending on their lagged excess return. Portfolios are re-balanced each month (i.e. $h = 1$). Table 4 shows results for these double sorts for formation periods of $f = 1, 3, 12$ months. There is no interesting difference between momentum returns among high versus low interest rate currencies. For example, the high minus low momentum return for a strategy with a one month formation period based on low interest rate currencies is 5.06% p.a. on average, whereas the same quantity is 5.36% p.a. for high interest rate currencies. Hence, the difference between these two high minus low momentum portfolios is less than 0.30% p.a. and not statistically significant (with a t-statistic of only 0.17). Findings for the other two formation periods are very similar.

TABLE 4 ABOUT HERE

As above, we do not find a strong relation between momentum and carry trade strategies and the double sorts suggest that the two strategies are largely independent. In fact, going long in currencies with high lagged returns and high interest rates whilst shorting currencies with low returns and low interest rates generates an excess return of 10.52% p.a. which is even larger than the spread in both momentum or carry trade portfolios taken individually.

Cross-sectional regressions. Finally, we want to separate the effects of lagged excess returns and lagged interest rate differentials on future excess returns. To this end, we run Fama-MacBeth type cross-sectional regressions of currency excess returns (or spot rate changes) on (i) lagged excess returns over the last h months, (ii) lagged forward discounts, and/or (iii) lagged spot rate changes for each month of our sample, i.e.

$$rx_{t+1}^k = \alpha_{t+1} + \beta_{t+1,rx} rx_{t+1-\ell;t}^k + \beta_{t+1,FD}(f_t - s_t) + \beta_{t+1,\Delta s} \Delta s_{t+1-\ell;t}^k + \varepsilon_{t+1} \quad (2)$$

where the subscript $t + 1 - \ell; t$ refers to a variable defined over the last ℓ months using information available at time t. This procedure in the spirit of Fama and MacBeth (1973) yields a time-series of coefficient estimates (α_t, β_t) and we report the mean of these time series and t-statistics based on Newey and West (1987) standard errors in Table 5.[8]

Panel A shows results for regressions where we use lagged excess returns, forward discounts, and/or spot rate changes over the last month as explanatory variables, whereas Panels B and C show results for using six or twelve months averages as explanatory variables, respectively.[9]

Turning to results for excess returns first (left part of Table 5), we find that lagged returns, lagged forward discounts, as well as lagged spot rate changes are cross-sectionally positively related to subsequent currency returns even when including them in joint specifications. Hence, momentum effects are robust to controlling for forward discounts (interest rate differentials). Furthermore, it seems interesting to note that lagged spot rate changes seem to do about as well as lagged excess returns in the cross-sectional regressions so that momentum seems to originate from spot rate changes and not from lagged interest rate differentials, which corroborates our finding that carry trades and momentum are different.

TABLE 5 ABOUT HERE

The right part of Table 5 shows the same calculations but with spot rate changes as dependent variables. While the effect of lagged returns or spot rate changes is very similar to our results described above, we find that the forward discount has a *negative* impact on future spot rate changes. However, the coefficients based on univariate regressions are always smaller than one in absolute value so that a one percent higher interest rate in a foreign country is only followed by a depreciation smaller than one percent relative to other currencies' excess returns against the USD, consistent with the existence of a forward bias (Fama, 1984). Note that these are *cross-sectional* regressions so that results do not necessarily translate into a time-series setting.

[8] See for example Gutierrez Jr. and Kelley (2008), who employ a similar methodology.

[9] For ease of interpretation, we multiply spot rate changes by minus one, so that higher values mean that the foreign currency is appreciating against the USD.

4.3. *Post-formation Momentum Returns*

Jegadeesh and Titman (2001) suggest that momentum returns are driven by slow information diffusion that leads to under-reaction and persistence in returns (also see Chui, Titman, and Wei, 2010). This initial under-reaction may furthermore be accompanied by subsequent over-reaction which magnifies the drift in returns but has to be corrected over the long run. To investigate these issues, Jegadeesh and Titman (2001) investigate the post-formation holding period returns of momentum strategies over longer time spans (i.e. the returns over long horizons after portfolio formation where the portfolio composition is held constant). They find a (roughly) "inverted U-shaped pattern", i.e. returns tend to increase for several months up to one year after portfolio formation but then peak and start to decrease significantly. Jegadeesh and Titman interpret this as evidence of initial under-reaction which drives prices and subsequent over-reaction to the series of high returns, pushing prices up above the fundamental value of the asset. This over-reaction is then corrected over longer periods, leading to the observed predictable pattern of increasing and decreasing returns after portfolio formation.[10]

As a first check of this hypothesis for currency markets, we plot cumulative post-formation excess returns over periods of $1, 2, \dots, 60$ months for the zero-cost long-short momentum portfolios with a one, six, and twelve months formation period (i.e. MOM_1, MOM_6, and MOM_{12}) in Figure 2. Returns in the post-formation period are overlapping since we form new portfolios each month but track these portfolios for 60 months. There is a clear pattern of increasing returns which peaks after $8 - 12$ months across strategies and a subsequent period of declining excess returns. The decline is more pronounced for momentum strategies with longer formation periods. Thus, on the face of it, this evidence looks very similar to equity markets as in Jegadeesh and Titman (2001), which seems interesting since it suggests that currency and equity market momentum may have similar roots.

[10]There is relatively little work on behavioral effects in currency markets (compared to equity markets). Burnside, Han, Hirshleifer, and Wang (2010) recently show, however, that concepts from behavioral finance may be useful to understand FX phenomena as well. In addition, Bacchetta and van Wincoop (2010) argue that many FX portfolios are still not actively managed but that portfolio decisions are often taken infrequently, which can be fully rational due to the costs of portfolio adjustments. This mechanism could also account for slow diffusion of information into prices in FX markets.

Figure 2 about here

We also provide the same results for post-formation drift in cumulative spot rate changes in Figure A.1 in the Appendix and find a very similar pattern (although with a somewhat lower magnitude with respect to the initial price increases) so that the result discussed above does not seem to be driven by interest rate differentials but also stems from price changes.

In sum, these results suggest that momentum returns may be (at least partly) driven by slow information processing and investor over-reaction. However, given the highly liquid and professional FX market it is hard to believe that investor irrationalities of this kind are not quickly arbitraged away. Thus, it seems likely that there could be some limits to arbitrage at work that effectively prevent arbitrage in at least the subset of currencies that produce positive momentum returns and the observed post-formation long-run return behavior uncovered here. Indeed, we turn to an investigation of possible factors that could limit arbitrage activity in the next section.

5. Understanding the Results

5.1. Transaction Costs

What role do transaction costs play for momentum returns? To address this question, we first report momentum returns after transaction costs in Table 6, which is otherwise identical to Table 1 but just deducts transaction costs. For this table, we impose the full quoted bid-ask spreads. This spread is known to be too large relative to actual effective spreads (Lyons, 2001). Hence, these results likely underestimate momentum returns, whereas neglecting spreads clearly overstates momentum returns.

Table 6 about here

The results show that transaction costs could be an important factor for understanding momentum returns in currency markets (Burnside, Eichenbaum, Kleshchelski, and Rebelo, 2006; Burnside, Eichenbaum, and Rebelo, 2007). When applying the full spread, returns for the best strategy (with $f, h = 1$) drop from nearly 10% to about 4% p.a. and they wipe out most of the profit of many other strategies. Interestingly, the effects of transaction costs on the average spot rate changes of portfolios (which are adjusted for bid-ask in an analogous fashion to excess returns) are relatively less affected. To make the full effect of transaction costs more transparent, we also plot cumulative net excess returns (after transaction costs) for the three baseline strategies $MOM_{1,1}$, $MOM_{6,1}$, and $MOM_{12,1}$ in Figure 3. Again, shaded areas correspond to NBER recessions. It can be seen that FX momentum strategies are much more profitable (after transaction costs) in the later part of the sample and that momentum strategies do not always deliver high returns to investors. Instead, there is much variation in profitability.

Figure 3 about here

Next, given that the quoted spread is known to be too high relative to effective spreads, we follow Goyal and Saretto (2009) and report results for momentum excess returns after transaction costs of 75% (Panel A) and 50% (Panel B) of quoted spreads in Table 7.

Table 7 about here

Results for these more realistic bid-ask spread adjustments indicate that transaction costs clearly matter but that they are not the sole driver of FX momentum returns as we find that many strategies still yield economically high and statistically significant returns on average.

Further scrutinizing this issue, we can break up the importance of transaction costs into turnover across portfolios and bid-ask spreads across portfolios. We provide results on both issues in the Appendix. Table A.2, Panel A, shows the average turnover of the winner and loser momentum portfolios and the average turnover across all six portfolios for a given combination of formation and holding period. Two main conclusions emerge from this exercise. First, turnover can be extremely high, reaching values of more than 70% per month for the strategy with a one month formation and holding period. Second, the winner and loser portfolios have slightly less turnover on average than the other portfolios in a given momentum cross-section. Hence, it is not the case that winner and loser currencies have abnormally high turnover.

Finally, Appendix Table A.2, Panel B, shows the average bid-ask spread at the time of portfolio formation (in basis points) minus the average bid-ask spread of all available currencies. We find that the winner and loser currencies do have higher transaction costs than the average exchange rate and the markup ranges from about 2.5 to 7 basis points per month. Accordingly, trading in the winner and loser currencies (as is necessary to set up a momentum strategy) is more costly than trading in the average currency pair. Hence, transaction costs seem to matter considerably.

However, given that transaction costs should be expected to decline over time due to more efficient trading technologies (such as electronic trading networks operated by e.g. EBS and Reuters), it seems unclear whether transaction costs are able to fully explain momentum returns. Figure 4 shows average bid-ask spreads across currencies for each month in our sample and separately for all countries and for the subsample of 15 developed countries as defined above. While there is a lot of time-series variation in average spreads, it is the case that spreads have trended downwards over our sample period. This downward trend is most clearly seen for the sample of developed countries for which we have almost complete data histories and for which average spreads are not driven by the frequent inclusion of emerging market currencies that induce some large spikes in average spreads when looking at the sample of all countries. Thus, it seems interesting to also investigate momentum strategies over a later part of our sample where bid-ask spreads tend to be lower on average since lower transaction costs could either (i) increase momentum returns due to lower trading costs or (ii) decrease momentum returns since lower trading costs facilitate more arbitrage activity in these strategies.

Figure 4 about here

Appendix Table A.4 shows results for the same calculations underlying Table 1 above but we only include the period January 1992 to January 2010 in order to learn about whether the profitability of momentum strategies increases or declines over this recent period of low transaction costs. We find that unadjusted momentum returns reach levels similar to those for the full sample (Panel A) but that transaction cost-adjusted net excess returns (Panel B) are clearly higher and, for example, reach average annualized values of more than 7% for the 1-month strategy $MOM_{1,1}$. Thus, lower bid-ask spreads do not necessarily lead to lower (unadjusted) excess returns, which further indicates that transaction costs are not the sole driving force behind momentum effects. This evidence indicates that momentum returns are a phenomenon which is still exploitable nowadays.

5.2. *Momentum Returns and Business Cycle Risk*

Table 8, Panel A, shows results from univariate time-series regressions of momentum returns on various risk factors or business cycle state variables. These factors include macro variables or other risk factors from the earlier literature: "Consumption" stands for real growth in non-durables and services consumption expenditures, "Employment" denotes U.S. total nonfarm employment growth, "ISM" denotes the ISM manufacturing index, "IP" denotes growth in real industrial production, "CPI" denotes the inflation rate, "M2" is the growth in real money balances, "Disp Inc" is growth in real disposable personal income, "TED" denotes the TED spread (the difference between 3-month interbank rate, Libor and 3-month T-Bill rate), "Term" denotes the term spread (20-year maturity minus 3-month T-Bill rate), HML_{FX} is the return to the carry trade long-short portfolio (Lustig, Roussanov, and Verdelhan, 2011), and VOL_{FX} is a proxy for global FX volatility (Menkhoff, Sarno, Schmeling, and Schrimpf, 2011). We note that the alphas in these regressions cannot be interpreted as a measure of risk-adjusted returns for most specifications since we are mainly employing macro variables or other non-return based factors here.

Statistical significance at the 5% level or below is indicated by bold numbers. However, looking across momentum strategies and macro risk factors, there is little evidence that standard factors can explain momentum returns. The adjusted R^2s are generally small and most slope coefficients are insignificantly different from zero.[11]

Table 8 about here

Panel B of Table 8 shows a multivariate regression of momentum returns on the three Fama-French factors augmented by the U.S. stock momentum factor (UMD), and it can again be seen that there is basically no explanatory power. Moreover, the alphas in these regressions (which are annualized and in percentages) can be interpreted as the risk-adjusted performance of momentum returns since the factors are excess returns in this case. Across strategies, the alphas are fairly high, as judged by this particular model for returns. Based on earlier research for the U.S. stock market, this result does not come as a surprise regarding the three Fama-French factors but it seems noteworthy that currency momentum is also unrelated to the UMD factor and, hence, largely independent from U.S. stock momentum.[12]

In sum, there is little evidence that standard business cycle variables or portfolio-based risk factors help to understand momentum returns, i.e. it seems that the latter are largely disconnected from U.S. business cycle risk. This finding squares well with earlier results for U.S. stock momentum, which is hard to explain by relying on its covariance with macro risk

[11] As mentioned earlier, one exception is the momentum strategy with a 12 months formation period and global FX volatility. We find a highly significant slope coefficient here and a positive R^2. Menkhoff, Sarno, Schmeling, and Schrimpf (2011) show for this momentum strategy that innovations to global FX volatility do indeed capture a large amount of the cross-sectional spread in returns and that volatility risk is significantly priced. However, we do not find that FX volatility helps much for understanding momentum returns to the strategies with short formation periods of one month or six months.

[12] We have also experimented with more elaborate cross-sectional asset pricing tests for both macro factors and return-based factors but, as may be expected on the basis of the time-series results reported in Table 8, did not find any improvement in results.

factors (e.g. Griffin and Martin, 2003; Cooper, Gutierrez, and Hameed, 2004).

5.3. Limits to Arbitrage: Time-variation in Momentum Profitability

Next, we are interested in the stability of momentum returns over time. Figure 5 plots average excess returns to the three long-short momentum portfolios $MOM_{1,1}$, $MOM_{6,1}$, and $MOM_{12,1}$ over rolling windows of 36 months. The left part shows unadjusted returns while the right part of the figure shows net excess returns after transaction costs. It can be seen that the profitability of momentum strategies is time-varying and that both adjusted and unadjusted returns seem to be higher over the second part of the sample. In fact, momentum returns for all three strategies have been rather high between 2000 and 2005 reaching levels of monthly net excess returns of about 2% per month.

Figure 5 about here

However, this figure also illustrates that momentum returns are far from being constant even over intermediate time intervals of several years. Hence, an investor seeking to profit from momentum returns has to have a long enough investment horizon. This result seems potentially important, since the bulk of currency speculation is accounted for by professional market participants and proprietary traders who have a rather short horizon over which their performance is evaluated (Lyons, 2001). This suggests that momentum strategies are potentially risky for myopic market participants, so that the large time-variation in the performance of momentum returns may impede arbitrage activity in these strategies by some of the major FX market participants.

5.4. Limits to Arbitrage: Idiosyncratic volatility

Unlike in stock markets, there are no natural short-selling constraints in FX. However, in order to arbitrage momentum effects in currency markets, an investor obviously has to set up positions in FX markets which he may wish to hedge such that the position becomes a pure bet on return continuation but not on any sort of systematic risk. Hence, we investigate whether momentum returns are different between currencies with high or low idiosyncratic volatility (relative to an FX asset pricing model). Finding that currency momentum is stronger among high idiosyncratic volatility currencies would imply that arbitraging these returns is risky since it will be hard to find a second pair of currencies that can be used as a hedge factor unrelated to simple return continuation.

To this end, Panel A of Table 9 shows results from double-sorting currencies first into two portfolios depending on whether a currency has a lagged idiosyncratic volatility above or below the median (of all available currencies), and then into three portfolios depending on their lagged excess return.[13] For all three formation periods we study (i.e. f is either $1, 6$, or 12), we find that momentum returns are higher among currencies with high idiosyncratic volatility than among currencies with low idiosyncratic volatility ($IVOL$). The returns differences are quite large in economic terms. For example, sorting on lagged idiosyncratic volatility and lagged one month returns leads to an annualized momentum excess return of 3.97% among currencies with low $IVOL$, whereas a momentum strategy among currencies with high $IVOL$ yields an average excess return of 8.09% p.a. Thus, momentum strategies are much more profitable among currencies with high idiosyncratic risk.

Table 9 about here

5.5. *Limits to Arbitrage: Country Risk*

Next, we perform the same analysis as above but sort instead on a measure of country risk ($CRISK$) and a measure of exchange rate stability risk ($XSTAB$). These data are based

[13] Idiosyncratic volatility for each currency j in month t is computed from a regression of currency returns on a constant, the Dollar risk factor, and the HML_{FX} factor of Lustig, Roussanov, and Verdelhan (2011). Idiosyncratic volatility is then computed as the absolute value of the regression residual in month t. We find similar results to those reported below when we employ the volatility risk factor proposed by Menkhoff, Sarno, Schmeling, and Schrimpf (2011).

on the International Country Risk Guide (ICRG) database from the Political Risk Services (PRS) group.[14] We employ the composite country risk rating (which comprises economic, political, and financial risk of a country) as a general proxy for the riskiness of a given country and exchange rate stability risk as a specific proxy for the risk of sharp currency movements of a country.[15] Data for these risk proxies start in January 1985 and we employ the log deviation of the risk rating of a country from the rating of the U.S. as a proxy of relative risk for a U.S. investor.

The setup here is somewhat akin to Avramov, Chordia, Jostova, and Philipov (2007, 2010), who show that U.S. stock momentum is mainly concentrated in high credit risk firms which are illiquid and hard to sell short.[16] Hence, credit risk proxies for hurdles to arbitrage activity. In our context, we focus on country risk which should proxy for limits to arbitrage in FX markets. High risk countries are more politically unstable, economically less developed and more volatile so that establishing positions in the associated currencies poses non-trivial threats of sudden capital account restrictions and non-convertibility of currency. In short, arbitrage activity in these countries should be clearly more risky compared to well developed and highly stable countries with low risk ratings similar to the U.S.

Panels B and C of Table 9 shows results for double sorts on either country risk or exchange rate stability risk and momentum. Corroborating our earlier findings for idiosyncratic volatility, we find that momentum returns are significantly positive and always larger in high-risk countries than in low-risk countries, where momentum strategies do not yield significant excess returns. Hence, for an investor to profit from currency momentum strategies, it is necessary to operate in risky countries. This is especially important since, unlike momentum strategies in domestic U.S. stocks, investments in foreign currency are always subject to risks of capital controls and non-convertibility. Therefore, country risk should be an important limit to arbitrage in FX markets.

[14] These data are quite common as proxies for country risk; see e.g. Bekaert, Harvey, and Lundblad (2007), who also use risk indicators from this database.

[15] The exchange rate stability risk proxy measures the perceived risk of large exchange rate movements in the near future.

[16] In a similar vein, Jostova, Nikolova, Philipov, and Stahel (2010) show that momentum profits in U.S. corporate bond returns derive solely from long and short positions in non-investment grade bonds.

Finally, we examine whether our findings above are driven by country risk being related linearly to the cross-sectional spread in momentum returns and whether momentum is differently affected than carry trades. Table A.8 (which, as an example, is based on the strategy with a one month formation and holding period) in the Appendix shows a clear pattern. Country risk and exchange rate stability risk are high for winner *and* loser currencies (Panel A) in the momentum strategy. Hence, it is not the case that these risk ratings are simple proxies for interest rate differentials which drive our results. Rather, currency momentum strategies require that an investor has to go long and short in the most risky countries. This is especially true, since momentum profits stem from both the long and short side of the position (see Table 2, Panel A) so that it is necessary to set up both positions. Contrary to this, the cross-section of carry trade portfolios (Table A.8, Panel B) shows a very different pattern. Country risk is highest for high interest rate currencies and lowest for low interest rate currencies. This squares well with the finding that most of the carry trade return comes from the long position of the strategy (2, Panel B). In any case, these results indicate that country risk has a non-linear impact on the cross-sectional spread in momentum portfolios' returns and, again, that momentum and carry trade are very different strategies.

Developed countries. Finally, a shortcut to looking at country risk may also be to define a sample of clearly developed countries that have stable exchange rate regimes and are most liquid. Table A.5 in the Appendix shows results before and after transaction costs similar to those in Table 1 but we limit the cross-section to 15 developed countries.[17] It is clear from this table that momentum returns are much smaller and basically non-existent after transaction costs when looking at currencies of developed countries. This finding is interesting since it suggests that the profitability of momentum strategies depends on whether smaller and presumably less liquid currencies are included or not.

[17]These countries are Australia, Belgium, Canada, Denmark, Euro area, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom.

6. Conclusion

We have empirically investigated momentum strategies in FX markets, which rely on return continuation among winner and loser currencies. We find that these momentum strategies yield surprisingly high unconditional average excess returns of up to 10% per year and that these returns are hard to understand in a framework that relies on covariance risk with standard risk factors. In contrast to an explanation based on conventional risk premia, we find evidence for under- and subsequent over-reaction in long-horizon momentum returns. In this sense, the evidence for currency momentum seems very similar to what has been found for equity markets in earlier literature.

We also find that momentum returns are very different from the popular carry trade in FX markets. Hence, it comes as no surprise that momentum is not well captured by the global factors that have been shown to be related to carry trade returns in the earlier literature. Rather, it suggests that momentum and the carry trade are different phenomena which require a different explanation.

However, currency momentum returns do not come as a free lunch for investors trying to exploit these strategies. We find that momentum portfolios in the FX market are significantly skewed towards minor currencies which have relatively high transaction costs, accounting for roughly 50% of momentum returns. Also, the concentration of minor currencies in momentum portfolios raises the need to set up trading positions in currencies with higher idiosyncratic volatility, higher country risk, and higher expected risk of exchange rate instabilities, which clearly imposes risks to investors that are not captured by standard risk factors in a covariance risk framework. Hence, there seem to be effective limits to arbitrage which prevent a straightforward exploitation of momentum returns. Furthermore, momentum profits are highly time-varying, which may also limit arbitrage activity for investors with short-term horizons (e.g. proprietary traders and hedge funds), who account for the bulk of FX market participants.

Seen from a broader perspective, momentum is a popular investment strategy in financial markets as it shows up in stocks (Jegadeesh and Titman, 1993, 2001), foreign exchange markets (Okunev and White, 2003; Asness, Moskowitz, and Pedersen, 2009), and (corporate) bonds (Jostova, Nikolova, Philipov, and Stahel, 2010). A main contribution of this research is to show that momentum strategies deliver high excess returns in foreign exchange markets, comparable in magnitude to the excess returns documented in stock markets. This occurs despite the special characteristics of currency markets, such as huge trading volume, mostly professional traders, and no short-selling constraints. However, these returns stem primarily from currencies that are hard to hedge and have high country risk, which is similar to the fact that equity momentum is concentrated in stocks with high credit risk (Avramov, Chordia, Jostova, and Philipov, 2007), and momentum in corporate bonds is concentrated in non-investment grade bonds (Jostova, Nikolova, Philipov, and Stahel, 2010). In sum, these findings suggest that there may be a common source of momentum profits across asset classes.

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Table 1. Momentum returns

This table shows annualized average returns for different momentum strategies ($\overline{r^{f,h}}$). The rows show formation periods (f) whereas the columns indicate holding periods (h). The formation and holding period can be $1, 3, 6, 9$, or 12 months, respectively. Numbers in brackets are t-statistics based Newey-West HAC standard errors. The left part of the table shows currency excess returns (spot rate changes adjusted for interest rate differentials) whereas the right part shows pure spot rate returns. The sample period is January 1976 – January 2010 and we employ monthly returns.

	Excess returns (without b/a)						Spot rate changes (without b/a)				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	9.46	7.00	6.17	5.15	5.75	1	7.91	4.42	3.38	4.75	3.13
	[5.31]	[4.11]	[3.13]	[2.73]	[3.6]		[4.55]	[3.07]	[1.93]	[2.94]	[2.02]
3	9.40	6.32	4.96	4.67	4.43	3	8.54	5.73	5.28	4.63	5.10
	[5.30]	[3.80]	[3.03]	[2.92]	[2.74]		[5.10]	[3.59]	[3.66]	[2.88]	[3.51]
6	8.54	6.31	3.66	3.25	3.14	6	6.50	5.75	3.47	3.64	3.17
	[4.78]	[3.63]	[2.06]	[1.79]	[1.69]		[3.88]	[4.00]	[2.15]	[2.32]	[1.80]
9	7.18	6.80	5.36	3.86	3.24	9	8.33	7.06	6.50	4.91	4.09
	[3.80]	[3.65]	[2.86]	[2.05]	[1.67]		[4.82]	[4.23]	[3.91]	[2.87]	[2.35]
12	6.16	5.48	3.02	2.05	1.89	12	7.59	6.04	3.94	3.19	3.03
	[3.40]	[3.24]	[1.75]	[1.17]	[1.04]		[4.63]	[4.02]	[2.59]	[1.97]	[1.92]

Table 2. Comparing momentum and carry trade portfolios

This Table shows descriptive statistics for six momentum (Panel A) and six carry trade portfolios (Panel B). Currencies are sorted into six portfolios depending on their lagged one month excess return rx_{-1} (momentum portfolios) or their lagged forward discount $(f-s)_{-1}$ (carry trade portfolios). The 1/6 (16.67%) of all currencies with the lowest lagged excess return (or forward discount) are allocated to portfolio "Low", whereas the 1/6 of all currencies with the highest lagged excess returns (or forward discounts) are allocated to portfolio "High". Portfolios $2-5$ each consist of 1/6 of all currencies and have increasingly higher lagged excess returns (or forward discounts). Portfolios are rebalanced monthly. We also report results for an the average of all six portfolios ("Av.") and a portfolio that is long in portfolio "High" and short in portfolio "Low" ("H–L"). Shown are average annualized excess returns, the standard deviation, skewness, and kurtosis of excess returns. The last two rows of each panel show average lagged excess returns $\overline{rx}_{-1}$ and forward discounts $(\overline{f-s})_{-1}$ for currencies in each portfolio at the time of portfolio formation. Also shown are average returns across the six portfolios ("Av.") and the difference between the "High" and "Low" portfolios ("H-L"). The sample period is Januar 1976 – January 2010.

	Panel A: Momentum Portfolios ($f=1$, $h=1$)							
	Low	2	3	4	5	High	Av.	H–L
Mean	-4.17	-0.87	0.27	2.25	2.08	5.28	0.81	9.46
	[-2.36]	[-0.49]	[0.16]	[1.31]	[1.25]	[2.94]	[0.53]	[5.26]
Stand. Dev.	2.88	2.57	2.61	2.57	2.64	2.64	2.28	2.87
Skewness	-0.27	-0.79	-0.32	-0.26	-0.58	-0.29	-0.42	0.06
Kurtosis	5.97	6.38	4.45	4.61	6.78	4.49	4.48	5.29
$\overline{rx}_{-1}$	-2.93	-1.03	-0.23	0.42	1.21	2.94		
$(\overline{f-s})_{-1}$	0.44	0.75	1.17	1.34	1.93	5.13		
	Panel B: Carry Trade Portfolios							
	Low	2	3	4	5	High	Av.	H–L
Mean	-3.39	-1.41	0.24	1.32	2.04	6.77	0.93	10.15
	[-1.94]	[-0.93]	[0.15]	[0.81]	[1.17]	[3.22]	[0.61]	[5.79]
Stand. Dev.	2.71	2.39	2.39	2.49	2.64	2.98	2.28	2.64
Skewness	-0.21	-0.42	-0.28	-0.37	-0.75	-0.35	-0.37	-0.69
Kurtosis	4.85	4.34	5.58	5.12	5.84	4.33	4.34	4.20
$\overline{rx}_{-1}$	-0.32	-0.11	0.01	0.13	0.23	0.52		
$(\overline{f-s})_{-1}$	-4.81	-1.79	0.02	1.59	4.02	11.65		

Table 3. Correlation of momentum and carry trade returns

This Table shows correlation coefficients between portfolio returns. Panel A shows correlation coefficients between momentum returns based on strategies with formation horizons of f equal to one, six, and twelve months and holding periods of $h = 1$ month (denoted $MOM_{1,1}, MOM_{6,1}, MOM_{12,1}$, respectively) and forward discount-sorted portfolio returns (denoted C since they form the basis of the carry trade). Returns are based on six portfolios and a long-short portfolio for both momentum and the carry trade. We only report correlations for corresponding pairs of portfolios. For example, in row $\rho(M_{1,1}, C)$ we report the correlation of the "Low" momentum portfolio with the "Low" carry trade portfolio in column "Low", the correlation of the third momentum portfolio with the third carry trade portfolio, and so on for all six portfolios and the long-short portfolios. Row $\rho(M_6, C)$ shows the correlations between portfolios pairs of the momentum strategy with a six months formation period with the carry trade and row $\rho(M_{12}, C)$ shows the correlations between portfolio pairs of the twelve months formation period momentum strategy and the carry trade. Panel B shows correlations for momentum portfolios with different formation horizons.

Panel A: Momentum and carry trade portfolios							
	Low	2	3	4	5	High	H–L
$\rho(MOM_{1,1}, C)$	0.68	0.84	0.83	0.85	0.81	0.73	0.04
$\rho(MOM_{6,1}, C)$	0.63	0.84	0.82	0.83	0.81	0.74	0.01
$\rho(MOM_{12,1}, C)$	0.67	0.85	0.81	0.87	0.82	0.74	0.07
Panel B: Momentum portfolios							
	Low	2	3	4	5	High	H–L
$\rho(MOM_{1,1}, MOM_{6,1})$	0.77	0.83	0.88	0.85	0.83	0.79	0.45
$\rho(MOM_{1,1}, MOM_{12,1})$	0.66	0.81	0.86	0.87	0.80	0.78	0.28
$\rho(MOM_{6,1}, MOM_{12,1})$	0.82	0.89	0.89	0.89	0.91	0.89	0.73

Table 4. Double sorts

This Table shows annualized mean excess returns for double-sorted portfolios. All currencies in the sample are first sorted on lagged forward discounts (FD) into two portfolios along the median. Next, currencies within each of the two subgroups are allocated into three momentum portfolios depending on their lagged excess returns over $f = 1, 6$, or 12 months. Hence, row FD_L denotes the 50% of all currencies with the lowest (lagged) forward discount whereas FD_H denotes the 50% of all currencies with the highest (lagged) forward discounts. Columns M_L, M_M, and M_H denote the 33% of all currencies with the lowest, intermediate, and the highest(lagged) returns, respectively. Columns $\triangle_M$ shows the return difference between high and low momentum portfolios ($M_H - M_L$) for each subgroup of currencies whereas e.g. $\triangle_{FD}$ shows the return difference between the forward discount-sorted portfolios for each momentum subgroup. The lower-right cell in each sub-panel shows the return difference between the two momentum "high minus low" portfolios of each forward discount category. We report annualized excess returns in percent for each portfolio and all high-minus-low portfolios. Numbers in brackets are HAC t-statistics and the sample runs from January 1976 – January 2010.

Carry Trade and Momentum												
	$f = 1, h = 1$				$f = 6, h = 1$				$f = 12, h = 1$			
	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$
FD_L	-4.52	-0.90	0.54	5.06	-4.40	-0.35	0.06	4.46	-3.94	-0.40	0.09	4.04
	[-2.90]	[-0.55]	[0.34]	[3.81]	[-2.81]	[-0.21]	[0.04]	[3.63]	[-2.34]	[-0.24]	[0.06]	[2.86]
FD_H	0.64	3.20	6.00	5.36	2.38	2.43	6.34	3.96	2.86	3.21	5.98	3.12
	[0.34]	[1.68]	[3.18]	[3.30]	[1.14]	[1.45]	[3.29]	[2.43]	[1.49]	[1.80]	[3.10]	[2.02]
$\triangle_{FD}$	5.16	4.10	5.45	0.30	6.77	2.78	6.27	-0.50	6.80	3.61	5.89	-0.91
	[4.00]	[3.43]	[3.89]	[0.17]	[4.33]	[2.57]	[4.58]	[-0.26]	[4.71]	[3.22]	[4.56]	[-0.49]

Table 5. Cross-sectional regressions

This Table shows results for cross-sectional regressions of individual currencies' excess returns (left part) or spot rate changes (right part) on lagged excess returns, lagged forward discounts, and/or lagged spot rate changes. Numbers in parentheses are standard errors of the cross-sectional R^2s. For ease of interpretation we have multiplied spot rate changes by minus one so that higher values indicate an appreciation of the foreign currency against the USD.

Panel A: One month									
Dependent: Excess returns					Dependent: Spot rate changes				
const.	rx	$f-s$	Δs	R^2	const.	rx	$f-s$	Δs	R^2
-0.02	0.16			0.15	-0.16	0.08			0.13
[-0.17]	[5.65]			(0.01)	[-1.52]	[2.95]			(0.01)
0.00		0.63		0.14	0.00		-0.37		0.09
[0.01]		[4.87]		(0.01)	[0.01]		[-2.89]		(0.01)
0.02			0.13	0.13	-0.16			0.13	0.14
[0.22]			[4.46]	(0.01)	[-1.59]			[4.55]	(0.01)
-0.07	0.12	0.57		0.26	-0.07	0.12	-0.43		0.20
[-0.76]	[4.42]	[4.68]		(0.01)	[-0.76]	[4.42]	[-3.52]		(0.01)
-0.07		0.68	0.14	0.26	-0.07		-0.32	0.14	0.21
[-0.72]		[5.89]	[4.82]	(0.01)	[-0.72]		[-2.83]	[4.82]	(0.01)
Panel B: Six months									
0.06	0.30			0.17	-0.05	0.15			0.15
[0.57]	[5.65]			(0.01)	[-0.46]	[3.07]			(0.01)
0.04		0.46		0.13	0.04		-0.52		0.09
[0.33]		[2.98]		(0.01)	[0.31]		[-3.33]		(0.01)
0.12			0.19	0.14	-0.03			0.25	0.15
[1.20]			[3.24]	(0.01)	[-0.30]			[4.87]	(0.01)
0.08	0.21	0.36		0.27	0.07	0.23	-0.64		0.24
[0.82]	[3.89]	[2.36]		(0.02)	[0.82]	[4.39]	[-4.20]		(0.01)
0.06		0.57	0.23	0.27	0.07		-0.41	0.23	0.24
[0.71]		[4.01]	[4.27]	(0.02)	[0.77]		[-2.90]	[4.33]	(0.01)
Panel C: Twelve months									
-0.05	0.28			0.16	-0.17	0.12			0.15
[-0.52]	[3.97]			(0.01)	[-1.66]	[1.79]			(0.01)
0.04		0.42		0.12	0.03		-0.51		0.09
[0.36]		[2.66]		(0.01)	[0.29]		[-3.22]		(0.01)
0.03			0.20	0.14	-0.05			0.32	0.14
[0.24]			[2.45]	(0.01)	[-0.47]			[4.52]	(0.01)
-0.06	0.20	0.28		0.25	-0.06	0.25	-0.66		0.24
[-0.66]	[2.58]	[1.74]		(0.01)	[-0.62]	[3.21]	[-4.06]		(0.01)
-0.04		0.48	0.24	0.25	-0.04		-0.42	0.27	0.24
[-0.47]		[3.21]	[3.14]	(0.01)	[-0.42]		[-2.70]	[3.41]	(0.01)

Table 6. Momentum returns after transaction costs

This table shows annualized average returns for different momentum strategies ($\overline{r^{f,h}}$) after adjusting for bid-ask spreads. The rows show formation periods (f) whereas the columns indicate holding periods (h). The formation and holding period can be $1, 3, 6, 9$, or 12 months, respectively. Numbers in brackets are t-statistics based Newey-West standard errors. The left part of the table shows net currency excess returns (spot rate changes adjusted for interest rate differentials) whereas the right part shows net spot rate returns. The sample period is January 1976 – January 2010 and we employ monthly returns.

	Net excess returns						Net spot rate changes				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	3.92	2.02	1.26	0.38	0.39	1	4.84	3.36	2.69	4.43	2.53
	[2.20]	[1.16]	[0.61]	[0.18]	[0.20]		[2.81]	[2.37]	[1.57]	[2.76]	[1.65]
3	4.41	2.12	0.88	0.97	-0.07	3	6.80	4.58	4.72	4.33	4.86
	[2.39]	[1.20]	[0.53]	[0.58]	[-0.04]		[3.99]	[2.81]	[3.18]	[2.58]	[3.32]
6	3.86	2.12	-0.27	-0.92	-1.28	6	5.06	4.83	3.06	3.27	3.29
	[2.09]	[1.19]	[-0.15]	[-0.49]	[-0.67]		[3.03]	[3.37]	[1.94]	[2.08]	[1.88]
9	2.48	2.43	0.99	-0.40	-1.06	9	7.53	6.73	6.19	4.81	3.84
	[1.26]	[1.27]	[0.51]	[-0.21]	[-0.54]		[4.34]	[4.00]	[3.69]	[2.88]	[2.20]
12	1.40	0.80	-1.46	-1.98	-2.44	12	6.65	5.53	3.75	2.92	2.77
	[0.74]	[0.45]	[-0.84]	[-1.11]	[-1.31]		[4.01]	[3.66]	[2.47]	[1.79]	[1.73]

Table 7. Momentum returns with effective spreads of 75% and 50%

This table reports transaction cost adjusted excess returns with effective spreads of 75% (Panel A) and 50% (Panel B) of the quoted spread, respectively. The table setup is the same as in Table 1 but we only show results for excess returns (and not for spot rate changes). The sample period is January 1976 – January 2010 and we employ monthly returns.

	Panel A: Effective spread of 75%						Panel B: Effective spread of 50%				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	5.28	3.24	2.51	1.53	1.69	1	6.64	4.47	3.77	2.69	3.00
	[2.98]	[1.89]	[1.25]	[0.76]	[0.88]		[3.76]	[2.62]	[1.89]	[1.36]	[1.61]
3	5.61	3.16	1.86	1.85	0.97	3	6.81	4.20	2.83	2.74	2.00
	[3.07]	[1.82]	[1.12]	[1.12]	[0.59]		[3.76]	[2.45]	[1.72]	[1.68]	[1.23]
6	5.03	3.17	0.70	0.15	-0.18	6	6.20	4.23	1.68	1.21	0.92
	[2.76]	[1.80]	[0.39]	[0.08]	[-0.10]		[3.43]	[2.41]	[0.94]	[0.66]	[0.49]
9	3.66	3.56	2.16	0.68	0.08	9	4.85	4.69	3.33	1.75	1.24
	[1.89]	[1.89]	[1.13]	[0.35]	[0.04]		[2.53]	[2.52]	[1.76]	[0.93]	[0.64]
12	2.60	1.97	-0.35	-0.94	-1.36	12	3.80	3.13	0.78	0.09	-0.28
	[1.39]	[1.12]	[-0.20]	[-0.53]	[-0.74]		[2.07]	[1.81]	[0.45]	[0.05]	[-0.15]

Table 8. Macro risk

This Table shows time-series regression estimates of currency momentum returns (long-short portfolios $MOM_{1,1}$, $MOM_{6,1}$, and $MOM_{12,1}$) on various macro factors and other risk factors. Consumption is real consumption growth, Employment denotes U.S. total nonfarm employment growth, ISM denotes the ISM manufacturing index, IP denotes growth in real industrial production, CPI denotes the inflation rate, M2 is the growth in real money balances, Disp Inc is growth in real disposable personal income, TED denotes the TED spread, Term denotes the term spread (20 years minus 3 months), HML_{FX} is the return to the carry trade long-short portfolio (Lustig, Roussanov, and Verdelhan, 2011), and VOL_{FX} is a proxy for global FX volatility (Menkhoff, Sarno, Schmeling, and Schrimpf, 2011). MKTRF, HML, and SMB are the Fama-French factors and UMD denotes the return to a long-short U.S. momentum portfolio. Panel A shows results for univariate regressions (intercepts α, slope coefficients β, and the adjusted R^2) whereas the Panel B shows results from a multivariate regression of momentum returns on the three Fama-French factors and UMD. Bold numbers indicate significance at the 5%-level or below.

Panel A: Univariate regressions

	$MOM_{1,1}$			$MOM_{6,1}$			$MOM_{12,1}$		
	α	β	R^2	α	β	R^2	α	β	R^2
Consumption	**9.65**	-0.05	0.00	**8.95**	-0.12	0.00	**6.03**	0.07	0.00
Employment	**10.57**	-0.72	0.00	**7.74**	0.62	0.00	**5.86**	0.23	0.00
ISM	**9.46**	0.04	0.00	**8.60**	0.03	0.00	**6.14**	0.04	0.00
IP	**9.72**	0.11	0.00	**8.72**	0.04	0.00	**6.26**	0.03	0.00
CPI	**11.73**	-0.55	0.00	**9.11**	-0.12	0.00	**6.60**	-0.10	0.00
M2	**9.97**	0.34	0.00	**8.68**	0.02	0.00	**6.18**	-0.01	0.00
Disp Inc	**9.33**	0.07	0.00	**8.42**	0.10	0.00	**5.95**	0.10	0.00
TED	**13.64**	**-0.38**	0.01	**11.95**	-0.30	0.01	**9.73**	-0.32	0.01
Term	4.48	**0.22**	0.01	**7.54**	0.05	0.00	5.05	0.05	0.00
HML_{FX}	**9.50**	0.04	0.00	**8.65**	0.02	0.00	**6.21**	0.08	0.00
VOL_{FX}	**11.70**	-0.44	0.00	**18.75**	-2.04	0.01	**27.59**	**-4.29**	0.04

Panel B: Multivariate regressions

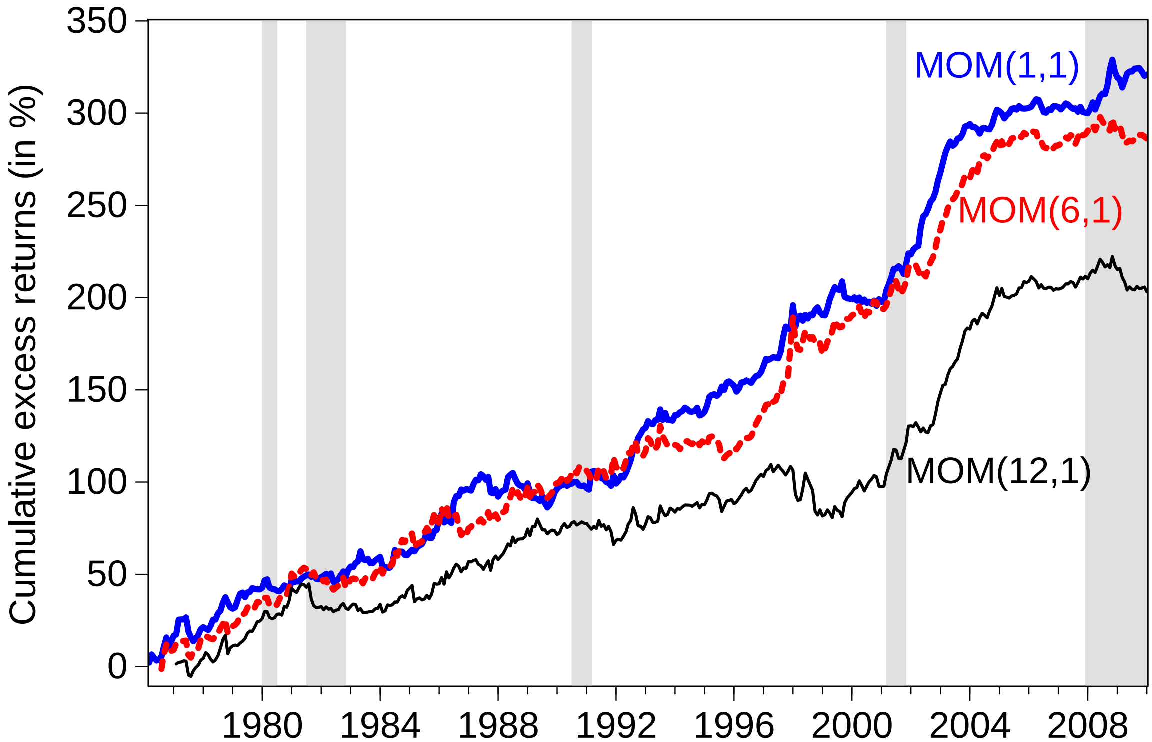
	$MOM_{1,1}$			$MOM_{6,1}$			$MOM_{12,1}$		
	α	β	R^2	α	β	R^2	α	β	R^2
MKTRF	**8.73**	0.00	0.00	**8.02**	0.04	0.00	**5.16**	0.02	0.00
SMB		0.97			-0.54			0.71	
HML		0.06			0.01			0.06	
UMD		0.02			0.03			0.04	

Table 9. Double sorts on idiosyncratic volatility or risk ratings and momentum

The setup of this Table is identical to Table 4 but here we sort on idiosyncratic volatility and momentum (Panel A), country risk and momentum (Panel B), and exchange rate stability risk and momentum (Panel C).

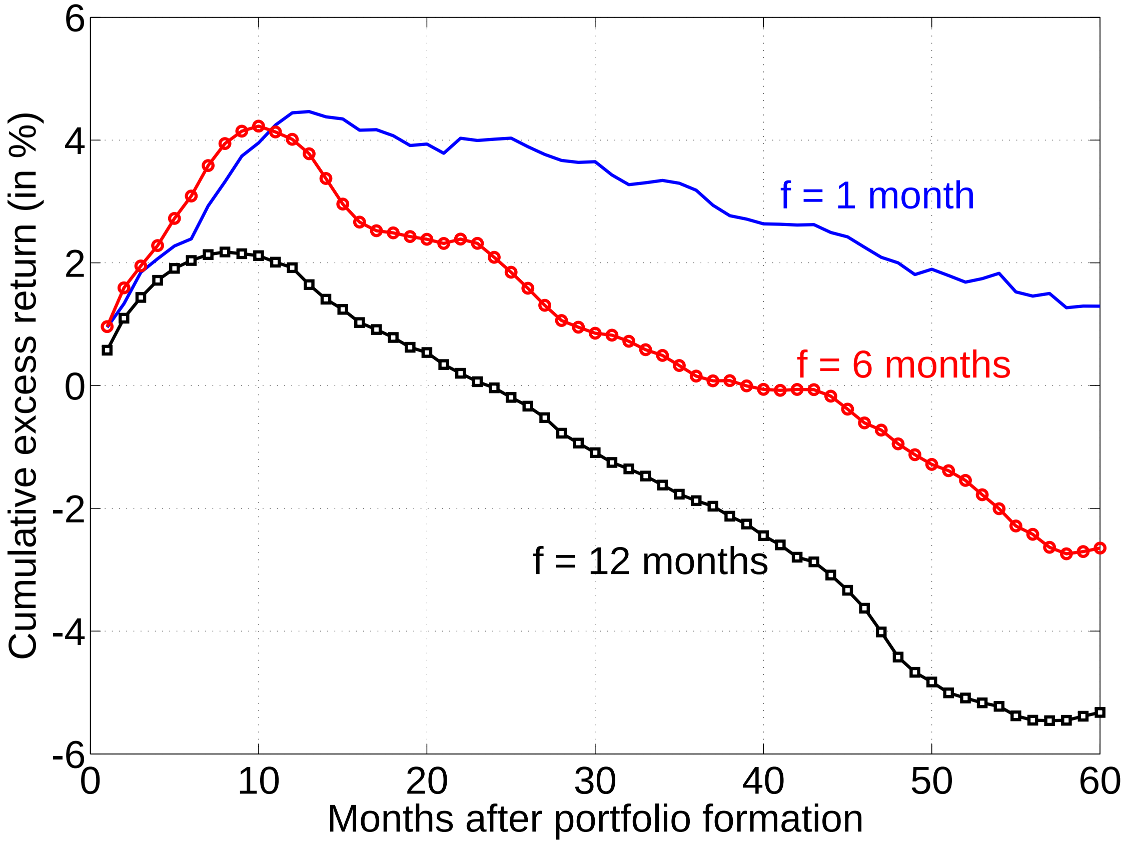
	$f=1,h=1$				$f=6,h=1$				$f=12,h=1$			
Panel A: Idiosyncratic Volatility and Momentum												
	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$
$IVOL_L$	-1.04	0.92	2.93	3.97	-0.85	1.08	2.82	3.67	0.15	1.13	2.27	2.12
	[-0.65]	[0.55]	[1.75]	[2.81]	[-0.50]	[0.66]	[1.79]	[3.04]	[0.10]	[0.67]	[1.31]	[1.58]
$IVOL_H$	-3.52	1.00	4.57	8.09	-2.22	0.24	4.77	6.99	-0.78	0.20	4.38	5.16
	[-1.83]	[0.57]	[2.48]	[4.72]	[-1.16]	[0.14]	[2.44]	[4.28]	[-0.41]	[0.11]	[2.30]	[3.01]
$\triangle_{IVOL}$	-2.48	0.07	1.64	4.11	-1.38	-0.84	1.95	3.33	-0.93	-0.94	2.11	3.04
	[-1.86]	[0.07]	[1.28]	[2.18]	[-1.15]	[-0.86]	[1.52]	[2.05]	[-0.80]	[-0.89]	[1.63]	[1.79]
Panel B: Country Risk and Momentum												
	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$
$CRISK_L$	0.01	3.41	4.51	4.50	0.95	3.14	4.26	3.31	1.65	3.24	3.86	2.21
	[0.01]	[1.78]	[2.52]	[3.12]	[0.49]	[1.67]	[2.33]	[2.67]	[0.80]	[1.67]	[2.10]	[1.51]
$CRISK_H$	-0.67	3.82	8.04	8.72	0.89	3.39	7.24	6.35	2.58	2.70	8.65	6.07
	[-0.34]	[1.90]	[3.72]	[4.19]	[0.40]	[1.94]	[3.24]	[2.92]	[1.29]	[1.43]	[3.56]	[2.34]
$\triangle_{CRISK}$	-0.68	0.41	3.53	4.22	-0.06	0.25	2.97	3.04	0.93	-0.54	3.79	3.87
	[-0.46]	[0.35]	[2.21]	[2.12]	[-0.04]	[0.20]	[2.02]	[1.72]	[0.54]	[-0.45]	[2.61]	[1.93]
Panel C: Exchange Rate Stability Risk and Momentum												
	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$	M_L	M_M	M_H	$\triangle_M$
$XSTAB_L$	1.27	0.15	3.25	1.98	1.56	0.30	3.60	2.04	0.80	1.40	3.22	2.42
	[0.83]	[0.10]	[2.17]	[1.39]	[0.96]	[0.23]	[2.32]	[1.31]	[0.50]	[1.04]	[2.15]	[1.70]
$XSTAB_H$	-0.48	4.04	6.09	6.56	0.51	3.35	6.06	5.55	1.58	3.38	6.36	4.78
	[-0.24]	[2.02]	[3.09]	[4.06]	[0.24]	[1.77]	[2.93]	[3.31]	[0.77]	[1.80]	[3.12]	[2.50]
$\triangle_{XSTAB}$	-1.75	3.89	2.84	4.59	-1.05	3.05	2.47	3.51	0.78	1.98	3.14	2.35
	[-1.06]	[2.47]	[1.58]	[2.44]	[-0.59]	[2.01]	[1.31]	[1.70]	[0.43]	[1.21]	[1.82]	[1.11]

Figure 1. Cumulative excess returns of momentum strategies



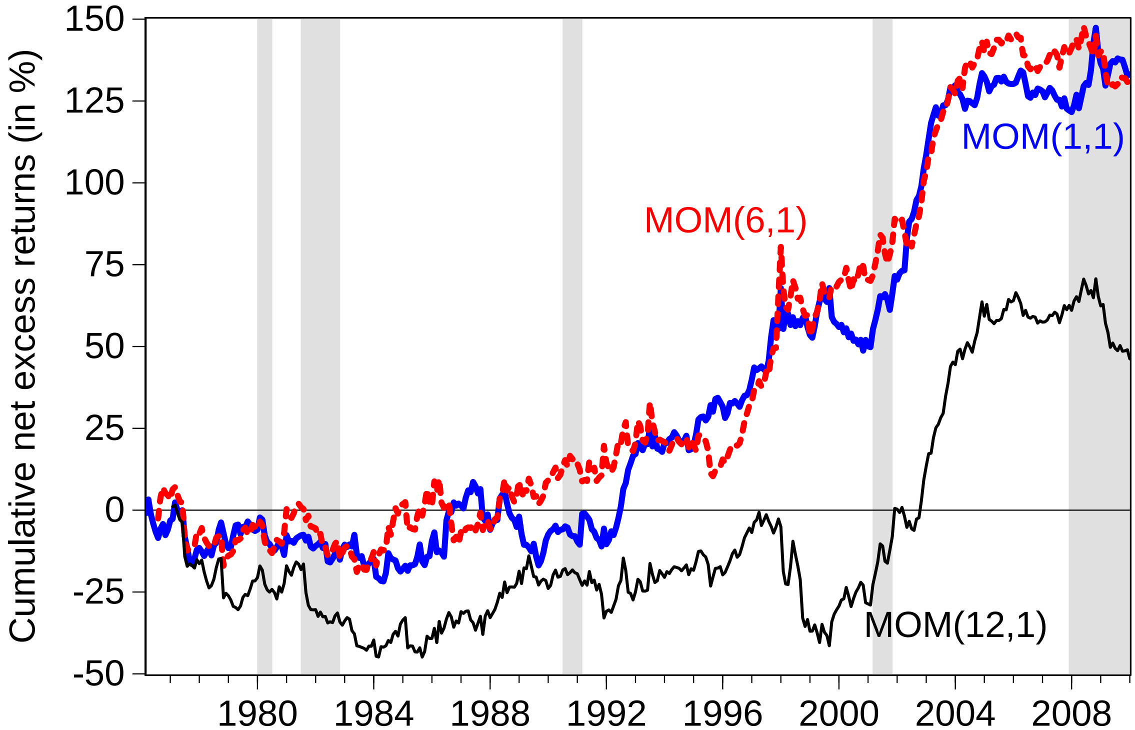
This figure shows cumulative log excess returns (not adjusted for transaction costs) accruing to three different momentum returns. The momentum strategies are for a formation period of 1, 6, and 12 months, respectively, and the holding period is one month. The bold, blue line shows returns to the momentum strategy with a one month formation period (MOM(1,1) in the figure), the dashed, red line shows returns to a strategy with a six months formation period (MOM(6,1)), whereas the thin, black line shows returns to a momentum strategy with a twelve months formation period (MOM(12,1)). Shaded areas correspond to NBER recessions.

Figure 2. Long-horizon momentum excess returns



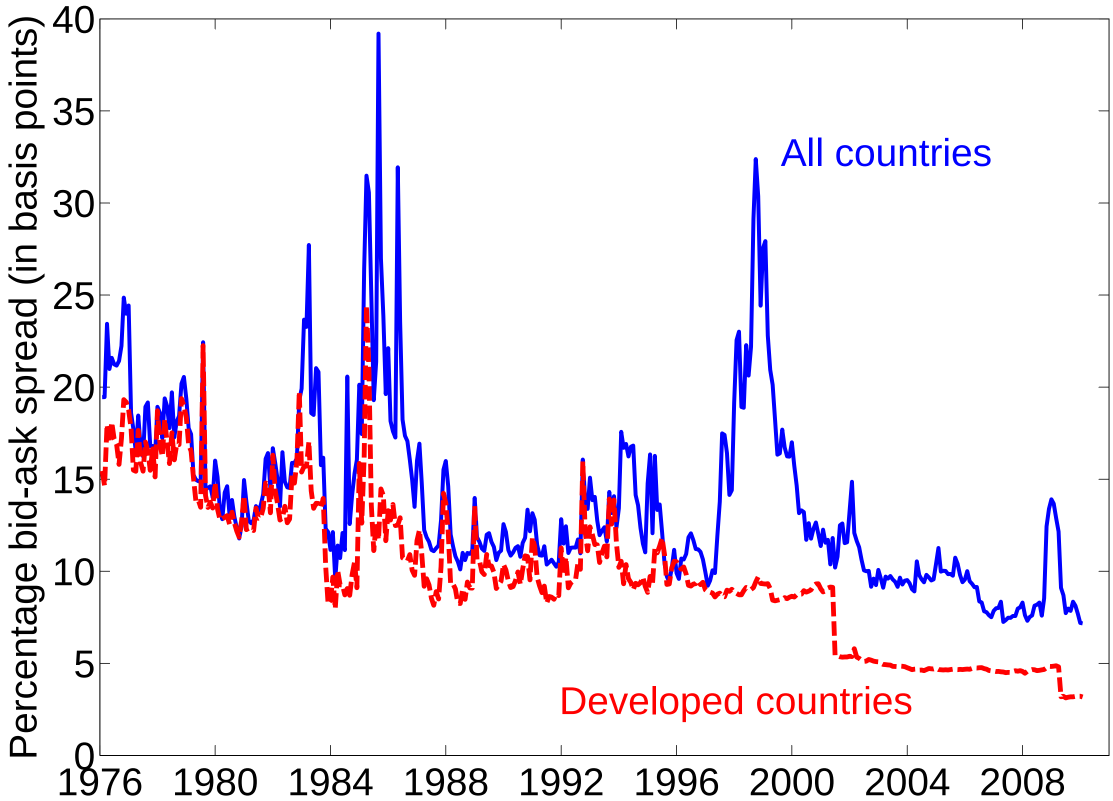
This figure shows cumulative average excess returns to three different long-short currency momentum portfolios after portfolio formation. Momentum portfolios differ in their formation period ($f = 1, 6, 12$ months) and post-formation returns are shown for $1, 2, \ldots, 60$ months following the formation period (i.e. we build new portfolios each months but track these portfolios for the first 60 months after their formation so that we are effectively using overlapping horizons). Excess returns are monthly and the sample period is 1976:1 – 2010:1.

Figure 3. Cumulative net excess returns of momentum strategies



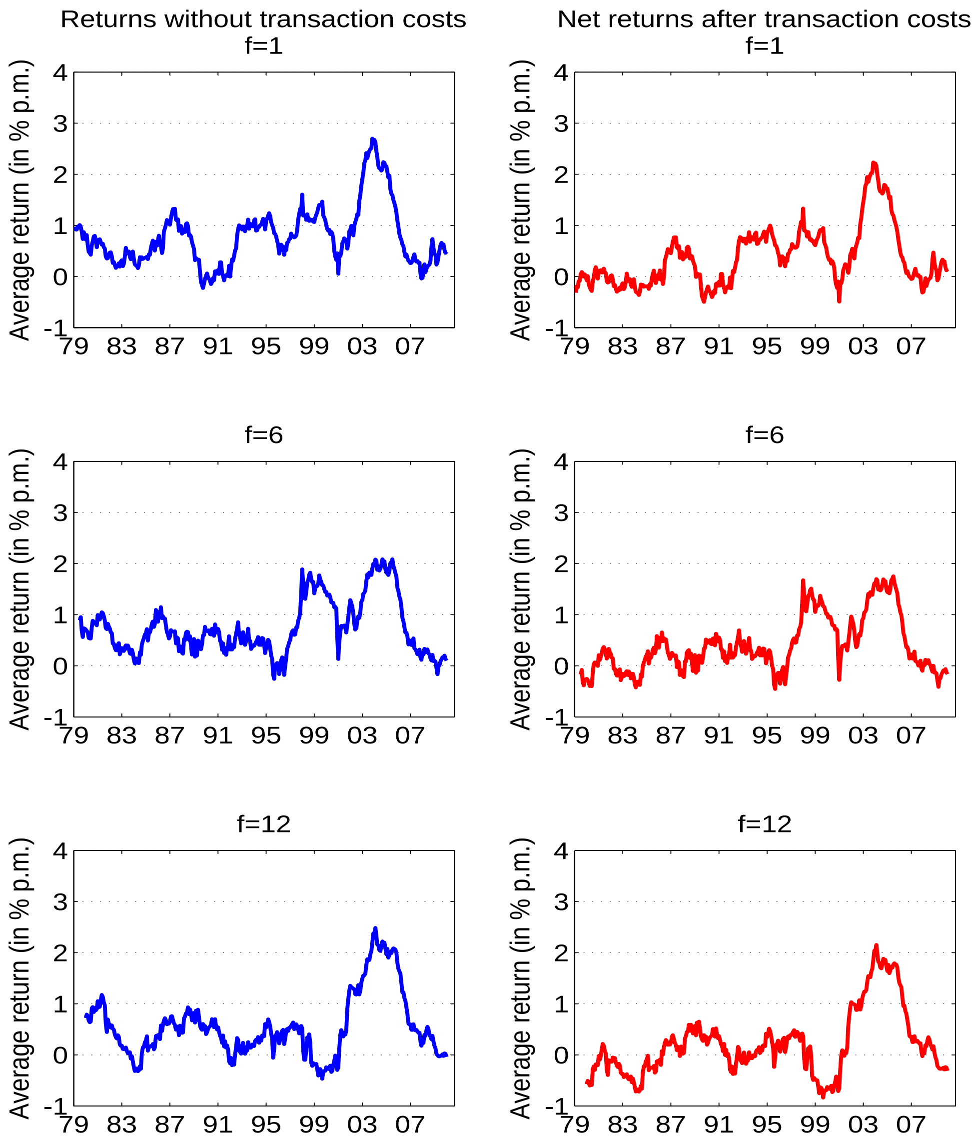
This figure shows cumulative log excess returns adjusted for transaction costs accruing to three different momentum returns. The momentum strategies are for a formation period of $1, 6$, and 12 months, respectively, and the holding period is one month. The bold, blue line shows returns to the momentum strategy with a one month formation period (MOM(1,1) in the figure), the dashed, red line shows returns to a strategy with a six months formation period (MOM(6,1)), whereas the thin, black line shows returns to a momentum strategy with a twelve months formation period (MOM(12,1)). Shaded areas correspond to NBER recessions.

Figure 4. Bid-ask spreads over time



This figure shows percentage bid-ask spreads in basis points for the sample period from 1976:1 to 2010:1. The blue solid line shows average spreads for all countries whereas the red dashed line shows spreads for a subset of 15 developed countries. Shown are the average bid-ask spread across countries in a given month and we include both bid-ask spreads between spot rates as well as 1-month forward rates.

Figure 5. Rolling average returns for three momentum strategies



This figure shows average monthly excess returns over rolling windows of 36 months for three long-short momentum strategies: $MOM_{1,1}, MOM_{6,1}$ and $MOM_{12,1}$ where $MOM_{j,h}$ denotes the return difference between a portfolio long in currencies with the highest lagged excess returns (measured over the last f months) and a portfolio short in currencies with the lowest excess return over the last f months. Portfolios are held for $h = 1$ month and we use excess returns without transaction costs (left part of the table) and net excess returns adjusted for transaction costs (right part). The sample runs from 1976:1 to 2010:1.

Appendix to accompany

Currency Momentum Strategies

Table A.1. Descriptive statistics: Individual currencies

This table shows descriptive statistics for individual currencies. Means and standard deviations for excess returns and forward discounts are annualized and in percent. Bid-ask spreads are in basis points. The sample period runs from January 1976 to January 2010.

	Sample		Excess returns		Forward discounts				Spreads	
Country	Start	End	mean	std	mean	std	max	min	mean	std
Australia	1984.12	2010.01	0.28	3.35	0.26	0.25	1.37	-0.57	12.92	6.47
Austria	1976.01	1998.12	-0.16	3.33	-0.32	0.28	0.54	-1.70	26.12	19.76
Belgium	1976.01	1998.12	-0.07	3.38	-0.10	0.33	2.23	-1.19	21.67	7.70
Brazil	2004.03	2010.01	1.45	4.49	0.81	0.35	0.69	-0.98	14.43	5.30
Bulgaria	2004.03	2010.01	0.24	3.12	0.06	0.19	1.17	-0.64	6.20	2.08
Canada	1976.01	2010.01	0.02	1.89	0.03	0.21	3.05	-0.35	7.60	2.44
Croatia	2004.03	2010.01	0.42	3.09	0.21	0.31	2.72	-1.12	17.93	6.74
Cyprus	2004.03	2007.12	0.43	2.05	0.01	0.17	1.77	-2.77	21.94	9.54
Czech Rep.	1997.01	2010.01	0.38	3.73	0.13	0.40	1.91	-0.85	13.80	9.41
Denmark	1976.01	2010.01	0.15	3.16	0.12	0.32	0.16	-0.55	13.12	6.92
Egypt	2004.03	2010.01	0.82	0.95	0.64	0.51	0.55	-1.52	43.86	18.60
Euro	1999.01	2010.01	0.12	3.03	-0.03	0.13	1.96	-0.95	4.99	1.83
Finland	1997.01	1998.12	-0.38	2.56	-0.19	0.03	1.93	-0.92	10.44	2.69
France	1976.01	1998.12	0.03	3.15	0.11	0.37	0.54	-1.07	14.31	10.80
Germany	1976.01	1998.12	-0.06	3.31	-0.22	0.34	1.80	-0.89	16.64	14.46
Greece	1997.01	2000.12	-0.31	3.12	0.41	0.25	-0.14	-0.25	11.17	5.69
Hong Kong	1983.1	2010.01	-0.01	0.21	-0.02	0.13	0.59	-2.04	4.10	6.98
Hungary	1997.1	2010.01	0.58	3.92	0.58	0.30	0.86	-0.60	16.74	7.87
Iceland	2004.03	2010.01	-0.20	5.77	0.60	0.20	21.51	-1.88	17.80	18.70
India	1997.1	2010.01	0.11	1.71	0.28	0.20	1.02	-1.80	10.34	8.01
Indonesia	1997.01	2010.01	-0.46	9.56	0.42	3.36	1.21	-1.11	61.67	80.27
Ireland	1976.01	1998.12	-0.31	2.72	0.08	0.24	3.34	-0.28	20.85	21.23
Israel	2004.03	2010.01	0.32	2.69	0.04	0.10	1.19	-0.15	18.67	6.42
Italy	1976.01	1998.12	0.14	3.11	0.42	0.39	1.38	0.07	18.61	11.56
Japan	1978.06	2010.01	-0.09	3.40	-0.30	0.27	1.02	-0.18	12.12	9.68
Kuwait	1997.01	2010.01	0.09	0.58	0.06	0.12	11.19	-17.43	11.45	16.30
Malaysia	1997.01	2010.01	-0.16	4.11	0.04	0.25	0.73	-0.23	6.66	9.84
Mexico	1997.01	2010.01	0.43	2.82	0.75	0.54	1.56	-0.32	9.56	8.47
Netherl.	1976.01	1998.12	-0.04	3.30	-0.16	0.29	2.81	0.14	17.06	16.45
New Z.	1984.12	2010.01	0.52	3.54	0.39	0.40	1.97	-0.03	22.15	15.67
Norway	1976.01	2010.01	0.14	2.94	0.15	0.37	0.72	-0.12	13.41	8.66
Philippines	1997.01	2010.01	0.08	2.85	0.44	0.33	7.62	-0.79	34.78	28.12
Poland	2002.02	2010.01	0.62	4.26	0.22	0.22	0.24	-0.27	14.18	4.60
Portugal	1976.01	1998.12	-0.05	3.36	0.74	1.03	0.34	-0.89	156.33	162.70
Russia	2004.03	2010.01	0.30	2.87	0.39	0.87	3.45	-1.15	6.83	3.23
S. Africa	1983.1	2010.01	0.55	5.19	1.15	2.30	1.00	-0.90	51.61	85.08

Table A.1. *(continued)*

	Sample		Excess returns		Forward discounts				Spreads	
Country	Start	End	mean	std	mean	std	max	min	mean	std
S. Korea	2002.02	2010.01	0.18	3.84	0.05	0.20	4.51	-0.20	17.56	18.83
Saudi A.	1997.01	2010.01	0.01	0.13	0.01	0.06	1.46	0.00	2.53	3.69
Singapore	1984.12	2010.01	0.02	1.53	-0.13	0.19	2.02	0.10	18.06	18.92
Slovakia	2002.02	2010.01	0.96	3.46	0.12	0.23	4.42	-0.27	14.48	5.38
Slovenia	2004.03	2006.12	0.25	2.21	0.02	0.15	0.58	-0.19	8.96	2.46
Spain	1976.01	1998.12	0.03	3.30	0.40	0.56	1.31	-0.20	24.61	14.74
Sweden	1976.01	2010.01	0.00	3.16	0.13	0.34	0.43	-0.20	14.85	6.08
Switz.	1976.01	2010.01	-0.07	3.57	-0.29	0.34	0.27	-0.14	16.11	15.88
Taiwan	1997.01	2010.01	-0.17	1.69	-0.07	0.30	1.15	0.10	17.09	11.17
Thai	1997.01	2010.01	0.07	3.76	0.22	0.52	0.35	-0.18	21.43	19.18
UK	1976.01	2010.01	0.12	3.10	0.18	0.24	0.42	-0.22	7.01	4.22
Ukraine	2004.03	2010.01	0.10	4.16	0.69	0.75	4.80	-0.33	61.04	55.17

Table A.2. Turnover and relative bid-ask spreads of momentum portfolios

This table shows turnover for different momentum portfolios, different combinations of formation (f) and holding (h) periods in Panel A. Numbers are in percent and show the average fraction of portfolio switches (relative to the total number of currencies in a portfolio) per month. We report results for the winner portfolio that contains currencies with the highest lagged excess returns (rows "High"), the loser portfolio that contains the currencies with the lowest lagged returns (rows "Low"), and the average across all six momentum portfolios for a given combination of f and h. Panel B shows relative bid-ask spreads for winner and loser portfolios. We report average bid-ask spreads (in basis points) in excess of the cross-sectional average bid-ask spread of all currencies in a given month. The sample period runs from January 1976 to January 2010.

Panel A: Turnover							Panel B: Bid-ask spreads						
		Holding period h							Holding period h				
f	PF	1	3	6	9	12	f	PF	1	3	6	9	12
1	High	74.3	24.5	12.2	7.9	5.9	1	High	2.6	1.4	1	0.1	0.8
	Low	72.2	26.0	13.1	8.8	6.5		Low	3.1	2.1	1.4	0.4	0.8
	All	77.8	26.3	13.4	8.6	6.4							
3	High	42.4	24.2	12.8	7.9	6.1	3	High	2.7	0.3	0.8	0	0.9
	Low	43.8	24.9	12.9	8.8	6.3		Low	2.6	0.6	-0.1	-0.2	0.1
	All	59.1	26.3	13.0	8.8	6.5							
6	High	29.9	17.7	12.6	8.4	6.8	6	High	2.6	1	0.4	0.9	0.1
	Low	31.1	17.6	12.3	8.4	6.7		Low	4.1	0.6	0.1	0.4	0.4
	All	48.4	22.3	13.0	8.6	6.7							
9	High	23.6	13.8	9.9	8.3	6.5	9	High	3.5	1.4	1.2	0.2	0.5
	Low	24.0	14.3	9.8	7.7	6.4		Low	5.3	1.6	0.6	0.7	0.4
	All	40.3	19.1	11.7	8.5	6.6							
12	High	21.9	12.0	9.2	8.1	6.5	12	High	3.3	0.9	0.3	0	0.1
	Low	20.3	12.5	8.8	6.8	6.0		Low	6.9	2.4	0.9	0.6	0.6
	All	37.2	18.0	11.4	8.4	6.6							

Table A.3. Momentum returns and capital controls

The setup of this table is identical to Table 1 but here we exclude countries with capital controls. More specifically, at each point in time, we exclude currencies of countries which have a score of less than or equal to zero in the capital account openness index of Chinn and Ito (which is based on an update of the data in Chinn and Ito (2006). Conversely, a currency must have a postive score in the index (both in the formation and holding period) to be tradable.

	Excess returns (without b/a)						Spot rate changes (without b/a)				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	9.22	6.46	6.02	4.54	4.63	1	5.14	3.07	3.75	2.84	2.90
	[4.61]	[3.47]	[2.87]	[2.42]	[2.39]		[2.79]	[1.86]	[1.86]	[1.58]	[1.57]
3	9.90	7.07	6.18	5.39	5.33	3	7.04	5.33	4.91	3.62	4.00
	[5.30]	[3.96]	[3.42]	[3.44]	[3.07]		[3.81]	[2.81]	[2.70]	[2.06]	[2.30]
6	9.65	8.11	4.71	3.42	4.22	6	6.48	7.29	3.32	2.14	1.33
	[5.29]	[4.52]	[2.52]	[1.74]	[2.26]		[3.30]	[4.11]	[1.72]	[1.14]	[0.68]
9	8.95	8.46	5.60	4.53	2.64	9	6.83	5.76	5.30	3.64	1.82
	[4.53]	[4.48]	[2.85]	[2.21]	[1.37]		[3.42]	[2.81]	[2.66]	[1.79]	[0.92]
12	6.90	6.51	3.77	2.54	1.40	12	4.61	4.20	1.73	1.42	-0.53
	[3.61]	[3.58]	[2.06]	[1.38]	[0.77]		[2.33]	[2.20]	[0.96]	[0.78]	[-0.28]

Table A.4. Momentum returns since 1992

This table is identical to Table 1 but here the sample period is January 1992 – January 2010 so that we are looking at a period where bid-ask spreads are significantly lower than in the very early part of our sample.

	Excess returns (without b/a)						Spot rate changes (without b/a)				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	11.69	7.74	8.15	5.08	7.45	1	7.88	2.80	1.82	2.18	3.99
	[4.54]	[3.06]	[2.73]	[1.85]	[2.58]		[3.27]	[1.41]	[0.72]	[1.01]	[1.57]
3	9.95	8.12	7.82	3.25	6.79	3	6.90	5.99	5.65	2.64	5.63
	[3.64]	[3.11]	[3.09]	[1.29]	[2.66]		[2.78]	[2.64]	[2.63]	[1.11]	[2.42]
6	9.96	7.99	5.74	5.26	4.41	6	6.02	4.77	2.33	3.63	3.61
	[3.51]	[2.82]	[2.13]	[1.84]	[1.55]		[2.53]	[2.52]	[1.07]	[1.61]	[1.54]
9	9.77	8.59	7.08	5.20	1.93	9	8.47	6.36	6.12	4.68	2.62
	[3.25]	[2.87]	[2.34]	[1.66]	[0.72]		[3.54]	[2.65]	[2.46]	[1.90]	[1.26]
12	7.04	7.18	4.12	2.95	1.70	12	6.66	5.66	2.64	1.21	0.34
	[2.36]	[2.60]	[1.47]	[1.02]	[0.61]		[2.66]	[2.61]	[1.30]	[0.53]	[0.17]

	Excess returns (with b/a)						Spot rate changes (with b/a)				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	7.27	4.21	4.87	2.07	4.33	1	4.55	1.49	1.06	1.81	3.70
	[2.85]	[1.70]	[1.68]	[0.75]	[1.54]		[1.89]	[0.77]	[0.43]	[0.84]	[1.46]
3	6.03	4.72	4.68	0.33	3.82	3	5.08	4.95	5.19	2.22	5.32
	[2.21]	[1.77]	[1.85]	[0.13]	[1.48]		[2.00]	[2.14]	[2.39]	[0.92]	[2.28]
6	6.41	4.70	2.86	2.16	1.51	6	4.69	4.05	1.74	3.30	3.41
	[2.28]	[1.64]	[1.05]	[0.75]	[0.52]		[1.96]	[2.13]	[0.80]	[1.47]	[1.45]
9	6.35	5.29	3.87	1.90	-0.86	9	7.53	5.80	5.73	4.39	2.47
	[2.07]	[1.76]	[1.27]	[0.59]	[-0.31]		[3.14]	[2.40]	[2.30]	[1.78]	[1.18]
12	3.79	4.00	1.12	0.08	-0.85	12	5.80	5.16	2.40	1.00	0.27
	[1.25]	[1.43]	[0.39]	[0.03]	[-0.30]		[2.31]	[2.36]	[1.17]	[0.44]	[0.13]

Table A.5. Momentum returns in developed countries

This setup of this table is identical to Table 1 but here we show results for a smaller subsample of 15 developed countries as defined in the main text.

	Excess returns						Spot rate changes				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	3.83	4.79	3.88	2.95	2.24	1	2.89	3.67	4.44	3.05	2.82
	[2.72]	[3.27]	[2.00]	[1.40]	[1.39]		[1.60]	[2.28]	[2.54]	[1.64]	[1.70]
3	5.71	3.85	2.26	2.60	2.42	3	4.94	2.74	1.83	2.03	1.21
	[3.58]	[1.68]	[1.97]	[0.76]	[2.17]		[2.99]	[1.63]	[1.07]	[1.30]	[0.77]
6	3.70	2.59	1.83	1.85	-0.14	6	2.14	2.50	1.91	1.87	0.27
	[2.46]	[1.49]	[1.91]	[1.12]	[0.63]		[1.23]	[1.47]	[1.18]	[1.02]	[0.15]
9	3.96	3.35	2.04	1.36	-0.82	9	4.04	4.06	3.42	3.10	0.98
	[1.61]	[1.63]	[1.32]	[0.85]	[-0.65]		[2.14]	[2.22]	[1.92]	[1.77]	[0.53]
12	3.14	2.98	0.54	1.27	-0.16	12	3.06	2.69	1.28	1.63	0.55
	[1.84]	[2.02]	[1.14]	[1.66]	[0.77]		[1.63]	[1.53]	[0.75]	[1.03]	[0.33]

Table A.6. Momentum returns in developed countries after transaction costs

This setup of this table is identical to Table 1 but here we show results for a smaller sub-sample of 15 developed countries as defined in the main text.

	Net excess returns						Net spot rate changes				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	0.79	2.11	1.38	1.50	0.50	1	0.86	3.00	4.14	2.83	2.58
	[0.44]	[1.23]	[0.77]	[0.79]	[0.29]		[0.47]	[1.83]	[2.39]	[1.52]	[1.55]
3	3.32	1.02	-1.23	1.31	-0.49	3	3.69	2.05	1.46	1.82	1.04
	[2.05]	[0.61]	[-0.73]	[0.79]	[-0.30]		[2.23]	[1.21]	[0.86]	[1.14]	[0.66]
6	1.96	0.83	-0.47	0.15	-1.87	6	1.33	2.03	1.59	1.65	0.11
	[1.18]	[0.49]	[-0.27]	[0.08]	[-1.04]		[0.76]	[1.19]	[0.94]	[0.87]	[0.06]
9	1.59	1.30	0.26	0.08	-3.55	9	3.38	3.66	3.15	2.88	0.79
	[0.89]	[0.76]	[0.14]	[0.05]	[-1.89]		[1.78]	[2.00]	[1.75]	[1.60]	[0.42]
12	1.25	1.05	-1.68	-0.17	-1.62	12	2.42	2.39	1.14	1.45	0.73
	[0.70]	[0.62]	[-0.95]	[-0.11]	[-1.01]		[1.29]	[1.36]	[0.65]	[0.89]	[0.42]

Table A.7. Momentum returns in developed countries starting in 1992

This setup of this table is identical to Table A.5 but here we show results for developed countries of the sample period 1992 – 2010.

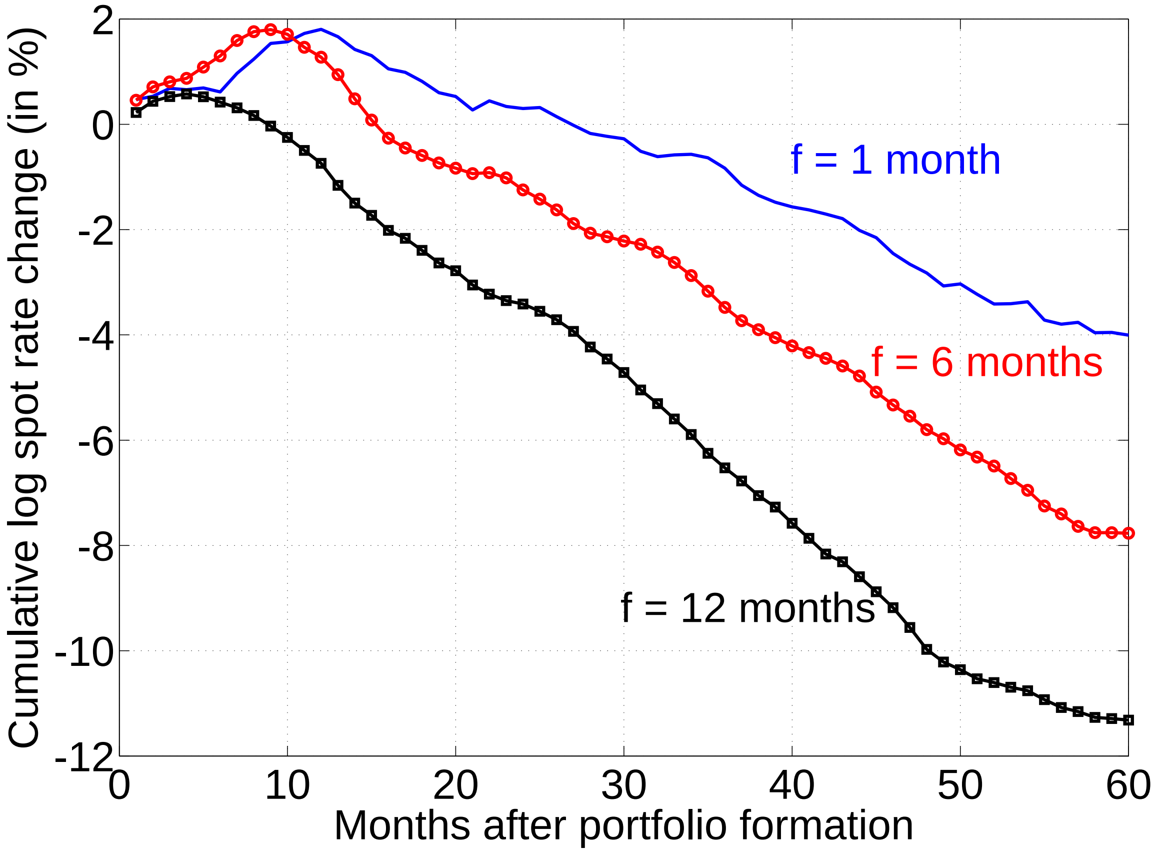
	Excess returns (without b/a)						Spot rate changes (without b/a)				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	1.56	4.34	2.76	0.55	2.94	1	0.08	2.76	1.80	-0.28	2.37
	[1.04]	[2.07]	[0.51]	[-0.12]	[1.11]		[0.03]	[1.22]	[0.79]	[-0.12]	[0.91]
3	3.62	2.39	1.70	-0.21	3.38	3	2.35	1.13	0.83	0.29	4.27
	[2.01]	[0.61]	[1.67]	[-0.88]	[1.18]		[1.06]	[0.52]	[0.38]	[0.15]	[2.07]
6	0.80	0.31	2.26	3.30	4.95	6	-0.96	-0.25	1.54	2.66	4.47
	[0.86]	[0.11]	[1.18]	[0.89]	[1.38]		[-0.42]	[-0.11]	[0.70]	[1.02]	[1.70]
9	3.13	1.84	1.22	0.89	1.35	9	1.48	1.27	1.99	1.63	1.93
	[0.82]	[0.65]	[0.83]	[0.23]	[0.52]		[0.58]	[0.52]	[0.77]	[0.70]	[0.90]
12	2.27	2.41	0.97	1.87	0.35	12	1.20	1.89	0.89	0.81	0.94
	[0.89]	[1.27]	[1.07]	[1.87]	[0.48]		[0.47]	[0.77]	[0.38]	[0.38]	[0.41]
	Excess returns (with b/a)						Spot rate changes (with b/a)				
	Holding period h						Holding period h				
$f =$	1	3	6	9	12	$f =$	1	3	6	9	12
1	-0.73	2.16	0.79	-0.27	1.38	1	-1.50	2.26	1.65	-0.48	2.25
	[-0.32]	[0.93]	[0.34]	[-0.10]	[0.54]		[-0.65]	[0.96]	[0.74]	[-0.19]	[0.85]
3	1.38	-0.24	-1.82	-0.84	2.20	3	1.32	0.60	0.57	0.13	4.15
	[0.61]	[-0.10]	[-0.73]	[-0.35]	[0.90]		[0.59]	[0.28]	[0.26]	[0.06]	[1.87]
6	-1.19	-0.45	0.84	2.29	4.70	6	-1.55	-0.55	1.35	2.50	4.34
	[-0.53]	[-0.20]	[0.35]	[0.80]	[1.58]		[-0.68]	[-0.25]	[0.56]	[0.89]	[1.50]
9	1.29	0.45	0.35	0.51	0.46	9	1.03	0.96	1.82	1.48	1.64
	[0.52]	[0.19]	[0.13]	[0.20]	[0.18]		[0.40]	[0.40]	[0.69]	[0.59]	[0.71]
12	1.23	1.30	-1.06	1.37	-1.14	12	0.72	1.77	0.93	0.66	0.81
	[0.48]	[0.53]	[-0.42]	[0.63]	[-0.51]		[0.28]	[0.72]	[0.37]	[0.29]	[0.33]

Table A.8. Comparing momentum and carry trade portfolios: Risk characteristics

This Table shows shows portfolio excess returns for a momentum strategy with a one month formation and holding period (Panel A) as well as for the carry trade strategy (Panel B). For each portfolio of the two strategies, we report the average value of the country risk rating ($CRISK$) and exchange rate stability risk rating ($XSTAB$) at the time of portfolio formation. The risk ratings for each country are relative to the risk rating of the U.S. (deviation in %) and a higher value indicates higher risk.

Panel A: Momentum Portfolios ($f = 1$, $h = 1$)							
	Low	2	3	4	5	High	H–L
$CRISK$	2.71	0.96	0.52	0.71	1.25	3.58	0.87
	[3.91]	[1.91]	[1.07]	[1.37]	[2.65]	[5.76]	[1.44]
$XSTAB$	3.19	-0.25	-1.03	-0.57	-0.13	2.72	-0.47
	[0.56]	[-0.05]	[-0.18]	[-0.10]	[-0.02]	[0.47]	[-0.47]
Panel B: Carry Trade Portfolios							
	Low	2	3	4	5	High	H–L
$CRISK$	-7.15	-5.36	-2.53	-1.99	0.44	4.72	11.87
	[-12.99]	[-8.57]	[-3.90]	[-3.22]	[0.68]	[8.44]	[20.47]
$XSTAB$	-7.66	-3.97	-1.67	-0.48	1.59	5.47	13.13
	[-1.30]	[-0.74]	[-0.30]	[-0.09]	[0.27]	[0.91]	[12.47]

Figure A.1. Long-horizon spot rate changes of momentum portfolios



This figure shows cumulative average spot rate changes to three different long-short currency momentum portfolios after portfolio formation. Momentum portfolios differ in their formation period ($f = 1, 6, 12$ months) and post-formation returns are shown for $1, 2, \ldots, 60$ months following the formation period (i.e. we build new portfolios each months but track these portfolios for the first 60 months after their formation so that we are effectively using overlapping horizons). Spot rate changes are monthly and the sample period is 1976:1 – 2010:1.