Aalto University
School of Business

Momentum's Got Style
Style Investing and Momentum in Foreign Exchange Markets

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Master's thesis

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Abstract

In this thesis I study the role of style investing in foreign exchange markets and its effect on the momentum anomaly. The heterogeneous agent model of Barberis and Shleifer (2003) offers several testable propositions about a market in which investors engage in style investing. I test three of these propositions: i) asset-level and style-level momentum strategies are profitable, ii) the existence of popular styles cause individual assets to exhibit momentum, and iii) assets that belong to the same style comove more than assets in different styles.

These propositions are studied with two style pairs. The first one consists of two styles that divide currencies into high-yielding and low-yielding ones. This division resembles the two carry trade portfolios. The second style pair defines the US dollar as one style and a portfolio of the other nine studied developed currencies as the other.

Conforming to the previous findings in the literature the currency-level momentum strategies are profitable over the sample period from 1985 to 2014. The momentum strategies that measure the past returns over the preceding one and nine months exhibit the highest mean excess returns of approximately 3% p.a.

The style-level momentum strategies for both style pairs exhibit also positive returns over the sample period. The best-performing style-level momentum strategy is a three-month strategy on the US dollar style pair which returns 4.64% p.a. with a Sharpe ratio of 0.54. Excluding the one-month momentum strategies, style-level momentum for both style pairs appears at least as profitable as the currency-level momentum. Robustness checks however show that the profitability of momentum in the interest rate style pair stems largely from its exposure to the currency carry trade. The momentum of the dollar style pair is robust to the underlying strategy which suggests that the US dollar appreciates (or depreciates) in trends against other developed currencies.

Multivariate regression models on panel data show that the future one-month excess returns of a currency depend more on the past returns of the style to which the currency belongs than on the past returns of the currency itself. This relation remains significant even after controlling for the level of interest rate of the currency, and provides some evidence that investors engage in style investing in foreign exchange markets which might, at least partially, cause the reported momentum anomaly.

Lastly, the examination of the correlation matrices of the excess returns of currencies and multivariate regression models provide evidence that currencies in the same style exhibit higher comovement than currencies in different styles.

Keywords Foreign Exchange, Momentum, Style Investing, Heterogeneous agent models, Carry Trade

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Tiivistelmä

Pro gradu –tutkielmassani tutkin tyylisijoittamista valuuttamarkkinoilla sekä sen vaikutusta momentum-ilmiöön. Barberis ja Shleifer (2003) kehittävät heterogeenisten agenttien mallin, joka tarjoaa useita ehdotelma liittyen markkinoihin, joilla sijoittajat tekevät allokointipäätöksiä perustuen tyylisijoittamiseen. Tutkin kolmea näistä ehdotelmista: i) momentum-strateioiden tuotot ovat positiivisia sekä valuutta- että tyylitasolla, ii) suositut sijoitustyylit vaikuttavat momentum-anomalian syntyyn, ja iii) valuutat jotka sijoittajat kategorisoivat samaan tyyliin liikkuvat tiiviimmin yhdessä kuin eri tyyleihin kuuluvat valuutat.

Näiden ehdotelmien tutkimuksessa hyödynnän kahta eri tyyliparia, joihin perustan tutkimuksessa käytetyt sijoitustyylit. Ensimmäinen tyylipari koostuu kahdesta tyylistä, jotka jakavat valuutat korkean ja matalan koron valuuttoihin. Tämä jako seuraa pitkälti ns. *carry tradessa* käytettyjä portfolioita. Toinen tyylipari jakaa valuutat Yhdysvaltain dollariin ja muihin kehittyneisiin valuuttoihin.

Mukaillen aikaisempia löydöksiä, valuuttatason momentum-strategiat tuottavat positiivisesti vuosien 1985-2014 välillä. Strategiat, jotka arvioivat menneitä tuottoja edellisen kolmen ja yhdeksän kuukauden ajalta tuottavat erityisen hyvin, n. 3% p.a.

Myös tyylitason momentum-strategioiden tuotot ovat positiivisia tutkittuna ajanjaksona. Parhaiten tuottava tyylitason strategia perustuu dollari-tyyliin ja arvioi menneitä tuottoja edellisen kolmen kuukauden ajalta. Tämä strategia tuottaa 4.64% p.a. Pois lukien yhden kuukauden momentum-strategiat, tyylitason momentum vaikuttaa olevan vähintään yhtä tuottoisa strategia kuin valuuttatason momentum. Tarkempi analyysi korkotyylin momentum-tuotoista paljastaa että niiden tuottavuus perustuu pitkälti carry traden tuottavuuteen. Dollarityylin momentum-tuotot ovat kuitenkin riippumattomia alla olevasta strategiasta, mikä tarkoittaa että Yhdysvaltain dollarilla on tapana vahvistua (tai heikentyä) muita kehittyneitä valuuttoja vastaan useampia kuukausia kerrallaan.

Paneelidatalla testatut monimuuttuja-regressio –mallit osoittavat että yksittäisten valuuttojen tulevat yhden kuukauden tulevat tuotot riippuvat enemmän sen tyylin menneistä tuotoista, johon kyseinen valuutta kuuluu, kuin valuutan omista menneistä tuotoista. Tämä löydös on tilastollisesti merkittävä myös sen jälkeen kun valuuttojen korkotasot ovat otettu huomioon, ja tukee argumenttia että sijoittavat hyödyntävät tyylisijoittamista valuuttamarkkinoilla, mikä osaltaan saattaa selittää niillä havaittua momentum-ilmiötä.

Lisäksi, korrelaatiomatriisit sekä monimuuttuja-regressiot tukevat argumenttia, jonka mukaan saman tyylin valuutat liikkuvat tiiviimmin yhdessä kuin eri tyylin valuutat.

Avainsanat Valuuttamarkkinat, Momentum, Tyylisijoittaminen, Heterogeenisten agenttien mallit, Valuuttastrategiat

Contents

1 Introduction

1.1 Background and motivation

Humans have an inborn tendency to categorize things into groups based on their observed similarity in characteristics. We classify cars based on their looks and purpose of use into, for example, SUVs, coupes, or sedans. Similar categorization is applicable to physical objects such as foods, furniture, or books but also to immaterial things like occupations, education, or even people. The main purpose of categorization is to optimize the use of our limited cognitive abilities so that we can make decisions with less effort than if we treated each object uniquely.

Categorization applies also to financial markets where information is abundant. Investors categorize individual assets into asset classes, such as equities, bonds, or currencies, to simplify asset allocation decisions. Assets in each asset class can then be subject to further categorization. Take equities for example. Categorization can occur based on several characteristics including the industry (e.g. technology stocks) or size (e.g. large caps). Perhaps one of the most common means to categorize stocks is into value and growth stocks based on some metric which relates their market price to the fundamental value of the company such as book-to-market value. Making asset allocation decisions between these categories, rather than between individual assets, is called style investing.

In this thesis I apply the concept of style investing to foreign exchange markets. Specifically, I study the profitability of style-level and currency-level momentum strategies, and test their importance in the determination of future excess returns of individual currencies. In addition, I examine whether currencies that belong to same style comove more with each other than currencies in different styles.

The investment styles in foreign exchange markets are based on the findings of Lustig, Roussanov, and Verdelhan (2011) who extract two pricing factors for the cross-section of currencies using principal components analysis. They dub these factors as the high-minus-low (HML) factor and the dollar (DOL) factor. The HML factor relates to the well-known currency carry trade. Among the practitioners in foreign exchange markets it is common to categorize individual currencies into high-yielding and low-yielding ones based on prevailing interest rates for each currency. Carry trade consists of two portfolios: one including high interest rate currencies, and one low-interest rate currencies. Carry trade investor then buys the high-yielding portfolio and sells the low-yielding one (i.e. lends with higher yield and borrows with lower yield). The risk is, of course, that the low-yielding currencies would appreciate, or the high-yielding ones depreciate, which reduces the return from the interest rate differentials. Historically carry trade has been spectacularly profitable. For example, Burnside et al. (2011) find that the carry trade returned 4.6% annually with a Sharpe ratio of 0.89 between 1976 and 2010. The HML factor essentially captures the tendency of high-interest rate currencies to provide higher excess returns than the low-interest rate currencies.

The dollar factor, on the other hand, relates to the general appreciation or depreciation of the US dollar which has historically been a dominant currency in foreign exchange markets. The existence of this factor suggests that there is a tendency of other currencies to appreciate or depreciate simultaneously against the US dollar. This is likely to stem from the role of the US dollar as the world's reserve currency and the dominant role of the US Federal Reserve among the central banks of the world. Investors might thus categorize currencies into the US dollar and others; a proposition I study in this thesis.

In this thesis I utilize these two factors to define two investment styles in foreign exchange markets. First, I define the two carry portfolios as separate investment styles. This pair of styles is referred as the high/low interest rate style, or the *HL* style for short. The division of currencies based on interest rates is comparable to the value/growth division in equity markets: traditionally high-yielding currencies have been those of emerging economies or, more appropriately for my sample, those that are exposed to emerging markets while the low-yielding portfolio has consisted mainly of the currencies of developed countries with diversified economies.

Second, I define the another pair of investment styles based on the dollar factor and refer to these styles as the *DOL* style pair. Namely, these two style portfolios are the long-dollar style and the short-dollar style. As one might guess, the former buys the US dollar against a portfolio of other currencies and the latter sells the US dollar against this portfolio.

Barberis and Shleifer (2003) offer the theoretical framework for the study. They introduce a heterogeneous-agent model that explains several stylized facts about asset markets by dividing investors into two separate types. The first type of investors, called switchers, recognize different investment styles and allocate funds to the styles that have performed well in relative basis in the recent past. The second type, called fundamental traders, trade only on the fundamental values of individual assets by buying the assets whose prices are below their fundamental value and selling overvalued assets.

Barberis and Shleifer (2003) make several propositions based on their model. I study three of their main propositions in this thesis in the context foreign exchange markets. First, the authors posit that momentum strategies are profitable both on asset-level and style-level. I test this proposition by backtesting several currency-level and style-level momentum strategies over a sample period from January 1985 to November 2014 on nine major currencies using the US dollar as the base currency.

Second, Barberis and Shleifer (2003) argue that high past returns of an asset might be due to that asset being a member of a style that has performed well in the recent past and thus attracted investors' attention. In other words, the existence of hot styles might be a major cause for asset-level momentum anomaly documented in several markets (for example in Asness, Moskowitz, and Pedersen (2013)). I introduce several regression models in order to study this proposition. In these models the future excess returns of individual currencies are regressed on the lagged own and style returns with several specifications. The relative importance of the explanatory variables are then studied to see which has the most significant impact on the future excess returns.

Third, Barberis and Shleifer (2003) argue that assets within a same style should correlate more than assets belonging to different styles. In order to study the currency-level correlations within and between styles, I examine the correlations of the excess returns of the currencies. I also regress these excess returns on the excess returns of two style portfolios: one consisting of currencies in the same style as the currency whose excess returns are being studied, and the other of currencies of different style.

1.2 Main findings

The findings of the thesis show that momentum strategies are profitable in foreign exchange markets both on currency-level and style-level. For the evaluation periods [1] of one and nine months the currency-level momentum strategies produce annual mean excess returns of approximately 3% which are statistically significant. The other evaluation periods generate also positive excess returns but to lesser extent. These findings are in line with earlier studies such as Menkhoff et al. (2012) who find that comparable momentum strategies on developed currencies return between 3% and 4% annually.

Momentum strategies based on the style portfolios of the HL and the DOL styles generate also statistically significant excess returns which are less sensitive to the selection of the evaluation period. With an evaluation period equal to or greater than three months the HL style portfolios exhibit annual momentum returns of approximately 2.5%. However, this profitability

[1] Evaluation period refers to the period over which the past returns are measured for the formation of momentum portfolios.

seems to stem from the exposure to the underlying strategy, i.e. the carry trade, meaning that the momentum strategies based on portfolios ranking currencies according to their relative interest rates do not offer investors excess returns over the carry trade.

Momentum strategies on the DOL style pair provide excess returns in the excess of 2.7% for all the evaluation periods. The strategy with a three-month evaluation period exhibits the highest returns for the DOL style pair, 4.6%. This is an interesting finding since the carry trade, which is known to be one of the strongest asset pricing anomalies (Burnside et al. (2011)), returns 4.1% annually over the sample period. Also, the momentum returns for the DOL style pair are robust to the exposure to the underlying strategy of passively holding a portfolio of the nine non-USD currencies.

In addition to being at least as profitable as the currency-level momentum strategies, the style-level momentum strategies also have a greater impact of the future excess returns of the individual currencies. This holds for both the HL style and the DOL style as well as for all the tested evaluation periods. Interestingly, the lagged style returns retain their significant explanatory power over future excess returns of individual currencies even after controlling for the forward discounts of the individual currencies. This finding provides some support for the argument of Barberis and Shleifer (2003) that asset-level momentum might be caused by investors' tendency to by the asset that are members of a "hot" style and sell the assets that belong to a "cold" style.

The examination of the correlation between the studied currencies also offers evidence that the currencies that are members of the same style co-move more than the currencies that belong to different styles. The average correlation coefficients conditional on whether the two currencies belong to the same style or not summarize this relation well: when the two currencies are members of the same style, the average correlation coefficient is 0.67 but only 0.55 when they belong to different styles.

1.3 Research questions and hypotheses

The main objective of this thesis is to clarify the role of style investing in foreign exchange markets, and examine its relation to the momentum anomaly. The model of Barberis and Shleifer (2003) provides testable propositions about the characteristics exhibited by a market in which investors engage in style investing. By testing these propositions in the context of foreign exchange markets I intend to answer the following research questions. The propositions of the Barberis and Shleifer (2003) model are covered in more detail in Section 2.1.1.

The first research question to be derived from these propositions is:

Do currency-level and style-level momentum exhibit positive expected returns in foreign exchange markets?

According to Barberis and Shleifer (2003) a market where allocation decisions are based on investment styles momentum strategies should be profitable both on asset-level and style-level. Furthermore, style-level momentum should be more profitable than asset-level momentum under the assumption that investors make all allocation decisions on style-level. Although this is a rather strict and unrealistic assumption, it provides a basis for the second research question:

What is the relation between currency-level and style-level momentum strategies in terms of profitability?

Barberis and Shleifer (2003) further argue the return of an asset is predicted by whether the asset belongs to a "hot" investment style. In their words: *"If an asset performed well last period, there is a good chance that the outperformance was due to the assets being a member of a hot style... If so, the style is likely to keep attracting inflows from switchers next period, making it likely that the asset itself also does well next period."* By answering the third research question I seek to clarify this predictability in currency returns:

Are the past style returns a better predictor of the future excess returns of a currency than the past returns of that currency?

Barberis and Shleifer (2003) also posit that an asset comoves more with the style portfolio it belongs to than with other style portfolios. This proposition serves as the motivation for the fourth research question:

Does style membership affect the comovement between currencies?

1.4 Contribution to the existing literature

The main contribution of this study to the existing literature is the context in which style investing is studied and how investment styles are defined. Previously style investing literature has concentrated mostly on equity markets. Out of the style literature on equity market style the closest ones to my approach are Teo and Woo (2004) and Wahal and Yavuz (2013) who also study the whether style membership and past style returns have predictive power over future returns of individual assets.

The style investing literature in the context of foreign exchange markets concentrates mainly on studying whether professional foreign exchange investors follow commonly known strategies such as carry, momentum, and value. These studies include Pojarliev and Levich (2008, 2010), Melvin and Shand (2011), and Verschoor and Zwinkels (2013). To my knowledge this is the first study to examine style investing in foreign exchange markets purely with market data instead of the data on professional asset managers focusing on foreign exchange markets.

In addition, I am not aware of any studies investigating style-level momentum in the context foreign exchange markets. The cross-sectional currency-level momentum has been studied and confirmed to varying extents by Okunev and White (2003), Asness, Moskowitz and Pedersen (2013), Burnside, Eichenbaum and Rebelo (2011), and Menkhoff et al. (2012). My research complements these findings by studying style membership and style-level momentum as a plausible cause for the cross-sectional momentum in foreign exchange markets.

1.5 Limitations of the study

The main limitation of this study is the relatively small number of currencies. Since I include only ten major currencies in the sample and one of them, the US dollar, is used as the base currency, the size of each of the strategy portfolios is rather limited. Therefore these portfolios contain a fair amount of idiosyncratic risk from the individual currencies, which might distort their returns. Similar studies in the context of equity markets utilize style portfolios containing hundreds of individual stocks, which effectively diversifies away idiosyncratic risks of individual stocks.

The decision to study only monthly changes in exchange rates might also cause problems with stale pricing, i.e. the observed exchange rate might not reflect the most recent available information due to their low observation frequency. However, I do not consider this a major issue in any form since the currencies included in the study are highly liquid and actively traded.

The scope of the study is also limited by the short interval over which future returns are studied. For the sake of clarity I study only the future returns over the month following the portfolio formation, and therefore completely ignore the impact the past returns might have over a longer period of time. In addition, the data includes only the month-end closing exchange rates, which entails that investors trying to exploit the studied strategies is not likely to be able to trade at the observed rates. The analysis also ignores transaction costs although their likely impact on the returns of certain strategies are discussed.

Since the chosen methodology follows so-called *frequentist* approach to econometrics, the estimated parameters and relation between estimated variables are assumed to be constant over time. This assumption might not hold in a stochastic environment such as financial markets. By allowing the studied parameters to be stochastic the future research might provide further insights to the studied topics.

1.6 Structure

Section 2 reviews the current literature on style investing, momentum, and carry, and also provides a more detailed description of the Barberis and Shleifer (2003) model. Section 3 introduces the methodologies used in the study. Section 4 describes and studies the data in general. Section 5 presents the results of the empirical analysis on currency-level and style-level momentum strategies. In Section 6 I perform several robustness checks on these results. Section 7 concludes.

2 Literature review and theoretical framework

2.1 Style investing

Style investing refers to making investment decisions based on grouping individual assets on some metric, and buying or selling a portfolio of similar assets without (at least much) regard which individual assets belong to that portfolio. Equity markets provide several straightforward examples of style investing. Individual equities could be grouped based on industries, and an investor might make her allocation decision in industry-level rather than picking individual stocks. Another common style investment scheme in equity markets is dividing stocks into value and growth stocks.

The main reason why investors might engage in style investing is that humans have a strong tendency to categorize different things based on their perceived similarity (for an overview on the subject, see Rosch (1999)). One of the main aims of categorization is the minimization of cognitive effort. The amount of information to process may be considerably less if one concentrates on the big picture rather than trying to sort out all the details needed to make a decision. Since investors have a limited ability to process information, there is a need for heuristics, or behavioral shortcuts that simplify the decision making process (Kahneman (1973) and Pashler and Johnston (2001) provide surveys on the subject). It might thus be easier and less time-consuming to analyze, say, 30 different industries in the stock market than hundreds or even thousands of stocks, and to make allocation decision on industry-level. Implications of limited attention in financial markets are discussed in Corwin and Coughenour (2008), Barber and Odean (2008), and Peng, Xiong, and Bollerslev (2007). Barberis and Shleifer (2003) provide an example specific to style investing by noting that small stocks were a popular investment style after Banz (1981) documented their strong performance in the preceding decades.

The heterogeneous agent model of Barberis and Shleifer (2003) has provided a framework for the relatively new strand of literature studying style investing and its effects on asset prices. However, majority of this research is in the context of equity markets undoubtedly because of the ease with which styles can be categorized in equity markets compared to several other markets.

Even before the model of Barberis and Shleifer (2003) Moskowitz and Grinblatt (1999) document the importance of industry-level momentum in explaining stock-level momentum in the US equity market. The authors find stock-level momentum becomes statistically insignificant once it is controlled for industry-level momentum. Industry-level momentum is also a more profitable trading strategy than stock-level momentum. Interestingly Moskowitz and Grinblatt (1999) also note that industry-level momentum returns are the strongest in short-term (namely the following month after portfolio formation) whereas stock-level momentum generates most of its returns in medium term.

Teo and Woo (2004) study the style investing returns in the context of value/growth and small/large style pairs in the US equity market. They find that there is a strong long-term reversal in style returns: styles with the lowest returns over the past two years have an alpha of 10.6% after adjusting for the factors of Fama-French (1997) compared to the alpha of 0.5% for the best performing styles. The authors also find weak evidence for short-term style-level momentum, especially for the value/growth style pair since the two styles are better substitutes for each other than small cap and large cap styles. This conforms to the so-called twin-style proposition of Barberis and Shleifer (2003) stating that styles which are close substitutes for each other should exhibit higher style-level momentum. In addition, there seems to be positive feedback effect on style-level returns in mutual fund flows which stock-level positive feedback trading cannot fully explain. This suggests that individual stock returns might be affected by style-return chasing as suggested by Barberis and Shleifer (2003).

Wahal and Yavuz (2013) find evidence that past style returns affect future returns of a stock but not as significantly as the stocks own past returns. Similar to Teo and Woo (2004) they provide stronger evidence for the twin-style argument of Barberis and Shleifer (2003). The authors divide stocks into terciles based on their comovement, and document that the momentum returns are largest within the highest comovement tercile. This finding advocates the argument that style-level momentum returns should be larger for styles which investors regard as substitutes for each other.

Jame and Tong (2014) document that retail investors tend to buy industries with good past performance, and this behavior negatively predicts the future industry returns over the next three to twelve month period. The authors also note that 60% of poor performance of retail investors is associated with bad industry selection.

The proposition of Barberis and Shleifer (2003) that style recognition increases comovement within styles has also been studied in Greenwood (2008), Boyer (2011), and Claessens and Yafeh (2012) who show that the returns of a stock become more correlated with an index once the stock is added to it.

While equity markets have dominated the style investing literature, there is also evidence of the prominence of style investing in foreign exchange markets. I review this literature in Section 2.1.2.

2.1.1 The model of Barberis and Shleifer (2003)

The model introduced by Barberis and Shleifer (2003) provides the theoretical foundation for my research. In this section I provide a brief overview of the model, its main assumptions, and main implications. Heterogeneous agent models similar to Barberis and Shleifer (2003) have been proposed by, for example, De Long et al. (1990) and Hong and Stein (1999). These, however, are based on the performance of individual assets instead of a group of assets (i.e. investment styles), as explained below. The focus on styles essentially allows to generalize the findings of the single asset models to a more general level.

The model assumes an economy with 2n risky assets. These 2n assets are divided into two styles, X and Y, so that assets from 1 to n belong to style X and assets from n+1 to n belong to style Y. Each asset has an underlying cash-flow structure consisting of market-wide, style-wide and asset-specific components. The underlying cash-flow structure can be viewed as fundamental information of the corresponding asset, and thus the fair value of the asset is the sum of its discounted expected cash-flows. The market-wide component affects all the assets in the economy while the style-wide component affects only the assets in that style. Therefore it is easy to see that the fundamentals of assets in the same style are more correlated than those of different styles.

The economy has two types of investors: switcher and fundamental traders. Switchers' trading behavior is characterized by two distinct rules. First, they allocate capital on style-level, and thus are indifferent which individual assets they hold within each style. Second, their allocation decisions are based on the relative past performance of the styles. This second characteristic differentiates the model of Barberis and Shleifer (2003) from, for example, Hong and Stein (1999) who assume that switchers allocate capital based on absolute past performance. The emphasis switchers put on past relative returns stems from extrapolative expectations on style returns, i.e. styles that have done well in the past are expected to continue to perform well. Barberis and Shleifer (2003) assume that switchers finance their purchase of the recent winner style by selling the recent loser style. Thus the styles do not need to be self-financing.

The second type of investor in the model are fundamental traders. As the name suggests, fundamental traders' demand for an asset is determined by its current price relative to the fair price (defined as the present value of an asset's expected future cash-flows). However, fundamental traders are assumed to have a rather short horizon over which they maximize their expected utility. This assumption is made in accordance with Shleifer and Vishny (1997), who argue that clients evaluate money managers' performance over a short period of time, and thus incentivize managers to care about their short-term returns. Because of this, fundamental traders are not able to absorb all the demand for a given asset from switchers.

The authors note that it would actually be profitable for arbitrageurs to buy into the demand of switchers if they recognize the existence of switchers as their own buying would create even more interest and demand from switchers. Thus the existence of rational arbitrageurs would amplify the predictions of the model that will be stated later.

Figures 1 and 2 demonstrate the effect a cash-flow shock has on the two styles and on assets in each style. Figure 1 shows the impulse response function to a positive style-level cash-flow shock on Style X. The initial shock causes the price of Style X to drift to the direction of the shock first and then reverse towards the fair value. Since there are only two assumed styles and they span all the assets, the price of Style Y mirrors the price of Style X.

Figure 2 exhibits the corresponding impulse response functions of three individual assets to an asset-level cash-flow shock to Asset 1. An important point to note in Figure 2 is that the cash-flow shock to Asset 1 causes Asset 2, which belongs to the same style as Asset 1, to appreciate in price as well. The authors call this "contagion" *externality* which signifies the comovement of the returns of assets in the same style.

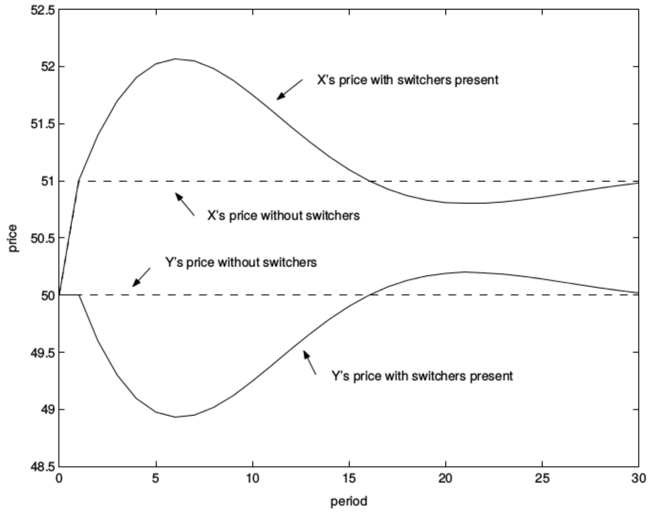

Figure 1: The figure shows the impact of a positive asset-level cash-flow shock on an asset belonging to the Style X on the prices of the two styles. The initial prices for both styles are set to 50. Adopted from Barberis and Shleifer (2003), p.172.

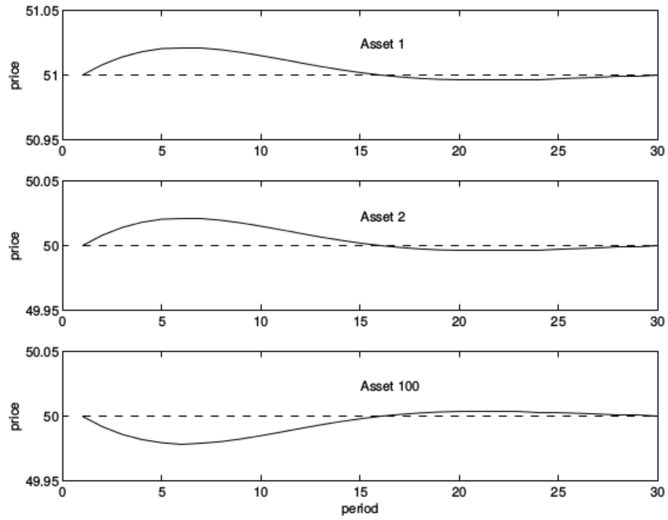

Figure 2: The figure shows the impact of a positive asset-level cash-flow shock on Asset 1 on the prices of individual assets. Assets 1 and 2 belong to Style X and Asset 100 to Style Y. All the initial prices are set to 50. Adopted from Barberis and Shleifer (2003), p.174.

The model and the assumptions outlined above allow the author to make a set of propositions about the behavior of asset prices in markets where investors engage in style investing. Below I list and highlight the most relevant ones for the research topic of this thesis.

Proposition 1. If two assets belong to the same style, their returns are more correlated than their fundamentals. If two assets do not belong to the same style, their returns are less correlated than their fundamentals. The authors note that this proposition offers a unique way of understanding the common factor approach to asset pricing. Often these factors are assumed to represent risk compensation for certain economic fundamentals that a group of assets have in common. The BS model explains them through investors' classification of asset into certain groups, and investors' tendency to allocate capital on style-level.

Proposition 2. Once an asset is added to a certain style, its correlation with that style increases. This proposition is a straight-forward extension of the externality described above: since a positive fundamental piece of news on an asset in style X causes also the prices of other assets belonging to style X to increase, an asset that is added to style X will correlate more with the style before.

Proposition 3. Style-level returns exhibit short-term momentum and long-term reversals. As switchers demand for all assets in a style with a high relative past return cause further upward price pressure on that style, the increase in the price of that style becomes self-reinforcing. In the absence of further positive fundamental news, this continues until the price pressure from switchers fades, and the price of the style revert to its fundamental level. Of course, this reversion does not happen monotonically: the price of the style goes below the fair price due to the impact the recent, negative relative performance (see Figure 1).

Proposition 4. Asset-level momentum and value strategies have strictly positive expected returns. The authors conclude that since the model predicts short-term momentum and long-term reversals through the externality effects on assets in the same style, momentum and value strategies must be profitable on asset-level. This conclusion conforms to the empirical findings about the profitability of momentum and value strategies in several asset classes, for example, in Asness, Moskowitz, and Pedersen (2013).

Proposition 5. Asset-level momentum and value strategies offer higher Sharpe ratios than their asset-level counterparts. Within-style momentum and value strategies have expected return of zero. Since noise trading (i.e. return chasing) happens on style-level instead of asset-level, a strategy that seeks to exploit it must be at least as profitable on style-level as on asset-level. The authors note, however, that not it is not realistic to assume all noise trading to take place in style-level but also to a certain extent on asset-level. In this case style-level strategies still perform well although not necessarily as well as asset-level strategies.

Proposition 6. The optimal strategy for an investor who knows the true price generating process presented by the model would be a combination of style and momentum strategies. Given the assumption that some arbitrageurs know the true price-generating process, there exist a strategy that gives the arbitrageurs the highest expected return. This strategy then depend on how much weight switchers put on the most recent relative performance. When switchers emphasize the most recent performance, the prices of the styles tend to deviate a lot from their fundamental level and the style-level momentum strategy dominates the style-level value strategy. For lower emphasis on recent performance, the opposite holds. In all cases the optimal strategy is a combination of the momentum and value strategies.

2.1.2 Style investing in foreign exchange markets

Pojarliev and Levich (2008) study the factors contributing the performance of 50-100 professional foreign exchange managers over 2001-2006. They find that three factors can explain roughly 66% of the returns of the professional foreign exchange managers: carry, trend (momentum) and value. Pojarliev and Levich (2010) extend their earlier analysis by studying how these strategies contributed to the returns of 80 professional foreign exchange managers right before and during the financial crises, namely in 2005-2008. They confirm the earlier findings: roughly half of the return variability of foreign exchange managers is explained by carry, trend and value strategies. The most prominent of these strategies seems to the trend strategy, suggesting that professional foreign exchange managers tend to buy currencies that have performed well and sell currencies with lower past performance. The second most significant style is carry.

In addition to the general exposures of foreign exchange managers, Pojarliev and Levich (2010) make an interesting notion that foreign exchange investors should not worry about crowded trades but also about crowded styles. The worst performance periods for both the trend and carry strategies followed their relative peak in popularity among the studied foreign exchange managers. This finding has resemblance to the 'Quant crisis' in August 2007 (for an overview and analysis see Khandani and Lo (2007)), and offers some evidence of the herding among professional foreign exchange managers.

Verschoor and Zwinkels (2013) offer additional insights to the risk factor exposure of professional foreign exchange managers. The authors study how the value, momentum, and carry strategies explain the returns of two foreign exchange manager indices. The findings are similar to the work of Pojarliev and Levich (2008, 2010) except that the index returns load significantly only on momentum and carry. Also, contrary to the predictions laid out by the Barberis and Shleifer (2003), Verschoor and Zwinkels note that foreign exchange managers (proxied by the two indices) act as negative feedback traders. They tend to increase their risk exposure to the strategies that have performed worst during the past 8 months while reducing their risk exposure to the past winner strategies. Nonetheless, Verschoor and Zwinkels (2013) offer further support for the argument that foreign exchange investors follow the momentum and carry strategies, and the past relative performance of these strategies has an impact on their capital allocation decisions.

Additionally, Galati and Melvin (2004), Galati et al. (2007), and Jylhä and Suominen (2011) provide evidence that practitioners engage in carry trade activities in foreign exchange markets. Brunnermeier, Nagel and Pedersen (2009) show that the interest differential between two currencies has negative relationship with the correlation of the two currencies after controlling common global and country-specific factors. In other words, currencies with high interest rates tend to move together while less so with currencies with low interest rates, and vice versa.

In addition to the assumption that investors recognize the investment styles in questions, the BS model implicitly assumes that investors affect prices with their actions. This begs the question whether this assumption is particularly realistic in the global foreign exchange market which averages over $5.3 trillion daily turnover. The Triennial Central Bank Survey 2013 provided by the Bank of International Settlements offers some insights to this issue. The information in the survey allows one to make a ballpark estimation of the amount of speculative capital that might utilize the trading strategies described above in the global foreign exchange market. The most prominent counterparties in foreign exchange transactions are so-called reporting dealers (i.e. large banks participating in the interbank markets) and other financial institutions who act at least as one counterparty for 91% of global foreign exchange turnover. Other financial institutions in this case includes non-reporting banks (24% of total global foreign exchange turnover), institutional investors (11%), hedge and proprietary funds (11%), official sector (1%), and some other instances (6%).

Out of the participants listed above, at least hedge and proprietary funds can be clearly classified as speculative capital although not all of their transactions in the foreign exchange market are necessarily speculative. Institutional investors, such as pension funds, can utilize some foreign exchange strategies but likely less than hedge and proprietary funds. In addition, reporting and non-reporting banks are likely to have a speculative component in their foreign exchange transactions.

These four participants account for about 85% of the turnover in the global foreign exchange market. Assuming that all the hedge and proprietary fund activity is speculative would mean that at least 11% of total turnover is speculative. This figure is further increased by the speculative foreign exchange activities of banks and institutional investors. For example, if this activity amounted to 9% of the total turnover, 20% of the total foreign exchange market turnover would be speculative and most likely enough to impact exchange rates.

As noted above, these figure are just back-of-the-envelope estimates but show that at least there are major participants in the global foreign exchange market whose activities are likely to be more or less speculative, and thus follow trading strategies that utilize investment styles.

2.2 Momentum

Momentum in the context of financial markets is commonly defined as the tendency of asset with high past returns (often called *winners*) to have high returns in future as well, and assets with low past returns (*losers*) to exhibit low returns in the future. This is referred as the cross-sectional momentum. On the other hand, momentum can also be defined in terms of time series of returns. Time series momentum is defined as the tendency of an asset appreciate if its past returns are positive, and vice versa. Throughout the rest of the thesis I refer to the cross-sectional momentum anomaly simply as momentum, and specifically state when time series momentum is referred to.

The momentum anomaly has attracted a fair amount of academic interest. While the profitability of momentum strategies is firmly confirmed in several asset classes, for example by Asness, Moskowitz and Pedersen (2013), the underlying reasons cause controversy among academics and practitioners.

The bulk of the literature on momentum has been in the context of the equity markets. Jegadeesh and Titman (1993) are commonly cited as the seminal work that sparked the academic interest in momentum. The authors find that past 12-2 months (i.e. past 12 months, skipping the most recent one) returns have a strong predictive power over the future returns up to 12 months on the cross-section of US stocks. Beyond the following 12 months the excess returns tend to reverse: winning stocks perform worse than loser stocks.

The finding of Jegadeesh and Titman (1993) were quickly confirmed to hold also in international equity markets. Rouwenhorst (1998) demonstrate the profitability of momentum in 12 European equity markets. Griffin et al.

(2003) and Chui et al. (2010) provide similar evidence for over 40 international equity markets.

In addition to international equities, several other asset classes have been shown to exhibit positive momentum returns. Jostova et al. (2013) find the momentum effect in corporate bond market, although it is mainly driven the non-investment grade bonds. Accordingly, Avramov et al. (2007) suggest that equity market momentum is also linked to the companies with lower credit ratings. Commodities markets also exhibit momentum as shown by Erb and Harvey (2006) and Gorton et al. (2013).

Asness, Moskowitz and Pedersen (2013) tie the previous findings on several asset classes together by demonstrating that momentum strategies based on the past 12-2 month provided positive returns in several highly-liquid international equity markets, country equity indices, currencies, fixed income, and commodities. Their findings also hold for aggregating all individual equities into one global market as well as for doing the same aggregation for the other asset classes. Momentum works even for one global market consisting of all individual assets studied.

The authors offer global funding liquidity as a partial explanation for the strong performance of the momentum strategy. Momentum returns tend to be high when global funding liquidity is good and vice versa. One explanation for this behavior is that assets which have risen in price recently tend to attract more attention from investors who can fund themselves cheaper when the global funding liquidity is high, thus causing strong contemporary momentum performance.

There is an abundance of literature covering other possible causes of the prevalence of momentum strategies. This literature can be divided into three categories: i) risk-based explanations, ii) behavioral explanations, iii) agent-based explanations.

Risk-based theories suggest that momentum anomaly is not necessarily an anomaly at all but rational compensation for some underlying risk factors. The evidence for this argument is mixed, however. Fama and French (1996) as well as Jegadeesh and Titman (2001) rebut the ability of the common asset pricing models to explain momentum returns. Conrad and Kaul (1998) contrast this with the possibility that momentum returns are explained by the variation in the cross-sectional expected returns. Berk, Green and Naik (1999) note that this variation might be due to firm-specific investment and growth opportunities. Wu (2002) argues that momentum returns could be explained time-varying risk exposure to macro-economic factors but does not identify these factors. Chordia and Shivakumar (2002) test this logic further with a model allowing for time-varying exposures to several macro-economic factors. They show that this model explains the excess momentum returns in the US equity market although Griffin et al. (2003) refute their findings in international equity markets. In general, the risk-based approaches suffer from poor empirical evidence and the inability to explain the long-term reversal.

The behavioral explanations offer several approaches to explaining momentum. Some market participants might underreact to new information causing asset prices to drift to the direction of the information for some time after the initial announcement. This view is hypothesized by Jegadeesh and Titman (1993) in their seminal work on momentum, and further purported by Barberis, Shleifer and Vishny (1998), Hong and Stein (1999) and Hvidkjaer (2006).

Grinblatt and Han (2005) propose that prospect theory and mental accounting[2] give rise to disposition effect which suggests that investors tend to sell asset they have capital gains on, and hold on to assets that exhibit capital losses for them. This behavior then creates the aforementioned under- and overreactions in short-term due to irrational selling and buying pressure causing the momentum effect.

Daniel et al. (1998) argue that investor overconfidence in their own abilities to process information and the following slow diffusion of new information cause the short-term underreaction and the long-term overreaction.

Several agent-based models are also able simulate markets exhibiting the momentum effect. Hong and Stein (1999) propose a model of heterogeneous agents in which one group of traders base their allocation decisions on the past performance of individual assets while other traders mitigate this price pressure by trading based on an assets fundamental value. However, the latter group cannot fully eliminate price deviations from the fair value, and thus asset prices exhibit short-term momentum and long-term reversal. As explained above, Barberis and Shleifer (2003) propose a similar model but in the context of investment styles. Vayanos and Woolley (2013) introduce the effects of delegated allocation decision in a similar framework. In their model investors respond to the cash-flow shocks of assets by switching capital from funds holding assets with negative cash-flow shocks to ones holding positive cash-flow shock assets.

Literature on momentum in foreign exchange markets has mainly focused on the time-series version of momentum (for a survey on the topic, see Menkhoff and Taylor (2007)). The few articles studying the cross-section of FX momentum include Okunev and White (2003), Asness, Moskowitz and

[2]Prospect theory refers to the tendency of people to be risk-averse about positive outcomes and risk-seeking about negative ones. The concept of mental accounting suggests that people treat outcomes of gambles in separate "accounts" instead of aggregating them togehter.

Pedersen (2013), Burnside, Eichenbaum and Rebelo (2011), and Menkhoff et al. (2012).

Okunev and White (2003) rank seven currencies based on a strategy utilizing two moving average combinations. The currencies with highest ranks are then bought while the currencies with lowest ones shorted. Over the period 1975-2000 this strategy generates positive excess returns between 40 and 60 basis points per month for several moving average lags. The returns are also robust for the selection of the home currency.

As mentioned above, Asness, Moskowitz, and Pedersen (2013) find that cross-sectional momentum works also in the global FX markets. They study ten major and liquid currencies over the period 1978-2011, and find that the 12-2 momentum strategy provides an annual excess return of 3.5% with a Sharpe ratio of 0.34.

Burnside, Eichenbaum, and Rebelo (2011) implement a momentum strategy that ranks 20 major currencies based on their past returns over the preceding month. This strategy generates annual excess mean returns of 4.5% and a Sharpe ratio of 0.62 over 1976-2010. On the other hand, a carry strategy returned 4.6% annually with an exceptional Sharpe ratio of 0.89. The authors go on to test a few possible explanations for these findings, and conclud the following. First, the momentum and carry strategies are not compensation for well-known risk factors, such as equity market risk or currency volatility. Second, they are not explained by so-called peso problems[3] unless an unreasonably high risk aversion is assumed. Third, price pressure cannot be ruled out as a possible cause for the profitability of momentum and carry strategies. The authors define price pressure as the impact an order has on prices given the quantity of the order. With a simple model the authors show that while the average profit of an arbitrage opportunity is positive, the marginal profit might be zero or even negative, which causes the arbitrage opportunity not to be fully exploited. Thus the momentum and carry strategies might be profitable on average but not for a marginal trader arriving late to the markets, which might lead an econometrician studying momentum profits to a false conclusion that there are profits to be made from exploiting the arbitrage opportunities.

Menkhoff et al. (2012a) study FX momentum on a sample of 48 currencies over the period of 1976-2010, and find that momentum strategies based on several evaluation and holding periods yield abnormally high returns. The most profitable momentum strategy, both in terms of mean excess and risk-adjusted returns, is the one-month, one-month strategy (i.e. forming

[3]Peso problems refer to low-probability problems that do not occur during the sample period but still belong to the plausible market states.

momentum portfolios only on the returns over the most recent month and holding that portfolio for one month). This strategy yield an annual mean excess return of 9.46% and a Sharpe ratio of 0.95.

The authors note, however, that the profitability is mainly driven by the minor and illiquid currencies. The high idiosyncratic volatility and other risks associated with these currencies effectively prohibits arbitraging away the profitability of momentum. This finding is also in line with Avramov et al. (2007) and Jostova et al. (2013) who find that momentum stems mainly from the companies with low credit ratings in both equity and corporate bond markets, respectively. According to the Menkhoff et al. (2012a) there might thus be a common factor driving momentum return across the different markets.

To exclude the impact of minor currencies Menkhoff et al. (2012a) test also the profitability of momentum strategies over the period 1992-2010 with only the currencies of developed countries. The annual excess returns are significantly lower (3.83% for the one-month, one-month strategy), and even negative when taking bid-ask spreads into account although the strategies with longer formation periods still provide positive excess returns due to lower portfolio turnover.

2.3 Carry

In the simplest form carry means buying high-yielding assets and selling low-yielding ones in order to profit from the difference in their yield. Carry strategies can be utilized in several markets such as credit, equities, and foreign exchange. One might, for example, buy low-quality, high-yielding corporate bonds and financing this trough sales of higher-quality but lower-yielding bonds with the expectation to earn the difference in their yields.

Koijen et al. (2013) offer an intriguing insight that carry provides high abnormal returns in several asset classes including global equities, bonds, credits as well as commodities, equity index options and currencies. A diversified strategy across all the studied assets provides a Sharpe ratio of 1.1. Essentially none of the traditional risk factors explain this spectacular performance. The authors note that the worst periods for the individual and combined carry strategies occur during global macroeconomic events such as the financial crises of 2007-2009. This finding suggests that carry is essentially compensation for risks related to global macroeconomic crashes, liquidity conditions (namely limited arbitrage capital) and/or high investor risk-aversion.

The currency carry trade has attracted an extensive interest in the academic literature mainly because of its spectacular performance in both raw and risk-adjusted basis. In practice the carry trade in foreign exchange markets works by borrowing in currencies with low interest rate and using the proceeds to lend in currencies with high interest rate. Essentially this is a bet the low-yield currencies will not appreciate against the high-yielding ones enough to eliminate the profit from the interest rate differential.

Uncovered interest rate parity (UIP) states that, assuming investors are risk-neutral and form rational expectations, this appreciation should happen, and thus wipe out all the profits from the interest rate differential. However, empirical results show that historically low-yielding currencies have not appreciated enough to compensate for the interest rate differential, resulting in so-called forward premium puzzle. This anomaly was first documented by Hansen and Hodrick (1980, 1983) and Fama (1984), and relates also to the findings of Rogoff and Meese (1983) who argue that foreign exchange rates are martingales, i.e. the expectation for the next period is the current exchange rate. As one can see, the failure of the UIP makes the carry trade a trading strategy with positive expected return in foreign exchange markets.

If the assumption of investors risk-neutrality is relaxed, the difference between the change in spot exchange rates and interest rate differential also reflects a risk premium. One explanation for the failure of UIP to hold is time-varying risk premium, an idea purported by Fama (1984). Specifying the risk factors for the time-varying risk premium has, however, turned out be a difficult task, and consequently the profitability of currency carry trade has remained largely unexplained.

Traditional risk factors, such as the Fama-French (1993) three factor model, Capital Asset Pricing Model and its extensions, and global equity market volatility have failed to explain currency carry returns (see, for example, Burnside et al. (2006, 2010) and Burnside (2011)). Lustig and Verdelhan (2007) provide evidence that consumption growth risk is related to the carry trade returns.

Lustig, Roussanov and Verdelhan (2011) propose two risk factors for currency markets based on principal components. The first factor is an excess return factor against the US dollar. The second factor is a slope factor which on which high interest rate currencies load positively and vice versa. Not surprisingly, as the slope factor resembles the carry strategy, the authors find that the slope factor explains variations in the currency carry. Burnside et al. (2011) also find evidence that the slope factor explains cross-sectional returns differential of currency portfolios sorted on the forward discount. Additionally they note that the dollar factor is significant but essentially constant for all the sorted portfolios, thus it does not offer insights into cross-sectional return differentials.

Recently several risk factors associated with market distress have emerged as an intriguing approach to explain the profitability of carry trade. Melvin and Taylor (2009) develop a financial distress index, and argue that it might have been able to offer downside protection for carry trade during the financial crisis of 2007-2008. Farhi and Gabaix (2008) purport that country-specific and time-varying exposure to extreme disaster risk can explain several of the documented anomalies in the foreign exchange market including the forward premium puzzle.

Brunnermeier, Nagel, and Pedersen (2009) show that carry trade returns are negatively skewed. Building on the model of funding liquidity of Brunnermeier and Pedersen (2009) they argue that the negative skewness could be a product of diminishing funding liquidity, which causes carry traders to unwind their positions simultaneously and thus causing sharp but temporary declines in the profitability of currency carry trade.

Menkhoff et al. (2012b) introduce a risk factor based on innovations in global currency volatility, and find that it high interest currencies load negatively on the factor while low interest rate currencies load positively on it, thus offering a hedge against unexpected volatility innovations. The authors note that the volatility factor accounts for over 90% of the spread between carry trade portfolios, and is strongly related to funding liquidity risk, suggested by Brunnermeier and Pedersen (2009) and Brunnermeier et al. (2009), but dominates it when jointly tested. These findings are in line with the macroeconomic considerations of Koijen et al. (2013).

Another approach has been to argue that currency carry trade returns could be caused by peso problems. Burnside et al. (2010) offer some evidence that peso problems might indeed cause the profitability of carry trade. However, the peso events seem to be more related to high risk aversion of investors using a currency carry strategy rather than large negative losses to carry strategy itself.

As with the case of momentum, the difficulty of explaining carry trade returns has also motivated a search for alternative, non-risk-based explanations. Burnside, Eichenbaum, and Rebelo (2009) propose a model explaining the forward premium puzzle based on market structure. Spronk, Verschoor, and Zwinkels (2011) develop a heterogeneous agent model to describe interaction between carry, fundamental, and technical traders. Their model is able produce several of the stylized facts about the foreign exchange markets. Burnside et al. (2006) suggest that high transaction costa severely limit the profitability of currency carry trade. However, Menkhoff et al. (2012) cannot find further support for this argument.

3 Methodology

3.1 Currency excess returns

The returns of the nine currencies against the USD are measured in excess if the short-term interest rate differential between the USD and the currency in question. These excess returns are calculated as follows. Let S_t^k denote the spot rate of foreign currency k (per USD) at time t, and r^d and r^k denote the one-period interest rate in the USD and currency k, respectively. Then the one-period excess return RX_{t+1}^k of currency k against the USD is given by (assuming continuous compounding of interest):

$$RX_{t+1}^k = \frac{S_t^k e^{rf - r^d}}{S_{t+1}^k} - 1 \tag{1}$$

Since S_t^k is expressed as the amount of currency k units per one USD, the next period spot rate S_{t+1}^k is in the denominator so that the appreciation of currency k (i.e. lower S_{t+1}^k than S_t^k) gives positive USD-nominated returns.

Covered interest rate parity (CIP) states that the forward rates are determined solely by the current spot rate and the interest rate differential between the two currencies. Thus if CIP holds, an arbitrageur cannot profit from lending in a higher interest rate currency and borrowing in a lower interest currency while hedging the currency risk with forwards. Akram, Rime, and Sarno (2008) show that while there are fleeting but economically significant short-term arbitrage profit opportunities caused by the failure of CIP, CIP seems to hold in daily and lower frequency data. If we let F_t^k denote the forward rate of currency k at time t, and assume that CIP holds since the study uses monthly data, F_t^k can be expressed as:

$$F_t^k = S_t^k e^{rf - r^d} \tag{2}$$

Thus (1) becomes:

$$RX_{t+1}^k = \frac{F_t^k}{S_{t+1}^k} - 1 \tag{3}$$

The excess currency returns used in the empirical analysis are calculated by using (3) as this formulation of the excess returns requires data only on spot and forward rates.

3.2 The formation of momentum and style portfolios

The formation of the two carry trade portfolios is straightforward. Since CIP holds for the monthly data, the one-month forward discount (the difference between the one-month forward rate and the current spot rate) fully reflects the interest rate differentials between the USD and the currency in question. Thus the currency with the highest forward discount has the highest short-term interest rate, and vice versa. Each month I rank the currencies according to their forward discount. The five currencies with the highest forward discounts form the asset portfolio, and the other four currencies the liability portfolio. Both portfolios are equally-weighted and the value of each amounts to one USD. The unequal number of currencies in the two portfolios is due to the assumption in the Barberis and Shleifer (2003) model that the styles span all the assets, and thus each currency must belong to at least one (and in this case only one) style portfolio.

The momentum portfolios used to study currency-level momentum strategies are formed as follows. The nine non-base currencies are ranked at the end of month t according to their excess return over an evaluation period from month t-l to t-1. Then I form two equally-weighted portfolios: the winner portfolio consisting of the three currencies with the highest past returns and the loser portfolio consisting of the three currencies with lowest past returns. The strategy then buys the winner portfolio and sells the loser portfolio so that the overall position is dollar-neutral. This position is then held for a month, and the procedure repeated.

A common practice in the literature is to set l equal to 12 months, and effectively evaluate the relative performance over the past year. The exact value of l does not seem to be of great significance when evaluating momentum strategies, and there are indications that l less than 12 months might be more appropriate for foreign exchange markets (e.g. Froot and Ramadorai (2005) and Pojarliev and Levich (2010)). Several studies on equity market momentum also skip the month preceding portfolio formation due to the documented liquidity-related short-term reversal in equity markets but, as Asness, Moskowitz, and Pedersen (2013) note, this is unlikely to affect extremely liquid markets and the preceding month is included in the portfolio formation.

To study the style-level momentum strategies, I utilize the style portfolios based on the HL (dividing currencies into high and low interest rate portfolios) and the DOL (the USD vs. other developed currencies) style pairs. The style-level momentum strategies are formed similarly to the currency-level momentum using the past returns of the style portfolios instead of individual currencies. The two portfolios for the HL styles are the two carry portfolios, and the style-level momentum strategy evaluates their past performances. Since the US dollar is the base currency, the long-dollar portfolio is formed by selling an equally weighted portfolio of the nine non-base currencies. Similarly, the short-dollar portfolio buys this portfolio. The style-level momentum strategy for the DOL styles then essentially buys or sells the US dollar based on whether it has depreciated or appreciated over the evaluation period. All the style portfolios are weighted so that their value is equal to one US dollar.

3.3 Regression analysis with panel data

In order to study whether style- and asset-level returns have an impact on future excess returns of individual currencies I evaluate a model with ordinary least squares (OLS) regression on panel data.

Panel data consists of observations of state variables over several time periods. All these observations are then pooled into one sample which is used to fit the proposed model. If the data has n state variables (firms, countries, etc.) and each of these state variables has observations for t time periods, the size of the panel sample is nt.

In the analysis of the HL and the DOL styles I utilize the following four models:

$$RX_t^k = \beta_0 + \beta_1 RX_{t-l}^k + \beta_2 \Sigma_{k=1}^8 c_k + \epsilon_t \tag{4}$$

$$RX_t^k = \beta_0 + \beta_1 RX_{t-l}^s + \beta_2 \Sigma_{k=1}^8 c_k + \epsilon_t \tag{5}$$

$$RX_t^k = \beta_0 + \beta_1 RX_{t-l}^k + \beta_2 RX_{t-l}^s + \beta_3 \Sigma_{k=1}^8 c_k + \epsilon_t \tag{6}$$

$$RX_t^k = \beta_0 + \beta_1 RX_{t-l}^k + \beta_2 RX_{t-l}^s + \beta_3 fwd_{t-1}^k + \beta_4 \Sigma_{k=1}^8 c_k + \epsilon_t \tag{7}$$

where RX_t^k is the excess return of currency k in month t, $RX_{t-1,t-l}^k$ is the past excess return of currency l from month $t-l$ to month $t-1$, RX_{t-l}^s is the past return on style s from month $t-l$ to month $t-1$, fwd_t^k is the forward discount of currency k at the end of month t, c is a dummy variable for each of the currencies, and $l \geq 1$.

The past style returns are evaluated based on the style portfolios defined above. In the case of the HL styles, if currency k belongs to the asset (liability portfolio) at the end of month $t-1$, the past l-month style return is the excess return over last l months on equally weighted portfolio of asset (liability) currencies. When calculating the lagged style returns, I exclude currency k from the corresponding style portfolio in order to avoid problems arising from excess correlation between the dependent and independent variables.

Thus each HL style portfolio consists of four currencies that belong to the same style with currency k.

The DOL style portfolios consist of either a short or a long position in all of the non-base currencies. When calculating the past returns, currency k is again excluded from the corresponding style portfolio. Therefore the lagged DOL style portfolios have eight currencies in them.

The inclusion of the forward discount as a control variable to Model 7 is motivated by the findings of Lustig, Roussanov and Verdelhan (2011) who propose a portfolio based on the interest rate differentials between currencies as a risk factor explaining cross-sectional return differences in foreign exchange markets. While the raw forward discount does not imitate this risk factor perfectly, it acts as a reasonable control for the documented tendency of high interest rate currencies to appreciate and the low interest rate currencies to depreciate. It is also worth noting that although the HL style portfolios are based on the forward discounts at time t as well, introducing the forward discount as a control variable does not cause problems with multicollinearity since it captures the impact of the level of interest rates on future one-month excess returns while the lagged HL style measure whether the past returns of the currencies with similar interest rates affect the future excess returns.

Since these models are being fitted on panel data, the differences between individual currencies might cause the OLS estimators to become biased[4] and inconsistent[5] due to the omitted variable bias. To mitigate this issue I introduce eight dummy variables to all four models. These dummy variables take value one when the observation is from the currency whose dummy variable is in question, and zero otherwise. The number of dummy variables (eight) is less than the number of currencies (nine) since the effect of one currency is included in the intercept term of the models. This approach to overcome the omitted variable bias in panel data is often referred as *individual fixed effects*. I do not report the estimates for these dummy variables.

3.3.1 Relative importance of explanatory variables

The relative importance of the explanatory variable is the main interest in order to answer the question whether past style returns are a better predictor of future excess returns of a currency than the past excess returns of the currency. There is a wide selection of methods to study the relative importance of explanatory variables, some rather straightforward while others are more

[4]When an estimator is biased, its expected value does not equal the true value of the parameter to be estimated.

[5]An inconsistent estimator does not converge to a value when the sample size grows.

computer-intensive in terms of calculations. Grömping (2006, 2007) surveys some of these methods and highlights the recent advancements in the field. The main goal of the relative importance methods is to decompose the R^2 of a regression model and evaluate how much each of the explanatory variables contribute to it. In general, the most recommended approach is to use several methods, see whether their result relate to each other, and base the final conclusions on solid theoretical framework.

In the empirical analysis I employ three methods to study the relative importance of past currency excess returns and past style returns on future currency excess returns. These methods are strongly based on Grm̈ping (2006). Note that the all the data used in the regression analysis is normalized for the relative importance methods.

The first method simply runs univariate regression and compares the R^2s of these regressions. As this method is extremely straightforward it completely ignore the correlation between the explanatory variables. Following Grm̈ping (2006) I call this method the *first* method for the rest of the paper.

The second method multiplies the coefficients of the standardized regression by the marginal correlation between the independent variable and the dependent variable. The sum of these products is the R^2 this approach is easy to understand intuitively. Grmping (2006) notes that this method is heavily criticized but also powerfully defended in Pratt (1987). Therefore this method is termed the *Pratt* method.

The third method is more intensive in terms of calculations and not as intuitive as the first two. This method was first introduced in Lindeman, Merenda, and Gold (1980) and accordingly is called the LMG method. Essentially this method calculates the marginal contribution of a variable v to the R^2 when it is added as an explanatory variable. Since this contribution depends on the number and the order of the already included explanatory variables, the LMG method takes the average of the contribution of variable v across all the possible combinations of explanatory variables. The exact calculation for LMG is presented, for example, in Grm̈ping (2006).

4 Data

4.1 Currency return data

The data consists of monthly spot and one-month forward exchange rates on ten major currencies from January 1985 to November 2014. The rates are end-of-month rates middle quote rates. The ten major currencies included are the Australian dollar (AUD), the Canadian dollar (CAD), the euro/Deutsche mark (EUR), the Japanese yen (JPY), the New Zealand dollar (NZD), the Norwegian krone (NOK), the Swedish krona (SEK), the Swiss franc (CHF), the Great Britain pound (GBP), and the United States dollar (USD). The Deutsche mark is used in the EUR data series until the introduction of the euro at the beginning of 1999. All the data are retrieved from Datastream.

The USD serves as the base currency, and the exchange rates for the other nine currencies are expressed as the amount of foreign currency units per USD (i.e. how many foreign currencies it takes to buy one USD). In effect this means that the investible universe spans nine assets that are measured against the USD.

Table 1: The table presents the descriptive statistics for each of the nine non-base currencies from 1/1985 to 11/2014. The return figures are presented in percentage terms and annualized from monthly data except for the maximum and minimum monthly returns which are stated in monthly-terms. The kurtosis reported is the excess kurtosis. The Sharpe ratio is calculated from a perspective of a US investors using the one-month USD deposit rate as the risk-free rate. The *Fwd Discount* columns shows the average annualized forward discount of each currency over the sample period.

	Mean	StDev	Max	Min	Skewness	Exc. Kurtosis	Sharpe	Fwd Discount
AUD	4.06	11.88	9.57	−15.72	−0.57	1.94	0.31	3.23
CAD	1.57	7.09	9.39	−11.86	−0.31	4.40	0.17	0.83
EUR	2.54	10.91	9.84	−10.38	−0.11	0.44	0.20	−0.39
JPY	0.67	11.48	16.83	−10.16	0.50	1.84	0.03	−2.49
NZD	6.82	12.41	13.28	−12.55	−0.13	1.80	0.52	4.35
NOK	3.63	10.86	7.64	−12.02	−0.35	0.89	0.30	2.16
SEK	2.86	11.28	9.23	−14.37	−0.30	0.96	0.22	1.59
CHF	2.43	11.78	13.43	−11.16	0.13	0.63	0.18	−1.57
GBP	3.47	10.20	14.78	−11.89	−0.02	2.61	0.31	1.94

Table 1 shows the descriptive statistics for each of the nine non-base currencies. These indicate several interesting characteristics of the data. First, the mean excess returns against the USD are positive for each of the non-base currencies, and exhibit rather high dispersion. For example, the JPY returned 0.67% annually while the excess return for the NZD was 6.82%. Second, there is almost monotonic relation between the mean excess return and the mean forward discount: the high forward discount currencies offer higher returns than low forward discount currencies. This conforms to the findings in the earlier literature on the profitability of the carry trade (e.g. Menkhoff et al. (2012b) and Burnside, Eichenbaum, and Rebelo (2011)), and suggests that the carry trade should be profitable over the sample period in question as well.

4.2 Analysis of comovement between currencies

Tables 2 shows the correlations between the excess returns of the non-base currencies for the sample period. All the correlations are positive, and seem to be higher for the currencies that are geographically close to each other.

Tables 3 and 4 present the correlations for the periods when the two currencies belong to the same or different HL style portfolio, respectively. Glancing over the tables one notes that the correlations tend to be generally higher when the two currencies belong to the same style portfolio although there are large exceptions from this pattern. The mean difference between the the same and different style correlations of all currency pairs is 0.04 (t-statistic 1.97) which provides preliminary support for the proposition of Barberis and Shleifer (2003) that assets comove more when they are members of the same style.

To test further the proposition that currencies within the same style comove more than currencies that belong to different styles I utilize three standardized OLS regression models:

$$rx_t^k = \beta_1 rx_t^s + \epsilon_t \tag{8}$$

$$rx_t^k = \beta_1 rx_t^e + \epsilon_t \tag{9}$$

$$rx_t^k = \beta_1 rx_t^s + \beta_2 rx_t^e + \epsilon_t \tag{10}$$

where s denotes the style to which currency k belongs, e is the style to which currency k does not belong, rx_t^k is the standardized excess return of currency k over month t, rx_t^S is the standardized return on a portfolio of style s excluding currency k, and rx^e is the standardized return on a portfolio of style e. Since all the variables are standardized, the intercept term becomes redundant. The styles portfolios are based on the HL style pair since the both DOL style portfolios include all the non-base currencies.

Table 5 presents the regression results for the three models. The same- and different-style portfolios clearly show statistical significance in all three models. However, the main interest lies, again, in their relative importance. Since all the variables are standardized, the regression coefficients represent

Table 2: The table reports the correlations between the monthly currency excess returns between each non-base currencies.

	AUD	CAD	EUR	JPY	NZD	NOK	SEK	CHF	GBP
AUD	1	0.59	0.39	0.12	0.71	0.44	0.47	0.31	0.36
CAD	0.59	1	0.31	0.03	0.48	0.42	0.43	0.24	0.31
EUR	0.39	0.31	1	0.45	0.48	0.85	0.84	0.90	0.70
JPY	0.12	0.03	0.45	1	0.22	0.36	0.35	0.52	0.35
NZD	0.71	0.48	0.48	0.22	1	0.48	0.52	0.45	0.44
NOK	0.44	0.42	0.85	0.36	0.48	1	0.84	0.76	0.67
SEK	0.47	0.43	0.84	0.35	0.52	0.84	1	0.76	0.67
CHF	0.31	0.24	0.90	0.52	0.45	0.76	0.76	1	0.66
GBP	0.36	0.31	0.70	0.35	0.44	0.67	0.67	0.66	1

Table 3: The table reports the correlations between the monthly excess returns of each non-base currency when the currencies belong the two same HL style portfolio, i.e. when both currencies are either in the asset or the liability portfolio.

	AUD	CAD	EUR	JPY	NZD	NOK	SEK	CHF	GBP
AUD	1	0.65	0.60	−0.12	0.72	0.52	0.53	−0.001	0.36
CAD	0.65	1	0.22	0.09	0.54	0.57	0.62	0.21	0.23
EUR	0.60	0.22	1	0.47	0.62	0.85	0.79	0.91	0.75
JPY	−0.12	0.09	0.47	1	0.10	0.60	0.34	0.51	0.20
NZD	0.72	0.54	0.62	0.10	1	0.53	0.54	0.32	0.41
NOK	0.52	0.57	0.85	0.60	0.53	1	0.86	0.87	0.66
SEK	0.53	0.62	0.79	0.34	0.54	0.86	1	0.84	0.67
CHF	−0.001	0.21	0.91	0.51	0.32	0.87	0.84	1	0.52
GBP	0.36	0.23	0.75	0.20	0.41	0.66	0.67	0.52	1

Table 4: The table reports the correlations between the monthly excess returns of each non-base currency when the two currencies are in different HL style portfolios, i.e. when one of the currencies belongs to the asset portfolio and the other to the liability portfolio.

	AUD	CAD	EUR	JPY	NZD	NOK	SEK	CHF	GBP
AUD	1	0.49	0.35	0.13	0.45	0.13	0.35	0.33	0.37
CAD	0.49	1	0.36	−0.02	0.40	0.30	0.31	0.25	0.37
EUR	0.35	0.36	1	0.41	0.44	0.86	0.86	0.90	0.67
JPY	0.13	−0.02	0.41	1	0.23	0.31	0.35	0.62	0.38
NZD	0.45	0.40	0.44	0.23	1	0.28	0.47	0.46	0.49
NOK	0.13	0.30	0.86	0.31	0.28	1	0.79	0.74	0.69
SEK	0.35	0.31	0.86	0.35	0.47	0.79	1	0.72	0.68
CHF	0.33	0.25	0.90	0.62	0.46	0.74	0.72	1	0.71
GBP	0.37	0.37	0.67	0.38	0.49	0.69	0.68	0.71	1

a response to a one-standard deviation shock to the variable of interest, and thus they are controlled for the differences in the distributions of underlying variables. Note, however, that normality of the variables is assumed. The standardization makes the comparison of the coefficients thus more rigorous which helps to determine their relative importance.

For the individual Models 8 and 9 the regression coefficients are 0.67 and 0.55, respectively. The coefficient is higher for Model 8 which has the same-style return as the independent variable. The adjusted R^2 is higher for Model 8 (0.45) than for Model 9 (0.30). This suggests that the same-style portfolio explains approximately 45% of the variation in monthly excess returns for individual currencies while the different-style portfolio explains only 30%. Also, since Models 8 and 9 have only one independent variable, their R^2s equal the squared correlation coefficient between the explained and explanatory variables. Thus the individual currency excess returns have a correlation of approximately 0.67 with the same-style portfolio but only 0.55 with the different-style portfolio.

The joint test of the same- and different-style portfolios provide futher support for increased comovement within style. In Model 10 the regression coefficient for the same-style portfolio is 0.554 while the different-style portfolio has a coefficient of 0.168, a difference of more than three-fold. The difference suggests that the same-style return is a more meaningful factor in determination of the returns for individual currencies than the different-style return. Since OLS regression measures how well the explanatory variable(s) explain(s) variations in the explained variable, the results suggest that individual currencies comove more with same-style portfolio than with the different-style portfolio. The situation is similar to the testing of the Capital Asset Pricing Model regression where individual stock returns are regressed on market returns, and the stocks that have a high regression coefficient (commonly called *beta*) are expected to covary more with the market.

Additionally, when the different-style portfolio is added as an independent variable to Model 8, the adjusted R^2 increases only by 0.01 (from 0.45 to 0.46). Thus the model with the same-style returns as an independent variable seems to explain variations in the individual currency excess returns almost as well as the model with both style portfolios as independent variables.

Table 5: The table reports the regression results for Models 8-10 (t-statistics in parenthesis). rx_t^k denotes the standardized excess returns of currency k over month t, rx_t^s denotes the excess return of the style portfolio to which currency k belongs to (excluding currency k), and rx_t^e denotes the other style portfolio.

	Explained variable:		
		rx_t^k	
	(8)	(9)	(10)
rx_t^s	0.67***		0.55***
	(51.12)		(31.32)
rx_t^e		0.55***	0.17***
		(37.10)	(9.48)
Observations	3,231	3,231	3,231
R^2	0.45	0.30	0.46
Adjusted R^2	0.45	0.30	0.46
Residual Std. Error	0.74 (df = 3229)	0.84 (df = 3229)	0.73 (df = 3228)
Note:			*p<0.1; **p<0.05; ***p<0.01

5 Empirical results

5.1 Currency strategies

Before studying style investing in foreign exchange markets in more detail I look at the overall performance of the currency trading strategies of interest. Table 6 reports the annual performance statistics for several strategies discussed in Section 4.3. These include momentum strategies with evaluation periods of one, three, six, nine, and twelve months, the carry strategy, the two carry portfolios (the asset portfolio and the liability portfolio), and a equally weighted portfolio of all nine non-base currencies. The respective strategies referred as Mom-1, Mom-3, Mom-6, Mom-9, Mom-12, Carry, Carry-A, Carry-L, and Total for the rest of the section. The graphs of their return serier are found in the appendix.

The reported statistics include the annualized mean excess return, standard deviation, the Sharpe ratio, semi-deviation, and the Sortino ratio. All figures are annualized from monthly data. The risk-free rate for the Sharpe ratio is the one-month US deposit rate.

Since none of the studied return series is normally distributed according to the Shapiro-Wilk test (statistics not reported), the statistical significance of the mean returns is evaluated with the Wilcoxon signed-rank test whose p-value is reported in parenthesis below the corresponding mean return.

In addition to the commonly used performance measures I calculate the semi-deviation and the Sortino ratio for each of the return series. The semi-deviation takes into account only the downside volatility whereas standard deviation includes both up- and downside variation in returns. Accordingly, the Sharpe ratio does not distinguish between the up- and downside volatility, and therefore penalizes strategies with high variation above the mean returns and low variation below the mean. The Sortino ratio is designed to mitigate this distortion by dividing the excess return by the corresponding semi-deviation.

Table 6 reveals that all the currency-level momentum specification had positive mean returns over the sample period. The momentum strategy with the highest mean return was Mom-1 with a mean return of 3.00%, and a Sharpe ratio of 0.30. The profitability of the momentum strategies decreases as the evaluation period is increased to three and six months. The performance of Mom-3 is still relatively good with a mean return of of 2.39% and a Sharpe ratio of 0.33 but the performance drops significantly for Mom-6.

Interestingly, when the evaluation period is increased further to nine months, the profitability of the currency-level momentum strategy reverses its decline. The mean return of the Mom-9 is 2.72%, more than double the mean return of the Mom-6, with a Sharpe ratio of 0.26. Once the evaluation period is extended to twelve months the mean return of the strategy declines to 1.51%.

The relatively good performance of Mom-1 is likely to be explained by the absence of transaction costs in the analysis due to the high portfolio turnover of the strategy. Similar to my findings, Menkhoff et al. (2012a) find that the one-month strategy based on the currencies of developed countries performs the best among different momentum specification when transaction costs are not included in the analysis. In their sample of 15 developed currencies the one-month strategy returns 3.83% annually. When the transaction costs are introduced, the performance of the one-month strategy becomes negative. Therefore it is reasonable to assume that the strong performance of the one-month strategy in the current sample is also attributable to the exclusion of transaction costs. The absence of transaction costs likely enhances the observed return of the other momentum strategies as well but the impact is likely to be less pronounced the longer the evaluation period is.

Otherwise the results in Table 6 are lower than for similar strategies in Menkhoff et al. (2012a). In their sample from 1976 to 2010 the three-month strategy returned 5.71%, the six-month strategy 3.70%, the nine-month strategy 3.96%, and the twelve-month strategy 3.14% annually. The different sample period is likely to explain some of these discrepancies as the authors test these strategies also over a shorter sample period from 1992 to 2010 and report lower mean returns for each (although still higher than in Table 6).

The findings of Froot and Ramadorai (2005) offer also a plausible explanation for the strong performance of Mom-1 and Mom-3. Froot and Ramadorai (2005) note that good recent performance up to one quarter cause money to flow to these good-performing currencies, and accordingly drive their exchange rates further away from its fundamental level causing short-term momentum. For time periods greater than nine months this effect reverses and results in long-term reversals.

In addition to being economically significant the mean returns for four out of five tested momentum strategies are also statistically significant with at least 10% level of significance. The only exception is Mom-3 whose p-value for the Wilcoxon signed-rank test is just above the threshold. The two best-performing strategies, Mom-1 and Mom-9, are statistically significant also at the 5% level. The strong performance of Mom-9 might be explained by the findings of Novy and Marx (2012) who argue that the main determinant of momentum returns in equity market is the past return from twelve to seven months before portfolio formation. However, testing this proposition in foreign exchange markets is out of the scope of this thesis.

Overall, the profitability of the currency-level momentum strategies appear sensitive to the selection of the evaluation period.

The performance of the carry strategy is significantly stronger over the sample period with an annual mean return of 4.08% and a Sharpe ratio of 0.53. Both of these figures are lower than Burnside et al. (2011) report. In their sample from 1976 to 2010 the carry trade returned 4.6% annually with a Sharpe ratio of 0.89. Menkhoff et al. (2012b) report respective figures of 5.72% and 0.56 over 1983-2009. Despite these differences, all of them indicate that the carry trade has been a highly profitable strategy over various sample periods.

A closer look into the performance of the carry strategy reveals that most of the profitability of comes from holding the asset portfolio (i.e. the high-yield portfolio). The annual mean return for this portfolio was 4.93%, and the Sharpe ratio 0.50 while the liability portfolio returned annually only 0.85%. In the light of these findings the short position in the liability portfolio reduced the overall profitability of the carry strategy. Yet, the carry strategy had a lower volatility than the asset portfolio (6.95% vs. 9.19%) which suggests that shorting the liability portfolio offered additional benefits in the terms of diversification since shorting the liability portfolio increases the number of currencies in the carry portfolio to nine from six in the asset portfolios.

As a quick non-reported robustness check, I study whether the profitability of the carry strategy was due to the contemporary exposure to high-interest rate currencies or due to the exposure to currencies that had high interest rates on average during the sample period. I do this by ranking the currencies based on their mean forward discount over the sample period, and forming two portfolios: one buying the five currencies with the highest mean forward discounts, and one shorting the four currencies with the lowest mean forward discounts.

The annual mean return over the sample period for this strategy was 2.37% with a standard deviation of 5.69%. While this portfolio has a significant positive return, the return is 42% lower than the mean annual return for the carry strategy. The difference is statistically significant with 5% level of significance. This finding suggests that the profitability of the carry strategy does not stem only from the exposure to the currencies that have high interest rates on average and happen to perform well over the sample period but also from the exposure to the currencies that have high interest rates at the moment of the portfolio formation.

The last row of Table 6 shows the returns statistics for the equally weighted portfolio of consisting of all nine non-base currencies. Essentially this portfolio is shorting the US dollar against a diversified portfolio of the

Table 6: **Performance of currency strategies.** Reported are mean raw returns (p-value for the Wilcoxon signed-rank test is presented in the parenthesis), standard deviation, the Sharpe ratio, semi-deviation, and the Sortino ratio for each strategy from January 1985 to November 2014. "Mom" stands for momentum strategies, and the following number expresses the length of the evaluation period (in months) over which the momentum portfolio is formed. The first evaluation period for each momentum strategy begins in January 1985. "Carry" represents the carry strategy. "Carry-A" and "Carry-L" are the asset and liability portfolios associated with the carry strategy, respectively. "Total" represents an equally weighted passive portfolio buying all the non-base currencies against the US dollar. The reported return and deviation figures are in annualized percentage terms.

	Mean	Stdev	Sharpe	Semdev	Sortino
Mom-1	3.00	8.82	0.30	6.17	0.43
	(0.04)				
Mom-3	2.39	8.71	0.23	6.10	0.33
	(0.10)				
Mom-6	1.23	8.55	0.10	6.38	0.14
	(0.09)				
Mom-9	2.72	9.14	0.26	6.77	0.35
	(0.02)				
Mom-12	1.51	9.06	0.13	6.78	0.17
	(0.07)				
Carry	4.08	6.99	0.53	5.19	0.72
	(0.00)				
Carry-A	4.93	9.19	0.50	6.68	0.69
	(0.00)				
Carry-L	0.85	8.42	0.06	5.82	0.09
	(0.77)				
Total	3.12	8.15	0.34	5.80	0.48
	(0.03)				

currencies of developed countries. Over the sample period this bet against the US dollar resulted in a rather good performance. The mean return of the portfolio was 3.12% and the Sharpe ratio 0.34. The mean return of 3.12% can be interpreted as a risk premium demanded by US investors for holding a diversified portfolio of the currencies of developed foreign countries.

It is noteworthy that this passive portfolio outperformed all the tested momentum strategies during the sample period in terms of both mean return and the Sortino ratio. On the contrary, the carry strategy and the asset portfolio provided US investors returns in the excess of the "market" portfolio in both raw and risk-adjusted basis.

5.2 Currency-level and style-level momentum strategies

Barberis and Shleifer (2003) propose that style-level momentum strategies have higher expected returns than their asset-level counterpart. In addition, they hypothesize that asset-level momentum could be caused by the asset being a member in a well-performing style which attracts buying pressure from investors. I test these proposition with two methods. First, I compare the returns of currency-level and style-level momentum strategies with several evaluation periods, and test whether they exhibit significantly different returns. Second, I evaluate regression models to explain one-month future excess returns for individual currencies with past own and style returns as independent variables, and examine their relative importance when tested jointly.

5.2.1 Comparison of currency-level and style-level momentum returns

Table 7 shows the return statistics for the style-level momentum strategies formed in accordance to Section 3.2. In addition to the statistics reported in Table 6 the last column of Table 7 shows the difference between the annualized mean return between the style-level and the currency-level momentum strategies for each evaluation period. The graphs for these strategies are presented in the appendix.

Focusing first only on the Panel A of Table 7, which shows the returns for the style-level momentum strategies for the HL style pair, one notes that almost all HL momentum strategies have positive returns over the sample period. However, there is a sharp contrast between the performance of the one-month strategy and all the other strategies. The one-month strategy has a mean return of 0.95% which is not statistically significant.

On the other hand, the three-, six-, nine-, and twelve-month specifications all have mean returns in the excess of 2%. The best performing specification in terms of raw returns is the nine-month strategy (2.57%) although the three- (2.52%) and twelve-month (2.46%) strategies are not too far behind. The Sharpe ratios for these three specification range from 0.25 to 0.31. When compared to the asset-level momentum strategies, the style-level strategies show less variation between evaluation periods from three to twelve months.

The last column of Table 7 shows the differences in annualized mean returns between the style-level and currency-level strategies. Comparing the performance of the style-level and currency-level momentum strategies reveals that the currency-level strategies dominate when the evaluation period is really short. For the evaluation period of one month the currency-level strategy performs better in terms of return and the Sharpe ratio than the style-level strategy. The return differential is 2.05% in the favor of the currency level strategy, and the Sortino ratio of the currency-level strategy is 0.43 compared with 0.13 of the style-level strategy. However, the inclusion of transaction costs would greatly reduce the difference in performance, as noted above.

There is little difference in the performances of the style-level and currency-level three-month strategies. The style-level strategy has somewhat higher Sharpe ratio (0.31 vs. 0.23) which is largely due to the lower volatility of the style-level strategies. The differences in the composition of the currency-level and asset-level momentum strategies is a likely culprit for the difference in volatility. Since the currency-level momentum strategy buys and sells portfolios consisting of three currencies, it is less diversified than the style-level momentum strategy that buys five and sells four currencies and thus utilizes all nine non-base currencies.

The difference in performances between the nine-month strategies is also rather small. The nine-month currency-level strategy performed really well compared to the other currency-level momentum strategies with longer evaluation periods (see Table 6), which is likely to explain the small difference in returns. Furthermore, the performance of the nine-month style-level strategy is in line with other style-level strategies with longer evaluation periods.

The style-level strategies dominate the currency-level strategies for evaluation periods of six and twelve months. The mean returns for the style-level momentum strategies are almost 1% higher than those of the currency-level strategies, and the Sharpe ratios are approximately 0.15 higher.

Panel B of Table 7 presents the style-level momentum returns for the DOL style pair. The results are somewhat similar to the HL style in that all the style-level momentum strategies have positive returns over the sample period. Again, the one-month specification shows the least significance in returns while the returns for the other evaluation periods are statistically significant at the 5% level.

The three-month strategy exhibits the strongest performance with a mean excess return of 4.64% and a Sharpe ratio of 0.54. The raw performance is somewhat lower for the evaluation periods longer than three months ranging from 2.79% to 3.36%.

Shifting attention to the last column of Panel B in Table 7 reveals that with the exception of the one-month strategy all the style-level momentum strategies have returns higher than currency-level momentum strategies. The difference is largest for the three-month and six-months specifications at 2.25% and 2.13%, respectively. Again, the strong performance of the nine-month currency-level momentum strategy results in a difference close to zero.

Overall, these findings provide support for two preliminary conclusions. First, style-level momentum strategies are profitable in foreign exchange markets for both the HL and the DOL style pairs. This holds especially for momentum strategies which form portfolios over evaluation periods ranging from three to twelve months. Second, style-level momentum strategies for both style pairs seem to be at least as profitable as currency-level strategies. The only clear exceptions are the one-month specifications whose significance is not likely to hold when transaction costs are introduced to the analysis. These two conclusions conform to the propositions of Barberis and Shleifer (2003).

5.2.2 Regression analysis with panel data

To test the impact of the style membership on future excess returns I study the explanatory power of the lagged style- and currency-level returns on the future one-month excess returns of individual currencies. The lagged returns are measured over the preceding three-, six- and twelve-month periods, and averaged to monthly means.

The regression results for past returns over three, six, and twelve months are presented in Tables 8, 9, and 10, respectively. The dependent variable for each regression is the future one-month future return of individual currencies. All of the models include an intercept term and currency-specific fixed effects both of which are not reported for the sake of clarity. The regression models are described in more detail in Section 3.3. For each evaluation period I evaluate a total of seven model: Model 4 once and Models 5, 6, and 7 for each of the two style pairs.

The regression results for Model 4 show that the lagged own returns have some explanatory power of the future excess returns as the regression estimate is significant at the 1% level for the three-month specification, and

Table 7: Reported are mean raw returns (p-value for the Wilcoxon signed-rank test is presented in the parenthesis), standard deviation, the Sharpe ratio, semi-deviation, and the Sortino ratio for each strategy from January 1985 to November 2014. "Mom" stands for momentum strategies, and the following number expresses the length of the evaluation period (in months) over which the momentum portfolio is formed. The first evaluation period for each momentum strategy begins in January 1985. Panel A presents the statistics for the style-level momentum strategies based on the HL style pair (HLMom). Panel B presents the same statistics for the DOL style pair (DOL-Mom). The last column of both panels reports the difference between the annualized mean returns of the style-level and the currency-level momentum strategies with the specified evaluation period. The reported return and deviation figures are in annualized percentage terms.

Panel A

	HL styles					Difference
	Mean	Stdev	Sharpe	Semdev	Sortino	$r_S - r_A$
HLMom-1	0.95	7.10	0.09	4.63	0.13	−2.05
	(0.95)					(0.19)
HLMom-3	2.52	7.08	0.31	4.72	0.46	0.13
	(0.12)					(0.78)
HLMom-6	2.15	7.10	0.25	4.92	0.37	0.92
	(0.10)					(0.83)
HLMom-9	2.57	7.09	0.31	4.94	0.45	−0.16
	(0.04)					(0.31)
HLMom-12	2.46	7.09	0.30	4.94	0.43	0.95
	(0.05)					(0.96)

Panel B

	DOL styles					Difference
	Mean	Stdev	Sharpe	Semdev	Sortino	$r_S - r_A$
DOLMom-1	2.93	8.16	0.32	5.60	0.46	−0.07
	(0.10)					(0.93)
DOLMom-3	4.64	7.99	0.54	5.65	0.76	2.25
	(0.00)					(0.30)
DOLMom-6	3.36	8.06	0.37	5.71	0.53	2.13
	(0.02)					(0.29)
DOLMom-9	2.79	7.98	0.31	5.81	0.42	0.07
	(0.02)					(0.75)
DOLMom-12	3.01	7.98	0.33	5.76	0.46	1.50
	(0.02)					(0.39)

at the 5% level for the six- and twelve-month specifications. The significance of the regression coefficients indicates that excess currency returns exhibit time series momentum to some extent. For example, if the mean return of a currency over the past three months increases by 1%, the expected excess return for the next month increases by 0.15%.

Barberis and Shleifer (2003) argue that this might be caused by the membership of the currency in a "hot" style. By evaluating Models 6-7 for the HL and the DOL styles I intend to control for this possibility and to study the impact of the lagged style returns on the future excess returns. The letter(s) preceding the model number in Tables 8-10 indicates whether the model is evaluated for the HL style or the DOL style.

The only explanatory variable for Model HL-5 is the lagged excess return of the asset or the liability portfolio depending on the style membership of the currency in question. Again, all the evaluation periods exhibit statistical significance. Both three- and six-month regressions are significant at the 1% level, and the twelve-month model again at the 5% level. The same holds for the DOL style (Model DOL-5) except that all the specifications exhibit significance at the 1% level. Irrespective of how styles are defined their lagged returns seem to explain the future excess returns of individual currencies.

Model 6 tests the lagged excess and style returns jointly. The results are rather similar whether the styles are defined by using the HL or the DOL style pairs.

Starting with the HL style pair, the regression coefficient in the three-month model for the lagged style return is 0.148 which is significant with the 1% significance level while the lagged currency-specific return loses its significance in the joint specification. Similar results hold also for the six-month evaluation period as the lagged HL style return has a loading of 0.158 which is significant at the 5% level. The lagged excess return, on the other hand, has a negative coefficient although not statistically significantly. However, this relation does not seem to hold for the lagged twelve-month returns as neither of the lagged return variables exhibits statistical significance in the twelve-month model.

The results are similar for the DOL style in Model DOL-6. First, the lagged excess returns lose their significance in all of the specifications. Second, the lagged DOL style returns are statistically significant for the three- and six-month specifications but not for the twelve-month specification. The three- and six-month specifications have regression coefficients of 0.167 and 0.216, respectively, and both exhibit significance at the 1% level.

The results for the three- and six-month specifications suggest that the lagged style pairs dominate the lagged excess returns in terms of explanatory power of future excess returns, and thus give preliminary support to the argument of Barberis and Shleifer (2003) that good past and future performance of an asset might be due to its style membership. These results also conform to the findings of Froot and Ramadorai (2005) and Pojarliev and Levich (2010) who note that feedback trading in foreign exchange markets seems occur over time periods shorter than twelve months.

Next I turn my attention to Model 7 which includes both lagged returns and the control variable for forward discount. Not surprisingly, the forward discount is significant in this specification for all three evaluation periods and for both the HL and the DOL styles. Interestingly, the lagged style returns for both style pairs remain statistically significant for the three- and six-month models. The estimates for the HL style decline to 0.135 and 0.129, respectively. Their respective statistical significances also decrease to 5% and 10%. The three- and six month regression estimates for the DOL style are 0.156% and 0.192% and thus remain closer to the estimates in Model DOL-6. The estimates are statistically significant at the 1% level.

Overall, since the lagged excess returns are insignificant in all of the joint specification, the results show that the lagged style returns are a more dominant factor in explaining future excess returns of individual currencies. This is suggestive of the importance of style membership in the determination of future returns, namely that the excess returns of individual currencies are likely to be higher if the currency belongs to a style that has performed well in the recent past.

To give the results an economic meaning, one might consider the following, although simplified, example. The coefficient for the lagged style return over past three months in the fourth regression specification is 0.135, and the standard deviation of the monthly mean returns over all the rolling three-month periods of the asset (liability) portfolio is 1.62% (1.47%). Thus a change of one standard deviation in the monthly mean return of the high-yield style over the past three month changes the expected one-month excess return of a currency belonging to that style by 0.227% (0.199%). Since the monthly mean excess return of all non-base currencies is 0.263%, the one-standard deviation change in the mean past return of the style portfolios seems to result also in an economically significant impact on the future one-month return.

5.2.3 Relative importance of lagged excess and style returns

The previous section showed that the lagged style returns are more significant in predicting the future excess returns of a currency than the lagged excess returns of the currency when the past returns are measured over the most recent three or six months. To test the robustness of this finding I utilize the

Table 8: The table shows the regression coefficients (t-statistics in parenthesis) for Models 4-7 for the HL and DOL style pairs with an evaluation period of three months. The explained variable for each model is the month t future excess return of currency k (RX_t^k). The explanatory variables include the mean lagged excess returns of currency k over the past three months (RX_{t-3}^k), the lagged mean excess return of the HL style portfolio to which currency k belongs (RX_{t-3}^{HL}), the lagged mean excess return of the lagged DOL style portfolio (RX_{t-3}^{DOL}), and the forward discount of currency k at the end of month $t-1$.

	Explained variable:						
	RX_t^k						
	4	HL-5	DOL-5	HL-6	DOL-6	HL-7	DOL-7
RX_{t-3}^k	0.151***			0.065	0.065	0.045	0.043
	(5.188)			(1.543)	(1.637)	(1.076)	(1.092)
RX_{t-3}^{HL}		0.207***		0.148***		0.135**	
		(5.710)		(2.833)		(2.576)	
RX_{t-3}^{DOL}			0.225***		0.167***		0.156***
			(5.884)		(3.214)		(2.995)
fwd_{t-1}^k						1.134***	1.134***
						(4.995)	(4.998)
Observations	3,204	3,204	3,204	3,204	3,204	3,204	3,204
R^2	0.008	0.010	0.011	0.011	0.012	0.019	0.019
Adjusted R^2	0.008	0.010	0.011	0.011	0.012	0.018	0.019
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 9: The table shows the regression coefficients (t-statistics in parenthesis) for Models 4-7 for the HL and DOL style pairs with an evaluation period of six months. The explained variable for each model is the month t future excess return of currency k (RX_t^k). The explanatory variables include the mean lagged excess returns of currency k over the past six months (RX_{t-6}^k), the lagged mean excess return of the HL style portfolio to which currency k belongs (RX_{t-6}^{HL}), the lagged mean excess return of the lagged DOL style portfolio (RX_{t-6}^{DOL}), and the forward discount of currency k at the end of month $t-1$.

	Explained variable:						
	RX_t^k						
	4	HL-5	DOL-5	HL-6	DOL-6	HL-7	DOL-7
RX_{t-6}^k	0.078**			-0.018	-0.041	-0.054	-0.081
	(1.961)			(-0.300)	(-0.732)	(-0.902)	(-1.442)
RX_{t-6}^{HL}		0.141***		0.158**		0.129*	
		(2.907)		(2.165)		(1.768)	
RX_{t-6}^{DOL}			0.179***		0.216***		0.192***
			(3.510)		(3.000)		(2.679)
fwd_{t-1}^k						1.251***	1.243***
						(5.332)	(5.307)
Observations	3,177	3,177	3,177	3,177	3,177	3,177	3,177
R^2	0.001	0.003	0.004	0.003	0.004	0.012	0.013
Adjusted R^2	0.001	0.003	0.004	0.003	0.004	0.012	0.013

Note: *p<0.1; **p<0.05; ***p<0.01

Table 10: The table shows the regression coefficients (t-statistics in parenthesis) for Models 4-7 for the HL and DOL style pairs with an evaluation period of twelve months. The explained variable for each model is the month t future excess return of currency k (RX_t^k). The explanatory variables include the mean lagged excess returns of currency k over the past twelve months (RX_{t-12}^k), the lagged mean excess return of the HL style portfolio to which currency k belongs (RX_{t-12}^{HL}), the lagged mean excess return of the lagged DOL style portfolio (RX_{t-12}^{DOL}), and the forward discount of currency k at the end of month $t-1$.

	Explained variable:						
	RX_t^k						
	4	HL-5	DOL-5	HL-6	DOL-6	HL-7	DOL-7
RX_{t-12}^k	0.136**			0.080	0.047	0.035	-0.004
	(2.504)			(0.966)	(0.602)	(0.425)	(-0.046)
RX_{t-12}^{HL}		0.165**		0.091		0.043	
		(2.479)		(0.898)		(0.425)	
RX_{t-12}^{DOL}			0.200***		0.157		0.117
			(2.899)		(1.579)		(1.179)
fwd_{t-1}^k						1.126***	1.112***
						(4.566)	(4.513)
Observations	3,123	3,123	3,123	3,123	3,123	3,123	3,123
R^2	0.002	0.002	0.003	0.002	0.003	0.009	0.009
Adjusted R^2	0.002	0.002	0.003	0.002	0.003	0.009	0.009
Note:					*p<0.1; **p<0.05; ***p<0.01		

relative importance measures introduced in Section 3.3.1 with Models 6 and 7 with the three-month evaluation period. The results for the models with a six-month evaluation period yield almost identical results, and thus are not reported here.

Table 11 shows the proportion of the R^2 each of the explanatory variables explains in the two models of interest for the HL style pair. Panel A in Table 11 presents the results for Model HL-6 and Panel B for Model HL-7.

For Model HL-6 the lagged style returns explain a larger proportion of the total R^2 with all relative importance measures. The First method shows that this proportion is 54% of the total while the Pratt method estimates the proportion to be 65%. The LMG method is between these two estimates at 57%.

Model HL-7, which includes also the forward discount as an explanatory variable, yields similar results in terms of the lagged style and excess returns. The highest proportion of the total R^2 is explained by the forward discount, which was anticipated based on the regression results in the previous section. Again, all three relative importance measures suggest that the lagged style returns explain a larger fraction of the total R^2 than the lagged excess returns. The proportion suggested by the First method are the closest to each other. The Pratt method shows more variation in the relative proportions with the lagged style returns explaining more than twice as much of the total R^2 than the lagged excess returns. The LMG method estimates that the explained proportion for the lagged style returns are about one-third higher than for the lagged excess returns.

Table 12 shows the same relative importance measures for the DOL style pair. All the results are extremely close to the results reported in the previous paragraphs for the HL style pair in that the lagged style returns explain a greater proportion of the total R^2s than the lagged excess returns. For Model DOL-6 this proportion ranges from 54% to 64% depending on the relative importance measure. The forward discount accounts for the largest share of R^2 for Model 7 while each of the relative importance measures propose that the lagged DOL style returns explain more of the R^2 than the lagged excess returns.

These results support the interpretation of the regression results in the previous section that the style membership is a more important factor in determination of future excess returns of individual currencies that the own lagged excess returns of these currencies.

Overall, the results in this section suggest that both currency-level and style-level momentum strategies yield positive returns in foreign exchange markets. However, several findings indicate that the style-level momentum ,as defined with the HL and DOL style pairs, dominates the currency-level

Table 11: The table shows the shares of R^2s each explanatory variable explains in Models HL-6 (Panel A) and HL-7 (Panel B) with three-month evaluation period. The *First* method measures the R^2 each explanatory variable has in a univariate regression. The *Pratt* method multiplies the coefficients of standardized regression by the marginal correlation between the independent variable and the dependent variable. The *LMG* method essentially takes the average marginal contribution of the explanatory variable to the R^2 in all possible regression specifications (for details see Grömping (2006)).

Panel A

	First	Pratt	LMG
RX_{t-3}^{k}	0.458	0.351	0.429
RX_{t-3}^{HL}	0.542	0.649	0.571

Panel B

	First	Pratt	LMG
RX_{t-3}^{k}	0.285	0.144	0.215
RX_{t-3}^{HL}	0.337	0.345	0.298
fwd_{t-1}^{k}	0.378	0.512	0.487

Table 12: The table shows the shares of R^2s each explanatory variable explains in Models DOL-6 (Panel A) and DOL-7 (Panel B) with three-month evaluation period. The *First* method measures the R^2 each explanatory variable has in a univariate regression. The *Pratt* method multiplies the coefficients of standardized regression by the marginal correlation between the independent variable and the dependent variable. The *LMG* method essentially takes the average marginal contribution of the explanatory variable to the R^2 in all possible regression specifications (for details see Grömping (2006)).

Panel A

	First	Pratt	LMG
RX^k_{t-3}	0.456	0.365	0.427
RX^{DOL}_{t-3}	0.544	0.635	0.573

Panel B

	First	Pratt	LMG
RX^k_{t-3}	0.284	0.128	0.208
RX^{DOL}_{t-3}	0.339	0.368	0.311
fwd^k_{t-1}	0.377	0.504	0.481

momentum. First, the style-level momentum strategies are more robust to the selection of the evaluation period. Second, the lagged style returns more economically and statistically significant in essentially all regression specifications compared to the lagged excess returns. This relation holds even after controlling for the level of interest rates for each currency. Third, all relative importance measures assign the lagged style returns a larger proportion of the explained variation in the future one-month excess returns of individual currencies.

6 Robustness tests

6.1 Alternative portfolio formations

Section 3.2 outlined the procedure for portfolio formation. In short, the winner and loser portfolios for currency-level momentum strategies consisted of three currencies, and the carry strategy had five currencies in the asset portfolio and four in the liability portfolio. Since the sample includes only nine non-base currencies the each of these strategy portfolios contain a fair amount of idiosyncratic risk from individual currencies which might impact the results presented in Section 5.2. To test whether these results are robust to the procedures used to form the strategy portfolios I complement the tests in Section 5.2 with three altered portfolio formation procedures. Since the two style portfolios for the DOL style consist of all the nine non-base currencies and altering this composition would undermine the underlying logic, the DOL style is excluded from the following analysis.

The first alternative strategy to be examined is a currency-level momentum strategy that buys five currencies with the highest excess returns over the evaluation period and sells the remaining four currencies instead of buying and selling only three currencies. This adjustment allows the alternative strategy to include all nine non-base currencies. The first five rows of Table 13 presents the return statistics for this strategy with evaluation periods of one, three, six, nine, and twelve months. These results exhibit several differences compared to the original strategy.

First, the volatility of the new strategy in all specifications is lower than the volatility of the original strategy in terms of standard deviation and semi-deviation. This is anticipated since the alternative strategy is more diversified than the original one.

Second, with the exception of the twelve-month specification the alternative strategies perform worse than the original ones. The underperformance is less pronounced for the one- and nine-month specifications which are again the two specifications with the highest returns. Especially in terms of Sharpe ratios these two specifications measure up well to the original strategy. The robustness of the nine-month strategy makes it good performance even more intriguing. Contrary to other strategies, the twelve-month specification actually performs better in the alternative strategy although this improvement is rather small in terms of return. The better risk-adjusted performance is thus largely attributable to the lower volatility.

For the second robustness check on portfolio formation I flip around the number of currencies in the two carry portfolios, and see if this impacts the returns of the carry strategy and the two carry portfolios. Under this alternative strategy the number of currencies in the asset (liability) portfolio is four (five). Last three rows in Table 13 show how these alternative carry specification performed over the sample period.

Interestingly, the mean return of the carry strategy decreases by almost one percent to 3.10% although it remains significantly above zero. Accordingly the risk-adjusted return measures decline as well. While the performance of the asset portfolio remains close to the original strategy, the liability portfolio performs better in the alternative strategy. The mean return of the liability portfolio increases approximately by 0.9% to 1.74%, and the risk-adjusted return measures by almost threefold. According to the Wilcoxon signed-rank test the mean return for the liability portfolio is still not significantly different from zero. Since the carry strategy shorts the liability portfolio, the strong performance of the liability portfolio under the alternative portfolio formation essentially explains the diminished returns of the carry strategy.

Table 14 shows the return statistics for the style-level momentum strategies based on the alternative carry portfolios defined above. The one- and three-month specifications perform better with the alternative carry portfolios while all the specification with evaluation periods longer than or equal to six months perform worse. The three-month strategy shows especially strong performance with a mean return of 2.82% which is higher than the mean return for any of style-level momentum strategies with the original portfolios.

The biggest difference to the style-level momentum strategies with the original carry portfolios is that while all the specifications have positive returns only the three-month specification is statistically significant. As noted above, the better performance of the alternative liability portfolio is a likely cause for the deterioration of profitability of the style-level momentum strategies.

The third alternative portfolio formation procedure uses the same logic for the momentum and carry portfolios. Instead of assigning each asset in

Table 13: The table shows return statistics for the alternative portfolios formations. The momentum strategies have five (four) currencies in the winner (loser) portfolio. The carry strategy has four (five) currencies in the asset (liability) portfolio. Reported are mean raw returns (p-value for the Wilcoxon signed-rank test is presented in the parenthesis), standard deviation, the Sharpe ratio, semi-deviation, and the Sortino ratio for each strategy from January 1985 to November 2014. "Mom" stands for momentum strategies, and the following number expresses the length of the evaluation period (in months) over which the momentum portfolio is formed. The first evaluation period for each momentum strategy begins in January 1985. "Carry" represents the carry strategy. "Carry-A" and "Carry-L" are the asset and liability portfolios associated with the carry strategy, respectively. "Total" represents an equally weighted passive portfolio buying all the non-base currencies against the US dollar. The reported return and deviation figures are in annualized percentage terms.

	Mean	Stdev	Sharpe	Semdev	Sortino
Mom-1	2.08	6.79	0.25	4.71	0.37
	(0.09)				
Mom-3	0.88	6.72	0.08	4.74	0.11
	(0.36)				
Mom-6	0.76	6.77	0.06	5.12	0.08
	(0.07)				
Mom-9	2.07	6.92	0.25	5.10	0.34
	(0.03)				
Mom-12	1.57	6.67	0.18	4.94	0.25
	(0.04)				
Carry	3.10	6.78	0.41	5.09	0.54
	(0.00)				
Carry-A	4.84	9.66	0.47	7.07	0.64
	(0.00)				
Carry-L	1.74	8.08	0.17	5.61	0.25
	(0.35)				

Table 14: The table reports the return statistics for the HL style pair with four (five) currencies in the asset (liability) portfolio. Reported are mean raw returns (p-value for the Wilcoxon signed-rank test is presented in the parenthesis), standard deviation, the Sharpe ratio, semi-deviation, and the Sortino ratio for each strategy from January 1985 to November 2014. "Mom" stands for momentum strategies, and the following number expresses the length of the evaluation period (in months) over which the momentum portfolio is formed. The first evaluation period for each momentum strategy begins in January 1985. Panel A presents the statistics for the style-level momentum strategies based on the HL style pair (HLMom). Panel B presents the same statistics for the DOL style pair (DOLMom). The reported return and deviation figures are in annualized percentage terms.

	Mean	Stdev	Sharpe	Semdev	Sortino
HLMom-1	0.97	6.84	0.09	4.63	0.13
	(0.76)				
HLMom-3	2.82	6.80	0.36	4.75	0.52
	(0.03)				
HLMom-6	1.67	6.84	0.19	4.86	0.27
	(0.14)				
HLMom-9	1.14	6.86	0.12	4.78	0.17
	(0.42)				
HLMom-12	1.08	6.85	0.11	4.72	0.16
	(0.54)				

a portfolio an equal weight the third procedure assigns weights based on the ranks of the assets. This is the approach used by, for example, Asness, Moskowitz, and Pedersen (2013).

The weight of each asset in a portfolio is given by the formula:

$$w_k = c(rank^S(k) - \Sigma_{k=1}^{n} rank^S(k)/n) \quad (11)$$

where w_k is the weight assigned to asset k, $rank^S$ indicates the rank of asset k in terms of style S, and c is a constant so that the long and short portfolio are worth one US dollar each.

The performance of the momentum and carry strategies using this weighting formula are presented in Tables 15 and 16. The returns for the currency-level momentum strategies are close to the returns of the original strategies with equally weighted portfolios. The mean return of the rank-weighted carry strategy is 4.90% which higher than the return of 4.09% for the equal-weight carry strategy although this higher return comes with increased volatility. The increased volatility is a direct consequence of the fact that the alternative portfolios are less diversified the the original ones as they assign greater relative weight to the higher-rank currencies.

The increased volatility in the carry strategy transforms to increased volatility also in the style-level momentum strategies. This increased volatility also leads to higher returns as Table 16 shows that all the style-level momentum strategies outperform their equally weighted counterparts. With the exception of the one-month specification all the style-level strategies are significant at the 5% level. Again, the three-month specification exhibits the highest returns 4.63%.

Overall, the currency-level momentum strategies seem to be sensitive to portfolio formation procedure in addition to the selection of evaluation period. There is also a fair amount of sensitivity in the carry strategy as its mean returns range from 3.10% to 4.90% depending on how the two carry portfolios are formed. Consequently, the HL style-level momentum strategies also exhibit a fair amount of sensitivity to the portfolio formation procedure. Nevertheless, the robust performance of the three-month style-level momentum strategy is a promising indication that style-level momentum is indeed profitable in foreign exchange markets.

6.2 Style-level momentum returns and the underlying strategies

In this section I study whether the style-level momentum returns of the HL and the dollar style pairs stem mainly from the exposure to the underlying

Table 15: The table shows return statistics for the alternative portfolios formations. The weights for each currency in each strategy are based on (11). Reported are mean raw returns (p-value for the Wilcoxon signed-rank test is presented in the parenthesis), standard deviation, the Sharpe ratio, semi-deviation, and the Sortino ratio for each strategy from January 1985 to November 2014. "Mom" stands for momentum strategies, and the following number expresses the length of the evaluation period (in months) over which the momentum portfolio is formed. The first evaluation period for each momentum strategy begins in January 1985. "Carry" represents the carry strategy. "Carry-A" and "Carry-L" are the asset and liability portfolios associated with the carry strategy, respectively. "Total" represents an equally weighted passive portfolio buying all the non-base currencies against the US dollar. The reported return and deviation figures are in annualized percentage terms.

	Mean	Stdev	Sharpe	Semdev	Sortino
Mom-1	2.39	8.59	0.24	5.96	0.34
	(0.11)				
Mom-3	2.35	8.48	0.24	5.92	0.34
	(0.10)				
Mom-6	1.54	8.36	0.14	6.23	0.19
	(0.06)				
Mom-9	2.54	8.89	0.25	6.54	0.34
	(0.03)				
Mom-12	1.57	8.73	0.14	6.44	0.19
	(0.09)				
Carry	4.90	8.93	0.51	6.91	0.66
	(0.00)				
Carry-A	5.64	10.31	0.51	7.54	0.70
	(0.00)				
Carry-L	0.74	8.94	0.04	6.07	0.06
	(0.94)				

Table 16: The table reports the return statistics for the HL style pair with the weights for each currency in the style portfolios based on (11). Reported are mean raw returns (p-value for the Wilcoxon signed-rank test is presented in the parenthesis), standard deviation, the Sharpe ratio, semi-deviation, and the Sortino ratio for each strategy from January 1985 to November 2014. "Mom" stands for momentum strategies, and the following number expresses the length of the evaluation period (in months) over which the momentum portfolio is formed. The first evaluation period for each momentum strategy begins in January 1985. Panel A presents the statistics for the style-level momentum strategies based on the HL style pair (HLMom). Panel B presents the same statistics for the DOL style pair (DOLMom). The reported return and deviation figures are in annualized percentage terms.

	Mean	Stdev	Sharpe	Semdev	Sortino
HLMOM-1	2.06	9.03	0.19	6.13	0.28
	(0.34)				
HLMom-3	4.63	8.96	0.48	6.32	0.68
	(0.00)				
HLMom-6	2.81	9.04	0.27	6.42	0.38
	(0.04)				
HLMom-9	3.99	9.01	0.40	6.36	0.57
	(0.01)				
HLMom-12	4.44	8.96	0.46	6.30	0.65
	(0.00)				

strategies, i.e. the carry trade for the HL style pair and the general strength of the US dollar for the dollar style.

Since the HL style-level momentum strategies are another manifestation of the timing of the carry trade, one might argue that the positive returns of the style-level momentum presented earlier are mostly due to the exposure to the carry trade. The fact that the style-level momentum strategies cannot match the performance of the carry trade supports this point of view. In other words, the profitability of the style-level momentum strategies might be solely due to being occasionally long the asset portfolio and short the liability portfolio.

Table 17 lists the mean returns conditional on the long-leg of the style-level momentum strategies studied in Section 5.2. The first column shows the mean returns for the strategies when they are long the asset portfolio and short the liability portfolio, and thus imitate the carry strategy. The second column shows the mean returns when the strategies are long the liability portfolio and short the asset portfolio and, in effect, betting against the carry strategy.

The results in Table 17 provide support for the argument that the profitability of the style-level momentum strategies is mainly due to the exposure to the carry strategy. Each of the style-level momentum strategies has mean returns in the excess of 4% when they are long the asset portfolio and short the liability portfolio. Similarly, the mean returns for all range from -2.5% to -4.0% when their holdings of the two portfolios are reversed. These results indicate that the profitability of the style-level momentum strategies is mainly due to the occasional imitation of the carry strategy and the two carry portfolios exhibit very little if any cross-sectional momentum. Thus the style-level momentum strategies as studied in this thesis fail miserably as timing tools for the carry strategy and an investor would be better off by just taking passive exposure to the carry trade.

Panel B of Table 17 shows the corresponding conditional means for the dollar style pair. The DOL style appears to be more robust to the exposure to the underlying strategy. Only the strategy with one-month evaluation period has a negative mean return when the strategy is long the US dollar and short the non-base currencies. For every other specification the style momentum strategy appears to ability to time the exposure to the underlying factor. Conforming to the findings in Section 5.2.2 the three-month specification does particularly well in timing the depreciation and appreciation of the US dollar. When the strategy is long (short) the non-base currencies against the US dollar, its mean return is 7.01% (1.68%).

Table 17: The table reports the mean annualized excess returns of the style-level momentum strategies conditioned on the style pair exposure to the underlying strategy. Panel A shows the mean excess returns for the HL momentum strategies conditioned on whether the strategy is long or short the carry trade. Panel B shows the same for the DOL style pair conditioned on whether the strategy is short or long the USD.

Panel A		
	Long Asset	Short Asset
HLMom-1	4.19	−3.91
HLMom-3	4.88	−2.48
HLMom-6	4.32	−3.34
HLMom-9	4.38	−3.00
HLMom-12	4.19	−3.95
Panel B		
	Short USD	Long USD
DOLMom-1	5.45	−0.27
DOLMom-3	7.01	1.68
DOLMom-6	5.32	0.35
DOLMom-9	4.71	0.06
DOLMom-12	4.67	0.46

6.3 Randomly assigned portfolios and comovement

The results in Section 4.2 indicated that currencies that are members in the same style comove more than currencies in different styles. To test whether these results are not significant purely by chance I replicate the regressions with randomly assigned currency portfolios. Each month all nine non-base currencies are randomly assigned to two equal-weighted portfolios. The returns for these two portfolios are measured over the next month, and a return time series spanning the sample period is generated from these returns. This procedure is repeated 1000 times to obtain 1000 time series of returns. Model 10 is then fitted on these data. If the mean beta of these 1000 for the same-style portfolios is significantly larger than the mean beta for different-style portfolio, the higher comovement within styles found in Section 4.2 is likely to be a peculiarity of the data.

The mean betas for the same-style and different-style portfolios are 0.366 and 0.355, respectively. The difference between the two estimated betas in Section 4.2 is 0.38. The two-sample t-test on the data derived from the randomly assigned portfolios indicates that the probability of a difference of this magnitude is essentially zero. Thus the findings in Section 4.2 appear to be robust in this sense.

7 Conclusion

In this thesis I study momentum in foreign exchange markets utilizing the framework of Barberis and Shleifer (2003) who provide several testable propositions about markets in which investors engage in style investing. The styles are defined with the factors Lustig, Roussanov, and Verdelhan (2011) extract from currency return data to explain the cross-section of currency returns. The two styles studied in the thesis divide currencies into high and low interest rate currencies and into the US dollar and other developed currencies.

Compatible to the previous findings in the literature, I find that currency-level cross-sectional momentum strategies are indeed profitable. Interestingly, the momentum strategies based on the style portfolios perform generally better than the currency-level momentum strategies. Especially the two style portfolios that either buy or sell the US dollar against a diversified portfolio of other developed currencies exhibit strong momentum. In practice this finding implies that once the US dollar has started to appreciate or depreciate against other currencies, the appreciation or depreciation tends to continue for some time. The study of the reasons for this is out of the scope of the thesis but provide possible a fruitful ground for future research.

In addition, evaluating several OLS models allows me conclude that the past style returns affect the future excess returns of individual currencies more than the past returns of the currencies themselves. This finding is interesting as it supports the argument of Barberis and Shleifer (2003) that style membership might be the cause for asset-level momentum anomaly. Future research might be able to shed more light to the role of style investing in asset pricing and specifically in the momentum anomaly.

Lastly, I find evidence that currencies that belong to the same style comove more than currencies that belong to different styles. This finding is indicative of investors engaging in style investing in foreign exchange market at least to some extent.

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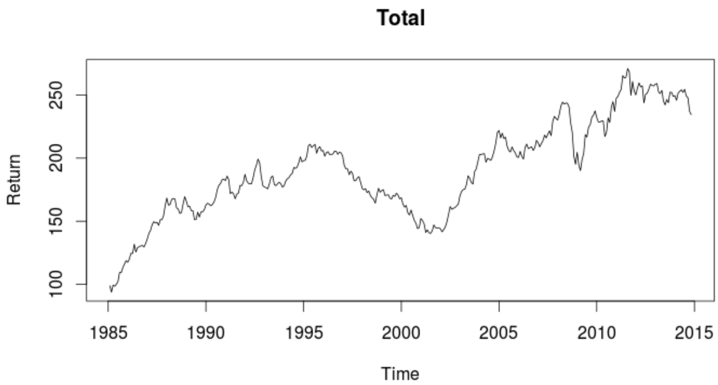
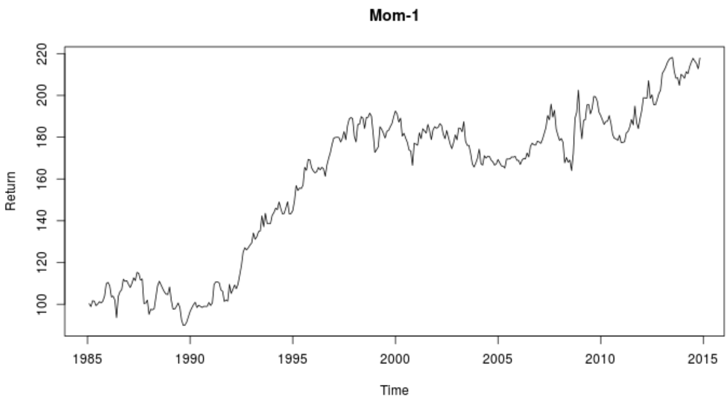
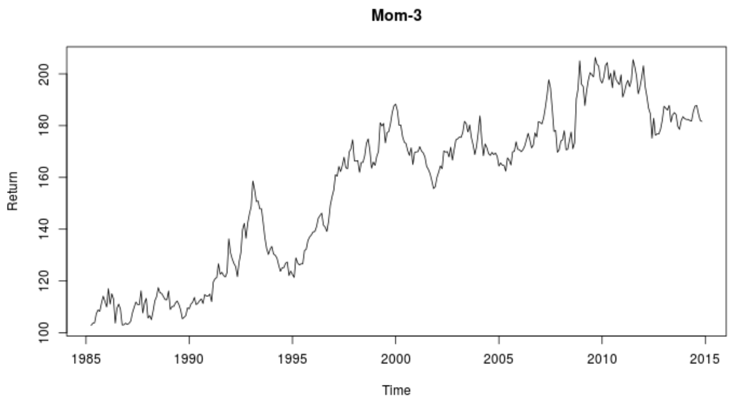
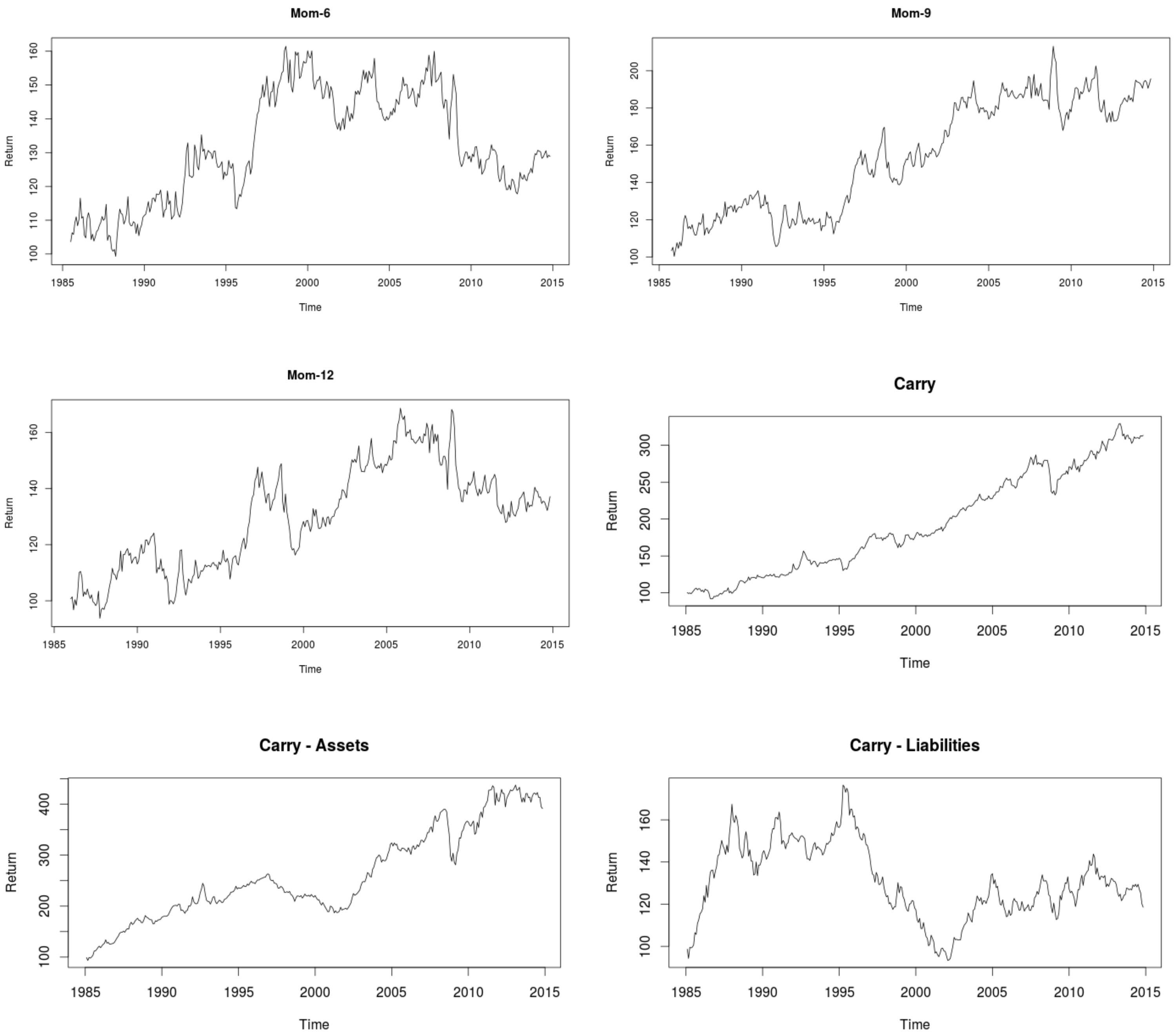
A Graphs

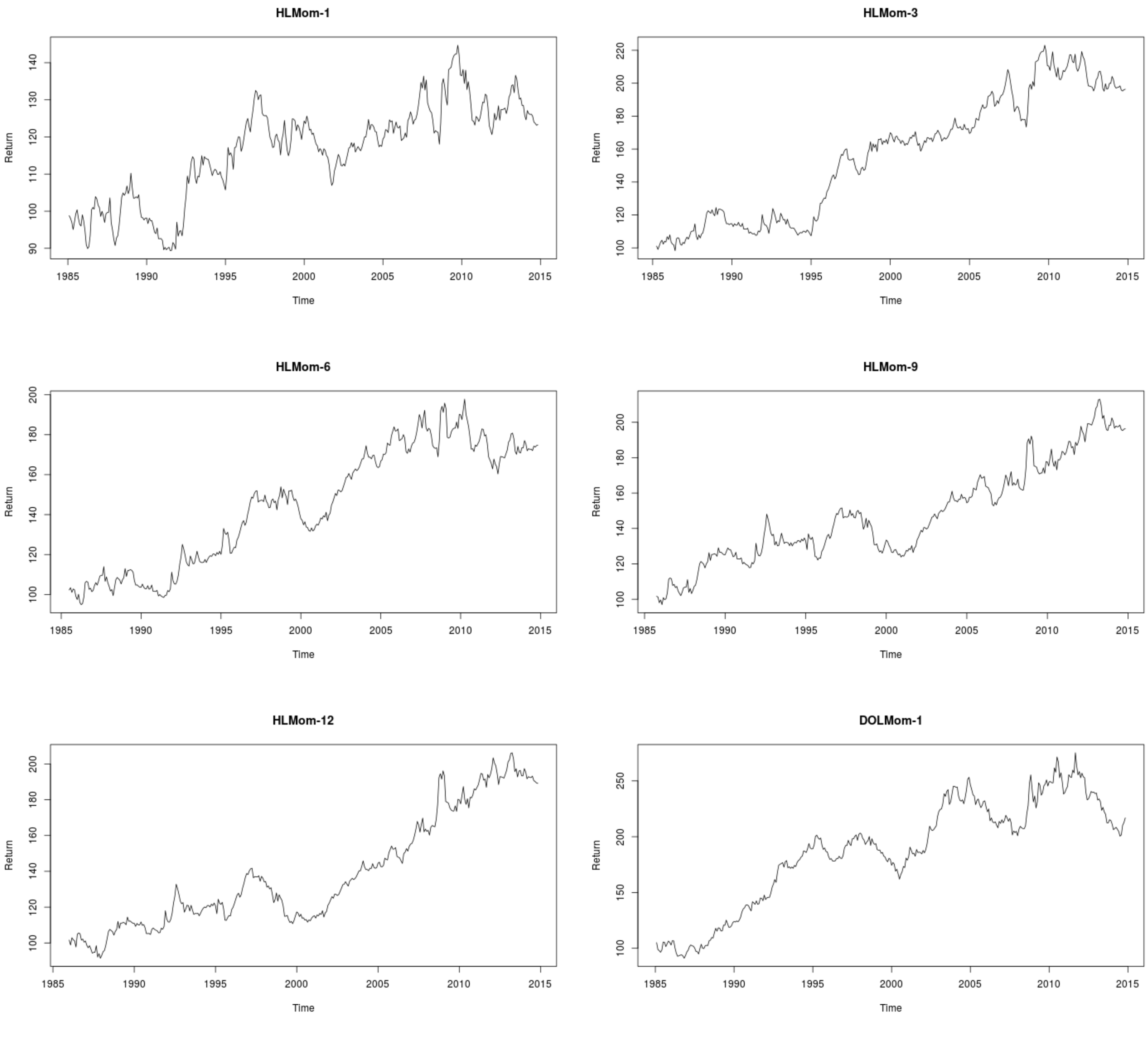
Appendix A presents the graphs for the returns of the strategies whose returns statistics are reported in Tables 6 and 7. Please note the scale of the y-axis varies between the graphs for the ease of readability.

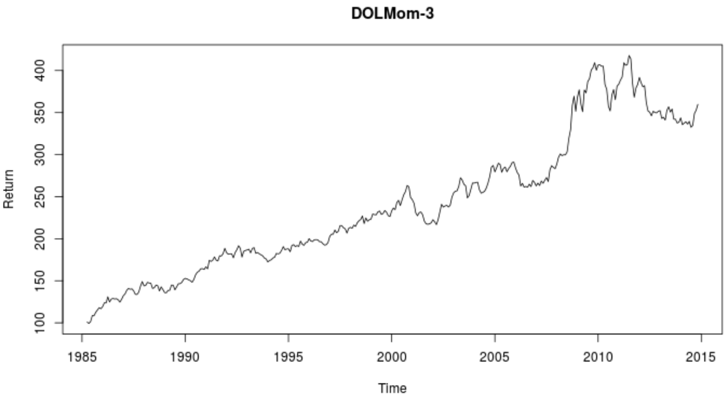


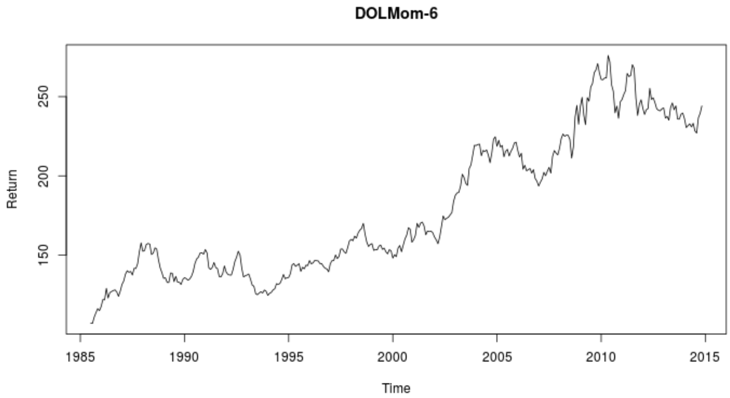





Mom-6
Mom-9
Mom-12
Carry
Carry - Assets
Carry - Liabilities
Return
Time
1985
1990
1995
2000
2005
2010
2015


HLMom-1
HLMom-3
HLMom-6
HLMom-9
HLMom-12
DOLMom-1
Return
Time


DOLMom-3
Return
100
150
200
250
300
350
400
Time
1985
1990
1995
2000
2005
2010
2015


DOLMom-6
Return
150
200
250
Time
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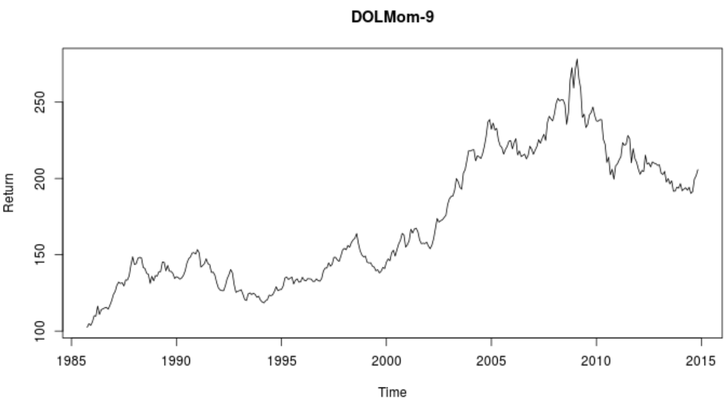
2010
2015


DOLMom-9
Return
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Time
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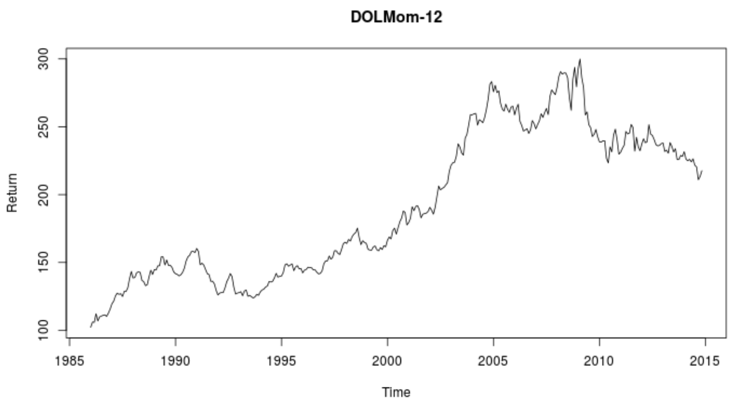
DOLMom-12
Return
100
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Time
1985
1990
1995
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2005
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