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Investigating Excess Returns in Emerging Market Exchange Rates

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ABSTRACT

Three investment strategies have been established in the currency market: carry, momentum, and value. These strategies have historically delivered abnormal returns, which contradicts finance theory. Uncovered interest parity postulates that a foreign currency's higher interest rate will be offset by currency depreciation; consequently, the excess return should be zero. However, the opposite is true; these currency strategies have delivered significantly positive excess returns in the past.

This dissertation investigates currency excess returns with a focus on emerging market currencies. The key finding is that emerging markets are the main source of currency returns, while currencies from industrialised countries have limited impact. This key finding is supported using multiple methods, including bootstrap analyses, permutation tests, and linear regressions.

The excess returns of the three currency strategies are a violation of uncovered interest rate parity (UIP). This violation is shown to be regime dependent with structural breaks. The Bai-Perron test and Markov regime-switching model confirm that the slope coefficient in the UIP regression is time varying and regime dependent.

An additional interesting question is how risk factors impact currency excess returns. The results show that common currency market risk factors, including the dollar risk factor (DOL), currency volatility innovation (VOL), and market risk factors, such as equity or commodity returns, have different implications for the carry, momentum, and value strategies. The DOL risk factor has positive loadings on carry returns but negative loadings on momentum returns, and it is not significant for value returns. In contrast, VOL loads negatively on carry returns and positively on momentum returns; it is also not significant for currency value. Moreover, the returns of these three strategies are not correlated with each other.

However, currency returns are sensitive to transaction costs. Since emerging market currencies are the major source of currency returns and, at the same time, have higher bid-ask spreads than developed market currencies, currency returns

are affected by transaction costs. Currency excess returns are also time varying and have performed poorly in the period following the financial crisis after 2008.

Resumen

Se han establecido tres estrategias en el mercado de divisas: carry, momentum y value. Históricamente, estas estrategias han generado retornos anormales, lo cual contrasta con la teoría financiera. La paridad de interés descubierta (UIP, por sus siglas en inglés)postula que una tasa de interés más alta en una divisa extranjera será compensada por una depreciación de la divisa. Como resultado, el retorno excesivo debería ser cero. Sin embargo, ocurre lo contrario; las estrategias de divisas han generado retornos excesivos significativamente positivos en el pasado.

Esta disertación investiga los retornos excesivos de las divisas centrándose en las divisas de mercados emergentes. El hallazgo clave es que los mercados emergentes son la principal fuente de retornos en divisas, mientras que el impacto de las divisas de países industrializados es limitado. Este hallazgo clave está respaldado por el uso de diferentes métodos, como análisis de bootstrap, pruebas de permutación o regresiones lineales.

Estos retornos excesivos de las tres estrategias de divisas violan la paridad de interés descubierta. En esta disertación se muestra que esta violación es régimen dependiente y contiene rupturas estructurales. Mediante el uso de la prueba de Bai-Perron y el modelo de cambio de régimen de Markov, se demuestra que el coeficiente de pendiente en la regresión de UIP es variable en el tiempo y régimen dependiente.

Otra pregunta de interés es el impacto de los factores de riesgo en los retornos excesivos de las divisas. Los factores de riesgo comunes en el mercado de divisas, como el factor de riesgo del dólar (DOL), la innovación de la volatilidad de las divisas (VOL) o los factores de riesgo del mercado, como los retornos de acciones o materias primas, tienen implicaciones diferentes para las estrategias carry, momentum y value. El factor de riesgo DOL tiene cargas positivas en los retornos de carry pero cargas negativas en los retornos de momentum, y no es significativo para los retornos de value. En contraste, la volatilidad de la divisa VOL tiene cargas negativas en los retornos de carry pero cargas positivas en los retornos de momentum, y tampoco es significativa para el valor de la divisa. Además, los retornos de las tres estrategias no están correlacionados entre sí.

Sin embargo, los retornos de divisas son sensibles a los costes de transacción. Dado que las divisas de mercados emergentes son la principal fuente de retornos en divisas y, al mismo tiempo, estas divisas tienen spreads de compra y venta más altos que las divisas de los mercados desarrollados, los retornos de divisas se ven afectados por los costes de transacción. Además, los retornos excesivos de divisas son variables en el tiempo y han tenido un rendimiento deficiente en el período posterior a las crisis financieras 2008.

KEY WORDS

Exchange rates, currencies, emerging markets, uncovered interest rate parity, carry, momentum, value, excess return

PALABRAS CLAVES

Tipos de cambio, divisas, mercados emergentes, paridad de interés descubierta, carry, momentum, value, retorno excesivo

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"The curious task of economics is to demonstrate to men how little they really know about what they imagine they can design". Friedrich August von Hayek (1899-1992).

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ABBREVIATIONS AND ACRONYMS

ADF, Augmented Dickey-Fuller test

AUD, Australian dollar

BRL, Brazilian real

CAD, Canadian dollar

CBOE, Chicago Board Options Exchange

CHF, Swiss franc

CIP, Covered interest rate parity

CLP, Chilean peso

COM, Commodities

COP, Colombian peso

CZK, Czech koruna

DOL, Dollar risk factor

EM, Emerging markets

EUR, Euro

EQ, Equation

FW, Forward rate

GBP, Great Britain pound

GFC, Global financial crisis

HML, High minus low

HUF, Hungarian forint

IDR, Indonesian rupiah

ILS, Israeli shekel

IND, Industrialised markets

INR, Indian rupee

INT, Interest rate

JPY, Japanese yen

KRW, South Korean won

LMS, Long minus short

MXN, Mexican peso

NOK, Norwegian krone

NZD, New Zealand dollar

PEN, Peruvian sol

PHP, Philippine peso

PLN, Polish zloty

PP, Phillips-Perron test

PPP, Purchasing power parity

RER, Real exchange rate

REER, Real effective exchange rate

RUB, Russian rouble

SEK, Swedish krona

SETAR, Self-exciting threshold autoregression

SP, Spot rate

TAR, Threshold autoregression

THB, Thai baht

TRY, Turkish lira

TWD, New Taiwan dollar

UIP, Uncovered interest rate parity

VAL, Value (strategy)

VIX, CBOE volatility index

VOL, Volatility innovation risk factor

ZAR, South African rand

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I – INTRODUCTION AND PRELIMINARY REMARKS

I - INTRODUCTION AND PRELIMINARY REMARKS

1.1. OBJECTIVE

This dissertation contributes to the existing research in the field of foreign exchange markets. Most studies focus on currencies from developed countries or on mixed data with currencies from developed and emerging countries. In contrast, this study elaborates on the importance of emerging market currencies with the question of how these currencies account for currency excess returns. The central result of this research is that emerging market currencies are in fact the source of currency excess returns, while the impact of currencies from industrialised countries is limited.

Since the collapse of Bretton Woods in the early 1970s, currencies have been extensively researched, leading to three established currency strategies: carry, momentum, and value. In the past, these strategies have delivered abnormal excess returns and have therefore been the subject of numerous studies. A common research question is whether excess returns are compensation for risk and, if so, which risk factors can explain excess returns.

However, the findings regarding currency excess returns contradict finance theory. According to the concept of uncovered interest rate parity (UIP), a higher foreign currency interest rate is compensated for by the foreign currency's depreciation. Thus, excess returns should not be observed. This is why excess returns, especially for the three identified currency strategies, is such an exciting research topic.

This study focuses on emerging market currencies. As later shown, emerging market currencies are the main driver of currency excess returns under the three strategies of carry, momentum, and value. To clearly distinguish between emerging and developed markets, the results are presented for both groups. This allows the difference between the excess returns of emerging and developed markets to be elaborated.

An additional question is how excess returns can be explained and to which risk factors they can be attributed. It is shown that the impact of common risk factors such as the dollar risk factor or the currency volatility risk factor is different for the carry, momentum and value strategies.

This thesis is structured as follows. After the introduction, chapter II presents the excess returns of a buy-and-hold currency strategy. The returns are shown to be time varying, but overall, this straightforward strategy fails to yield any profit. The concept of UIP, which is presented in chapter III, is a key element in currency markets. The Bai-Perron test and Markov regime-switching model show that the failure of UIP is regime dependent and subject to structural breaks. Chapters IV, V, and VI present the excess returns of the carry, momentum, and value currency strategies, respectively. The focus is on emerging markets, and emerging market currencies are shown to be the crucial element of currency returns, while industrialised currencies have limited impact. In addition, how risk factors influence currency returns is examined in each of the three chapters. The risk factors are demonstrated to have different impacts depending on the currency strategy. Finally, Chapter VII concludes and discusses the study's limitations.

1.2. DATA

The focus of the thesis is emerging markets, which are the markets in countries that are evolving from developing to industrialised. However, there is no unified definition for emerging markets. This thesis uses MSCI´s definition, where 24 countries worldwide are classified as emerging markets. Important aspects of MSCI´s market classification framework are market accessibility and liquidity.[1] This is relevant for the implementation of currency strategies in practice. Other definitions, such as that of the OECD, define about 140 countries as emerging markets. However, the currencies of these countries are partly not liquid due to trade restrictions.

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[1] An overview of emerging markets and the MSCI Market Classification Framework can be found on the MSCI Inc. homepage at https://www.msci.com/our-solutions/indexes/market-classification.

Some of the 24 emerging market countries have pegged their currencies to other currencies, primarily the US dollar, the Euro, or a basket of different currencies. The following currencies from emerging markets were in the past or are currently pegged to other currencies, so they are not appropriate for the investigations in this dissertation: in the Middle East, the Egyptian pound, Kuwaiti dinar, Qatari riyal, Saudi riyal, and United Arab Emirates dirham, and in Asia, the Malaysian ringgit and Chinese renminbi. In Europe, Greece, among other countries, is considered an emerging market. The Greek drachma has been replaced by the Euro and is therefore not further considered in this research. Russia has not been included as an emerging market since 2022, as it no longer fulfils the emerging market conditions of the MSCI Market Classification Framework. Since Russia was considered a developing country until 2021 and market data for Russian currency are still available for 2022, this currency is included in the analyses.

In total, data from 17 emerging market currencies are examined. Table 1 shows the currencies of the emerging markets sorted by continent.

Table 1: Emerging Market Countries

EUROPE	AMERICA	AFRICA	ASIA
Czech Republic (CZK)	Brazil (BRL)	South Africa (ZAR)	India (INR)
Hungary (HUF)	Chile (CLP)		Indonesia (IDR)
Poland (PLN)	Columbia (COP)		Philippines (PHP)
Russia (RUB)	Mexico (MXN)		South Korea (KRW)
Turkey (TRY)	Peru (PEN)		Taiwan (TWD)
			Thailand (THB)

Note. The table shows the currencies of those emerging markets that are examined in this research. The ISO codes of the currencies are given in brackets.

To highlight the differences between the currencies of emerging markets and those of developed countries, both groups are regularly compared in this dissertation. MSCI's definition identifies 23 developed countries worldwide. The currencies of some of these countries, including Singapore, Hong Kong, and Denmark, are pegged to other currencies or a basket of currencies. Ten industrialised countries belong to the European Monetary Union. Thus, the 23 industrialised countries have a total of eleven different currencies or currency areas with floating currency regimes. Table 2 shows the currencies of the industrialised countries examined in this dissertation, sorted by continent.

Table 2: Currencies of Industrialised Countries

EUROPE	AMERICA	AUSTRALIA	ASIA
United Kingdom (GBP)	USA (USD)	Australia (AUD)	Japan (JPY)
Switzerland (CHF)	Canada (CAD)	New Zeeland (NZD)	Israel (ILS)
Norway (NOK)			
Sweden (SEK)			
European Monetary Union (EUR)			

Note. The table shows the currencies of the industrialised countries studied in this dissertation. The ISO codes of the currencies are given in brackets.

Since two currencies are always necessary for currency trading and the US dollar is predominantly used as the base currency in this research, the number of industrialised country currency pairs examined is reduced to ten.

A single currency pair incorporates ideosyncratic risk. Following Lustig et al. (2014), this study examines two currency baskets in addition to individual currency pairs to eliminate ideosyncratic risk. Due to this dissertation's focus on emerging markets, the first currency basket consists of the 17 emerging market currencies. The basket reflects the average excess return of the 17 emerging market currencies against the base currency, the US dollar. The second currency basket includes the 10 industrialised countries' currencies. This basket reflects the average excess return of the 10 industrialised countries' currencies against the US dollar.

Unless stated otherwise, the data source is Refinitiv Eikon. The available data histories of the developed and emerging market currencies differ. In addition, longer time series are available for spot rates than for forward rates. Table 3 shows the start date of the available data.

Table 3: Data Availability

Currency	ISO Code	Availability Spot	Availability Forward
Emerging Markets			
Brazilian real	BRL	Jan 1991	Aug 2000
Chilean peso	CLP	Nov 1990	Dec 2002
Colombian peso	COP	Nov 1989	Jan 2004
Czech koruna	CZK	Jan 1991	Dec 1996
Hungarian forint	HUF	Jun 1993	Sep 1996
Indian rupee	INR	< Jan 1980	Aug 1996
Indonesian rupiah	IDR	Dec 1987	Nov 1990
Mexican peso	MXN	Nov 1989	Dec 1998
New Taiwan dollar	TWD	Oct 1983	Oct 2000
Peruvian sol	PEN	Jan 1991	Aug 2003
Philippine peso	PHP	May 1992	Aug 1996
Polish zloty	PLN	Jun 1993	Aug 1996
Russian rouble	RUB	Sep 1994	Feb 2000
South African rand	ZAR	< Jan 1980	May 1990
South Korean won	KRW	Apr 1981	March 2001
Thai baht	THB	Jan 1981	March 1995
Turkish lira	TRY	Nov 1989	Jul 1995
Developed Countries			
Australian dollar	AUD	< Jan 1980	May 1990
Canadian dollar	CAD	< Jan 1980	May 1990
Eurozone, euro	EUR	< Jan 1980	May 1990
Great Britain pound	GBP	< Jan 1980	May 1990
Israeli shekel	ILS	< Jan 1980	Jan 2002
Japanese yen	JPY	< Jan 1980	May 1990
New Zealand dollar	NZD	< Jan 1980	May 1990
Norwegian krone	NOK	< Jan 1980	May 1990
Swedish krona	SEK	< Jan 1980	May 1990

Swiss franc	CHF	< Jan 1980	May 1990

Note. Availability of spot and forward rates via Refinitiv Eikon for the various currencies.

For the emerging market currencies, forward prices are available from 1997 for 9 of the 17 currencies. The period before 1997 is not suitable for consideration due to lack of data. Hence, data from January 1997 to December 2022 are used for the analyses. Refinitiv Eikon uses different identifiers for the data, which are presented in Appendix A1.

1.3. EXCESS RETURN DEFINITION

Investors can allocate their capital to different asset classes. Most notably, these include equities, real estate, and bonds, although foreign currencies represent another possible asset class. The profitability of a foreign currency investment is made up of two components: the risk-free interest rate and the nominal exchange rate. First, the level of the foreign currency's risk-free interest rate is relevant because if it is higher than the home currency's interest rate, it has an advantage compared to a risk-free money market investment in the domestic currency. Second, the nominal exchange rate is relevant because it fluctuates over time. Appreciation in a foreign currency leads to a gain, while depreciation leads to a loss.

A foreign currency money market investment's excess return is thus the difference between the log future spot price sp_{t+1} and the log current spot price sp_t plus the interest rate differential between the foreign currency interest rate i^* and the alternative domestic interest rate i. Expressed in logs, the formula for excess returns is shown in Eq. (1):

$$r_{t+1} = sp_{t+1} - sp_t + i_t^* - i_t \quad (1)$$

The variable sp_t is the logarithmic price in US dollars for one unit of the foreign currency.

According to the concept of covered interest rate parity (CIP), the interest rate differential between two countries corresponds to the difference between the spot price sp_t and the forward price fw_t, so Eq. (2) applies:

$$i_t^* - i_t = sp_t - fw_t \quad (2)$$

Under the condition that CIP holds, the excess return of a foreign currency money market investment can, in addition to Eq. (1), also be expressed as in Eq. (3):

$$r_{t+1} = sp_{t+1} - fw_t \tag{3}$$

The studies in this thesis involve a duration of one month unless otherwise stated. The exchange rates used are end-of-month values. For clarity, duration is not shown in the variables. For example, the forward rate $fw_{t,k}$ represents the forward price at time t with a maturity k. Since the maturity k is usually one month in this research, duration is not indicated.

Excess returns as shown in Eq. (1) are only possible if uncovered interest rate parity (UIP) fails. UIP is an important concept in finance theory which postulates that the interest rate difference between two currencies is equal to the difference between the future and current spot price (Fama 1984), so Eq. (4) applies.

$$i_t - i_t^* = sp_{t+1} - sp_t \tag{4}$$

Under the condition that UIP holds, the excess return in Eq. (1) corresponds to zero.

In contrast to UIP, CIP in Eq. (2) is a no-arbitrage condition, that is, deviations from CIP reveal the opportunity of risk-free arbitrage profits. If, for example, the interest rate abroad is higher than at home, but at the same time the forward price corresponds to the spot price, then arbitrage profit is possible. Investors would borrow money domestically, convert it at the spot rate and invest it abroad at a higher interest rate. At the same time, investors would eliminate the currency risk by selling the foreign currency at the forward price. Since this price is identical to the spot price, investors generate arbitrage profits.

Akram et al. (2008) show that although there are deviations from CIP, this arbitrage is quickly exploited by the market; therefore a researcher can assume that CIP holds. However, deviations from CIP have intensified since the global financial crisis (Du et al. 2018; Liao 2020). Cerutti et al. (2021) argue that deviations from CIP are due to funding constraints. If banks and corporations are unable to raise the required amount of liquidity in US dollars, they must raise it synthetically. They borrow in the domestic currency and swap the equivalent into US dollars. If the conditions for direct funding differ from those for synthetic funding, this leads to deviations from CIP or to a dollar basis ≠ 0 (Cerutti et al. 2021).

From the perspective of an investor who is not subject to funding constraints but wants to invest money, deviations from CIP may even be an advantage. US investors have two options for investing in foreign currency. They can convert their capital into foreign currency at the spot rate sp_t, invest the equivalent at the foreign interest rate i^*, and convert the amount back at maturity at the future spot rate sp_{t+1}. The excess return above the risk-free interest rate then corresponds to equation (1). However, investors can also continue to invest their liquidity domestically at a risk-free rate and synthetically implement an investment in foreign currency. In this case, investors acquire the foreign currency through a forward fw_t but do not enter into physical delivery, instead closing out the forward at the future spot rate sp_{t+1} on the maturity date. The excess return then corresponds to that from equation (3). Under the condition that both execution methods involve the same risk, investors will choose the method expected to produce the highest returns.

In this dissertation, the focus is on the excess return synthetically generated by the forward transaction, which has several advantages. It excludes the risks associated with the physical purchase of a foreign currency, such as risks from capital controls, country risk, or foreign counterparty risk. Moreover, tax differences for domestic and foreign money market investments do not play a role. The forward transaction counterparty risks are negligible if appropriately hedged with collateral, as required in the European Union.

The dissertation's focus is on emerging market currencies. Since currencies are always traded in pairs, a base currency against which the target currency is traded must be defined. The US dollar is primarily used for this purpose. At relevant stages, the robustness of the results is assessed by additionally using the Euro and the British pound as base currencies.

Currency excess returns can be investigated both for a single currency and for a basket of currencies. However, idiosyncratic risk exists in the case of a single currency. To eliminate this risk, excess returns on currency baskets are examined in addition to excess returns on individual currencies. The monthly excess return on a currency basket is the average of the monthly excess returns of the individual currencies in the basket, as shown in Eq. (5):

$$r_{t+1}^{B} = \frac{1}{n}\sum_{i=1}^{n} r_{t+1}^{i} \tag{5}$$

The excess return of currency basket r_{t+1}^{B} can be considered the excess return of an investor who invests in that currency basket, which comprises n currencies. To distinguish the currencies of emerging markets from those of industrialised countries, two currency baskets are defined. One currency basket consists of 17 emerging market currencies, while the other includes 10 currencies from industrialised countries.

1.4. RISK FACTORS

Investing in currencies involves exposure to risk. Therefore, an interesting question is which risk factors impact currencies' excess returns. The literature presents numerous risk factors, while for currency markets the dollar risk factor (Lustig et al. 2011) and currency volatility (Menkhoff et al. 2012a) are among the most important. In addition, various studies show that market risk factors, such as equity or commodity market risks, are relevant (Dobrynskaya 2014; Byrne et al. 2019).

This section provides a description of the risk factors. In the further course of this dissertation, the risk factors are then applied to different currency strategies.

Dollar risk factor

Lustig et al. (2011) introduced an important risk factor for currency markets. In their oft-cited study, the authors show that the dollar risk factor (DOL) accounts for a major part of currency excess returns in the cross-section. Using a time frame of 11/1983 to 12/2009, they sort 35 currencies according to their forward discount and then assign them to six different portfolios. Lustig et al. (2011) find that the DOL can explain more than 70% of the portfolios' excess returns.

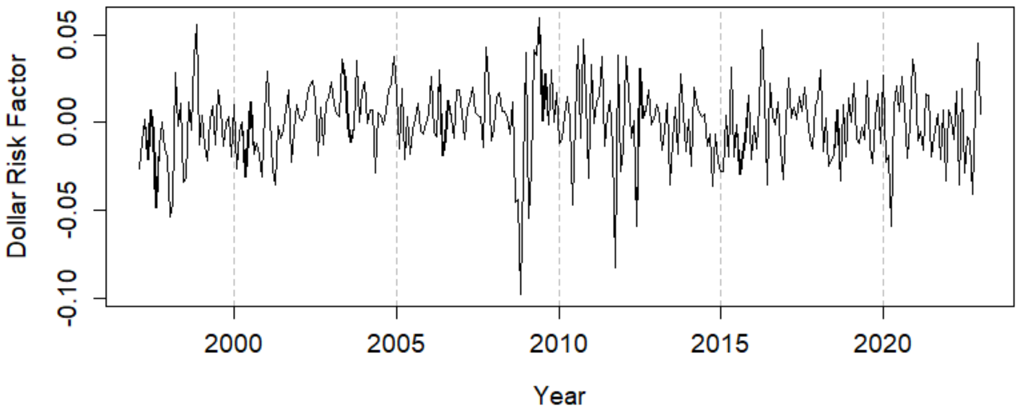
The DOL is a straightforward representation of the US dollar's average return against a bundle of exchange rates. It is calculated in Eq. (6) as

$$r_{t+1}^{DOL} = \frac{1}{n}\sum_{i=1}^{n} r_{t+1}^{i} \tag{6}$$

Since DOL represents the average excess return of different currencies, it is equal to the currency basket as shown in Eq. (5). The interpretation of this risk factor is that a specific investment strategy that has significant and positive loadings on DOL is exposed to broad currency risk. In this study, the monthly average excess returns of the 27 currencies are used to calculate the DOL.

Figure 1 shows the monthly values of the DOL risk factor.

Figure 1: Dollar Risk Factor



Note. The figure shows the time series of the dollar risk factor DOL.

Verdelhan (2018) complements Lustig et al.'s (2011) studies and shows that the DOL accounts for a large part of dynamics in bilateral exchange rates. In addition, he shows that individual currency factor loadings can be very different.

The DOL represents the US dollar's development against a bundle of currencies and is considered a global risk factor (Lustig et al. 2014). Various studies demonstrate the importance of the US dollar as a risk factor (Jiang et al. 2020; Avdjiev et al. 2019; Bruno et al. 2022).

Volatility risk factor

Another risk factor that is important for currency markets is currency volatility. In their oft-cited study, Menkhoff et al. (2012a) introduce the volatility innovation risk factor (VOL). They report that currencies with low interest rates offer a hedge in times of high volatility, while currencies with high interest rates deliver poor returns when volatility is high.

This study applies the volatility risk proxy used in Menkhoff et al. (2012a). For each currency *c*, the absolute daily change in the spot rate is calculated with Eq. (7):

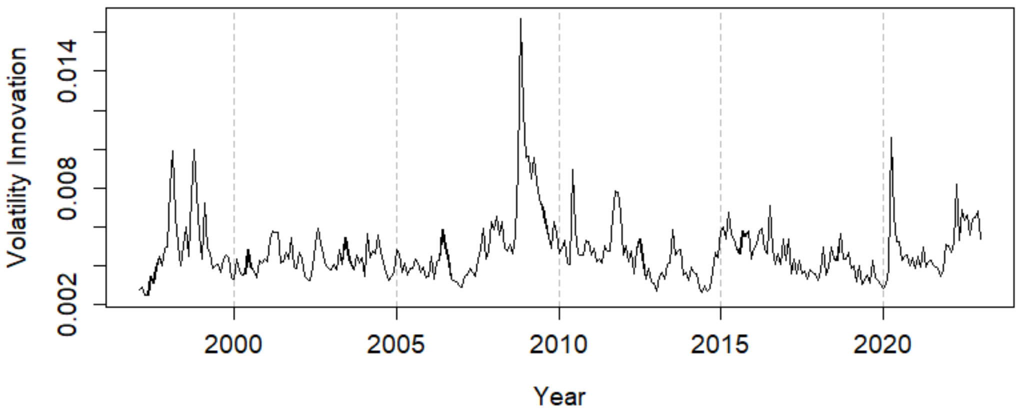
$$\left|r_{c,\tau}\right| = |\Delta sp_\tau| \tag{7}$$

Then, for each day τ, the average absolute change $\left|r_{c,\tau}\right|$ of all available currencies c is calculated. From these daily average values, the average value of each month t is calculated, which is used as the monthly volatility risk proxy. Mathematically, Eq. (8) shows the calculation of VOL.

$$\sigma_t^{FX} = \frac{1}{T_t} \sum_{\tau \in T_t} \left[\sum_{c \in C_\tau} \left(\frac{\left|r_{c,\tau}\right|}{C_\tau} \right) \right] \tag{8}$$

The number of currencies available on day τ is indicated by C_τ. The value T_t corresponds to the number of days τ in month t. The monthly volatility innovation σ_t^{FX} thus corresponds to the average daily absolute change in the spot rates of the available currencies. Figure 2 shows the time series of the volatility risk proxy between January 1997 and December 2022.

Figure 2: Volatility Innovations as a Risk Proxy



Note. The figure shows the time series of the volatility innovation risk factor VOL.

The risk factor shows notable spikes during the global financial crisis. Higher values can also be seen during the Asian crisis in the 1990s and the pandemic in 2020.

Market risk factors

Investors who hold foreign currencies are interested in whether the currency risk has positive loadings on other asset classes. If, for example, stock markets fall in 'bad times' and at the same time, foreign currencies perform poorly, the latter are less attractive from an allocation point of view.

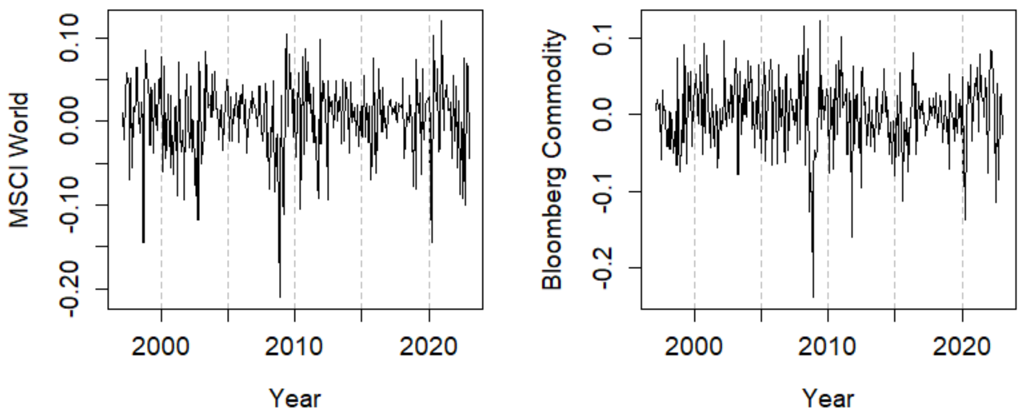
The relationship between currency excess returns and market risk factors, such as equities or commodities, has been studied by various scholars (Atanasov and Nitschka 2014; Dobrynskaya 2014; Lettau et al. 2014). These studies show that currencies have positive loadings on equity markets. In times of weak stock prices, currencies perform poorly against the US dollar.

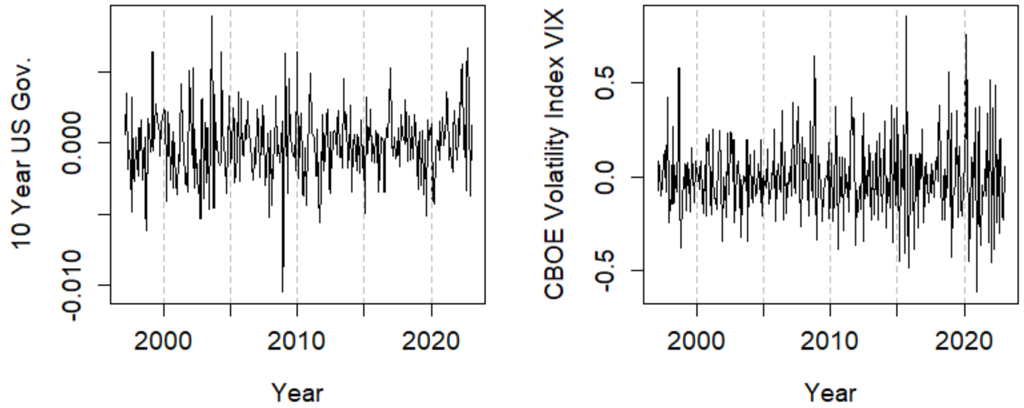
In the following, three different asset classes are examined regarding their impact on currency returns: equities, interest rates, and commodities. In addition, stock markets´ volatility is used as a risk factor.

Equities are represented by the monthly return of the MSCI World index (MSCI) and commodities are represented by the Bloomberg Commodity Total Return Index (COM). The monthly change in the yield of 10-year US government bonds with constant maturity is used as the interest rate risk factor (INT). In addition, the monthly change in the CBOE volatility index (VIX) is used as a market risk factor for volatility. The VIX represents the implied volatility for equity options on the S&P 500 with a remaining maturity of 30 days.

Figure 3 shows the time series of the market risk factors.

Figure 3: Market Risk Factors





Note. The figure shows the time series of different risk factors: equity, commodity, interest rate, and equity volatility.

In total, six different risk factors are used in this study. Two of them, VOL and VIX, are related to volatility. These risk factors correlate negatively with the other four risk factors. In addition, the latter correlate positively with each other. Table 4 shows the correlation matrix of the six risk factors.

Table 4: Risk Factors´ Correlations

	DOL	VOL	MSCI	COM	INT	VIX
DOL	1.00	–0.22	0.627	0.556	0.007	–0.415
VOL	–0.22	1.00	–0.3	–0.281	–0.138	0.058
MSCI	0.627	–0.3	1.00	0.449	0.193	–0.697
COM	0.556	–0.281	0.449	1.00	0.125	–0.27
INT	0.007	–0.138	0.193	0.125	1.00	–0.16
VIX	–0.415	0.058	–0.697	–0.27	–0.16	1.00

Note. The table presents correlations of the DOL, VOL and market risk factors.

This study examines the impact of these risk factors on currency excess returns. As will be shown later, their influence varies depending on the currency strategy.

II – CURRENCY EXCESS RETURNS

II - CURRENCY EXCESS RETURNS

2.1. CHAPTER INTRODUCTION

Three main strategies have been established in currency markets: carry, momentum, and value. The literature reports abnormal returns for these strategies (see sections 4.2, 5.2, and 6.2). Counterpoint to this are the returns of a long-term buy-and-hold strategy. As shown in this chapter, this strategy does not provide an excess return. One would also expect an excess return of zero if UIP holds. UIP is an important financial theory that postulates that a higher interest rate in a foreign currency is accompanied by depreciation in that currency. Due to the importance of UIP, Chapter III is dedicated to this topic.

The present chapter examines the excess returns for a buy-and-hold investor from January 1997 to December 2022 based on the assumption that a forward contract with a one-month maturity is rolled every month. Contradictory to carry, momentum, and value strategies, there is no statistically significant excess return for buy-and-hold investors. Even after eliminating idiosyncratic risk by building currency baskets, no significant excess return is observed.

Moreover, the returns are time varying. Only between 2001 and 2006 was it possible for a US investor to achieve significant excess returns by investing in emerging market currencies.

This chapter provides the results of currency returns for a buy-and-hold investor and is structured as follows. Section 2.2 offers a review of the existing literature. Section 2.3 reports descriptive analyses of monthly excess returns from the perspective of a US investor. The robustness of these results is verified using the Euro and British pound as base currencies, in addition to the US dollar. The results are presented in section 2.4. A single currency pair is exposed to idiosyncratic risk. To eliminate this, section 2.5 evaluates the excess returns of two currency baskets consisting of 17 emerging markets and 10 developed markets' currencies. Section 2.6 examines the time-variance of excess returns. Section 2.7 investigates the impact of various risk factors on currency excess returns, and section 2.8 concludes.

2.2. LITERATURE REVIEW

Under the Bretton Woods system, which was in effect until the early 1970s, currencies were pegged to the gold price via the US dollar. The exchange rate variance was small, so currencies were not an interesting field for research. After the collapse of Bretton Woods in 1973, a system of floating exchange rates was established. As a result, currency markets increasingly became a research focus, since currency rates were now determined by supply and demand.

A major research question since the 1970s has been whether economic models such as UIP are really applicable in practice. According to UIP, the change in a spot price is offset by the interest rate differential between the two countries involved. Under the condition that CIP holds, UIP states that a currency's forward price is an unbiased estimator of the future spot price. Hence, UIP failure is a prerequisite for generating currency excess returns. In fact, there are large numbers of studies showing that UIP does not hold, and thus currency excess returns are possible.

Meese and Rogoff (1983) showed that a forward price does not predict the future spot price any better than a random walk. Exchange rate behaviour can thus be better explained by a random walk than by economic models.

Fama (1984) investigated UIP by using linear regression to examine the relationship between forward prices and future spot prices. Contrary to expectations based on UIP, he showed that currencies with high interest rates do not depreciate but actually appreciate. This contradiction has since been called the Fama puzzle, forward premium puzzle, or UIP puzzle. Numerous other studies have confirmed Fama's (1984) findings of UIP failure (Hodrick 1987; Engel 1996; Bansal 1997; Chinn 2006).

As a consequence of the UIP failure, three strategies have emerged in theory and practice: carry, momentum, and value. The literature documents abnormal returns for these strategies (see sections 4.2, 5.2, and 6.2). In contrast, the excess returns of buy-and-hold strategies are limited and often not statistically significant. Consequently, researchers do not focus on buy-and-hold strategies.

The spare literature on currency buy-and-hold strategy shows that excess returns are rarely statistically significant. Evans (2020) examines 17 currencies against the US dollar between 2006 and 2015; only four of the 17 currencies had positive excess returns during this period.

Gospodinov (2009) reports excess returns close to zero against the US dollar for five major currencies from 1975 to 2006. Gilmore and Hayashi (2011) examine emerging and developed market currencies with monthly data from 1996 to 2010. For 19 out of 20 emerging market currencies, they report positive excess returns, and 7 of these were significant at the 5% level. They also examine the excess returns of nine currencies from industrialised countries. These countries all have positive excess returns, but they are not significant at the 5% level.

Accominotti et al. (2019) present statistics for 18 different currencies between 1971 and 2017 with the British pound as the base currency. Only half of the currencies achieved positive average returns. However, with the exception of the New Zealand dollar, the returns are not statistically significant for any currency.

Della Corte et al. (2022) provide statistics for 21 different currencies, including 14 emerging market currencies. The period studied is from 2003 to 2017, with 14 of 21 currencies showing positive average excess returns. However, only for three currencies the returns are statistically significant at the 5% level.

The literature on buy-and-hold currency strategies shows that, in most cases, no statistically significant excess returns can be achieved with this strategy. This underlines Meese and Rogoff´s (1983) findings that currencies follow a random walk.

2.3. BUY-AND-HOLD EXCESS RETURNS

This section examines monthly excess returns from January 1997 to November 2022 from the perspective of a US investor. The buy-and-hold position is created by buying the respective currency at the forward price with a maturity of one month. At the end of the month, the position is closed at the spot price and a new position is opened. However, as illustrated by Gilmore and Hayashi (2011), in practice the position is not closed but rolled using FX swaps, reducing transaction costs. Accordingly, the monthly excess return is calculated with bid prices using Eq. (9).

$$r_{t+1} = sp_{t+1}^{BID} - fw_t^{BID} \tag{9}$$

To aid in interpreting the values for the emerging market currencies, the results for the industrialised countries´ currencies are also reported. Table 5 shows the summary statistics for the excess returns of different currencies from the perspective of a US investor.

Table 5: Monthly Excess Returns

	mean	standard error	t-value ($\mu = 0$)	standard deviation	skew-ness	kurto-sis	Sharpe ratio
Emerging Markets							
INR	0.001432	0.001099	1.3029	0.019418	–0.2821	5.7793	0.26
KRW	–0.000123	0.001924	–0.06412	0.031085	–0.464	7.6978	–0.01
RUB	0.002515	0.002962	0.84904	0.049026	–0.0223	12.131	0.18
BRL	0.001731	0.003171	0.54579	0.051914	–0.5911	5.0409	0.12
IDR	0.000206	0.003746	0.054948	0.066172	–2.4301	32.091	0.01
MXN	0.002344	0.001902	1.2323	0.032280	–1.2552	8.714	0.25
TRY	–0.00947***	0.002925	–3.237	0.051668	–1.9246	12.658	–0.63
ZAR	0.001275	0.002628	0.48511	0.046414	–0.3866	3.6461	0.10
CLP	–0.000032	0.002384	–0.01341	0.036002	–0.8712	5.9071	0.00
COP	–0.001287	0.002776	–0.46348	0.040707	–0.228	3.5742	–0.11
PLN	0.002162	0.002087	1.0362	0.036859	–0.6713	4.9622	0.20
CZK	0.000904	0.001946	0.46459	0.034367	–0.2421	3.5695	0.09
HUF	0.00098	0.002166	0.45254	0.038265	–0.8879	6.7372	0.09
PHP	0.000161	0.00129	0.12477	0.022793	–1.2145	10.08	0.02
TWD	–0.000933	0.00089	–1.0485	0.014508	0.0545	3.8221	–0.22
THB	–0.000822	0.001783	–0.46141	0.031486	–0.8097	20.821	–0.09
PEN	0.000889	0.001158	0.76791	0.017173	0.2532	4.9727	0.18
Developed Markets							
EUR	–0.00121	0.00156	–0.77542	0.027557	–0.124	4.2079	–0.15
GPB	–0.000806	0.0014	–0.57565	0.02472	–0.3328	4.4191	–0.11
JPY	–0.002425	0.001696	–1.4299	0.029951	0.4299	5.6654	–0.28
CHF	–0.000489	0.001628	–0.30055	0.02876	0.1877	4.6696	–0.06
AUD	0.000758	0.002002	0.3785	0.035368	–0.4017	4.6614	0.07
CAD	–0.000019	0.001388	–0.01359	0.024521	–0.5146	6.2232	0.00
ILS	0.001369	0.001448	0.94531	0.022936	–0.2869	3.696	0.21
NZD	0.001281	0.00208	0.61584	0.036746	–0.2854	4.1535	0.12
NOK	–0.000887	0.001879	–0.47229	0.033181	–0.2573	3.7007	–0.09
SEK	–0.001905	0.001787	–1.0663	0.03156	0.0183	3.3861	–0.21

Note. Table 5 reports summary statistics for 27 currencies against the US dollar. The Sharpe ratio is annualised and calculated as the quotient of the mean × 12 and the standard deviation × √12. Values for the t-statistics test H_0 with mean = 0. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The average monthly excess return is close to 0% for almost all currencies. One exception is the Turkish lira, which has an average monthly excess return of –0.947%. The returns of the emerging market currencies are a minimum of –0.947% and a maximum of 0.2515%; for the industrialised countries, the range is between –0.2425% and 0.1369%. The standard deviation for emerging markets ranges from 1.45% to 6.62%, while for developed markets, the lowest and highest values are 2.29% and 3.67%, respectively. Divergent values are found in the skewness, which is more negative for some emerging markets. Sharpe ratios are highest for the Indian rupee at 0.26 and the Mexican peso at 0.25.

Average monthly excess returns close to zero lead to the presumption that a permanent investment in emerging market currencies does not yield any advantages compared to a risk-free domestic money market investment. To test this, a two-sided one-sample t-test is conducted with the null hypothesis defined as an excess return of zero. The values for the t-statistics are presented in Table 5 above. Except for the Turkish lira, none of the currencies have t-values that are significant at the 5% level. Moreover, the Turkish lira's average excess return is negative and was thus not profitable from an investor's perspective.

The 17 emerging and 10 developed market currencies show no abnormal excess returns from a buy-and-hold perspective. Among the emerging markets, 11 of 17 currencies have positive excess returns, but they are not significantly different from zero. A higher interest rate in a foreign currency is thus offset by devaluation of the foreign currency and vice versa.

The excess returns shown in Table 5 are from the perspective of a US investor. Since currencies are always traded in pairs, a change in the exchange rate means appreciation in one currency and depreciation in the other. The excess returns shown in Table 5 thus all have a common factor, that is, the US dollar. General appreciation of the US dollar would therefore affect not only a single currency pair but all or at least several currency pairs quoted against the US dollar. Hence, the individual currencies' excess returns are expected to be correlated with each other.

To evaluate the correlations of the individual currencies' excess returns, the Pearson correlation coefficient for all 27 currencies (17 emerging market currencies and 10 currencies from industrialised countries) is calculated as in equation (10):

$$\rho_{r_a, r_b} = \frac{\sum_{t=1}^{n}(r_{t,a} - \bar{r_a})(r_{t,b} - \bar{r_b})}{\sqrt{\sum_{t=1}^{n}(r_{t,a} - \bar{r_a})^2 \sum_{t=1}^{n}(r_{t,b} - \bar{r_b})^2}} \tag{10}$$

with $r_{t,a}$ and $r_{t,b}$ as the excess returns of currencies a and b, respectively, at time t, and n = 27. In total, there are $27 \times 26 \div 2 = 351$ different correlation coefficients. The highest correlation, 0.87, is found for the excess returns of the EUR (euro) and CZK (Czech coruna). The average of all 351 correlation coefficients is 0.41. This indicates that appreciation of the US dollar is not related to just a single currency but to a broad bundle of currency pairs. However, the Japanese yen is an exception. The yen's excess returns only weakly correlate with the other currencies' excess returns, averaging 0.17. The lowest correlation value of –0.09 is found in the excess returns of the Japanese yen (JPY) and Russian ruble (RUB). Appendix B1 shows the complete correlation matrix.

The p-values of the individual correlation coefficients, except that of the Japanese yen (JPY), are almost all smaller than 0.01. One currency's excess return is thus predominantly not independent of another currency's excess return. This means that general appreciation or depreciation of the US dollar not only manifests for a single currency pair but in several currencies quoted against the US dollar at the same time. As a consequence, the investigation of other base currencies than the US dollar is of interest, which is carried out in the next section.

2.4. DIFFERENT BASE CURRENCIES

The excess returns in Table 5 are presented from the perspective of a US investor. To verify the robustness of the results, the excess returns are also studied for other base currencies, specifically, the euro and the British pound. Table 6 shows the excess returns of the 27 currencies from the perspective of a EUR-based investor. The results from the perspective of a British investor are shown in Appendix B2.

Table 6: Monthly Excess Returns, Base Currency = EUR

	mean	standard error	t-statistics ($\mu = 0$)	standard deviation	skew-ness	kurto-sis	Sharpe ratio
Emerging Markets							
INR	0.002642°	0.001529	1.7275	0.027015	0.0221	3.1378	0.34
KRW	–0.000346	0.001691	–0.20448	0.027319	–0.7366	6.7586	–0.04
RUB	0.002724	0.003011	0.90466	0.049840	0.287	12.768	0.19
BRL	0.001593	0.003138	0.50766	0.051375	–0.5877	5.6858	0.11
IDR	0.001416	0.00377	0.37551	0.066588	–2.1487	27.852	0.07
MXN	0.003321	0.002057	1.6146	0.034908	–0.5846	5.3706	0.33
TRY	–0.00826**	0.002906	–2.8423	0.051325	–1.7119	11.316	–0.56
ZAR	0.002484	0.002453	1.013	0.043320	–0.4483	3.9746	0.20
CLP	0.001438	0.002162	0.66533	0.032643	0.1367	3.4591	0.15
COP	0.000464	0.002514	0.18475	0.036858	–0.1844	3.9884	0.04
PLN	0.003372*	0.00137	2.461	0.024203	–0.6012	4.4112	0.48
CZK	0.002114*	0.000971	2.1762	0.017156	–0.5866	5.7143	0.43
HUF	0.002190°	0.001235	1.773	0.021819	–0.7401	6.9623	0.35
PHP	0.001371	0.001748	0.78423	0.030874	–0.2348	4.5663	0.15
TWD	–0.001254	0.001446	–0.86754	0.023583	0.0178	4.2105	–0.18
THB	0.000387	0.001977	0.19584	0.034929	–0.1273	9.8025	0.04
PEN	0.002294	0.001797	1.2765	0.026656	–0.1405	4.5859	0.30
Developed Markets							
USD	0.001210	0.00156	0.77542	0.027557	0.1240	4.2079	0.15
GPB	0.000404	0.00127	0.31812	0.022440	–1.0230	9.0211	0.06
JPY	–0.001215	0.001939	–0.62653	0.034249	0.9412	6.4901	–0.12
CHF	0.00072	0.000979	0.7362	0.017284	2.5213	20.981	0.14
AUD	0.001968	0.001561	1.2607	0.027567	–0.2399	2.9001	0.25
CAD	0.001191	0.001479	0.80508	0.026128	–0.1189	3.4844	0.16
ILS	0.001076	0.00161	0.66847	0.025513	–0.1984	3.4374	0.15
NZD	0.002491	0.001596	1.561	0.028186	–0.2073	3.1621	0.31
NOK	0.000323	0.00122	0.26445	0.021544	–0.3688	5.6502	0.05
SEK	–0.000695	0.00092	–0.75622	0.016243	0.1467	5.2315	–0.15

Note. The table shows the summary statistics of the excess returns of 27 currencies against the euro. The Sharpe ratio is the quotient of the mean × 12 and the standard deviation × √12. Additionally, t-statistics for mean = 0 are reported. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The excess returns from the perspective of a European investor are predominantly distributed around 0%. The Eastern European currencies, that is, the Polish zloty (PLN) and Czech koruna (CZK), are positive at the 5% significance level. The Turkish lira shows a negative excess return, significant at the 1% level.

Even from a EUR investor's perspective, a long-term buy-and-hold investment in different currencies is not profitable. This applies to currencies from both emerging markets and developed countries. The statistics for excess returns from a British investor's perspective are shown in Appendix B2.

Analogous to the case where the USD is the base currency, no positive excess return exists for any currency at the 5% significance level. Only the excess return for the Turkish lira is significant, but it is negative. The results for EUR-based and GBP-based investors are thus similar to the results for USD-based investors, which underlines their robustness.

2.5. EXCESS RETURNS FOR CURRENCY BASKETS

Individual currency pairs exhibit idiosyncratic risk, which can be eliminated by looking at several currencies at the same time. Therefore, two baskets of currencies are investigated, one for the 17 emerging market currencies and the other for the 10 industrialised market currencies. The monthly excess returns of the baskets corresponds to the average excess returns of the individual currencies.

$$r_{t+1}^{Basket} = \frac{1}{n}\sum_{i=1}^{n} r_{t+1}^{i} \quad (11)$$

The currencies in the baskets are equally weighted and rebalanced monthly. The monthly excess return of a single currency is indicated by r_{t+1}^{i}, the number of currencies in the basket is denoted by n, with the maximum number of emerging (industrialised) market currencies being 17 (10).

Table 7 presents statistics of the baskets´ monthly excess returns with the US dollar, euro and British pound as base currencies. Emerging market baskets are denoted EM and industrialised country baskets are denoted IND:

Table 7: Monthly Excess Returns for Baskets

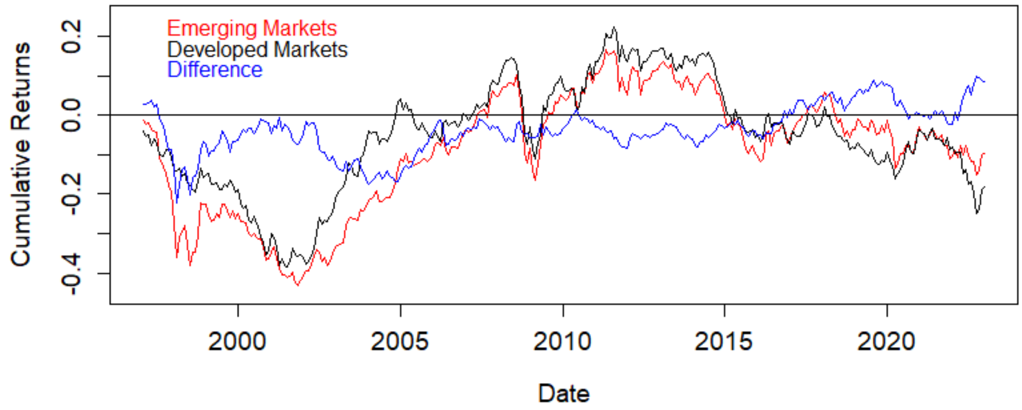
	mean	standard error	t-statistics ($\mu = 0$)	standard deviation	skew-ness	kurto-sis	Sharpe ratio
USD based investor							
EM	–0.000308	0.001356	–0.22737	0.023952	–0.6403	5.1174	–0.04
IND	–0.000582	0.001282	–0.45385	0.022638	–0.1344	4.0028	–0.09
EUR based investor							
EM	0.000901	0.001235	0.72453	0.021977	–0.3076	3.7909	0.14
IND	0.000765	0.00085	0.90065	0.015005	0.0032	3.7772	0.18
GBP based investor							
EM	0.000497	0.001422	0.34977	0.025115	0.2799	5.0766	0.07
IND	0.00031	0.001114	0.27844	0.019673	0.8585	6.8975	0.05

Note. Table 7 presents summary statistics of the excess returns for the two currency baskets. The returns are shown from the perspective of a USD, EUR, and GBP investor. The Sharpe ratios are annualised (mean × 12 ÷ standard deviation × √12).

The evaluation of the currency baskets also leads to the conclusion that an investment in a bundle of foreign currencies does not produce an excess return. In addition, the differences in the means and standard deviations of the emerging and developed markets are not notable. The results hold from the perspective of a USD investor and from the perspectives of EUR and GBP investors, which demonstrates the robustness of the results.

It can also be seen graphically that the excess returns for the two currency baskets are close to zero. Figure 4 shows the cumulative excess returns for the two baskets and the difference between the emerging and developed market baskets from the perspective of a US investor.

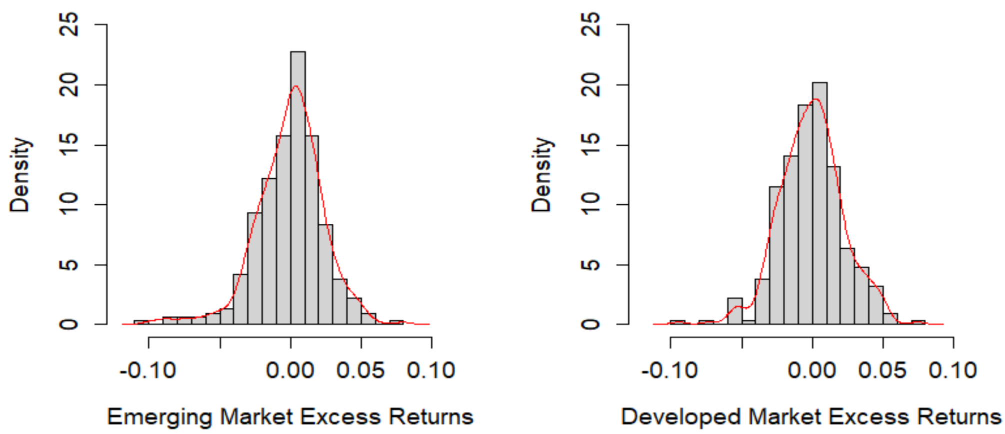
Figure 4: Cumulative Excess Returns for Currency Baskets



Note. The figure shows the accumulated excess returns for emerging and developed market baskets and their accumulated differences.

A notable pattern is the similar development of the two baskets. Periods of predominantly positive excess returns for emerging market currencies are accompanied by positive excess returns for industrialised countries, as shown by the correlation coefficient of 0.76. Between 1997 and 2002, investing in foreign currencies was unprofitable in both the emerging and developed market currencies' baskets. Between 2002 and 2012, predominantly positive returns prevailed. From 2012 onwards, the cumulative excess return dropped again. It is, therefore, conceivable that excess returns are time dependent, which is examined in the next section. The distribution of the excess returns for the two baskets is presented in Figure 5.

Figure 5: Excess Return Histogram



Note. Figure 5 shows the distribution of the monthly excess returns for emerging and developed markets and its density.

Differences between the emerging and developed currencies are only slightly noticeable in the graphs. Emerging market currencies show a more pronounced kurtosis than developed countries' currencies, while the negative skewness is slightly more pronounced for emerging market currencies.

2.6. TIME-VARYING EXCESS RETURNS

The analyses in the previous section show that in the long term, the average excess return of an investment in a bundle of different currencies is close to 0%. The evaluations cover 312 months from January 1997 to December 2022. However, it is conceivable that the average monthly excess return for shorter periods differs from the average monthly excess return for the entire period of 312 months. To examine this, rolling time periods with durations of 36 months are analysed following Lustig et al. (2011) and Menkhoff et al. (2012a).

Figure 6 shows the rolling average monthly excess returns for an investment period of 36 months. The returns are presented for the two currency baskets.

Figure 6: 36-month Rolling Returns

Note. The figure shows the rolling excess returns (monthly average) for emerging and developed market currency baskets with a duration of 36 months.

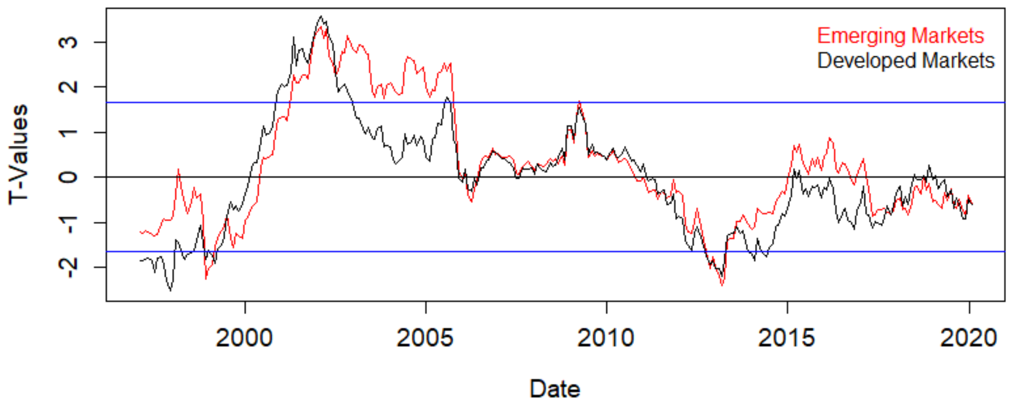
The rolling returns do not show a robust pattern. The highest monthly average excess return for the 36-month periods is 0.83% for emerging markets and 1.12% for developed markets. The lowest value is –0.75% for emerging markets and

–0.74% for developed markets. However, in numerous rolling periods the returns are predominantly close to zero, making it conceivable that the returns shown are not significantly different from zero. Therefore, a rolling evaluation of the t-values is performed, considering the standard deviation *sd* and number of months with $n = 36$. The expected mean μ is assumed to be zero. This tests whether the rolling returns are statistically significant. The formula shown in Eq. (6)

$$T = \frac{\bar{x} - \mu(0)}{sd \times \sqrt{n}} \tag{12}$$

is used to calculate the rolling t-values. Figure 7 illustrates the rolling t-values of the excess returns for emerging and developed market currencies:

Figure 7: T-Values for Rolling Returns (36 months)



Note. Rolling t-values for a 36-month rolling investment in emerging and developed market currency baskets. The blue lines mark the 5% significance level.

In addition to the t-values and zero line, the critical values for the 5% significance level based on the t-distribution table, 1.688 and –1.688, are shown as horizontal blue lines. The rolling 36-month returns were positive at the 5% significance level only at the beginning of the 2000s. Primarily positive returns were achieved between 2000 and 2010; since then, the rolling returns have been predominantly negative. Excess returns are therefore time varying. Significantly positive excess returns were only achieved in the early 2000s.

2.7. RISK FACTORS

The previous sections in this chapter show that there have been no significant excess returns for a buy-and-hold strategy over the last 26 years; moreover, the returns are time varying. This chapter examines how risk factors impact currency returns.

The risk factors used were presented in section 1.4 in detail. The relationship between the risk factors and the excess returns are analysed with single linear regressions as shown in Eq. (13):

$$r_t = \alpha + \beta RF_t + \varepsilon_t \quad (13)$$

with RF_t as the respective risk factor at time t.

In total, six different risk factors are investigated. First, the results for the DOL risk factor are presented in Table 8.

Table 8: Dollar Risk Factor Regressions

	constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
Emerging Markets					
INR	0.001628°	0.519595***	0.04092	12.698	0.3422
KRW	–0.001178	1.038261***	0.061296	16.939	0.5256
RUB	0.002023	1.013411***	0.122465	8.275	0.2011
BRL	0.00072	1.42382***	0.117114	12.158	0.3572
IDR	0.000752	1.4482***	0.150978	9.592	0.2289
MXN	0.002117	0.940674***	0.069808	13.47	0.3883
TRY	–0.009033***	1.155488***	0.117109	9.867	0.239
ZAR	0.001809	1.415114***	0.089904	15.74	0.4442
CLP	–0.000137	1.083285***	0.078722	13.761	0.4559
COP	–0.000926	1.336642***	0.081715	16.36	0.5568
PLN	0.002668*	1.340216***	0.058115	23.061	0.6318
CZK	0.001357	1.201825***	0.057565	20.88	0.5844
HUF	0.001501	1.380396***	0.061138	22.578	0.6219
PHP	0.000355	0.514718***	0.051501	9.994	0.2437
TWD	–0.001333*	0.443553***	0.030657	14.468	0.4423
THB	–0.000526	0.786103***	0.06855	11.468	0.2979
PEN	0.000848	0.398386***	0.043439	9.171	0.2784

Developed Markets					
EUR	–0.000836	0.990867***	0.044264	22.385	0.6178
GPB	–0.00055	0.676613***	0.051463	13.15	0.358
JPY	–0.002267	0.418374***	0.074102	5.646	0.0932
CHF	–0.000162	0.868712***	0.056119	15.48	0.436
AUD	0.001266	1.34698***	0.050908	26.459	0.6931
CAD	0.000277	0.784388***	0.045546	17.222	0.4889
ILS	0.000723	0.603289***	0.053778	11.218	0.3357
NZD	0.001793	1.357562***	0.056305	24.111	0.6522
NOK	–0.000432	1.206206***	0.052338	23.047	0.6315
SEK	–0.001463	1.172077***	0.047877	24.48	0.6591

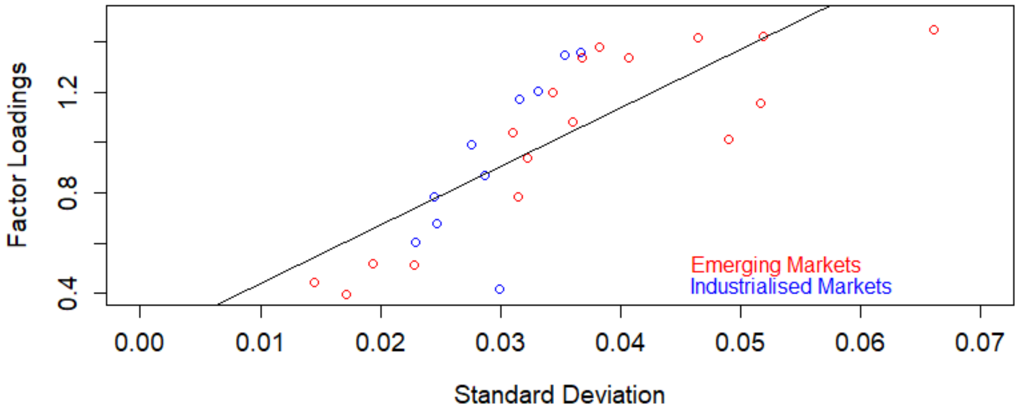
Note. The table presents the results of a single linear regression with the dollar risk factor (DOL) as the independent variable. The dependent variable is the individual currency's excess return. °, *, ** and *** indicate significance at the 10%, 5%, 1% and 0.1% levels, respectively.

The DOL is significant for all 27 excess returns at the 0.1% level. In addition, a substantial part of the cross-sectional currency returns can be explained by the DOL. R^2 is partially above 0.6, with the lowest value of 0.09 for the Japanese yen.

The slope coefficients are positive for all currencies and range between 0.40 and 1.42. The loadings for the emerging market currencies are above 1 for 11 out of 17 currencies; for the industrialised countries, this is the case for 4 out of 10 currencies.

A comparison of the DOL loadings to the excess returns standard deviations shows a positive relationship. The higher the excess returns standard deviation, the higher the factor loadings. The correlation coefficient of the two variables is 0.78. Figure 8 presents the factor loadings and excess returns standard deviation, as reported in Table 5 on page 50.

Figure 8: Regression of Factor Loadings on Excess Returns Standard Deviation



Note. The figure illustrates the relationship between the excess returns standard deviation and DOL risk factor loadings. The black line represents the regression line.

An investor who buys currencies with high loadings on the DOL must also accept higher excess returns variance. The Indonesian rupiah and Brazilian real have the highest factor loadings and standard deviations.

Overall, the DOL is relevant in terms of bilateral exchange rates. The broader dynamics of the US dollar are thus a relevant global risk factor. This also underlines the correlation of bilateral exchange rates with the US dollar, which is, in part, very high, as reported in Appendix B1. The DOL's impact implies that as the US dollar rises, it tends to strengthen not only against one currency but simultaneously against several different currencies.

Another important risk factor is currency volatility VOL. Again, the impact of this risk factor on currency excess returns is examined with linear regression, as shown in Eq. (14):

$$r_t = \alpha + \beta VOL_t + \varepsilon_t \quad (14)$$

The regressions´ results are shown in Table 9.

Table 9: Volatility Risk Factor Regressions

	constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
Emerging Markets					
INR	0.01449	–2.76191***	0.67548	–4.089	0.0512

KRW	0.021713	–4.614032***	1.186391	–3.889	0.0552
RUB	0.006002	–0.739751	1.910007	–0.387	0.0006
BRL	0.030988	–6.178998**	1.997328	–3.094	0.0347
IDR	0.03587	–7.54076**	2.3402	–3.245	0.0329
MXN	0.033383	–6.610813***	1.18147	–5.595	0.0987
TRY	0.020477	–6.331776***	1.809784	–3.499	0.038
ZAR	0.022774	–4.545947**	1.6373	–2.776	0.0243
CLP	0.014363	–3.004201*	1.423476	–2.11	0.0193
COP	0.018238	–4.055399*	1.613419	–2.514	0.0288
PLN	0.027739	–5.408043***	1.279985	–4.225	0.0545
CZK	0.013419	–2.64627*	1.218072	–2.173	0.015
HUF	0.024792	–5.034933***	1.336281	–3.768	0.0438
PHP	0.006879	–1.420459°	0.809968	–1.754	0.0098
TWD	0.005348	–1.325254*	0.01688	–2.356	0.0206
THB	0.008893	–2.054183°	1.11837	–1.837	0.0108
PEN	0.000082	0.168283	0.6873	0.245	0.0003
Developed Markets					
EUR	0.007916	–1.929606*	0.978008	–1.973	0.0124
GPB	0.014448	–3.22521***	0.863594	–3.735	0.0431
JPY	–0.019135	3.533227***	1.050619	3.363	0.0352
CHF	0.001597	–0.441078	1.02677	–0.43	0.0006
AUD	0.016904	–3.414074**	1.248097	–2.735	0.0236
CAD	0.015505	–3.282487***	0.855636	–3.836	0.0453
ILS	0.013229	–2.501743**	0.889419	–2.813	0.0308
NZD	0.019438	–3.839186**	1.29404	–2.967	0.0276
NOK	0.018073	–4.008938***	1.1629	–3.447	0.0369
SEK	0.013	–3.151507**	1.112755	–2.832	0.0252

Note. The table presents the results for the regression shown in Eq. (14). °, *, **, and ***, indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

Most currencies have significantly negative loadings on volatility. This means that as currency volatility increases, lower or negative excess returns are to be expected. A significantly positive factor loading is found only for the Japanese yen. However, R^2 are very low for each regression.

These findings are consistent with those of Menkhoff et al. (2012a) that currency volatility negatively loads on currency excess returns. One possible interpretation is that in times of uncertainty, approximated by VOL, capital pours into the US dollar, which thus acts as a safe haven and tends to appreciate. In addition, the Japanese yen acts as a safe haven, giving it a positive factor loading.

Finally, the impact of four market risk factors on currency excess returns is examined. A description of the risk factors is presented in section 1.4 on page 39. Again, a linear regression is used with the respective risk factor as independent variable and the currency excess returns as dependent variable. Using single linear regressions allows to determine each single risk factor´s impact on currency excess returns. Table 10 gives the results of the individual regressions. For convenience, only the slope coefficient, the corresponding t-value and the R^2 are given for all four risk factor regressions in one single table.

Table 10: Single Linear Regressions on Market Risk Factors

	MSCI	COM	INT	VIX
Emerging Markets				
INR	0.1888***	0.1327***	–0.1948	–0.0279***
	(8.81), [0.2]	(5.916), [0.101]	(–0.447), [0.001]	(–5.6), [0.092]
KRW	0.3681***	0.2507***	–0.1375	–0.0445***
	(10.409), [0.295]	(6.653), [0.146]	(–0.182), [0]	(–5.285), [0.097]
RUB	0.3052***	0.3421***	3.7427**	–0.0597***
	(4.937), [0.082]	(5.76), [0.109]	(3.265), [0.038]	(–4.49), [0.069]
BRL	0.5846***	0.4479***	3.9076**	–0.0827***
	(9.93), [0.27]	(7.263), [0.166]	(3.183), [0.037]	(–6.012), [0.12]
IDR	0.2959***	0.1783*	1.4152	–0.0365*
	(3.701), [0.042]	(2.229), [0.016]	(0.955), [0.003]	(–2.06), [0.014]
MXN	0.3974***	0.2914***	1.7877*	–0.0656***
	(11.503), [0.316]	(7.961), [0.181]	(2.399), [0.02]	(–8.053), [0.185]
TRY	0.3439***	0.2965***	0.7085	–0.0614***
	(5.664), [0.094]	(4.887), [0.072]	(0.612), [0.001]	(–4.557), [0.063]
ZAR	0.4563***	0.3917***	0.8714	–0.078***
	(8.929), [0.205]	(7.532), [0.155]	(0.838), [0.002]	(–6.679), [0.126]
CLP	0.3851***	0.3508***	–0.5043	–0.0611***
	(8.327), [0.235]	(8.035), [0.222]	(–0.512), [0.001]	(–6.199), [0.145]
COP	0.4663***	0.3965***	0.5127	–0.0729***
	(9.126), [0.281]	(7.943), [0.229]	(0.447), [0.001]	(–6.587), [0.169]
PLN	0.4513***	0.3829***	0.1074	–0.0617***
	(12.004), [0.317]	(9.742), [0.234]	(0.13), [0]	(–6.65), [0.125]

CZK	0.2942***	0.3203***	–0.838	–0.0355***
	(7.544), [0.155]	(8.49), [0.189]	(–1.089), [0.004]	(–3.936), [0.048]
HUF	0.388***	0.3688***	–0.7081	–0.0544***
	(9.285), [0.218]	(8.852), [0.202]	(–0.826), [0.002]	(–5.538), [0.09]
PHP	0.1415***	0.0684*	–0.021	–0.02***
	(5.249), [0.082]	(2.485), [0.02]	(–0.041), [0]	(–3.329), [0.035]
TWD	0.1492***	0.1162***	–0.24	–0.0179***
	(8.773), [0.226]	(6.65), [0.144]	(–0.687), [0.002]	(–4.515), [0.072]
THB	0.2196***	0.0857*	0.8252	–0.0257***
	(5.965), [0.103]	(2.253), [0.016]	(1.171), [0.004]	(–3.072), [0.03]
PEN	0.122***	0.0814***	–0.198	–0.0204***
	(5.104), [0.107]	(3.515), [0.054]	(–0.412), [0.001]	(–4.159), [0.074]
Developed Markets				
EUR	0.2129***	0.2467***	–1.508*	–0.0247***
	(6.696), [0.126]	(8.082), [0.174]	(–2.464), [0.019]	(–3.389), [0.036]
GPB	0.2128***	0.2204***	0.2938	–0.0223***
	(7.592), [0.157]	(8.042), [0.173]	(0.53), [0.001]	(3–408.), [0.036]
JPY	0.0174	0.0416	–4.3211***	0.0132
	(0.472), [0.001]	(1.142), [0.004]	(–6.908), [0.133]	(1.639), [0.009]
CHF	0.1280***	0.203***	–2.5529***	–0.01
	(3.688), [0.042]	(6.134), [0.108]	(–4.061), [0.051]	(–1.308), [0.005]
AUD	0.489***	0.4639***	–0.2905	–0.00756***
	(14.513), [0.405]	(13.602), [0.374]	(–0.366), [0]	(–8.891), [0.203]
CAD	0.3259***	0.299***	0.9692°	–0.0476***
	(13.61), [0.374]	(12.16), [0.323]	(1.771), [0.01]	(–7.899), [0.168]
ILS	0.2696***	0.1493***	0.0913	–0.0346***
	(10.072), [0.29]	(5.168), [0.1]	(0.16), [0]	(–5.538), [0.11]
NZD	0.4598***	0.3906***	–0.543	–0.0702***
	(12.397), [0.331]	(14.04), [0.246]	(–0.659), [0.001]	(–7.748), [0.162]
NOK	0.3594***	0.4118***	0.0129	–0.0511***
	(10.121), [0.248]	(12.485), [0.335]	(0.017), [0]	(–6.043), [0.105]
SEK	0.347***	0.3434***	–0.8842	–0.0404***
	(10.323), [0.256]	(10.359), [0.257]	(–1.252), [0.005]	(–4.943), [0.073]

Note. The table presents slope coefficients for the regressions of currency excess returns on four different market risk factors. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. Values in parentheses indicate the slope coefficients´ t-values, and values in brackets show the regressions´ R^2.

Similar patterns emerge for all currencies except the Japanese yen. The equity market risk factor (MSCI) is significant at the 0.1% level. R^2 reaches up to 0.405. The situation is similar for the commodity market risk factor, which is significant at the 5% level for all currencies except the yen. Here, R^2 is at a maximum of 0.374. The interest rate´s slope coefficient is not significant for most currencies. The slope coefficient of equity market volatility is negative and significant at the 5% level for all currencies except the Japanese yen and the Swiss franc.

However, no different patterns emerge for emerging market and developed market currencies. Overall, equity and commodity market risk have the greatest impact on the 27 currencies´ excess returns measured by R^2. The slope coefficients of these risk factors are positive. Investors who buy currencies thus load positively on equity and commodity risk.

2.8. CHAPTER CONCLUSION

UIP postulates that the interest rate differential between two currencies are compensated for by appreciation/depreciation of the nominal exchange rate. Accordingly, an investor who invests in a single currency or in a bundle of currencies would not generate an excess return above the domestic money market interest rate. The evaluations performed in this chapter confirm that a long-term buy-and-hold strategy in individual currencies or a basket of currencies would not have generated significant excess returns. This applies to currencies from both emerging markets and industrialised countries.

When examining rolling investments with a duration of 36 months, periods with both positive and negative excess returns are observed. However, the returns are only positive at the 5% significance level in the early 2000s. The results are robust even when currencies other than the US dollar are used as the base currency.

The analyses conducted indicate the validity of UIP theory, at least with a long-term horizon. The interest rate difference between two currencies is offset by the change in the nominal exchange rate, so the excess return is close to zero. UIP theory will therefore be examined in more detail in the following chapter.

In addition, this chapter shows that time-varying excess returns are related to market risks, such as equity or commodity markets; currency returns have positive loadings on these two risk factors. Furthermore, the DOL and VOL risk factors account for currency excess returns. The former can explain up to 60% of bilateral exchange rate dynamics.

III – UNCOVERED INTEREST RATE PARITY

III - UNCOVERED INTEREST RATE PARITY

3.1. CHAPTER INTRODUCTION

The excess return on an investment in foreign currencies is determined by the interest rate differential and the change in the nominal exchange rate. According to the concept of UIP, the interest rate difference is compensated for by the expected change in the exchange rate between t_0 and t_1, as shown in Eq. (15).

$$i_t^* - i_t = sp_t - E_t[sp_{t+1}] \tag{15}$$

The domestic interest rate is given as i_t and the foreign interest rate as i_t^*. The exchange rate $s\rho_t$ is the log US dollar price for one unit of foreign currency. According to UIP, currencies with interest rates higher than the domestic interest rate depreciate, and currencies with lower interest rates appreciate. As a result, an investment in foreign currency would yield an excess return above the risk-free domestic interest rate of 0%.

In fact, section 2.3 shows that investing in a bundle of currencies leads to an excess return that is not different from zero at the 5% significance level. The interest rate differences are thus offset by currency appreciation/depreciation, which is an indication that UIP could hold.

However, numerous studies show that this is not the case. Many studies even show the opposite: if interest rates abroad are higher than at home, it results in appreciation of the foreign currency. This is also known as the UIP puzzle or forward premium puzzle (Fama 1984).

This chapter examines whether UIP is valid. If so, no excess return can be achieved with an investment in a foreign currency since interest rate advantages are compensated for by currency devaluation. The failure of UIP is thus the prerequisite for excess returns.

The analyses in this chapter show that UIP is time varying. The Bai-Perron test for structural breaks and the Markov regime switching model show that the slope coefficient of the UIP regression can take both positive and negative values. There are periods and regimes in which UIP is rejected at the 5% significance level and periods and regimes where this is not the case. In addition, UIP is rejected more often for developed countries than for emerging market countries.

Further research in this chapter shows that deviations from UIP are related to risk. A presumption of UIP is the existence of risk-neutral market participants. The studies in this section show that market participants are risk-averse and demand a risk premium that is higher for emerging markets than for developed markets. Moreover, a risk proxy, the VIX index, can explain part of the deviation from UIP.

A further assumption of UIP is rational expectations. Rational expectations assumes that market participants' expectations, for example, regarding the future development of exchange rates, coincide with economic models. The studies in this chapter show that market participants have systematic expectational errors. This misalignment of forecasts is another reason for the failure of UIP.

This chapter is structured as follows: Section 3.2 presents the existing literature on UIP. Section 3.3 examines UIP for both emerging and developed markets. Sections 3.4 and 3.5 analyse whether deviations from UIP are time varying, using the Bai-Perron test for structural breaks and the Markov regime switching model. Section 3.6 examines whether deviations from UIP are due to a risk premium, and section 3.7 considers deviations from UIP in terms of non-rational expectations. Section 3.8 provides a summary and conclusion for this chapter.

3.2. LITERATURE REVIEW

UIP is a central element of economics and has been widely studied since the collapse of Bretton Woods in 1973. Along with Hansen and Hodrick (1980) and Bilson (1981), Fama (1984) was one of the first to test UIP using linear regression. He examined the relationship between the change in the spot rate $sp_{t+1} - sp_t$ and the forward premium $fw_t - sp_t$.

According to the UIP concept, the beta factor in the regression set up by Fama (1984) shown in Eq. (13)

$$sp_{t+1} - sp_t = \alpha + \beta(fw_t - sp_t) + \varepsilon_t \tag{16}$$

is expected to equal 1. A major result of his investigations is that the beta factor not only deviates from unity but is, in fact, negative. An interest rate advantage in a foreign currency money market position would thus additionally result in appreciation of the foreign currency. This connection has since been called the UIP puzzle, forward premium puzzle, or Fama puzzle.

Fama (1984) was followed by numerous other investigations in subsequent years that confirmed the negative beta factor (Frankel and Chinn 1993; Hodrick 1987; Mark and Wu 1998; Engel 1996; Bekaert and Hodrick 1993). However, there was limited data for the studies in the 1990s, since time series usually start from the collapse of Bretton Woods in 1973 or thereafter. Later studies, especially those in recent years, include historical data up to 50 years. These studies have been unable to fully confirm the negative slope coefficient and thus offer an unclear picture. The beta factor is time varying and whether UIP is rejected or not is subject to the time series used.

Engel et al. (2022) investigate major currencies against the US dollar. They show that there is little evidence against UIP. In particular, for the period after the global financial crisis, the slope coefficient in Eq. (16) is positive. Moreover, its standard error is very high, which is why the null hypothesis of the Fama regression with $\beta = 1$ cannot be rejected. Engel et al. (2022) also conduct rolling regressions with a time horizon of ten years. They conclude that the slope factor is time varying and smaller than unity at the 5% significance level, mainly in the 1980s. Most of the time, however, the null hypothesis that the coefficient is 1 cannot be rejected at the 5% level.

Bussière et al. (2022) show that the slope coefficient in the Fama regression is positive during and after the financial crisis. This means that a higher interest rate abroad leads to depreciation of the foreign currency. The authors use data from 1999 to 2021 to contradict the results of Fama (1984) and call this the New Fama Puzzle.

Ismailov and Rossi (2018) show that deviations from UIP are large during periods of high uncertainty, while UIP holds when uncertainty is low. To define uncertainty, they introduce an index that measures uncertainty in foreign exchange markets. They deduce that deviations from UIP are due to a time-varying risk premium.

Cheung and Wang (2022) investigate different subperiods for nine currencies quoted against the US dollar. They use proxy variables to explain the deviations from UIP. They show that including these variables reduces the deviations from the beta factor of 1. The slope coefficient is negative between Q3 1997 and Q2 2007 for all nine currency pairs and is not equal to 1 in five cases at the 5% significance level. Between Q3 2007 and Q4 2018, all slope coefficients are positive. Furthermore, the null for $\beta = 1$ cannot be rejected at the 5% significance level for any single currency for this period.

In addition to the studies mentioned above, there are numerous studies on UIP (Boudoukh et al. 2016; Chinn and Zhang 2018; Galí 2020; Cheung and Wang 2022; Lee and Jung 2020; Londono and Zhou 2017). For an overview of studies prior to 2014, see Engel (2014); an overview of the older studies can be found in Engel (1996).

In a meta-study, Zigraiova et al. (2021) analyse 91 studies with 3,643 estimates of UIP. They show that the negative slope coefficient in Eq. (16) is due to publication bias, which is the tendency to publish results that are statistically significant and consistent with the results of other research (Christensen and Miguel 2018). Zigraiova et al. (2021) adjust the slope coefficient for publication bias, showing that it is no longer negative but still less than 1. For emerging (developed) markets, it is 0.98 (0.31). In addition, they show that the coefficient is influenced by the choice of data and the base currency.

Many studies examine the currencies of industrialised countries; however, studies that include or focus exclusively on emerging markets are less numerous. One of the first to examine the differences between emerging and developed markets was Bansal and Dahlquist (2000). They studied 28 currencies and show that for some emerging market currencies, the beta factor is positive. Chinn (2006) computes the Fama regression for 14 emerging market currencies between December 1996 and April 2004. In six cases, the null hypothesis of $\beta = 1$ cannot be rejected; in eight cases, the beta factor is not negative.

Coudert and Mignon (2013) examine 18 emerging market currencies with respect to different time periods: before, during, and after the global financial crisis. The slope coefficient of the Fama regression is time varying and larger than unity during the financial crisis. Frankel and Poonawala (2010) confirm the negative beta factor for developed market currencies. They also examine 14 emerging markets and find that the beta factor for these currencies is predominantly positive. Other studies on UIP in emerging markets include Coulibaly and Kempf (2019), Alper et al. (2009), and Backé and Schardax (2009).

Further studies do not focus on a broad set of currencies but examine specific individual currencies. Vasilyev et al. (2017) examine UIP for the Russian rouble between 2001 and 2014, reporting a beta factor of 1.63. If the period during the global financial crisis is excluded in the sample, the beta factor drops to 0.27.

Czech (2017) investigates UIP for the Polish zloty with the Japanese yen as the base currency using data from January 2000 to December 2015. Applying the Markov switching model with two regimes, he shows that the slope coefficient in the Fama regression is regime dependent with values of –0.01 and 1.3. In times of high volatility, UIP is valid, while in times of low volatility, the opposite is true.

The UIP literature thus shows inconsistent results. Depending on the period chosen for the investigation, the null hypothesis that the beta factor of the regression in Eq. (16) corresponds to unity is rejected or not. The Fama puzzle refers to the fact that the slope coefficient is negative, and thus an interest rate advantage abroad is associated with additional appreciation of the foreign currency. However, this seems to be limited to the 20th century, while later studies find that the beta factor is time varying.

The literature provides different reasons for the deviations from UIP. One major explanation is the existence of a risk premium. Investors are only willing to accept the risk of varying exchange rates if they are remunerated for it. Since the risk appetites of agents are difficult to measure, UIP makes the assumption that market participants are risk neutral. According to prospect theory, however, this is not the case in real life (Kahneman and Tversky 1979). Agents are risk averse and demand a risk premium for risky assets.

Fama (1984) argues that under the assumption of a risk premium, it follows that the expected future spot price $E[sp_{t+1}]$ is not equal to the forward price fw_t, so that Eq. (17) holds

$$E[sp_{t+1}] = fw_t + rp_t + \varepsilon_t \tag{17}$$

The risk premium rp_t thus fills the gap between the forward price and expected spot price, with many studies considering it to be time varying. However, it should be noted that a US investor's risk premium in the form of a discount on the expected future spot price is, at the same time, a (negative) risk premium from a foreign investor's perspective when investing in US dollars. Engel (1996) and Frankel (1979) show this relationship.

A US investor investing in the Indian rupee, for example, would only buy the currency at a discount to the forward price, with the discount representing the risk premium. From the perspective of an Indian investor investing in US dollars, this discount would have to be exactly the opposite of that of the US dollar. However, not both conditions are possible at the same time. Either the rupee trades at a discount to the dollar, or the dollar trades at a discount to the rupee. This means that a positive risk premium from a US investor's perspective would at the same time be a negative risk premium from an Indian investor's perspective.

The literature usually focuses on a US investor's perspective, which predominantly confirms the existence of a risk premium. Lustig et al. (2011) show that the interest rate differential between a country's interest rate and the US interest rate plays a role in the risk premium. Exposure to a currency with a high interest rate implies high risk. These interest rate differentials are countercyclical, just like the risk premium.

Farhi and Gabaix (2016) come to similar conclusions. They attribute the risk premium to potential rare disasters that cause market participants to demand a risk premium in good times, especially for currencies with high interest rates. This premium is compensation for a possible strong devaluation in bad times.

Della Corte et al. (2022) relate the risk premium to sovereign default risk. They investigate whether higher excess returns occur for countries with poor ratings. Their assumption is that in the event of a country default, the currency will depreciate sharply or even become worthless. In this respect, the default risk for a currency would have to be compensated for by a risk premium. Using linear regression, Della Corte et al. (2022) examine the excess returns of various foreign currencies depending on changes in credit default swaps. They find that the beta factors in the regressions are negative for all currencies examined. Deterioration in the credit spread thus means negative excess returns. From this, they conclude that the currencies of countries with poor ratings have high risk premiums.

Colacito et al. (2020) attribute risk premiums to business cycles and show that risk is related to the output gap. Further evidence for the existence of risk premiums can be found in Londono and Zhou (2017), Ismailov and Rossi (2018), Engel (2016), Gospodinov (2009), and in older publications on this topic in Fama (1984) and Froot and Frankel (1989).

The literature also cites reasons other than risk premiums for the failure of UIP, including market participants' non-rational expectations. Rational expectations theory states that market participants' expectations coincide with macroeconomic models (Muth 1961). Future values and parameters, such as exchange rates or inflation, are subject to uncertainty. According to rational expectations theory, market participants' expectations regarding these economic variables are correct in the long run. However, if market participants have non-rational expectations about the future exchange rate, it would lead to violation of UIP.

To verify if UIP violation is caused by market participants having non-rational expectations, Bussière et al. (2022) test UIP using survey data. They investigate the Fama regression using the ex-ante expected change in a currency instead of the ex-post change. They find that the negative slope coefficient in the Fama regression is related to expectation errors. Chinn and Frankel (2019) also study UIP using foreign exchange forecasts and find that the interest rate differential is positively correlated with the expected spot price change. They also show that FX forecasts contain a risk premium.

In addition to the risk premium and rational expectation errors, the literature presents other reasons for the failure of UIP. These include, for example, the peso problem (Froot and Thaler 1990; Burnside et al. 2011a). The peso problem refers to the fact that market participants consider the risk of a large, unexpected intervention by central banks, which does not actually occur over a longer period of time. Other studies show that UIP failure is due to crash risk (Farhi and Gabaix 2016; Chernov et al. 2018), while yet another explanation is overshooting and investor overconfidence (Burnside et al. 2011c).

Most research uses time series starting after the fall of Bretton Woods in 1973; thus, the failure of UIP could be due to a limited amount of data. This motivated researchers to extend their investigation periods to the years before Bretton Woods. The results contradict those for the post Bretton Woods period. Lothian (2016) studies 16 currency pairs over periods ranging from 90 to 217 years and shows that, in the long run, UIP holds. In earlier work, Lothian and Wu (2011) split a 200+ year time series into different periods. They find that the beta factors of the UIP regressions are positive except when the period is predominantly during the 1980s.

The results of the many studies on the forward premium puzzle are thus puzzling themselves. The findings are partly contradictory, depending on which period or which currencies are considered. This indicates that UIP is subject to structural breaks or regime switching. The following sections therefore examine UIP in this respect.

3.3. UIP REGRESSION

The results from section 2.3 support the assumption that there is a relationship between the interest rate differential and the spot rate change. In the long run, an investment in foreign currencies leads to excess returns close to zero. It follows that the interest rate differential, that is, the forward premium or discount, equals the change in the spot rate.

UIP represents the non-arbitrage relationship between the expected change in the exchange rate and the interest rate differential:

$$E_t[sp_{t+1}] - sp_t = i_t - i_t^* \quad (18)$$

The value sp_t is the USD price in logs for one unit of foreign currency. A rising sp_t thus indicates appreciation of the foreign currency and depreciation of the US dollar. $E_t[sp_{t+1}]$ indicates the market's expected value of the exchange rate in $t + 1$. The interest rates at time t are indicated by i_t, where the * marks the foreign currency's interest rate. If the interest rate abroad is higher than the interest rate at home, the foreign currency is subsequently expected to devalue.

Assuming that CIP holds, the interest rate difference $i_t - i_t^*$ corresponds to the forward premium/discount:

$$i_t - i_t^* = fw_t - sp_t \quad (19)$$

According to UIP, the expected change in the spot price thus corresponds to the difference between the forward and spot prices; that is, the forward price is an unbiased predictor of the future spot price:

$$E_t[sp_{t+1}] - sp_t = fw_t - sp_t \quad (20)$$

Fama (1984) examines the relationship between the forward discount and change in the spot rate with the help of linear regression. In the so-called Fama regression in Eq. (21)

$$sp_{t+1} - sp_t = \alpha + \beta(fw_t - sp_t) + \varepsilon_t \quad (21)$$

the focus is on the β-value, as seen in Eq. (22):

$$\beta = \frac{\text{cov}(sp_{t+1} - sp_t, fw_t - sp_t)}{\text{var}(fw_t - sp_t)} \quad (22)$$

Assuming that the change in the spot rate corresponds to the interest rate differential, that is, the forward discount, this results in a β of 1.

In this section, the Fama regression is used to test whether the forward discount/premium is an unbiased predictor of the change in the exchange rate. The data cover January 1997 to December 2022, and monthly data are used. The following table shows the results of the Fama regression from Eq. (21).

Table 11: Results of the Fama or UIP Regression

	constant	β	standard error for β	t–statistics (β = 1)	R^2
Emerging Markets					
INR	–0.001604	0.263306°	0.422240	–1.7447	0.0013
KRW	0.00029	–0.262605	0.795449	–1.5873	0.0004
RUB	–0.004203	–0.138645***	0.311076	–3.6603	0.0007
BRL	–0.004005	–0.005676***	0.223009	–4.5096	0
IDR	–0.011971*	–0.948111***	0.557399	–3.4950	0.0092
MXN	–0.00555°	–0.681973**	0.581716	–2.8914	0.0048
TRY	–0.009398	0.289063	0.496431	–1.4321	0.0016
ZAR	–0.01453*	–1.920370**	1.176440	–2.4824	0.0085
CLP	–0.000356	0.789442	1.139689	–0.1848	0.0021
COP	–0.001872	0.715514	1.020128	–0.2789	0.0023
PLN	0.000474	0.520146	0.486022	–0.9873	0.0037
CZK	0.000869	0.884320	0.739444	–0.1564	0.0046
HUF	–0.002929	–0.067216°	0.559135	–1.9087	0
PHP	0.000689	1.205468	0.495869	0.4144	0.0187

TWD	0.000302	–0.090040	0.753994	–1.4457	0
THB	–0.000879	0.592647**	0.151968	–2.6805	0.0468
PEN	–0.000189	0.252165	0.473344	–1.5799	0.0013
Developed Markets					
EUR	0.000919	–2.030993*	1.342067	–2.2585	0.0073
GPB	–0.001484	–1.186229°	1.276719	–1.7124	0.0028
JPY	–0.002809	1.189215	0.919536	0.2058	0.0054
CHF	0.0033	–1.253121°	1.285873	–1.7522	0.0031
AUD	–0.0024	–1.521033*	1.250452	–2.0161	0.0048
CAD	0.000066	–0.512700	1.641000	–0.9218	0.0003
ILS	0.001115	0.188842	0.773956	–1.0481	0.0002
NZD	–0.001734	–0.857456	1.319887	–1.4073	0.0014
NOK	–0.00179	–0.976399°	1.103507	–1.7910	0.0025
SEK	–0.00056	–1.392063°	1.219303	–1.9618	0.0042

Note. B values marked with °, *, **, and *** deviate from 1 at the significance levels of 10%, 5%, 1%, and 0.1%, respectively. Constant´s significant deviations from 0 are equally marked.

For the 17 emerging market currencies, the null hypothesis of a slope coefficient of unity is rejected at the 5% significance level in six cases. For the industrialised countries, this is the case for the euro, and the Australian dollar. The slope is negative for eight emerging market currencies and eight developed market currencies. This means that a foreign currency interest rate advantage is expected to accompany appreciation of that currency. The results are in line with existing studies. However, for emerging markets, more than half the beta factors are positive, and most do not deviate statistically from unity at the 5% significance level.

As described in section 1.3, in addition to bilateral exchange rates, currency baskets are examined to eliminate ideosyncratic risk. Looking at the two diversified currency baskets, the difference between emerging and developed countries becomes even more evident. The slope coefficient of the Fama regression is positive for the emerging market basket (EM) and above unity. For the industrialised countries (IND), the beta factor is negative and deviates from 1 at the 5% significance level.

Table 12: Fama Regression for Baskets

	constant	β	standard error for β	t-statistics (β = 1)	R^2
EM	0.000626	1.041615	0.481373	0.0865	0.0149
IND	–0.000225	–1.687184*	1.134317	–2.369	0.0071

Note. β values marked with °, *, **, and *** deviate from 1 at the significance levels of 10%, 5%, 1%, and 0.1%, respectively. The constants are not significantly different from zero.

For the currency baskets, the null hypothesis that the beta factor is 1 and thus the forward price is an unbiased predictor for the future spot price must be rejected for the industrialised countries. The null hypothesis is not rejected for the emerging market countries. However, R^2 is very small, analogous to the individual currency pairs in Table 11.

There is a major difference in the interest rate differentials of the emerging market and industrialised countries' currencies. The average interest rate differential of emerging market currencies to the US dollar is 0.30% per month, while that of industrialised countries is only 0.01%. With a beta factor of –1.687 for the industrialised countries and a forward discount of 0.01%, for example, considering the constant of –0.000225, the interest rate differential estimator would be –0.019%. In Eq. (21), the smaller the interest rate differential, the smaller the beta factor's influence on the estimated change in the exchange rate. This could be one reason the beta factor for the industrialised countries deviates from unity at the 5% significance level, but the R^2 shows that the regression cannot explain the change in the spot rate.

Overall, the analyses conducted in this section present an unclear picture. For some individual currencies, UIP must be rejected, while for others, it is valid. The currencies of industrialised countries seem to violate UIP more than those of emerging market currencies. For the former, the slope coefficient is predominantly negative. For emerging market currencies, the hypothesis that the slope coefficient is different from 1 cannot be rejected at the 5% significance level for the currency basket and for most individual currencies.

3.4. STRUCTURAL BREAKS

One possible explanation for the unclear results in the previous section is that the slope coefficient of the UIP regression is time varying, which is the conclusion of some recent studies. For example, Bussière et al. (2022) show that the beta factor is regime dependent and that different beta factors arise in different time periods. Cheung and Wang (2022) and Ismailov and Rossi (2018) also come to this conclusion (see section 3.2).

In this section, it is investigated whether the slope coefficient of the UIP regression is subject to structural breaks and thus whether it is time varying. To identify structural breaks, the Bai-Peron test (Bai and Perron 1998) is applied, following Bussière et al. (2022). The dates of the breaks are unknown variables estimated by the test. The structural breaks do not have to occur at the same time for each currency.

Bussière et al. (2022) divide the data into three periods, assuming that there are two breaks. However, the number of breaks is unknown and could be different than two. Therefore, to obtain robust results, different settings for the number of breaks are used with a minimum value of one and a maximum value of three. The results for two breaks are presented in Table 13, and the results for the other settings are shown in Appendix C1 and Appendix C2.

In the following, the UIP regression as shown in Eq. (21) on page 77 is examined again, but now two structural breaks are taking into account. As a result, different slope coefficients β_{P1}, β_{P2} and β_{P3} are calculated for the first, second and third period, respectively. Table 13 shows the regression´s results, that is the slope coefficients and its standard errors. The number of observations in each period is given by *n*.

Table 13: Beta Factors for Three Different Time Periods

	β_{P1}	se (β_{P1})	*n*	β_{P2}	se (β_{P2})	*n*	β_{P3}	se (β_{P3})	*n*
Emerging Markets									
INR	0.17°	0.49	175	–5.11*	2.74	56	0.24	0.81	81
KRW	–2.55	2.77	42	–8.1***	1.73	50	3.09°	1.10	169
RUB	1.55*	0.22	129	11.18***	2.16	50	–1.47***	0.55	95
BRL	–0.05**	0.32	45	1.37	0.66	86	–0.05	1.21	137

IDR	–2.19*	1.54	52	–1.92***	0.72	173	–4.37**	1.70	87
MXN	–0.8**	0.54	122	–6.76**	2.52	109	7.54	4.50	57
TRY	–8.3***	1.87	42	4.8*	1.69	121	0.03	0.85	52
ZAR	–1.7	1.65	60	–4.5*	2.11	70	–1.95	2.79	182
CLP	12.71°	6.90	58	–1.74	1.69	34	0.7	1.50	136
COP	–4.48*	2.59	39	1.81	1.25	75	–1.21	2.17	101
PLN	1.31	0.80	98	10.87**	3.62	48	0.82	1.68	166
CZK	–0.32	1.20	46	–1.04	2.00	92	1.58	1.65	174
HUF	1.2	0.70	134	–27.05**	8.15	46	–0.12***	0.04	132
PHP	2.21	1.75	46	1	0.71	87	–3.23***	1.10	179
TWD	0.44	1.26	47	–6.43**	2.72	42	–0.42	1.16	177
THB	1.95	1.11	52	0.23***	0.13	80	0.74	0.16	180
PEN	0.05	0.72	103	–1.34*	0.91	35	–3.88***	1.32	82
Developed Markets									
EUR	–1.36	3.62	61	–3.64*	2.18	74	0.67	1.95	177
GPB	–4.25*	2.22	95	8.93*	3.17	46	–1.32	2.68	171
JPY	–1.53	1.94	126	3.4	1.78	55	4.96°	2.25	131
CHF	5.07	6.46	53	–1.77	2.51	122	2.45	1.99	137
AUD	–2.49°	1.94	143	13.78	8.71	46	2.42	2.14	123
CAD	–2.27°	1.85	130	–19.05*	8.50	46	4.52	2.58	136
ILS	–0.89*	0.94	66	15.9**	4.72	61	–1.02	1.57	124
NZD	–4.51**	1.82	100	16.29**	5.72	47	–2.13	2.03	165
NOK	–2.65**	1.23	118	7.22°	3.73	75	1.39	2.46	119
SEK	–2.29*	1.55	207	16.5***	3.82	46	–1.31	3.22	59

Note. The table shows the slope coefficients and standard errors for the regression of the spot rate change on the forward discount. β values marked with °, *, **, and *** deviate from 1 at the significance levels of 10%, 5%, 1%, and 0.1%, respectively. The number of observations in the respective period is given by n.

The results in Table 13 show that the slope coefficient assumes both positive and negative values. The middle period includes the global financial crisis for several currencies. In this period, the UIP hypothesis is rejected for most currencies. During the first period, the beta factor was negative for almost all developed markets′ currencies; however, this is not the case for the emerging markets' currencies.

In the third period, UIP cannot be rejected for any of the ten developed market currencies. The slope coefficient does not deviate from 1 at the 5% significance level. For emerging markets, this is the case for 12 out of 17 currencies.

Table 13 thus shows that the slope coefficient of the Fama regression is time varying, and its sign changes depending on the market situation for most currencies. Bussière et al. (2022) referred to this aspect as 'the new Fama puzzle'. The results are robust even if one or three structural breaks are used instead of two. The results for these settings are presented in Appendix C1 and Appendix C2.

Looking at the Fama coefficients for the emerging and developed markets' baskets, the variance in the beta factors becomes apparent. Table 14 shows the Fama regression for the emerging and developed markets' baskets for three different periods.

Table 14: Fama Coefficients with Two Structural Breaks for Baskets

	Emerging Markets	Developed Markets
First period [*n*]	01/1997 – 10/2000 [46]	01/1997 – 10/2008 [142]
α	–0.01715 (0.01278)	0.00026 (0.00178)
β	–0.62162 (1.46481)	–3.16237** (1.3474)
R^2	0.004	0.038
Second period [*n*]	11/2000 – 07/2008 [93]	11/2008 – 09/2012 [47]
α	0.00416° (0.00212)	0.02794* (0.00996)
β	0.40497 (0.56133)	30.95768* (11.48166)
R^2	0.006	0.139
Third period [*n*]	08/2008 – 12/2022 [173]	10/2012 – 12/2022 [123]
α	0.00015 (0.00449)	–0.00325 (0.00203)
β	1.43578 (1.35703)	1.9209 (2.10066)
R^2	0.007	0.007

Note. The table shows the regression of the spot rate change on the forward discount. Standard errors are given in parentheses, and the number of observations *n* in the respective period is given in brackets. β (α) values marked with °, *, **, and *** deviate from 1 (0) at the significance levels of 10%, 5%, 1%, and 0.1%, respectively.

The breaks for emerging market currencies are in October 2000 and July 2008. In the late 1990s, emerging market exchange rates were affected by the Asian crisis. The second structural break was in 2008, shortly before the peak of the global financial crisis. For developed markets, the first structural break occurred in October 2008 and the second occurred in 2012.

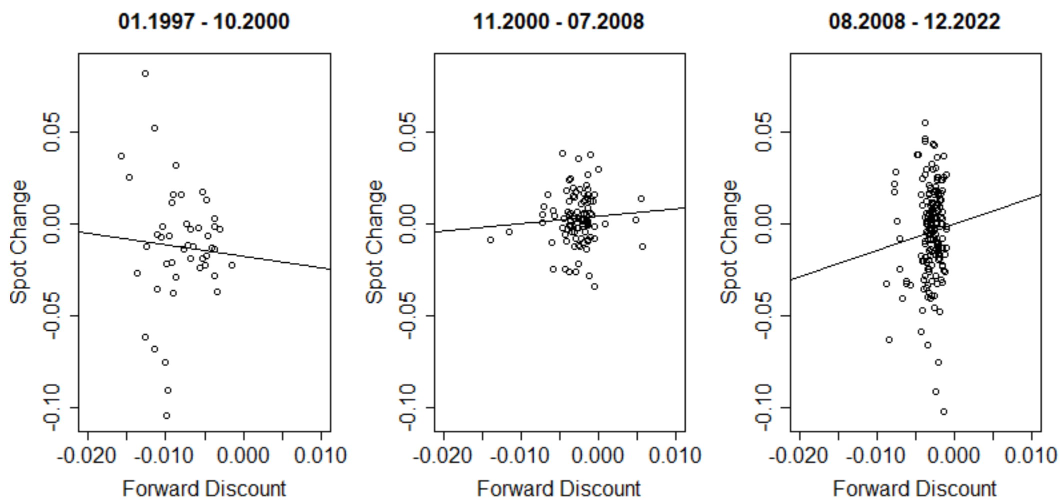
For emerging markets, the slope was positive in the second and third periods. The null of $\beta = 1$ is not rejected for all three periods. Taking structural breaks into account, UIP for emerging markets can thus not be rejected at the 5% significance level.

There is also a time-varying slope coefficient for the developed markets, which is negative in the first period and positive in the other two periods. In the first and second periods, UIP where $\beta = 1$ is rejected at the 5% significance level. However, R^2 is low except in the second period.

Overall, the results indicating a time-varying UIP regression´s slope coefficient are also robust for the baskets. The robustness tests when one or three structural breaks are assumed are presented in Appendix C3 and Appendix C4.

The changes in the beta factor can also be seen graphically. Figure 9 and Figure 10 plot the Fama regression from Eq. (21) for the emerging and developed markets' baskets.

Figure 9: Regressions in Three Periods (Emerging Markets)

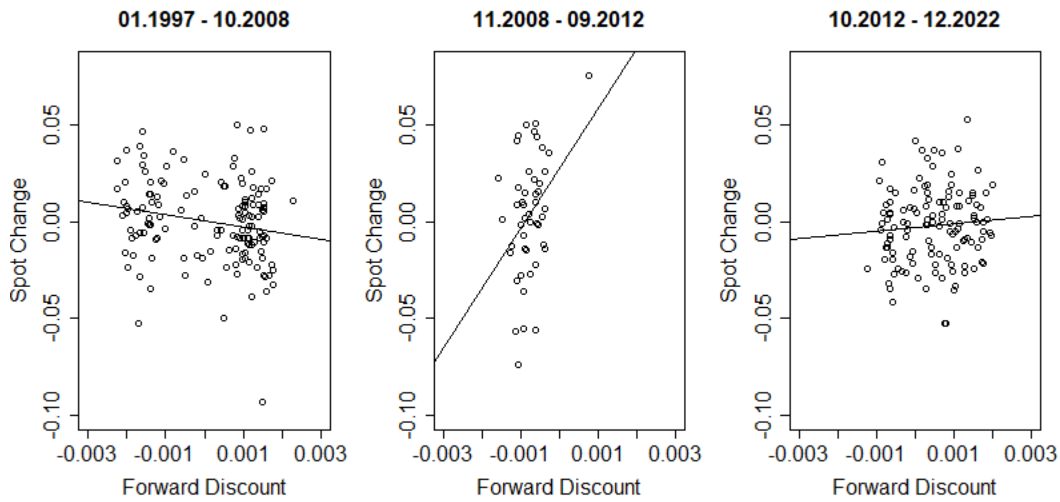


Note. The figure shows the regression of the spot rate change on the forward discount in three different periods for a basket of 17 emerging market currencies.

The slope coefficient is both positive and negative depending on the period. The null hypothesis of $\beta = 1$ is not rejected in any of the three periods. UIP can thus not be ruled out for the basket of 17 emerging market currencies.

For the industrialised countries, the beta factors in the second and third periods are positive, as is the case for emerging markets.

Figure 10: Structural Breaks and Regressions for Industrialised Countries



Note. The table shows the regression of the spot rate change on the forward discount in three different periods for a basket of 10 industrialised countries' currencies.

The slope for the period after the global financial crisis is very high at just under 31. This is due to the low interest rate differential in this period and the higher variance of spot changes. In contrast to emerging markets, UIP fails in industrialised countries in the first and second periods. However, even for the third period, the spot change cannot be explained by the forward discount, as indicated by the low R^2.

These analyses show that the beta factor is time varying and takes both positive and negative values. For developed markets, there are periods in which the null hypothesis that the slope coefficient is unity is rejected. For emerging markets, however, UIP cannot be rejected at the 5% significance level. The UIP puzzle thus appears to be relevant for developed markets, while it is not significant for emerging markets.

One possible reason for the different results for emerging and industrialised countries is the interest rate differential, that is, the forward discount. Interest rates are usually higher in emerging markets. The emerging market basket interest rate was, on average, 0.30% per month higher than the US interest rate. For the developed markets, the interest rates in the US were, on average, 0.01% higher than the basket's interest.

However, the R^2 is very low for both the emerging and developed markets. Considering two structural breaks, the R^2 for the regression of spot changes on the forward discount is 0.05 (0.07) for the emerging (developed) markets. The forward price can thus only marginally explain the future spot rate, even after allowing for structural breaks.

3.5. MARKOV REGIME SWITCHING MODEL

In the previous section, structural breaks were used to investigate whether the UIP regression slope coefficient is time varying. Using regime switching models is another approach to analysing time-varying changes in the beta factor.

Markov switching models have been used for currency market research, by, among others, Czech (2017), Beyaert et al. (2007), and Dueker and Neely (2007). Accordingly, currency markets have different cycles and regimes during which currencies behave differently. In the following, a Markov switching model (Hamilton 1989) is used to investigate whether UIP exhibits a time-varying pattern.

Markov switching models endogenously identify the presence of several breaks. Additionally, the identification of regimes that appear several times allows to test the significance of the UIP regression´s slope coefficient based on more observations belonging to different subsamples, that is, with more degrees of freedom.

The model uses two regimes and is specified in Eq. (23):

$$sp_{t+1} - sp_t = \alpha_0 + \beta_{v_t}(fw_t - sp_t) + \varepsilon_{v_t} \tag{23}$$

with $v_t \in \{1,2\}$. The term v_t is an unobserved variable and describes two different regimes. The process for v_t is a first-order Markov process, whose transition probabilities are defined by the matrix P. For $v_t = 1$, the model from Eq. (23) is in regime 1; for $v_t = 2$, it is in regime 2. The transition matrix is defined in Eq. (24):

$$P = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix}, p_{ij} \geq 0 \quad (24)$$

Row j, column i indicates the transition probability for p_{ij}, that is, the probability that regime i is followed by regime j.

Following Ichiue and Koyama (2011) the intercept α is considered not to switch. This assumes that regime switches should be interpreted as changes in the relationship between the interest rate differentials and spot price changes, rather than just switches in the trend. However, even if α is assumed to switch, the conclusions regarding the time-varying slope coefficient remain unchanged, that is, β is time varying regardless of whether α is allowed to change or not.

Table 15 shows the results of the UIP regression from Eq. (23) for all 27 currencies.

Table 15: Markov Switching Regimes, All Currencies

	β_1	se (β_1)	β_2	se (β_2)	p_{11}	p_{22}	d_1	d_2
Emerging Markets								
INR	1.10481	0.35909	0.63752°	0.21597	0.969	0.913	32.6	11.5
KRW	–0.22004	2.56904	–0.41541	0.94681	0.790	0.975	4.76	39.8
RUB	0.18421*	0.39138	0.46313	0.33366	0.957	0.957	23.3	23.1
BRL	3.68344	2.41294	–0.26794***	0.19443	0.516	0.948	2.06	19.1
IDR	–0.27894	1.00762	–1.52803***	0.46672	0.921	0.980	12.6	49.5
MXN	1.51579	1.74889	–0.76381***	0.42278	0.901	0.971	10.1	34.5
TRY	13.49479°	6.50645	0.28888***	0.05375	0.000	0.966	1.00	29.6
ZAR	3.82913	3.43891	–4.00441***	1.45359	0.378	0.865	1.61	7.40
CLP	12.84507**	4.46104	–2.34837*	1.33664	0.142	0.777	1.16	4.49
COP	1.73818	1.54289	0.08874	1.10951	0.936	0.932	15.7	14.8
PLN	3.83792	3.15038	0.55096	0.40596	0.971	0.995	34.4	216
CZK	2.87057	1.19080	–1.01591	1.45196	0.000	0.063	1.00	1.07
HUF	0.12733°	0.45098	–0.01580	2.18818	0.992	0.963	130	27.0
PHP	2.22665	0.96792	–0.75457***	0.47997	0.926	0.982	13.5	56.4
TWD	–0.39994***	0.00406	–0.94800***	0.55455	0.002	0.989	1.00	89.4
THB	0.62280	0.84502	0.54260	1.00208	0.866	0.984	7.44	60.6
PEN	0.69756	0.60325	0.20391°	0.43002	0.906	0.843	10.7	6.36
Developed Markets								
EUR	–0.15911	1.87341	–6.09982*	3.16600	0.973	0.960	37.7	25.2

GPB	2.23136	9.52264	–1.30215°	1.24116	0.856	0.992	6.93	123
JPY	1.13859	1.15063	0.22188	1.35420	0.948	0.935	19.2	15.5
CHF	0.70940	10.89268	–1.60301*	1.30909	0.678	0.977	3.1	43.3
AUD	4.23362	6.97295	–2.39147**	1.21516	0.812	0.988	5.32	84.8
CAD	0.14862	1.49094	–8.25962	14.89390	0.971	0.619	33.9	2.62
ILS	3.51530	4.55686	–0.33289*	0.64810	0.962	0.984	26.0	61.7
NZD	5.87909	5.86714	–2.07666*	1.31376	0.847	0.990	6.53	99.1
NOK	0.36938***	0.04334	–1.01703°	1.11841	0.268	0.983	1.37	59.0
SEK	1.23918	6.50410	–1.76038*	1.21086	0.970	0.996	33.0	225

Note. °, *, **, and *** indicate values for β that deviate from 1 with significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The probability of remaining in regime 1 or 2 is indicated by p, and the duration in months for each regime is indicated by d.

The analyses for each individual currency show that the UIP regression slope coefficient is time varying. For the emerging markets, the slope coefficient is positive in both regimes for seven out of 17 currencies. For seven currencies, the sign changes. The null hypothesis that $\beta = 1$ is rejected at the 5% significance level in regime 1 for three of the 17 emerging market currencies, and in regime 2 it is rejected for eight currencies.

For developed markets, the pattern is even more distinct. With the exception of the euro, the slope coefficient´s sign changes for all currencies. In regime 2, the slope is negative for all currencies except the Japanese yen. In addition, the UIP hypothesis of $\beta = 1$ is rejected for six out of ten currencies in regime 2.

Table 15 thus shows that the UIP regression slope coefficient is time varying and has both negative and positive signs. When the individual currencies are aggregated by the currency baskets, a similar pattern emerges. Table 16 shows the results of the UIP regression from Eq. (23) for the two currency baskets comprising 17 emerging market currencies (EM) and 10 industrialised countries' currencies (IND).

Table 16: UIP Regression with Markov Switching Model

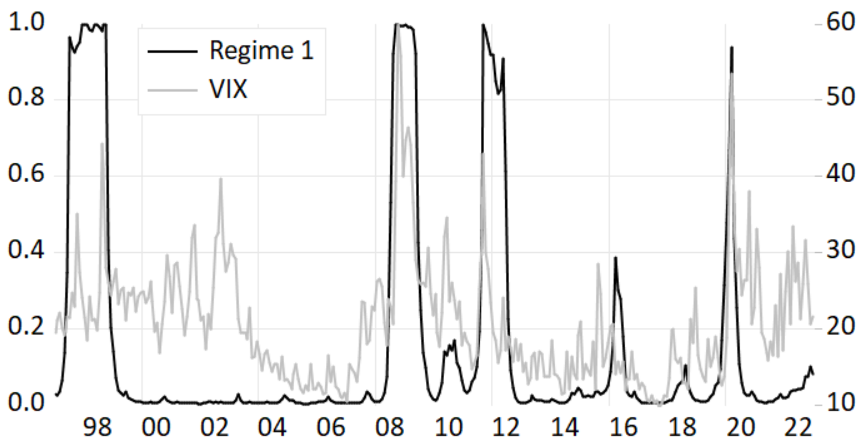
	α	β_1	β_2	p_{11}	p_{22}	d_1	d_2
EM	0.00142	1.59243	0.89937	0.873	0.977	7.86	43.9
	(0.00195)	(0.92323)	(0.51278)				

IND	0.00030	1.69345	–2.29941**	0.964	0.991	27.5	110
	(0.00123)	(4.90962)	(1.09748)				

Note. °, *, **, and *** indicate values for β that deviate from 1 at the 10%, 5%, 1%, and 0.1% significance levels, respectively. The probability of remaining in regime 1 or 2 is indicated by p, as well as the duration in months for each regime is indicated by d. The standard errors are given in parentheses.

For both currency groups, regime 2 predominates. The persistence probability in this regime is 0.977 for emerging markets, and the slope coefficient is 0.89937. The slope in regime 1 is positive at 1.59243. For both regimes, the null hypothesis of $\beta = 1$ cannot be rejected. Figure 11 illustrates the smoothed probabilities for regime 1 for emerging markets. In addition, the VIX is shown to highlight periods when equity market volatility, and therefore risk, is high.

Figure 11: Smoothed Probabilities for Regime 1, Emerging Markets

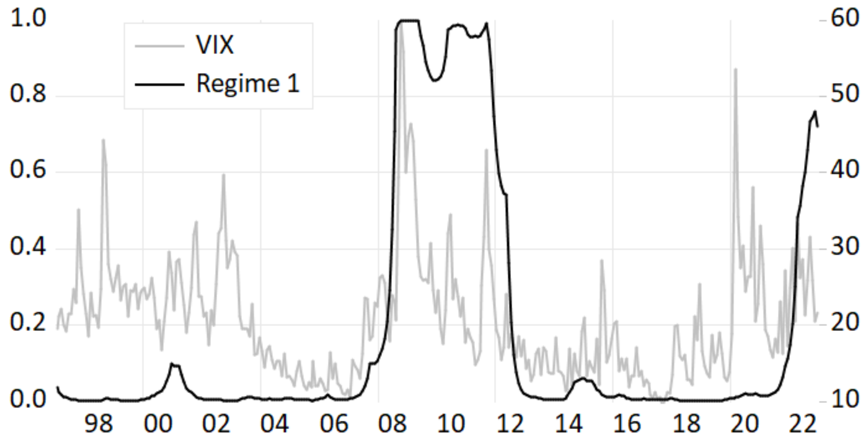


Note. Figure 11 illustrates the smoothed probabilities for regime 1 for emerging markets. Additionally, the VIX is plotted as a risk proxy.

A total of four episodes can be identified in which the model shifts to regime 1: the Asian crisis in the late 1990s, the global financial crisis, the euro debt crisis in 2011, and the pandemic in 2020. During this periods, a rising VIX can be observed. This indicates that emerging markets´ currencies switch to regime 1 when market risk is high.

Table 16 also reports the values for the industrialised countries' currencies. The slope coefficient signs are different at 1.69345 in regime 1 and –2.29941 in regime 2. The predominant regime, analogous to the situation in the emerging markets, is also regime 2, where the slope has lower values than in regime 1. However, the expected duration of 110 months for the developed markets is longer than that for the emerging markets. Figure 12 shows the smoothed probabilities for regime 1 for the developed markets. Again, the VIX is plotted as a risk proxy.

Figure 12: Smoothed Probabilities for Regime 1, Developed Markets



Note. Figure 12 shows the smoothed probabilities for regime 1 for developed markets and the VIX.

Developed markets experienced a regime shift between 2008 and 2012, coinciding with the financial crisis and the euro debt crisis. During this period, VIX also rised temporarily. The recent increase may be due to the change in the monetary environment, that is, the rise in interest rates in several countries, and the associated rise in the US dollar. In regime 1, the beta factor is positive and above 1. In this case, an interest rate advantage in a foreign currency is eliminated through currency depreciation, that is, the US dollar rises.

The currency baskets thus show a different picture for the emerging and industrialised market currencies. For the latter, UIP regression slope coefficient as shown in Eq. (23) changes its sign depending on the regime. The UIP hypothesis that the interest rate differential is an unbiased predictor for the future change in the spot price is rejected at the 1% level in regime 2. However, the UIP hypothesis cannot be rejected for emerging markets, neither in regime 1 nor in regime 2.

The results when Markov switching model is applied are in line with the findings in section 3.4, where the Bai-Perron test is used to identify structural breaks in the UIP regression. In the latter model, the slope coefficient for the emerging market currency basket is predominantly positive and only negative in the period from January 1997 to October 2000. The UIP hypothesis cannot be rejected using both the Bai-Perron test and the Markov switching model for emerging market currencies.

Overall, the evaluations in this section show that the beta factor of the UIP regression is mostly time varying. For emerging market currencies, the null hypothesis of β = 1 cannot be rejected for the currency basket and for most currencies if the currencies are divided into two regimes using the Markov switching model. This is different for currencies from industrialised countries. In regime 2, where the beta factor is mainly negative, the null hypothesis of β = 1 is predominantly rejected. The UIP puzzle thus applies more strongly to developed market currencies than to emerging market currencies.

3.6. RISK PREMIUM

The last two sections showed that the slope coefficient of the Fama regression is time varying and that there are periods or regimes in which UIP does not hold. Numerous studies suggest that deviations from UIP are due to a risk premium. This aspect is investigated in this section.

UIP is a joint hypothesis that makes three assumptions. The first assumption in Eq. (25) refers to CIP:

$$f\omega_t - sp_t = i_t - i_t^* + \varepsilon_t^{\text{cov}} \tag{25}$$

CIP describes the non-arbitrage relationship between the interest rate differential and the forward discount. If CIP holds, $\varepsilon_t^{\text{cov}}$ is an i.i.d. error term with zero mean.

The second assumption is related to risk-neutral market participants. Under this assumption, agents do not charge a risk premium for holding foreign currencies, so Eq. (26) applies:

$$f\omega_t = E_t[sp_{t+1}] + \varepsilon_t^{\text{risk}} \tag{26}$$

The forward price is equal to the expected future spot price and a disturbance term with zero mean. Risk-neutral market participants who buy at the forward price expect an excess return of zero since the expected future rate corresponds to the forward rate.

The third assumption is that market participants have rational expectations. As a result, in the long run, there are no deviations between the ex-post spot rate sp_{t+1} and the expected spot rate $E_t[sp_{t+1}]$, as seen in Eq. (27):

$$sp_{t+1} = E_t[sp_{t+1}] + \varepsilon_t^{\text{rat}} \tag{27}$$

If market participants have rational expectations regarding future parameters like the future spot rate, the error term $\varepsilon_t^{\text{rat}}$ is i.i.d. with zero mean.

UIP is thus a joint hypothesis with the conditions $\varepsilon_t^{\text{cov}} = 0$, $\varepsilon_t^{\text{risk}} = 0$, and $\varepsilon_t^{\text{rat}} = 0$. Deviations from these conditions lead to the slope coefficient in the Fama regression being different than 1.

The UIP assumption that market participants are risk-neutral has been investigated in various studies. According to prospect theory, market participants are risk-averse rather than risk-neutral (Kahneman and Tversky 1979). This means that they charge a risk premium for holding foreign currencies, since the future exchange rate sp_{t+1} is unknown. It follows that market participants are not willing to buy a foreign currency at the forward price if this price corresponds to the expected future spot price $E_t[sp_{t+1}]$. They will only buy the currency at the forward price if it trades at a risk discount to the expected future spot price.

Survey data can be used to measure the risk premium demanded by market participants (Chinn and Frankel 2019; Bussière et al. 2022). Under the assumption of risk-averse market participants, the risk premium η corresponds to the discount of the forward price on the expected future spot price, as in Eq. (28):

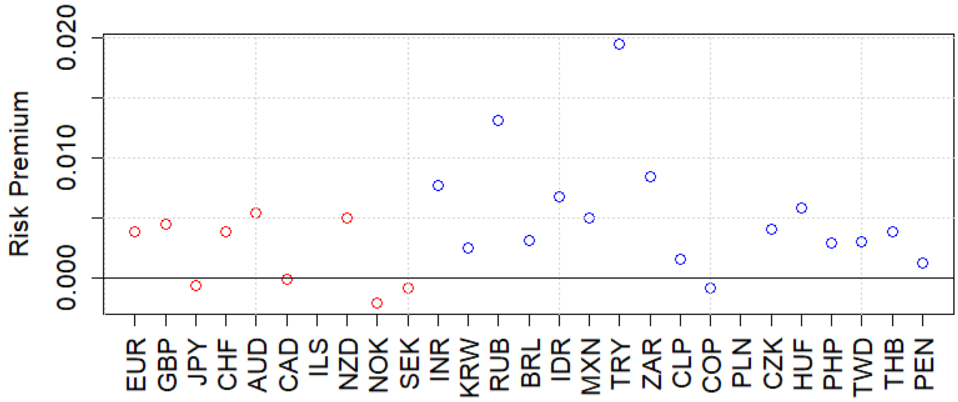
$$E\left[sp_{t+1,i}\right] - f\omega_t = \eta \tag{28}$$

Reuters surveys, which are provided by Refinitiv, are used to calculate the risk premium for the individual currencies in the following analysis. Reuters questions several banks regarding their forecast for individual currencies. The number of banks providing estimates for individual currencies varies by currency and sometimes totals several dozen.

The expected future spot price $E_t\left[sp_{t+1,i}\right]$ is the median of the participating banks' estimates at time t for currency i. Survey data are available for emerging market currencies beginning from April 2012, so the data until the end of 2022 cover

129 months. Figure 13 shows the monthly average risk premium for the individual currencies according to Eq. (28). Survey data for the Israeli shekel (ILS) and the Polish zloty (PLN) are not available.

Figure 13: Risk Premium



Note. The figure shows the monthly average risk premium for 25 currencies. No survey data are available for the Israeli shekel (ILS) and Polish zloty (PLN). Emerging market currencies are marked in blue, and industrialised countries' currencies are marked red.

The average risk premium for the nine currencies from industrialised countries is 0.20% per month; for the emerging market currencies, the average risk premium is 0.54% per month. Furthermore, the risk premium variance is higher for emerging markets. The highest risk premiums were charged for the Turkish lira and the Russian rouble. For the emerging market currencies, the risk premiums for the South American currencies (Chilean peso CLP, Colombian peso COP, and Peruvian sol PEN) were the lowest.

The risk premium is negative on average for five currencies. As noted in section 3.2, a positive risk premium from a US investor's perspective is at the same time a negative risk premium from the perspective of the foreign currency country. Conversely, if a foreign investor demands a risk premium for holding US dollars, negative risk premiums are possible from the perspective of a US investor.

As shown in Eq. (28) and Figure 13, a risk premium can be derived from a straightforward comparison between the forward price and expected future spot price. A more formal way to capture if the failure of UIP is related to risk is to use a risk proxy variable. One variable that is commonly used is the volatility index VIX (Bussière et al. 2022; Ismailov and Rossi 2018; Brunnermeier et al. 2008; Engel et al. 2022). This index measures the implied volatility of equity options on the S&P 500 index.

To measure a risk premium´s impact on UIP, Fama's regression (Eq. (21) in section 3.3) is extended including the change in the VIX:

$$sp_{t+1} - sp_t = \alpha + \beta_1(fw_t - sp_t) + \beta_2 VIX + \varepsilon_t \quad (29)$$

VIX is the monthly log change in the VIX index. If deviations from the UIP are due to a risk premium, the VIX as a risk proxy is expected to explain part of the changes in the spot rate. Table 17 shows the results of the regression.

Table 17: UIP Regression and Risk Premium

	constant	β_1	se for β_1	β_2	se for β_2	R^2
Emerging Markets						
INR	–0.00108	0.389708	0.404168	–0.027474***	0.00498	0.0908
KRW	0.000246	–0.273426°	0.756735	–0.044502***	0.008383	0.0989
RUB	–0.003769	–0.062445***	0.301711	–0.057059***	0.013051	0.0666
BRL	–0.003574	0.056708***	0.209921	–0.07971***	0.013296	0.1194
IDR	–0.011785*	–0.919012***	0.554894	–0.03488*	0.017398	0.022
MXN	–0.005682°	–0.704356**	0.524133	–0.065765***	0.008016	0.1949
TRY	–0.008143	0.400826	0.480361	–0.057315***	0.014218	0.0727
ZAR	–0.014234*	–1.866848*	1.100639	–0.077828***	0.011577	0.135
CLP	–0.00025	0.828818	1.055995	–0.061085***	0.009877	0.1471
COP	–0.000915	1.094095	0.933931	–0.072993***	0.011118	0.1709
PLN	0.000506	0.527324	0.45533	–0.061718***	0.009283	0.1284
CZK	0.000896	0.961664	0.723093	–0.035531***	0.009048	0.0519
HUF	–0.002463	0.058211°	0.53518	–0.053695***	0.009804	0.0885
PHP	0.000783	1.240993	0.488083	–0.02014***	0.006039	0.0528
TWD	0.000276	–0.072264	0.727735	–0.017827***	0.003947	0.072
THB	–0.000875	0.596972**	0.14994	–0.025445**	0.008269	0.0751
PEN	0.000069	0.4095	0.4592	–0.01988***	0.00492	0.0712
Developed Markets						
EUR	0.000775	–1.823311*	1.322609	–0.023958**	0.007253	0.0412
GPB	–0.00146	–1.117473°	1.255803	–0.022094***	0.006516	0.0386
JPY	–0.002781	1.174872	0.917109	0.013144	0.008043	0.0139
CHF	0.003198	–1.192014°	1.285665	–0.009599	0.007704	0.008
AUD	–0.002001	–1.20997°	1.118824	–0.075057***	0.008465	0.2066

CAD	0.000053	–0.1897	1.501	–0.04745***	0.00603	0.1672
ILS	0.001114	0.173219	0.731489	–0.034577***	0.006235	0.1105
NZD	–0.002034	–1.047134°	1.208558	–0.07047***	0.009031	0.1658
NOK	–0.001681	–0.749465°	1.046798	–0.050553***	0.008432	0.1065
SEK	–0.000673	–1.183088°	1.177334	–0.039894***	0.008155	0.0758

Note. The table presents the results of the regression in Eq. (29). Deviations from constant = 0, $\beta_1 = 1$ and $\beta_2 = 0$ are marked with °, *, **, and *** to indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

Note that Eq. (29) tests different values for β_1 and β_2. If UIP perfectly holds, β_1 is 1 as shown in Eq.(22) on page 77. The VIX´s impact is measured by β_1 which is 0 if VIX does not affect the change in the spot price.

For all currencies except the Japanese yen, the VIX slope coefficient is negative. Moreover, it is more pronounced for emerging markets. For these currencies, the median of β_2 is –0.0537, while for developed countries' currencies, it is –0.0372. For all currencies except the Japanese yen and Swiss franc, β_2 is significant at the 5% level, and for most currencies, even at the 0.1% level. By introducing the VIX as an explanatory variable, R^2 increases substantially up to 0.202 compared to the UIP regression in Eq. (21) on page 77.

The situation for the currency baskets is similar to that for the individual currencies. The beta factor for the VIX is more pronounced for emerging markets, and R^2 is also higher than for industrialised countries:

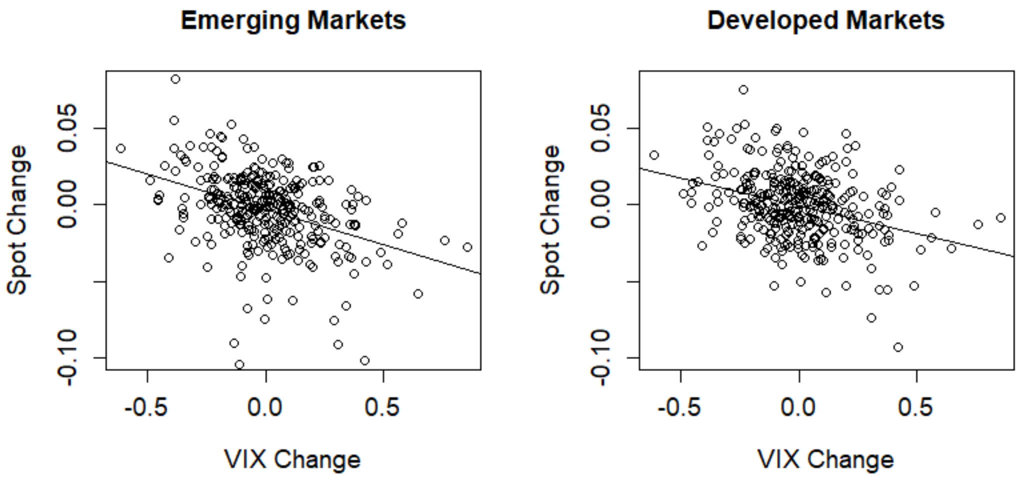
Table 18: Risk Premium for Baskets

	constant	β_1	se for β_1	β_2	se for β_2	R^2
EM	0.001274	1.217612	0.440804	–0.047065***	0.005994	0.1787
IND	–0.000245	–1.509828*	1.070522	–0.035737***	0.005701	0.1191

Note. The table presents the results of the regression for the currency baskets using Eq. (29). Deviations from $\beta_1 = 1$ and $\beta_2 = 0$ are marked with °, *, **, and *** for significance at the 10%, 5%, 1%, and 0.1% significance levels, respectively.

Selecting VIX as a risk proxy can explain part of the spot rate change. Rising VIX leads to a loss in foreign currencies. Deviations from UIP can thus be partly explained by a risk proxy. Risk sensitivity is more pronounced for emerging markets than for industrialised countries. However, the VIX is also significant as a risk proxy for the industrialised countries. The impact of the VIX on the UIP regression is further illustrated in Figure 14, which shows the single linear regression of the change in the spot price on the change in the VIX:

Figure 14: Regression of Spot Price Changes on VIX



Note. Spot change regression on VIX for emerging and developed markets.

The single linear regression of the spot changes on the change in the VIX shows only minor differences between emerging and developed markets. The negative slope coefficient indicates that the exchange rates are related to risk. By introducing the VIX as a risk proxy, R^2 of the Fama regression increases; that is, UIP failure is partly related to risk.

In addition to the VIX index, another risk proxy, the Global Economic Policy Uncertainty Index, was tested in Eq. (29) as an explanatory variable. This index was introduced by Baker et al. (2016) and measures economic uncertainty using an approach based on newspaper coverage. However, unlike the VIX, this index is not significant, and R^2 remains close to zero. Therefore, the results are not presented in this study.

This section shows that deviations from the UIP regression are related to risk. The change in the spot rate examined in the UIP regression is dependent on the risk proxy VIX with a negative slope coefficient. If uncertainty in the markets increases, thus increasing the VIX, devaluation of the foreign currency is to be expected, which applies to both emerging and developed markets. In addition, the risk premium from the perspective of a US investor is higher for emerging market currencies than for developed market currencies.

3.7. RATIONAL EXPECTATIONS

UIP assumes rational expectations. This presumption goes back to Muth (1961) and states that market participants' expectations coincide with economic models. The failure of UIP, as described in section 3.3, could therefore be caused by non-rational expectations. Assuming rational expectations, the spot rate's forecast would be an unbiased estimator of the future exchange rate. The expected spot rate change thus corresponds to the ex-post observable change, which can be represented with Eq. (30):

$$\Delta sp_{t\to t+1} = \alpha + \beta E[\Delta sp_{t\to t+1}] + \varepsilon_{t+1} \tag{30}$$

where $\Delta sp_{t\to t+1}$ is the ex-post change in the spot rate, $E[\Delta sp_{t\to t+1}]$ is the expected change in the spot rate based on surveys at time t, and ε_{t+1} is an i.i.d. error term with $N\sim(0,\sigma^2)$. Unless market participants make systematically biased forecasts of the spot rate change, β is expected to be 1 and α is expected to be 0.

This section examines whether non-rational expectations are a possible reason for UIP failure. Reuters polls, which have been available since April 2012, are used to measure market participants′ expectations regarding the future spot price, For Eq. (30), the median of the different banks′ estimates at time t is used.

Table 19 shows the results of the regression in Eq. (30) for all 25 currencies using 129 monthly observations. The mean of the expected spot rate change is given by $\overline{E[\Delta sp_{t\to t+1}]}$, and $\overline{\Delta sp_{t\to t+1}}$ represents the mean of the ex-post change.

Table 19: Survey Data and Ex-post Spot Changes

	$\overline{E[\Delta sp_{t\to t+1}]}$	$\overline{\Delta sp_{t\to t+1}}$	α	β	standard error for β	R^2
Emerging Markets						
INR	–0.002897	–0.003769	–0.002852	0.396702*	0.311364	0.0137
KRW	–0.00271	–0.00084	–0.001112	0.052821***	0.16473	0.0009
RUB	–0.004712	–0.007019	–0.003309	0.923655	0.105032	0.386
BRL	0.002571	–0.008241	–0.00907*	0.34062**	0.251085	0.0155
IDR	–0.003053	–0.004128	–0.002727	–0.14645***	0.103334	0.0178

MXN	–0.001182	–0.003252	–0.003391	0.18257***	0.239656	0.0049
TRY	–0.008136	–0.018225	–0.020195***	–0.11027***	0.227446	0.0021
ZAR	–0.003915	–0.006192	–0.004516	0.395695*	0.269462	0.0168
CLP	0.000572	–0.00428	–0.004392	0.436233**	0.182215	0.0491
COP	0.00341	–0.007735	–0.009092*	0.238794***	0.177889	0.016
CZK	–0.004527	–0.001512	–0.000025	0.3245**	0.2538	0.013
HUF	–0.00495	–0.004079	–0.000706	0.73103	0.237482	0.071
PHP	–0.001907	–0.002024	–0.002159	–0.12216***	0.100413	0.0132
TWD	–0.003879	–0.000275	–0.00075	–0.189***	0.095418	0.0341
THB	–0.003649	–0.0009	–0.000933	–0.11858***	0.128431	0.0076
PEN	0.001158	–0.002755	–0.002792°	0.173693***	0.144202	0.0129
Industrialised Markets						
EUR	–0.00495	–0.001708	0.000196	0.384596*	0.255031	0.0176
GPB	–0.004836	–0.002173	–0.001068	0.228423**	0.252525	0.0064
JPY	–0.000346	–0.003564	–0.003491	0.211472**	0.281701	0.0044
CHF	–0.005320	–0.00019	0.002656	0.535065*	0.231050	0.0405
AUD	–0.004659	–0.003239	–0.002652	0.126009***	0.230096	0.0024
CAD	0.000217	–0.002372	–0.002465	0.431132*	0.240929	0.0246
NZD	–0.004085	–0.001968	–0.001017	0.232942***	0.214352	0.0092
NOK	0.002099	–0.004210	–0.002402	0.075598***	0.194096	0.0014
SEK	–0.000101	–0.00353	–0.003031	0.013923***	0.191869	0

Note. The table shows the mean of the expected spot rate change, the mean of the actual change, and the regression of the actual change on the expected change. Values for α and β that deviate significantly from 0 and 1, respectively, are marked with °, *, **, and ***, which represent significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

In nominal terms, all currencies have depreciated against the US dollar since April 2012. In fact, the US dollar was at a very low level in 2012 and has gained broadly since then. The nominal broad US dollar index gained 34% from April 2012 to December 2022. The dollar's structural appreciation was largely correctly recognised by market participants. For 19 out of 25 currencies, the average expected change in the foreign currency was negative.

If market participants could correctly forecast the future exchange rate, the value for α in Eq. (30) would be 0, and the value for β would be 1. The null hypothesis that the change in the spot rate can be explained by the expected change must be rejected at the 5% significance level for all currencies except the Russian rouble (RUB) and Hungarian forint (HUF). R^2 is very small for almost all currencies;

it is below 0.08 for all currencies except the Russian rouble, which is 0.386. Although market participants were mostly able to anticipate the depreciation of currencies against the US dollar, in general, their estimates were not an unbiased predictor of the ex-post spot change. This applies equally to emerging and developed markets.

The survey data used in Eq. (30) are available beginning in April 2012. To further highlight the differences between emerging and developed markets, the single currencies are aggregated into two currency groups. The results are presented in Table 20.

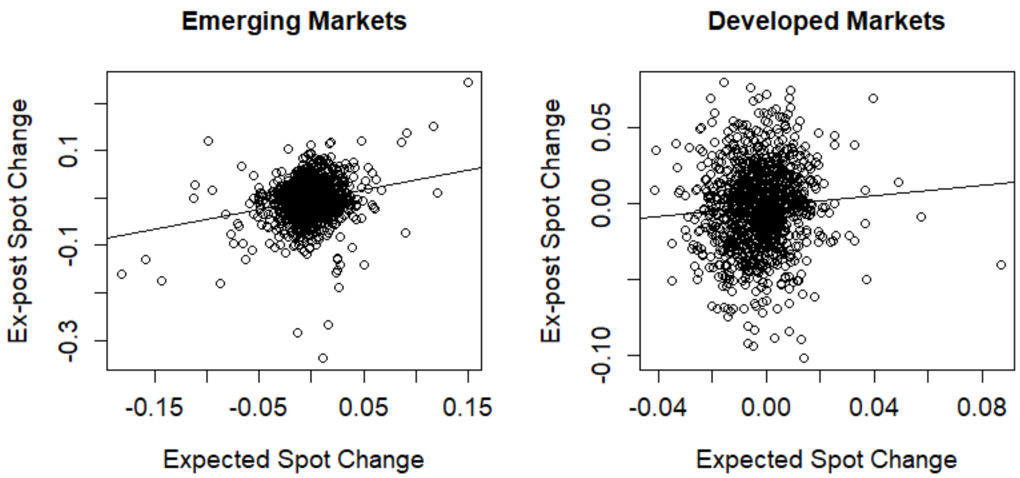
Table 20: Regressions for Emerging and Developed Markets

	α	standard error for α	β	standard error for β	R^2	DF
EM	–0.003741***	0.000806	0.411304***	0.042501	0.0475	1876
IND	–0.001822*	0.000825	0.170942***	0.071249	0.0051	1115

Note. The table shows the regression of the ex-post spot change on the expected spot change as shown in Eq. (30) . *, **, and *** indicate values that are significantly different from $\alpha = 0$ and $\beta = 1$ at the 5%, 1%, and 0.1% levels, respectively.

Aggregating single currency data to currency groups results in smaller standard errors for α and β. However, R^2 is very low. Market participants` expectations regarding changes in the spot rate cannot explain the actual ex-post change. Figure 15 shows the expected and ex-post changes graphically. If market participants can forecast future changes, a linear relationship is expected. This cannot be seen in the graphs.

Figure 15: Expected Change and Ex-post Spot Rate Change



Note. Figure 15 shows the market participants' expected spot rate change based on surveys and the actual changes for emerging and developed markets.

The analyses in Table 19, Table 20, and Figure 15 show that market participants' expectations regarding the future currency spot price are not an unbiased estimator of the actual ex-post spot price. Although market participants were able to forecast the US dollar's general appreciation between 2012 and 2022, there is no linear relationship between market expectations and the ex-post observation of exchange rate changes. This means that market participants suffer from rational expectations errors regarding the expected future spot price.

If market participants lack rational expectations in terms of the spot rate change, this could cause UIP to fail. The evaluations so far lead to the conclusion that market participants do not have rational expectations.

Market participants' failure to correctly forecast the future spot price can additionally be captured by their adjustment behaviour with regard to their forecasts. Forecast errors cause market participants to revise their errors for the following forecast. If, for example, a foreign currency rate's ex-post depreciation was 2% higher than forecasted, market participants will adjust their next forecasts by 2%.

As a result, a linear connection emerges, which can be estimated via the regression in Eq. (31):

$$E[sp_{t\to t+1}] - E[sp_{t-1\to t}] = \alpha + \beta(sp_t - E[sp_{t-1\to t}]) + \varepsilon_t \quad (31)$$

Eq. (31) thus investigates whether the delta between the old forecast $E[sp_{t-1\to t}]$ and new forecast $E[sp_{t\to t+1}]$ can be explained by the recent forecast error. Table 21 shows the results of the regression from Eq. (31).

Table 21: Forecast Error Correction

	α	β	standard error for β	R^2
Emerging Markets				
INR	–0.000698	0.815513***	0.03068	0.8611
KRW	–0.00099	0.62694***	0.056587	0.539
RUB	-0.004257	0.47455***	0.080305	0.2254
BRL	-0.001994	0.758926***	0.034077	0.8158
IDR	-0.000767	0.535368***	0.092952	0.2401
MXN	-0.001002	0.787964***	0.042765	0.7519
TRY	-0.004846°	0.772779***	0.049177	0.7017
ZAR	-0.001911	0.732045***	0.031201	0.8162
CLP	-0.00275	0.533406***	0.046816	0.5528
COP	-0.003128	0.645321***	0.057025	0.5495
CZK	-0.000636	0.760594***	0.03066	0.8357
HUF	-0.001839°	0.671249***	0.030688	0.7982
PHP	-0.001528	0.444604***	0.084963	0.2068
TWD	-0.000411	0.513784***	0.091381	0.2314
THB	-0.000428	0.597795***	0.070882	0.4038
PEN	-0.001562	0.478392***	0.066612	0.3294
Developed Markets				
EUR	-0.00043	0.777004***	0.031091	0.8321
GPB	-0.00054	0.807281***	0.03517	0.807
JPY	-0.000966	0.797546***	0.030533	0.8441
CHF	-0.00008	0.7194***	-0.03872	0.7326
AUD	-0.001009	0.742452***	0.031957	0.8107
CAD	-0.000665	0.727616***	0.032683	0.7973
NZD	-0.000896	0.667179***	0.030916	0.7871
NOK	-0.000917	0.647466***	0.051922	0.6258
SEK	-0.001316	0.660114***	0.053462	0.6211
Currency Baskets (Emerging Markets, EM, and Industrialised Markets, IND)				

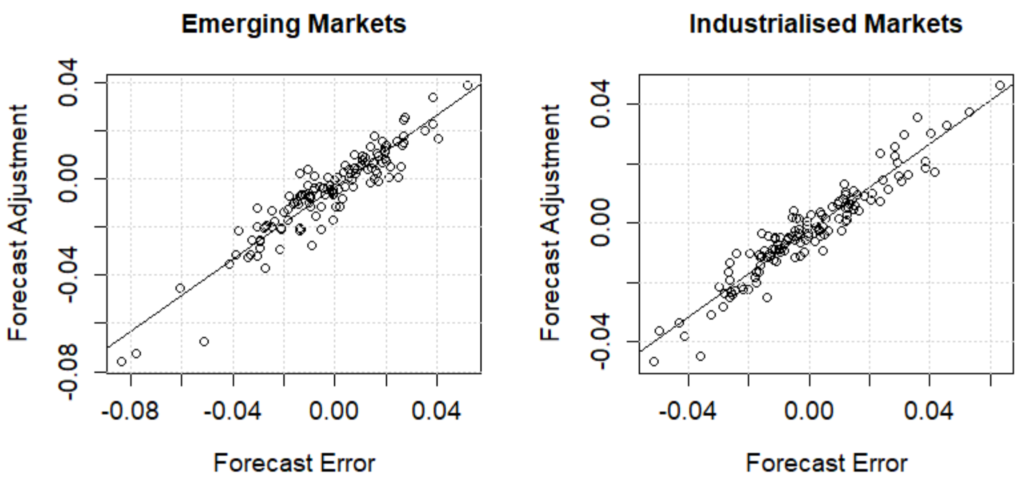
EM	-0.00243**	0.722286***	0.039947	0.7218
IND	-0.000955	0.736328***	0.029182	0.8348

Note. The table shows the regression of the forecast revision on the forecast error of the previous period. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

R^2 is partially above 0.80, and the slope coefficient is significant at the 0.1% level for each currency. The linear regression clearly shows that the forecast adjustments follow the forecast errors. In this respect, the exchange rate forecast is not a predictor for the future development of a currency but precisely the opposite: the forecast errors can explain future adjustments of the forecasts.

The linear relationship from Eq. (31) for the basket consisting of 16 emerging market currencies and 9 industrialised currencies is also shown graphically in Figure 16.

Figure 16: Forecast Error and Forecast Adjustments



Note. The figure illustrates the forecast errors of the future spot price and the forecast adjustment in the subsequent month for the emerging and developed market currency baskets.

The linear dependency is clearly apparent: the more the currency forecast deviates from the true ex-post development (x-axis), the more the following forecast is corrected. Market participants' forecasts are thus not an unbiased predictor of the future spot price (see Figure 15 on page 99). Conversely, exchange rate forecast adjustments depend on the previous period's forecast error.

Restrictively, it should be noted that market participants' forecasts are based on information Ω at time *t*. The previous analyses are based on a one-month horizon. Within this horizon, political or economic fundamentals might change, which could impact foreign currency prices. In this context, market participants could have rational expectations, but their price forecasts would still not be accurate because the economic environment changes, too. In this context, currency forecasting would not be possible, and a random walk would explain future currency prices better than an economic model such as UIP (Meese and Rogoff 1983).

Overall, the results in this section show that market participants have non-rational expectations regarding future spot prices. In fact, there is no relationship between currency forecasts and the future spot rate. This has implications for UIP, since rational expectations is a prerequisite of UIP. If market participants fail to make valid assessments of future spot prices, it could lead to UIP failure. The studies conducted thus confirm the findings of Bussière et al. (2022) and Chinn and Frankel (2019) that non-rational expectations contribute to the failure of UIP.

3.8. CHAPTER CONCLUSION

This chapter presents analyses of UIP. A large body of literature shows that the coefficient of the UIP regression is negative; this finding is known as the forward premium puzzle. The research conducted shows an unclear picture of developed and emerging market currencies. For an emerging market currency basket, the slope coefficient of the UIP regression is close to unity; for developed markets, it is negative and different from 1 at the 5% significance level. However, the slopes for both emerging and developed markets are time varying and include structural breaks. With the help of the Bai-Perron test for structural breaks and the Markov regime switching model, it could be shown that the slope coefficients of the UIP regression are not persistent, instead they take on both positive and negative values in different periods and under different regimes.

Under UIP, market participants are assumed to be risk-neutral and have rational expectations. In this chapter, it was shown that UIP failure is related to risk. To measure this, the VIX is added to the UIP regression as a risk proxy. The investigations show that the VIX significantly influences the UIP regression for almost all currencies. One exception is the Japanese yen, which is the only currency with a positive VIX slope coefficient. Adding the VIX to the UIP regression as a risk proxy increases the R^2 from 0.01 to 0.18 for emerging markets and from 0.00 to 0.12 for industrialised countries. UIP failure is thus partly related to risk.

Finally, using survey data on the future spot price, this chapter examines whether UIP failure is due to non-rational expectations. Using single linear regression, it is shown for both emerging and developed markets that market participants cannot predict the future exchange rate. In fact, the relationship is the opposite: market participants' failure to forecast the spot rate leads them to adjust their forecasts by the previous period's forecast error. This means that the previous period's forecast error can explain the adjustment in the subsequent period's forecast. For some currencies, R^2 is above 0.8. Overall, it seems that market participants have non-rational expectations of future spot prices. Since UIP presupposes rational expectations, its failure can be partly attributed to market participants' non-rational expectations.

IV – CARRY TRADE EXCESS RETURNS

IV - CARRY TRADE EXCESS RETURNS

4.1. CHAPTER INTRODUCTION

The last chapter showed that the forward price is not an unbiased predictor of the future spot rate. This means that UIP theory is violated since a currency's interest rate advantage is not necessarily compensated for by that currency's depreciation. This failure of UIP is called the forward premium puzzle. In fact, running tests for structural breaks and allowing for different regimes showed that the Fama regression's slope coefficient is time varying and even partially negative. This provides the prerequisite for achieving excess returns with an investment in foreign currencies.

One of the most important strategies in currency markets that has generated excess returns in the past is carry trades. This strategy involves buying the currencies with the highest interest rates. At the same time, the currencies with the lowest interest rates are sold. This strategy is labelled HML (high minus low), and it is dollar neutral, as currencies are both bought and sold against the dollar.

Carry trades' excess returns are well documented in the literature (Brunnermeier et al. 2008; Byrne et al. 2019; Menkhoff et al. 2012a). Economists attribute these excess returns mainly to the presence of a risk premium (Lustig and Verdelhan 2007; Jurek 2014), which means that currencies with high interest rates have higher risk than those with lower interest rates.

This chapter examines carry trades and confirms the excess returns documented in the literature. An HML carry strategy generated average monthly excess returns ranging from 0.61% to 0.92% from 1997 to 2022, depending on the strategy's setting. The annualised Sharpe ratio is between 0.47 and 0.87.

The research in this chapter also highlights that emerging markets are the key contributors to carry excess returns. It shows that a carry strategy that uses only emerging market currencies delivers average monthly excess returns between 0.58% and 1.08%, significant at the 1% level. Conversely, a carry strategy using only developed market currencies was only able to generate average monthly excess returns between 0.08% and 0.21%, which is not significant at the 5% level.

Moreover, emerging market carry trades have advantages in terms of skewness that is less negative than the skewness of industrialised market carry trades. To better understand the importance of emerging and industrialised market currencies for carry returns, bootstrapped returns are analysed. The results show that carry trades in emerging markets not only have higher returns but also have significantly higher Sharpe ratios than carry trades that use only industrialised market currencies.

Another interesting question in this chapter is whether carry trade returns are compensation for risk. The standard risk factors for currencies discussed in the literature, such as the dollar risk factor DOL or currency volatility VOL, have significant loadings on carry returns. However, the importance of the risk factors differs for emerging and industrialised market carry trades. These findings show that the risk profile of carry trades varies depending on which currencies are used.

This chapter is structured as follows. Section 4.2 gives a detailed description of the literature on carry trades. Carry excess returns are presented in section 4.3. To assess the importance of emerging market currencies for carry returns, bootstrap analyses are conducted in section 4.4. The results show that carry trades in emerging market currencies have significantly better results in terms of average returns, skewness, and Sharpe ratios than carry trades generated in currencies of industrialised countries.

Section 4.5 examines the role of DOL, VOL, and market risk factors in carry returns. Developed market currency carry trades are found to have higher loadings on these risk factors than emerging market currency carry trades. Section 4.6 presents carry returns when transaction costs are considered. The bid-ask spread reduces carry returns, but they remain significantly positive. In addition, carry returns are shown to be time varying and particularly strong between 1997 and the global financial crisis, while they have been subdued in the last decade. Section 4.7 concludes.

4.2. LITERATURE REVIEW

Carry trades were used in practice by hedge funds in the 20th century (Fung and Hsieh 2000; Becker and Clifton 2007), enabling them to achieve abnormal returns. These returns contradict UIP, which is why they have been investigated in numerous studies. In fact, the studies confirm the positive returns. Compared to equities, carry trades have in some cases delivered even higher Sharpe ratios in the past (Burnside et al. 2008). This section presents the existing carry trade literature.

In their well-cited paper, Brunnermeier et al. (2008) show that carry trades deliver significant returns but are also exposed to crash risk, that is, currencies with high interest rates exhibit conditional negative skewness. They examine eight major currencies against the US dollar from 1986 to 2006 and report an annual excess return of 7.2% with a Sharpe ratio of 0.784. A key aspect of their work is that carry trades exhibit crash risk and fat tails. Carry returns are negatively skewed with a value of –0.977, indicating skewness somewhat more pronounced than for US equity markets, where it is –0.88 for the same period. Brunnermeier et al. (2008) show that the negative skewness primarily results from the sudden unwinding of leveraged carry positions. When market participants must close existing carry trades due to funding constraints, they intensify existing currency market trends. Consequently, other market participants are affected, which further exacerbates funding constraints and the unwinding of carry positions.

Lustig and Verdelhan (2007) report an excess carry trade return of 4.97% per annum with a Sharpe ratio of 0.55 between 1983 and 2009. They also show that market risk factors, such as the US stock market, can explain more than 50% of carry trade returns. They find that portfolios of currencies with high interest rates have positive and large loadings on market risk, while portfolios of currencies with low interest rates have negative loadings. They deduce that the carry strategy returns are compensation for risk, as the strategy suffers in 'bad times'. Moreover, they show that macroeconomic risk factors like US consumption growth can partially explain carry returns with an R^2 of 0.14. However, the loadings are time varying and can be non-significant depending on the period.

In an oft-cited study, Lustig et al. (2011) examine risk factors in currency markets. They use 35 different currencies from both industrialised and emerging markets between 1983 and 2009 and allocate the individual currencies to six portfolios depending on their forward discount. The return of the HML portfolio reflects the carry strategy, where the portfolio with high interest rate currencies is bought, and the portfolio with low interest rate currencies is sold. For this strategy, they report an annual excess return of 4.54% with a Sharpe ratio of 0.50 after considering the bid-ask spread. Using principal component analysis, Lustig et al.

(2011) also show that 80% of the portfolio returns can be explained by two factors. They declare that DOL, which reflects the average return of all currencies against the US dollar, is one component. The second risk factor is the HML portfolio, which they label the carry trade risk factor. They also show that equity volatility accounts for carry trade returns. Currencies with high interest rates thus suffer from high volatility, while currencies with low interest rates benefit when equity market volatility is high.

The risk factor introduced by Lustig et al. (2011) is used in many subsequent studies, and this factor is determined to be important for currency markets. Note that DOL is an endogenous risk factor, as it is derived from the same data as the portfolio returns it explains.

Another risk factor that explains carry trade excess returns is currency volatility. Menkhoff et al. (2012a) introduce a measure of currency volatility innovation that they label VOL. They show that in times of high volatility, carry trades do not yield profits, while in times of low volatility, they generate excess returns. They also find that currencies with high interest rates load negatively on volatility, which means that currencies with high interest rates generate losses in times of high currency volatility. Currencies with low interest rates serve as a hedge during this time, as they profit during periods of high volatility. They report an annual excess return for carry trades of 7.23% with a Sharpe ratio of 0.74 for the period between 1983 and 2009.

Other studies confirm the importance of currency volatility. Cho et al. (2019) investigate whether carry returns are time varying and subject to different volatility regimes. Their analysis covers 1985 to 2016 using six major currencies against the US dollar, and the results show that carry trades perform better when volatility is low. In times of high volatility, carry trades exhibit losses. For their analyses, they use a regime switching model with VOL as an autoregressive latent factor. This allows them to identify whether a currency market is in a high or low volatility regime. Cho et al.'s (2019) study confirms earlier findings by Baillie and Chang (2011). They use a logistic smooth transition regression and find that carry trades perform differently depending on the volatility regime.

Burnside et al. (2011b) examine the carry trade excess returns of G10 currencies between 1976 and 2010. For this period, they report an annual excess return of 4.6% with a Sharp ratio of 0.89 and skewness of –0.53. They also investigate whether carry returns are related to risk and show that classical models, such as CAPM or consumption-based CAPM, cannot explain them. However, using time-series regressions, they show that currency risk factors such as DOL and VOL have significant loadings on carry returns.

In another study, Burnside et al. (2011a) investigate if carry returns are related to peso problems, that is, a discrete shift of fundamental variables in the future is considered possible by market participants. They show that asset pricing models based on consumption do not work very well in currency markets. Consequently, they consider peso problems relevant for carry trade excess returns. Using options, they create a hedged carry trade that protects against losses in the peso event. They conclude that a hedged carry trade's excess return is similar and statistically not different from those of an unhedged carry trade. Thus, peso problems cannot account for carry trade returns.

Jurek (2014) also uses options to investigate the role of crash risk in carry returns. For this, he compares two carry trade strategies, one of which uses out-of-the-money options to hedge against large currency swings. One of his major findings is that crash risk premia account for one third of carry excess returns. By examining ten G10 currencies between 1990 and 2012, he reports annual carry returns of 2.61% with skewness of –0.63 and a Sharpe ratio of 0.39. Jurek's (2014) findings thus point in the same direction as those of Brunnermeier et al. (2008), who argue that carry returns are sensitive to crash risk due to sudden unwinding of positions.

In addition to DOL, introduced by Lustig et al. (2011), and VOL, proposed by Menkhoff et al. (2012a), other studies examine the influence of market-based risk factors such as equities, bonds, or commodities. Christiansen et al. (2011) examine G10 currency carry returns between 1995 and 2008 using the S&P 500 index and a future contract of 10-year US government bonds as risk factors. In addition, they allow the risk proxies to depend on volatility and funding liquidity regimes; the results show that carry returns are regime dependent. They find that equity markets have positive loadings on carry returns, which are even more pronounced in crises. Carry returns when volatility is high are driven to one-third by the two market risk factors of stocks and bonds.

Tse and Zhao (2012) show that carry returns and US stock market returns are significantly correlated. They apply an EGARCH model to additionally show that an increase in stock market volatility has spillover effects on carry trade volatility. They conclude that carry and stock market returns are thus more correlated when volatility is high.

Fung et al. (2013) come to similar conclusions, finding a significant relationship between Asian stock market returns and carry returns between 1995 and 2011. They also show that volatility spillover effects exist between stock markets and carry returns.

Carry returns are particularly related to stock market downside risk, as shown by Dobrynskaya (2014), who finds that currencies with high interest rates have a high downside beta to stock markets. The carry strategy returns are thus compensation for downside equity risk. Liu and Yang (2017) argue in a similar way, using a conditional value-at-risk model to show that carry trade returns depend on stock market tail risks.

However, carry returns are not only affected by equity markets but also by commodities. Byrne et al. (2019) find evidence that carry trade excess returns are related to a commodity common risk factor. In particular, they show that agricultural commodities are linked to emerging market currencies and metals are linked to developed markets. Their study covers 1983 to 2013 for developed markets and 1997 to 2013 for emerging markets. They report a carry strategy annual excess return of 2.48% for developed markets and 6.59% for emerging markets, with standard deviations of 8.35% and 10.68%, respectively.

Other researchers question whether solvency risk might be a source of carry trade returns. A country's default is generally accompanied by a currency devaluation. In this respect, currencies of countries with poor ratings should be subject to a risk premium. Orlov (2019) examines whether carry trade risk premiums are due to solvency risk. He shows that risk premiums are time varying and depend on a country’s solvency. He also finds that currencies with high interest rates perform poorly when solvency risk is high.

Although the carry strategy’s excess returns are well documented in the literature, they have been poor in recent years, as Burnside (2019) demonstrates. He examines the G10 currencies between 1976 and 2018 and shows that carry trade excess returns have deteriorated following the global financial crisis, falling from

7.0% between 1976 and 2007 to 0.9% between 2008 and 2018. He argues that this is due to the lower interest rate differential that has existed since 2008.

The poor performance of carry trades in recent years is also confirmed by Geyikçi and Özyıldırım (2021). They show that carry returns dropped to 1.94% per annum between 2004 and 2019 and that carry return Sharpe ratios were significantly worse than those of equities after the global financial crisis.

To increase carry returns, Bekaert and Panayotov (2020) apply an optimisation technique to carry trades and examine the currencies of the G10 countries from 1985 to 2014. For optimisation, the number of currencies bought and sold vary depending on the historical Sharpe ratio. They show that optimisation can improve the Sharpe ratio from 0.32 to 0.61. In addition, it improves skewness, which is sometimes even positive depending on the carry strategy's setting.

Most studies focus on the post-Bretton Woods era. However, some studies, such as Accominotti et al. (2019), investigate the long-term behaviour of carry returns. They examine carry trades in different currency regimes and study 19 currencies from 1919 to 2017. They show that carry trade excess returns can be realised under free-floating currency regimes, where the annual excess return is 7.11% with a Sharpe ratio of 0.46. They also find that carry returns in fixed exchange rate regimes are completely eroded by the collapse of the peg. Thus, a loss of 0.55% per year is achieved for currencies with fixed exchange rates.

Doskov and Swinkels (2015) also study a long period with several exchange rate regimes, namely, from 1900 to 2012. They find that carry trades were a successful strategy during the entire period. However, the annual return and Sharpe ratio in the pre-Bretton Woods era are only 2.4% and 0.26, respectively. Thus, carry trades performed better after the Bretton Woods breakdown.

Overall, the literature provides strong evidence that carry trades have delivered abnormal returns in the past. The literature also presents different risk factors that affect carry returns. The following sections analyse carry trade excess returns and the risk factors that contribute to them. Of particular interest is the role that emerging market currencies play in carry returns.

4.3. CARRY RETURNS

This section presents the excess returns of carry trades. As stated in section 1.2, end-of-month data from January 1997 to December 2022 are used for 27 currencies against the US dollar, including 17 emerging and 10 industrialised market currencies.

To calculate carry trade returns, a number n out of 27 currencies is assigned to each of two portfolios. Three different settings are applied for n with $n \in \{1, 3, 5\}$; that is, the number of currencies in the long and short portfolios is 1, 3, or 5, each. The high portfolio contains those n currencies with the highest interest rates, that is, the highest forward discounts against the US dollar. The low portfolio is formed of those n currencies with the lowest interest rates. The two portfolios are reallocated monthly. The carry strategy excess return is defined as the difference between the high portfolio's return and the low portfolio's return, as in Eq. (32):

$$r_{t+1}^{HML} = \frac{1}{n}\sum_{h=1}^{n}(sp_{t+1}^{h} - fw_{t}^{h}) - \frac{1}{n}\sum_{l=1}^{n}(sp_{t+1}^{l} - fw_{t}^{l}) \qquad (32)$$

with n as the number of currencies in each of the high and low portfolios, h as the currencies with the highest forward discounts, and l as the currencies with the lowest forward discounts. Using three different values for n allows testing the results′ robustness.

Note that there are different ways to form a carry strategy. From the perspective of a US investor, one should buy those currencies with higher interest rates than the US currency and, at the same time, sell those currencies with lower interest rates. This way of calculating carry trades is referred to as dollar carry trade (Lustig et al. 2014). Another possibility is to buy half the currencies with the highest interest rates and sell the other half; this carry trade is referred to as an equally weighted carry trade (Daniel et al. 2014). From the perspective of a US investor, this strategy would allow currencies to be purchased even if their interest rates are below the US rate.

Another common method for carry trades is forming portfolios (Lustig et al. 2011; Menkhoff et al. 2012a). Here, the currencies are sorted according to their forward discount and assigned to different portfolios. The portfolio with the highest forward discount is bought and that with the lowest forward discount is sold. In this procedure, the carry return corresponds to Eq. (32) above. This procedure is also used for this research. In contrast to Lustig et al.'s (2011) work, not all six portfolios are examined, as the focus is only on the carry strategy, which is the difference between the high and low portfolios. This approach's advantage is that the number of currencies in the portfolios can be varied for the purpose of robustness tests. In this study, 1, 3, and 5 are the number of currencies assigned to the high and low portfolios. In a setting where $n = 1$, only one currency is bought and one currency is sold. Consequently, there is an idiosyncratic currency risk for this specific currency pair, while the portfolios with $n = 3$ and $n = 5$ are diversified.

Table 22 shows the statistics for the monthly excess returns of the HML carry trade strategy as formulated in Eq. (32). Significant returns are observed for all settings of n. In addition, the statistics for the high and low portfolios are presented separately:

Table 22: Carry Trade Returns for All 27 Currencies

	mean return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
High, $n = 1$	0.006509°	0.003621	1.7977	0.063951	–0.1223	0.35
Low, $n = 1$	–0.002675	0.00214	–1.2498	0.037807	–0.7668	–0.25
HML, $n = 1$	0.009184*	0.003829	2.3986	0.06763	–0.4563	0.47
High, $n = 3$	0.006039**	0.002059	2.9338	0.036361	–0.4203	0.58
Low, $n = 3$	–0.002893*	0.001268	–2.2824	0.022389	–0.2179	–0.45
HML, $n = 3$	0.008932***	0.002014	4.4343	0.035581	–0.4302	0.87
High, $n = 5$	0.003847*	0.001757	2.1903	0.031026	–0.5125	0.43
Low, $n = 5$	–0.00224°	0.001159	–1.932	0.020477	–0.0111	–0.38
HML, $n = 5$	0.006087***	0.001533	3.9704	0.02708	–0.5165	0.78

Note. The table shows monthly return statistics for carry trades applied to 27 currencies. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

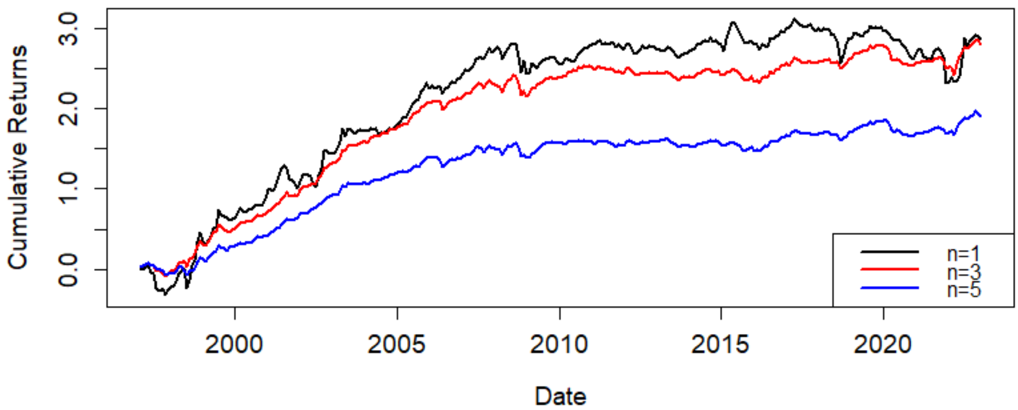
The returns are significant not only for the carry trade but also partly for the individual high and low portfolios, at least at the 10% level. Note that the low portfolios are sold so the negative return is positively captured through the carry trade.

The Sharpe ratios for the carry strategy range between 0.52 and 0.87. Furthermore, all portfolios and the HML carry trade are negatively skewed. This is consistent with the findings of Brunnermeier et al. (2008), which they determine are the result of funding constraints facing market participants with leveraged carry positions. Overall, this analysis confirms the existing findings in the literature that carry trades are profitable and deliver significant excess returns.

The results are robust for different settings for the number of currencies in the high and low portfolios. The base currency is of little importance for HML carry returns, as the strategy is dollar neutral: currencies are both bought and sold against the US dollar. In this respect, only minor deviations may be expected if the carry returns are calculated for other base currencies, such as the euro or British pound, instead of the US dollar. These small deviations arise because the carry returns are collected in the base currency. If carry returns with the USD as the base currency are compared to carry returns with the EUR as the base currency, the deviations thus result from the variation in the USD-EUR exchange rate.

Figure 17 illustrates the cumulative excess returns of the HML carry strategy.

Figure 17: Cumulative Excess Return



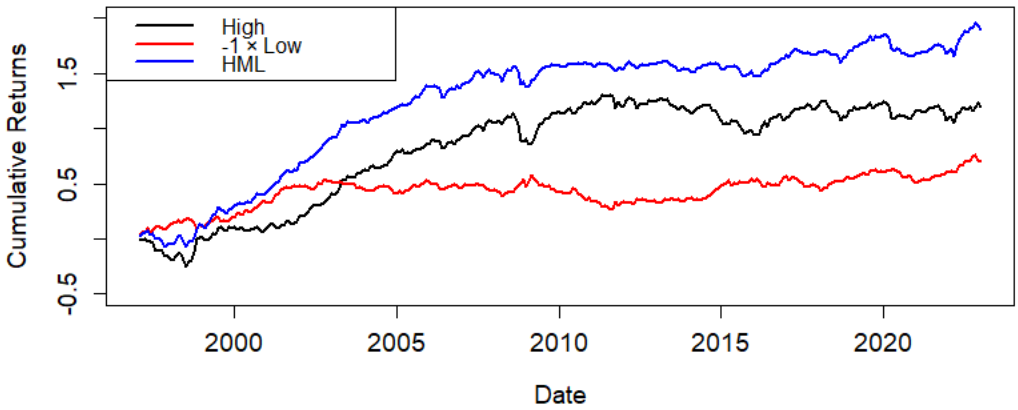
Note. The figure plots the carry strategy's cumulative returns. The number of currencies in the high and low portfolios is denoted by *n*.

Carry trades performed best up to the global financial crisis. Since then, returns have been modest. If the time series of 312 months is straightforwardly divided into two parts, the first half from 01/1997 to 12/2009 yields an average monthly excess return of 1.01% for $n = 5$, while it is only 0.21% for the second half from 01/2010 to 12/2022. For the second half from 2010 onwards, returns are still positive for all settings of n, except they are no longer significant at the 5% level for $n = 1$. These findings are consistent with those of Burnside (2019), who demonstrates that carry returns performed poorly after the global financial crisis.

Another interesting question concerns the differences between the high and low portfolios. UIP failure is evident in both portfolios: currencies with high interest rates tend to depreciate less than UIP expects. The interest rate advantage in these currencies is not compensated for by exchange rate depreciation, which is why the high portfolio shows a positive excess return. The low portfolio behaves in the opposite way: currencies with low interest rates – insofar as the interest rate is lower than the US interest rate – appreciate according to UIP. However, this appreciation is less pronounced than UIP predicts. The interest rate disadvantage compared to a USD investment is not sufficiently compensated for by the foreign currency's appreciation, which is why the low portfolio has a negative excess return. This relationship is reflected in the returns of the high and low portfolios presented in Table 22. The high portfolios show positive excess returns, and the low portfolios show negative returns.

The cumulative excess returns for the high and low portfolios are shown in Figure 18. For comparability, the low portfolio's return is multiplied by –1, as this portfolio is sold.

Figure 18: High and Low Portfolio for $n = 5$



Note. Figure 18 presents the cumulative returns for the high, low, and HML portfolios separately, where the low portfolio is multiplied by –1.

The high and low portfolios also illustrate that returns since the global financial crisis have been positive but less pronounced than in the prior period. The correlation coefficients between the high and low portfolios are 0.26, 0.34, and 0.51 for $n = 1$, $n = 3$, and $n = 5$, respectively.

This study focuses on emerging market currencies. Therefore, the influence of these currencies on the carry trades´ return will be examined. For this purpose, carry returns are calculated separately for both currency groups.

Table 23 shows the returns when the carry strategy is generated only from the 17 emerging market currencies. Again, n currencies with the highest forward discounts are bought, and n currencies with the lowest forward discounts are sold. It is not necessary that the latter currencies have lower interest rates than the US dollar.

Table 23: Carry Trade Returns for 17 Emerging Market Currencies

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
High, $n = 1$	0.006509°	0.003621	1.7977	0.063951	–0.1223	0.35
Low, $n = 1$	–0.004252*	0.001879	–2.263	0.033185	–1.6325	–0.44
HML, $n = 1$	0.01076**	0.003801	2.831	0.067137	0.1681	0.56
High, $n = 3$	0.006059**	0.002058	2.9442	0.036353	–0.4217	0.58
Low, $n = 3$	–0.002907*	0.00117	–2.4851	0.020661	–0.1994	–0.49
HML, $n = 3$	0.008966***	0.001832	4.8944	0.032358	–0.0896	0.96
High, $n = 5$	0.003866*	0.001747	2.2126	0.030867	–0.467	0.43
Low, $n = 5$	–0.001935°	0.001076	–1.7977	0.019012	–0.2521	–0.35
HML, $n = 5$	0.005801***	0.001335	4.3465	0.023576	–0.1645	0.85

Note. The table provides statistics for carry trades analogous to those in Table 22 but applied only to 17 emerging market currencies. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

For emerging market carry trades, the excess returns are significant at the 1% level for all settings of n. The Sharpe ratio can be further increased up to 0.96. Interestingly, the emerging market carry trade skewness is less negative than the version with all currencies. One possible explanation can be found in the low portfolio's skewness. Skewness is –1.6325 for emerging markets and –0.2035 for all currencies (see Table 22) for n = 1. Since the low portfolio is sold, this portfolio's negative skewness has a positive effect on the skewness of the HML carry strategy.

The emerging market carry trade returns are close to the returns achieved when all 27 currencies are included. This is a first indication that carry trade excess returns are determined by emerging market currencies. To compare to the industrialised market currency results, the next step is to apply the carry trade exclusively to that currency group. Table 33 reports the statistics of the carry trades generated using the 10 developed market currencies.

Table 24: Carry Trade Returns for 10 Developed Market Currencies

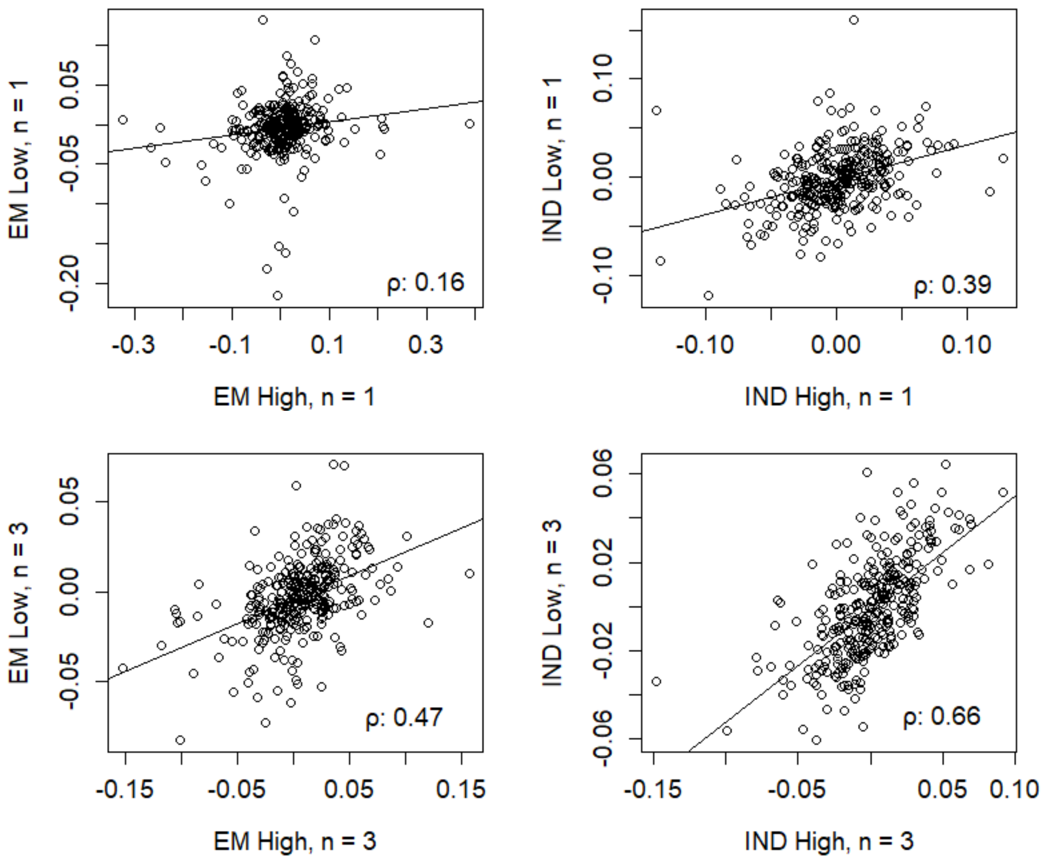
	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
High, n = 1	0.000575	0.001932	0.29774	0.034129	–0.209	0.06
Low, n = 1	–0.001559	0.001752	–0.88999	0.030944	0.3078	–0.17
HML, n = 1	0.002134	0.00204	1.0462	0.036037	–0.67	0.21
High, n = 3	0.000388	0.001622	0.23903	0.028653	–0.4894	0.05
Low, n = 3	–0.000954	0.001273	–0.74791	0.02248	0.2051	–0.15
HML, n = 3	0.001342	0.001244	1.079	0.021966	–0.8903	0.21
High, n = 5	–0.00002	0.001456	–0.01637	0.025722	–0.4767	0
Low, n = 5	–0.000806	0.00123	–0.65545	0.021727	0.1343	–0.13
HML, n = 5	0.000782	0.000933	0.83893	0.016473	–0.6737	0.16

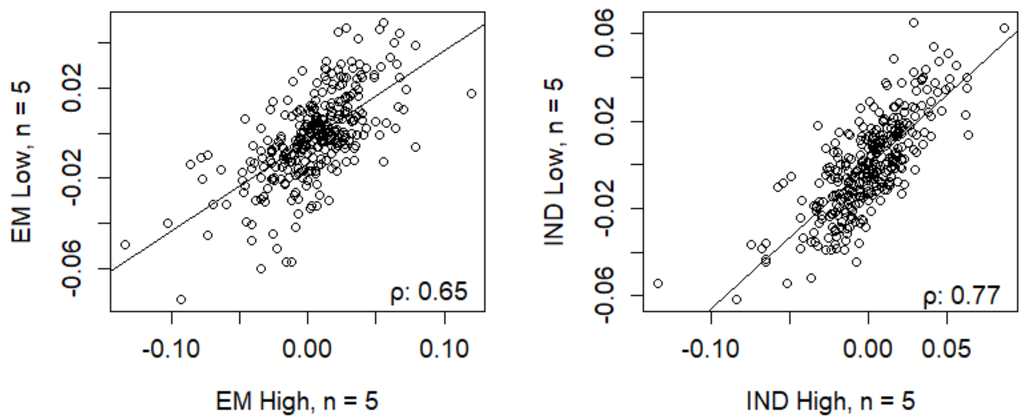
Note. The table presents statistics for carry trades applied to 10 industrialised market currencies. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

Excess returns are not significant for any setting of n, and the Sharpe ratio reaches a maximum value of 0.21. Furthermore, skewness differs depending on whether the carry trade is formed with emerging or developed market currencies. For the HML portfolio, skewness ranges between –0.67 and –0.89 for developed market currencies, between –0.20 and –0.52 for all currencies, and between –0.09 and 0.17 for emerging market currencies. The carry strategy generated by developed market currencies seems to be more exposed to crash risk than the one that uses emerging market currencies. One possible explanation could be the positive skewness of low-yielding developed market currencies, which are considered safe havens. The Japanese yen and Swiss franc have skewness of 0.43 and 0.19, respectively, against the US dollar, (see Table 5 on page 50). If these currencies are sold in the carry strategy, then the short position has a negative impact on the carry trade's skewness.

A carry trade comprises a long position in the high portfolio and a short position in the low portfolio. Thus, the relationship between the high and low portfolios is of interest. The higher the correlation between the high and low portfolios, the more positive the effect on the carry trade statistics since the high portfolio is bought, and the low portfolio is sold. Figure 19 plots the carry returns for both currency groups, emerging markets (EM), and industrialised markets (IND) for all settings of n.

Figure 19: Correlations Between the High and Low Portfolios





Note. Figure 19 plots returns for the high and low portfolios separated into emerging market carry trades (EM) and industrialised market carry trades (IND). The correlation coefficients are reported in the single graphs.

The correlation between the high and low portfolios is positive for all settings and improves as n increases. Consequently, combining a long position in the high portfolio and a short position in the low portfolio is beneficial, as both positions then correlate negatively. This is also reflected in the Sharpe ratio, which is lowest for $n = 1$.

The analyses in this section revealed that in terms of excess returns, carry trades in emerging market currencies dominate carry trades in developed market currencies. Moreover, the less negative skewness suggests that emerging market carry trades have better crash risk characteristics. Note that the calculations so far do not consider transaction costs. Section 4.6 shows carry trade returns considering the bid-ask spread.

The focus of this research is on excess returns in emerging market currencies. As shown in this section, emerging market currencies do indeed seem to be the source of carry trade returns, while developed market currencies have only a limited impact. The following section examines this aspect of carry trade excess returns in more detail.

4.4. CARRY RETURN ANALYSES AND BOOTSTRAPPING

The previous section shows that carry trades in emerging market currencies deliver significant returns, while the same strategy with developed market currencies does not. This section, therefore, examines carry excess returns in more detail, looking at how emerging market currencies affect them. Two different methods are applied for this purpose.

First, a Welch test is used to compare the emerging and developed market carry trade excess returns. Second, bootstrap analyses are employed to test the hypothesis that emerging market carry trades dominate industrialised market carry trades.

In the previous section, the carry strategy excess returns were calculated for two different groups, emerging and developed markets (see Table 23 and Table 24). The average monthly excess returns for the two currency groups differ at 0.5801% and 0.0782%, respectively, for n = 5. The standard deviations for the two groups also differ, at 2.3576% and 1.6473%, respectively. When the carry trade strategy is applied to all 27 currencies, the monthly average excess return is 0.6087% with a standard deviation of 2.708%. For n = 1 and n = 3, the picture is similar in that both the return and standard deviation are higher for emerging markets' currencies than for industrialised markets' currencies.

Whether emerging markets' currencies are the main source of carry returns is an interest of this study. The null hypothesis is therefore defined as emerging market carry trades having no distinctive characteristics compared to developed market carry trades. The Welch test examines whether the monthly average excess returns of emerging and developed market carry trades are different; the null hypothesis is thus defined as in Eq. (33)

$$H_0\colon \overline{r_{EM}^{HML}} - \overline{r_{IND}^{HML}} = 0 \tag{33}$$

with $\overline{r_{EM}^{HML}}$ as the average monthly excess return of the HML carry strategy when applied exclusively to 17 emerging market currencies and $\overline{r_{IND}^{HML}}$ as the monthly average excess return of the industrialised currencies' carry trade. The null hypothesis is rejected when the t-value computed with Eq. (34)

$$T = \frac{\overline{r_{EM}^{HML}} - \overline{r_{IND}^{HML}}}{\sqrt{\mathrm{var}(r_{EM}^{HML})\ /\ m + \mathrm{var}(r_{IND}^{HML})\ /\ m}} \tag{34}$$

is above the critical value. There are 312 monthly observations, giving m = 312. Table 25 presents the results of the Welch test, as shown in Eq. (34). In addition, the carry returns are not only compared for emerging market currencies (EM) and industrialised country currencies (IND), but the carry returns of both currency groups are also compared with the excess returns when the carry strategy is applied to all 27 currencies (ALL). The average returns are the same as shown in Table 22, Table 23, and Table 24; n denotes the number of currencies in the high and low portfolios.

Table 25: Welch Test for EM, IND, and ALL Carry Trade Returns

	$\overline{r_{EM}^{HML}}$	$\overline{r_{IND}^{HML}}$	$\overline{r_{ALL}^{HML}}$	return difference	t-value	p-value
$n = 1$						
EM vs. IND	0.01076	0.002134		0.008626*	1.9996	0.0461
EM vs ALL	0.01076		0.009184	0.001576	0.2922	0.7702
IND vs ALL		0.002134	0.009184	–0.00705	–1.6249	0.1049
$n = 3$						
EM vs. IND	0.008966	0.001342		0.007624***	3.4435	0.00006
EM vs ALL	0.008966		0.008932	0.000034	0.0124	0.9901
IND vs ALL		0.001342	0.008932	–0.00759**	–3.2063	0.0014
$n = 5$						
EM vs. IND	0.005801	0.000782		0.005019**	3.0824	0.0022
EM vs ALL	0.005801		0.006087	–0.000286	–0.1405	0.8883
IND vs ALL		0.000782	0.006087	–0.005305**	–2.9561	0.0033

Note. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The results of the Welch test are clear: carry trade excess returns for emerging and developed markets are significantly different. The null hypothesis that the returns when the strategy is applied to all 27 currencies are equal to the returns when it is applied only to emerging market currencies cannot be rejected. However, the hypothesis that carry returns are equal for all 27 currencies and developed market currencies must be rejected in two out of three cases at the 1% significance level. Table 25 thus shows that emerging market currencies have a significant impact on carry trade excess returns; however, the influence of currencies from industrialised countries is limited.

Table 23 and Table 24 on pages 118 and 119 also show that emerging market carry trades have higher Sharpe ratios than developed market carry trades. In addition, the negative skewness is more pronounced in the latter. These aspects are further investigated using bootstraps in the second step of this section.

Comparing two parameters of interest is not always possible with tests such as the Welch test, which compares whether the mean of two distributions is different under unequal variances. However, there are no tests to compare the higher moments of two distributions. Therefore, the bootstrap method is used for this purpose.

Let r_{EM}^{HML} and r_{IND}^{HML} indicate the excess returns of two HML carry trade strategies, one comprised of emerging market currencies and the other of industrialised market currencies. The returns are calculated based on sample data for emerging and industrialised markets between January 1997 and December 2022, a total of 312 months. The question of interest is to what extent r_{EM}^{HML} and r_{IND}^{HML} differ from each other. However, not only the monthly average excess returns are compared, but also the standard deviations, skewness, and Sharpe ratios.

For this comparison, two random samples of 312 months each are drawn, one from r_{EM}^{HML} and the other from r_{IND}^{HML}. One bootstrap sample, r_{EM}^{HML*} or r_{IND}^{HML*}, is marked with a star to show that this is not the original data set but a bootstrap. Note that the random selection is made with replacement. Accordingly, a single month's excess return may appear in a bootstrap sample several times or not at all. The probability of one observation being selected for a given month is 1 in 312.

After randomised assignment, the statistics for the bootstrap samples can be observed. For example, the standard deviation for r_{EM}^{HML} with $n = 5$ is calculated as 0.0232576 (see Table 23), and the standard deviation for r_{EM}^{HML*} could be 0.024558. The next step is to run a sufficient number of bootstrap replications; 30,000 replications are used for this study. The results are similar to using 10,000 repetitions, so the number is robust.

If the bootstrap replication is repeated 30,000 times, 30,000 different statistics which gives the distributions for r_{EM}^{HML*} and for r_{IND}^{HML*} are obtained, each consisting of 312 monthly excess returns. The parameter of interest $\hat{\theta}^*$, such as the standard deviation, skewness, or Sharpe ratio, can be calculated for each of the 30,000 distributions.

Of interest is the difference between the parameter for emerging market carry trades $\hat{\theta}^{EM,*}$ and that for industrialised market carry trades $\hat{\theta}^{IND,*}$. Therefore, the standard error for the desired parameter $\hat{\theta}^*$ is calculated from the 30,000 differences. The standard error corresponds to the standard deviation of the parameter $\hat{\theta}^*$ in the bootstrap replications, calculated using Eq. (35):

$$se_{30,000}(\hat{\theta}^{EM,*} - \hat{\theta}^{IND,*}) = \sqrt{\frac{1}{n-1}\sum_{n=1}^{30,000}\left((\hat{\theta}^{EM,*} - \hat{\theta}^{IND,*}) - \overline{(\hat{\theta}^{EM,*} - \hat{\theta}^{IND,*})}\right)^2} \quad (35)$$

The standard errors for the differences in the parameters $\hat{\theta}^*$ determined using the bootstrap procedure are presented in Table 26. The parameters of interest are the monthly average excess return, standard deviation, skewness, and Sharpe ratio.

Table 26: Bootstrap Differences for EM and IND

	return	standard dev.	skewness	Sharpe ratio
$n = 1$				
HML^{EM}	0.01076	0.067137	0.1681	0.56
HML^{IND}	0.002134	0.036037	–0.67	0.21
Difference	0.008626*	0.0311***	0.8381	0.35°
$\widehat{se}_{30,000}$	0.00433	0.006046	0.8322	0.285
t-statistic	1.9921	5.1439	1.0071	1.2281
$n = 3$				
HML^{EM}	0.008966	0.032358	–0.0896	0.96
HML^{IND}	0.001342	0.021966	–0.8903	0.21
Difference	0,007624***	0.010392***	0.8007°	0.75*
$\widehat{se}_{30,000}$	0.002219	0.002387	0.4659	0.292
t-statistic	3.4358	4.3536	1.7186	2.5685
$n = 5$				
HML^{EM}	0.005801	0.023576	–0.1645	0.85
HML^{IND}	0.000782	0.016473	–0.6737	0.16
Difference	0.005019**	0.007103***	0.5092	0.69*
$\widehat{se}_{30,000}$	0.001632	0.001622	0.4094	0.289
t-statistic	3.0754	4.3792	1.2438	2.3875

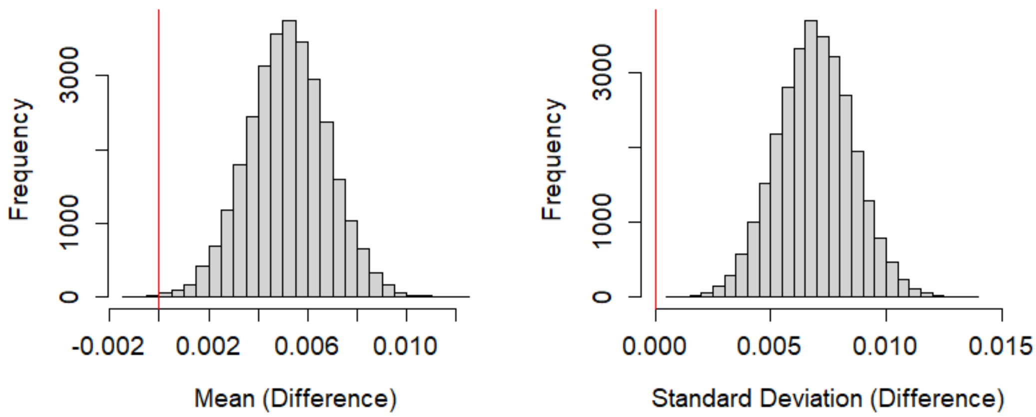
Note. The table reports the results of the bootstrap analysis. Carry trade return statistics are provided for two currency groups: emerging markets (EM) and industrialised markets (IND). °, *, **, and *** indicate significant differences between the two groups at the 10%, 5%, 1%, and 0.1% levels, respectively.

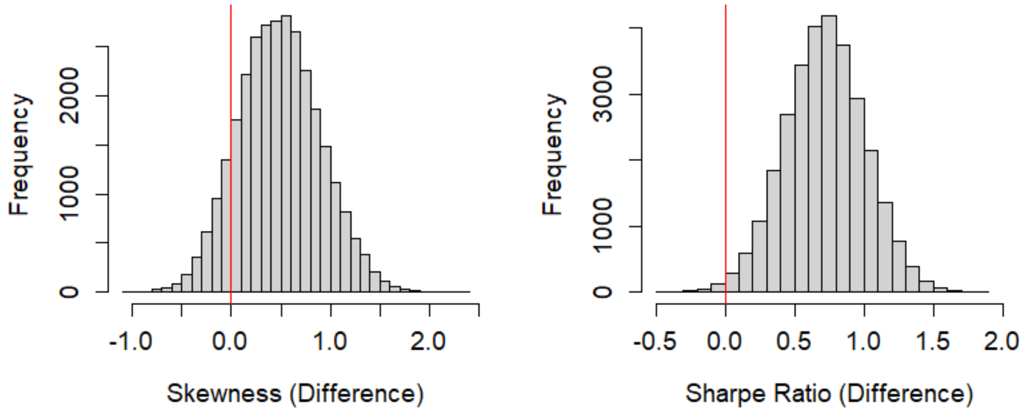
There is a significant difference between the monthly excess returns of carry trades based on emerging markets' currencies and those based on industrialised markets' currencies, consistent with the results of the Welch test in Table 25.

The emerging market carry trade standard deviation is significantly higher than that of the industrialised carry trade for n = 1, 3, and 5. Nevertheless, the emerging markets Sharpe ratio is significantly higher than that of the industrialised countries at the 5% significance level, at least for n = 3 and n = 5. Skewness is less negative for the emerging market carry trade than for the industrialised countries market carry trade. However, this is only significant for n = 3 at the 5% level.

Figure 20 shows the distribution of the differences between the parameter of interest $\hat{\theta}$ for emerging and industrialised market currencies, $\hat{\theta}^{EM,*} - \hat{\theta}^{IND,*}$. The zero difference is marked in red, and the number of currencies in the long and short portfolio is 5 each, that is, n = 5.

Figure 20: Bootstrapped Differences Between EM and IND Carry Trades





Note. Figure 20 illustrates the bootstrapped differences between emerging markets' carry trades and industrialised markets' carry trades for the parameters of interest. The red vertical lines mark the differences from zero.

For the average return and Sharpe ratio, it is apparent that emerging market carry trade returns are significantly better than those of carry trades that are formed only by industrialised countries' currencies. In addition, however, the standard deviation is also significantly higher for the emerging markets' carry trade returns. Skewness is higher for emerging markets, although not as significant as the other values.

The analyses of the bootstrapped carry returns for the two currency groups, emerging and developed markets, thus clearly show the dominance of emerging market currencies. The monthly average returns, skewness, and Sharpe ratios improve for all settings of n. However, the carry return standard deviation is also higher for emerging market currencies.

4.5. RISK FACTORS

The previous sections provide evidence that a carry trade in an HML portfolio delivers significant excess returns. From an investment perspective, a question of interest is whether risk factors can be identified that account for the carry returns.

Section 2.7 shows that DOL can explain a large part of bilateral currency returns. The R^2 for individual currencies is above 0.6. Therefore, the first investigation in this chapter questions whether investors who are engaged in carry trades also have high loadings on the DOL risk factor (Lustig et al. 2011). Table 27 presents the results of the single linear regression of carry returns on the DOL risk factor. To compare emerging (HML^{EM}) and industrialised markets (HML^{IND}), the regression results are presented for both currency groups and for all currencies (HML^{ALL}).

Table 27: Carry Returns and DOL Risk Factor

	constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
$n = 1$					
HML^{ALL}	0.009433*	0.660828***	0.171662	3.85	0.0456
HML^{EM}	0.011036**	0.730017***	0.169436	4.309	0.0565
HML^{IND}	0.002333	0.526123***	0.088736	5.929	0.1018
$n = 3$					
HML^{ALL}	0.009118***	0.493264***	0.0881	5.599	0.0918
HML^{EM}	0.009137***	0.453267***	0.080034	5.663	0.0938
HML^{IND}	0.001491	0.39476***	0.052484	7.522	0.1543
$n = 5$					
HML^{ALL}	0.006254***	0.442483***	0.065717	6.733	0.1276
HML^{EM}	0.005962***	0.425235***	0.056293	7.554	0.1555
HML^{IND}	0.000878	0.252521***	0.040327	6.262	0.1123

Note. Table 27 presents results for the DOL risk factor. Linear regression is applied with carry returns (HML) as the dependent variable and DOL as the regressor. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The impact of the DOL risk factor is lower for the carry strategy than for bilateral currencies, as reported in section 2.7. R^2 lies between 0.05 and 0.16. Nevertheless, the DOL risk factor is significant for all settings of n for both emerging and industrialised market carry trades.

Investors who are interested in reducing loadings on the DOL risk factor thus prefer the carry strategy to bilateral currencies. The slope coefficients of the bilateral currencies were partly greater than 1, while the slope for the carry trades lies between 0.25 and 0.73. Hence, the carry trade is not only favourable compared to the buy and hold strategy in terms of expected mean returns but also in terms of lower loadings on the DOL risk factor.

Another relevant risk factor for exchange rates is the currency volatility VOL (Menkhoff et al. 2012a). The description and importance of this risk factor for bilateral exchange rates are presented in section 2.7. From the perspective of a US investor, increasing volatility in currency markets is a burden on currency excess returns, as presented in Table 9 on page 61. The relevance of currency volatility for the carry trade strategy, measured by the VOL risk factor, is shown in Table 28. Again, a single linear regression is performed of the carry returns on the VOL risk factor.

Table 28: Carry Returns and VOL Risk Factor

	constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
$n = 1$					
HML^{ALL}	0.02061°	–2.41539	2.41132	–1.002	0.0032
HML^{EM}	0.009288	0.311282	2.397528	0.13	0.0001
HML^{IND}	0.022176***	–4.237753***	1.264264	–3.352	0.035
$n = 3$					
HML^{ALL}	0.02453***	–3.2982**	1.2568	–2.624	0.0217
HML^{EM}	0.0161**	–1.508302	1.152395	–1.309	0.0055
HML^{IND}	0.021414***	–4.24422***	0.746501	–5.685	0.0944
$n = 5$					
HML^{ALL}	0.021392***	–3.236089***	0.949441	–3.408	0.0361
HML^{EM}	0.01068*	–1.03239	0.8399	–1.229	0.0049
HML^{IND}	0.016371***	–3.296039***	0.557721	–5.91	0.1013

Note. The table shows the impact of the VOL risk factor on carry returns, measured using a single linear regression. °, *, **, and *** indicate significant values at the 10%, 5%, 1%, and 0.1% levels, respectively.

VOL´s impact on carry returns is statistically significant for industrialised market carry trades (HML^{IND}), but nor for emerging market carry trades (HML^{EM}). This is interesting because a natural assumption would be that VOL as a volatility risk proxy affects HML^{EM} more than HML^{IND}. However, it seems that HML^{EM} involve less risk.

A rational explanation for this is that the short position in the low portfolio partially offsets the variance of the high portfolio. For industrialized countries' currencies, low interest rate currencies such as the Japanese yen or Swiss franc serve as safe havens in times of crisis. If currency volatility is high and the safe haven currencies appreciate, short positions in these currencies suffer. Consequently, the HML^{IND} carry strategy has high negative loadings on volatility. In contrast, there are no safe haven currencies for emerging markets. When currency volatility rises, the high portfolio suffers, but the carry strategy gains due to the short position in the low portfolio. As a result, the volatility loadings are less pronounced for the HML^{EM} carry strategy.

Investors who would like to participate in carry trade returns but wish to reduce currency volatility loadings should therefore prefer carry trades composed only of emerging market currencies. However, the R^2 for the VOL risk factor is low at values less than 0.1. It is, therefore, less important for carry returns than the DOL risk factor.

Besides the DOL and VOL, market risk factors also play a role in currency markets, as discussed in section 2.7. The risk factors examined are, analogous to those in section 2.7, the MSCI World index (MSCI), the CBOE volatility index (VIX), the Bloomberg Commodity Total Return index (COM), and the monthly change in the 10-year US government bond yield (INT). The risk factors thus reflect three asset classes – equities, commodities, and interest rates – as well as equity market volatility. The risk factors′ impact is investigated by single linear regressions as shown in Eq. (36).

$$r_t^{HML} = \alpha + \beta RF_t + \varepsilon_t \tag{36}$$

with RF_t as the respective risk factor at time t. Table 29 presents the results of the four individual regressions. For convenience, only the slope coefficient, the corresponding t-value and the R^2 are given.

Table 29: Regression of Carry Returns on Market Risk Factors

	MSCI	COM	INT	VIX
n = 1				
HML^{ALL}	0.0306	0.2022*	2.3416	–0.0415*
	(0.366), [0]	(2.477), [0.019]	(–1.511), [0.008]	(–2.301), [0.017]
HML^{EM}	–0.0065	0.2056*	0.9788	–0.032°
	(–0.078), [0]	(2.539), [0.02]	(0.65), [0.001]	(–1.778), [0.01]
HML^{IND}	0.2365***	0.1839***	1.0831	–0.0468***
	(5.577), [0.091]	(4.311), [0.057]	(1.344), [0.006]	(–5.019), [0.075]

$n = 3$				
HML^{ALL}	0.1551***	0.1681***	2.4848**	–0.0426***
	(3.605), [0.04]	(3.974), [0.048]	(3.163), [0.031]	(–4.598), [0.064]
HML^{EM}	0.1005*	0.149***	1.4671*	–0.0295
	(2.542), [0.02]	(3.87), [0.046]	(2.034), [0.013]	(–3.448), [0.037]
HML^{IND}	0.2325***	0.1927***	1.8885***	–0.0429***
	(9.818), [0.237]	(7.89), [0.167]	(3.927), [0.047]	(–7.95), [0.169]
$n = 5$				
HML^{ALL}	0.1596***	0.132***	2.3832***	–0.0382***
	(4.96), [0.074]	(4.106), [0.052]	(4.024), [0.05]	(–5.487), [0.089]
HML^{EM}	0.1132***	0.1237***	1.1211*	–0.0267***
	(3.987), [0.049]	(4.439), [0.06]	(2.135), [0.014]	(–4.315), [0.057]
HML^{IND}	0.1699***	0.1340***	1.5937***	–0.0315***
	(9.492), [0.225]	(7.216), [0.144]	(4.448), [0.06]	(–7.751), [0.162]

Note. The table presents slope coefficients for the single linear regressions of carry trade excess returns on four different market risk factors. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. Values in parentheses indicate the slope coefficients´ t-values, and values in brackets show the regressions´ R^2.

The risk factors´ slope coefficients are mostly significant for $n = 3$ and $n = 5$ for all four risk factors. Measured by R^2, interest rates have the lowest impact on carry returns. Additionally, equity and commodity risk show different patterns for HML^{IND} and HML^{EM} in terms of R^2. The maximum value of the former is 0.237 for HML^{IND} and $n = 3$. In this setting, R^2 reaches only 0.02 for HML^{EM}.

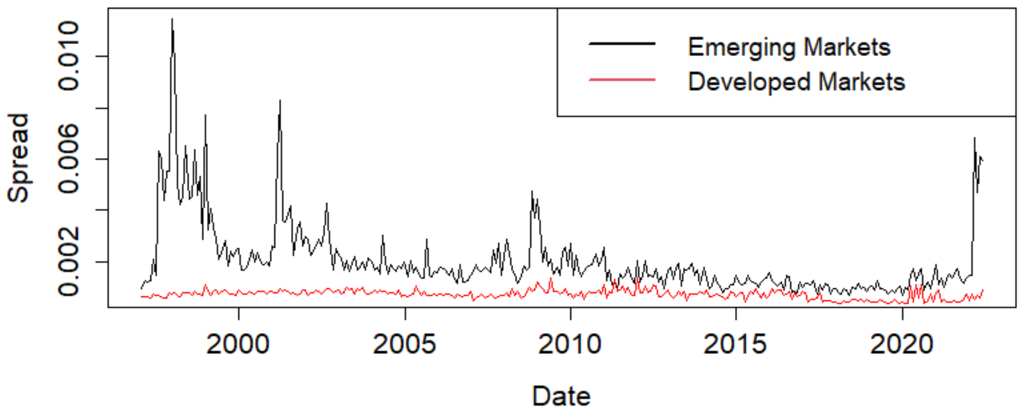
The higher R^2 indicate that HML^{IND} is more exposed to market risk than HML^{EM}. In other words, HML^{EM} should be more effective in diversifying an existing market portfolio than HML^{IND}.

4.6. ARBITRAGE LIMITS

The results so far in this chapter are based on bid prices and therefore do not include transaction costs. For currency markets, the bid-ask spread plays a role when it comes to putting currency strategies into practice (Barroso and Santa-Clara 2015a). This section examines the impact of transaction costs on carry returns as a limiting factor in realising the strategy's returns.

The bid-ask spread is higher for emerging markets' currencies than for developed markets' currencies. For the former, the mean is 0.20% with a standard deviation of 0.15%. For developed markets, the average bid-ask spread is 0.07%, with a standard deviation of 0.02%. Figure 21 plots the time series of the bid-ask spreads for both emerging and developed market currencies.

Figure 21: Bid-Ask Spreads



Note. The figure illustrates the time series of bid-ask spreads for both emerging and developed markets' currencies.

Sections 4.3 and 4.4 demonstrated that the carry strategy returns are particularly due to emerging market currencies. Since the transaction costs for these currencies are higher than for currencies from industrialised countries, the carry returns are likely to be diminished by the bid-ask spreads.

To correctly consider the bid-ask spread requires distinguishing whether foreign currencies are bought (high portfolio) or sold (low portfolio). In addition, it must be considered that currencies that are allocated to the high or low portfolios in period t and remain in that portfolio in the following period $t+1$ can be prolongated. These positions, therefore, do not have to be closed and reopened with the full bid-ask spread but can be rolled via currency swaps, significantly reducing transaction costs (Gilmore and Hayashi 2011).

The excess returns of currencies that are allocated to the high portfolio but were not allocated to this portfolio in the previous period is thus calculated using Eq. (37):

$$r_{t+1} = sp_{t+1}^{BID} - fw_{t}^{ASK} \tag{37}$$

The excess returns of currencies that are allocated to the low portfolio but were not allocated to this portfolio in the previous period is calculated as in Eq. (38):

$$r_{t+1} = sp_{t+1}^{ASK} - fw_t^{BID} \tag{38}$$

If a currency is assigned to either the high or low portfolio in a period and remains in that portfolio in the following period, the excess return for that currency is calculated with Eq. (39), analogously to the calculations in section 4.3 using bid prices:

$$r_{t+1} = sp_{t+1}^{BID} - fw_t^{BID} \tag{39}$$

Table 30 shows the carry strategy returns for all 27 currencies, considering the bid-ask spread.

Table 30: Carry Trade Returns for all 27 Currencies After Transaction Costs

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
High, n = 1	0.005386	0.00359	1.5005	0.063405	–0.2812	0.29
Low, n = 1	–0.002438	0.002173	–1.1217	0.038386	–0.6861	–0.22
HML, n = 1	0.007824*	0.003807	2.055	0.067251	–0.586	0.4
High, n = 3	0.005605**	0.002062	2.7176	0.036429	–0.4276	0.53
Low, n = 3	–0.002375°	0.001271	–1.869	0.022444	–0.1117	–0.37
HML, n = 3	0.00798***	0.002014	3.9611	0.035583	–0.4114	0.78
High, n = 5	0.003472*	0.001762	1.9704	0.031124	–0.5237	0.39
Low, n = 5	–0.00154	0.001163	–1.3241	0.020549	0.0328	–0.26
HML, n = 5	0.005012**	0.00154	3.2556	0.027194	–0.5345	0.64

Note. The table presents statistics of the carry trades for 27 currencies as given in Table 22 on page 115 after considering bid-ask spreads. °, *, **, and *** indicate bid-ask returns that are significant at the 10%, 5%, 1%, and 0.1% levels, respectively.

The carry strategy, which buys n currencies in the high portfolio and sells n currencies in the low portfolio, can achieve significant excess returns for all settings of n, even after transaction costs are considered. For n = 1, the monthly average excess return drops from 0.009184 without transaction costs to 0.007824 with transaction costs; for $n = 3$, the return falls from 0.008932 to 0.00798; and for $n = 5$, it drops from 0.006087 to 0.005012. Looking at the high and low portfolios separately, excess returns are predominantly no longer significant at the 5% level.

If the carry trade is only applied to the 17 emerging market currencies, a similar picture emerges: the returns of the HML portfolio are still significantly positive at the 5% level.

Table 31: Carry Returns After Transaction Costs, EM Currencies

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
High, $n = 1$	0.005386	0.00359	1.5005	0.063405	–0.2812	0.29
Low, $n = 1$	–0.003579°	0.001909	–1.8751	0.003713	–1.3777	–0.37
HML, $n = 1$	0.008965*	0.003784	2.3695	0.066832	0.0443	0.46
High, $n = 3$	0.005629**	0.002062	2.73	0.036421	–0.4292	0.54
Low, $n = 3$	–0.00174	0.001178	–1.4767	0.020814	–0.0833	–0.29
HML, $n = 3$	0.007369***	0.001846	3.9916	0.032611	–0.1237	0.78
High, $n = 5$	0.003483*	0.001751	1.9888	0.030933	–0.4704	0.39
Low, $n = 5$	–0.000353	0.001077	–0.32811	0.019022	–0.1696	–0.06
HML, $n = 5$	0.003836**	0.001336	2.8714	0.023598	–0.1672	0.56

Note. The table corresponds to Table 23 on page 118 and presents carry trade statistics when the strategy is applied exclusively to the 17 emerging market currencies. In Table 31, transaction costs are considered. °, *, **, and *** indicate excess returns that are significant at the 10%, 5%, 1%, and 0.1% levels, respectively.

After considering transaction costs, the monthly average excess return drops from 0.01076 to 0.008965 for $n = 1$, from 0.008966 to 0.007369 for $n = 3$, and from 0.005801 to 0.003836 for $n = 5$. For emerging markets, the high and low portfolios in isolation only partly deviate significantly from zero at the 5% level.

The transaction costs for currencies from industrialised countries are lower than those for emerging market currencies. However, even without considering transaction costs, the industrialised market carry trade excess returns were not significant (see Table 24 on page 119). Table 32 presents the results of the carry strategy considering transaction costs for the 10 industrialised countries' currencies.

Table 32: Carry Returns After Transaction Costs, IND Currencies

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
High, n = 1	0.000375	0.00193	0.19445	0.034085	–0.2066	0.04
Low, n = 1	–0.001353	0.001754	–0.7715	0.030977	0.3048	–0.15
HML, n = 1	0.001728	0.002041	0.84685	0.036048	–0.6819	0.17
High, n = 3	0.000247	0.001622	0.15218	0.028654	–0.4856	0.03
Low, n = 3	–0.000625	0.001272	–0.49117	0.022471	0.2044	–0.1
HML, n = 3	0.000872	0.001245	0.70014	0.021992	–0.8826	0.14
High, n = 5	–0.000124	0.001456	–0.08501	0.025723	–0.4824	–0.02
Low, n = 5	–0.000353	0.001229	–0.28748	0.021702	0.1323	–0.06
HML, n = 5	0.000229	0.000934	0.24573	0.016491	–0.6819	0.05

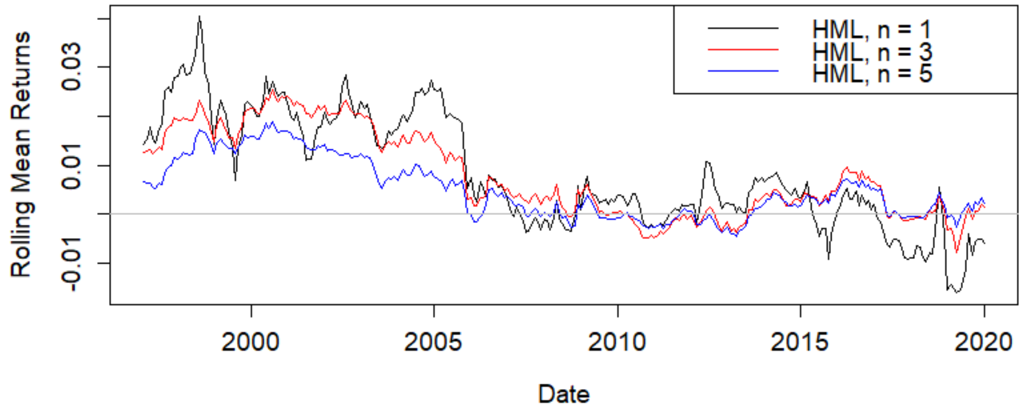
Note. The table presents statistics on industrialised market carry trades after considering transaction costs, thus corresponding to the results in Table 24 on page 119 without transaction costs. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The carry returns for industrialised countries' currencies after considering transaction costs show the same pattern as the returns without transaction costs. Carry returns of the HML portfolio are positive but not significant.

Overall, transaction costs reduce the carry strategy returns, but they do not lead to a different valuation: carry returns are significant when emerging market currencies are employed, regardless of whether the calculation is made with or without transaction costs.

Another aspect of exploiting carry returns in practice is the stability of returns over time. A rolling investment with a 36-month horizon is used to verify return stability. Figure 22 shows the rolling 36-month returns when the carry strategy is applied to all 27 currencies. The returns are after transaction costs.

Figure 22: Rolling 36-month Returns



Note. The figure illustrates average monthly rolling returns with a 36-month investment horizon and after transaction costs.

An investment in the carry strategy with a 36-month horizon was successful between 1997 and 2005. However, the results for subsequent years are mixed. Depending on the investment's starting point, there are both positive and negative average monthly excess returns. This is the case for all settings of n. The carry returns are time varying and have been lacklustre since the financial crisis. These results are in line with the findings from chapter III, where it was shown that the slope coefficient is time varying when regressing the forward discount on the spot change. After the global financial crisis, the slope is greater than 1 for both emerging and developed market currencies (see Table 14 on page 82). As a result, a currency's interest rate advantage is overcompensated for by currency depreciation. Consequently, currency excess returns are not possible during this period. The weak performance of the carry strategy since the financial crisis underlines the findings from sections 3.4 and 3.5.

4.7. CHAPTER CONCLUSION

Carry trades generated significant excess returns between 1997 and 2022. However, the key element of carry returns is emerging market currencies. By employing bootstrap analyses, this chapter has demonstrated that emerging market currency carry trades significantly outperform developed market currency carry trades in terms of monthly average returns and Sharpe ratios. Moreover, the returns´ skewness is less negative for emerging market carry trades.

Carry returns are a contradiction to UIP and thus confirm the findings in chapter III. The high portfolio, which consists of the currencies with the highest interest rates, delivers significantly positive returns, while the low portfolio, which includes the currencies with the lowest interest rates, delivers significantly negative returns. These results are consistent with existing findings in the literature, which show that currencies with high interest rates are exposed to risk and thus provide a risk premium (Lustig and Verdelhan 2007).

However, carry returns are time varying and performed the best before the global financial crisis. Transaction costs only reduce carry trades' performance to a limited extent; that is, the returns are still significantly positive even after considering the bid-ask spread.

Another interesting question deals with the impact of risk factors. The results show that DOL is less relevant for carry trades than for bilateral exchange rates, as presented in chapter II. R^2 is at most 0.1555, and the factor loadings are smaller than 1. Nevertheless, DOL is significant for carry returns, as is VOL.

Differences between emerging markets' and industrialised markets' carry trades are also evident in the risk factors. The latter are more negatively affected by currency volatility than emerging markets´ carry trades. This aspect is interesting, as an intuitive interpretation would be that emerging markets' carry trades are riskier than industrialised markets' carry trades. As far as the factor loadings on currency volatility are concerned, the opposite is the case.

Market risk factors such as equities or commodities are relevant for carry trade excess returns. However, the regression´s R^2 indicate that HML^{IND} is more exposed to market risk than HML^{EM}.

Overall, there is evidence that emerging markets' currencies rather than developed markets' currencies are the source of carry trade returns. Carry returns are compensation for risk, with several risk factors significantly impacting them.

V – MOMENTUM EXCESS RETURNS

V - MOMENTUM EXCESS RETURNS

5.1. CHAPTER INTRODUCTION

Momentum is a common strategy in currency markets and other asset classes. This strategy involves buying those currencies that have in the past performed the best relative to other currencies. At the same time, the currencies that have in the past performed poorly relative to others are sold. Excess returns for the momentum strategy are documented in numerous studies (Burnside et al. 2011b; Menkhoff et al. 2012b; Eriksen 2019).

This section examines the momentum strategy's excess returns for 27 currencies from emerging and developed markets. A question of interest is the extent to which emerging markets' currencies contribute to excess returns. The research in this section shows that a momentum strategy that focuses exclusively on industrialised countries' currencies is not successful. If the momentum strategy is applied to emerging markets' currencies, there are significantly positive returns. In fact, after applying permutation tests, momentum excess returns are shown to result from emerging markets' currencies, while developed markets' currencies have no impact.

In addition, the role of currency risk factors is examined. Interestingly, the loadings for some risk factors have signs opposite the ones they have for carry trade returns. DOL has a significantly negative slope coefficient, while for carry trades, it is significantly positive. The slope for VOL is significantly positive for momentum returns but negative for carry returns. Market risk factors, such as equities or commodities, do not play a role in momentum returns. Moreover, the correlation between momentum and carry returns is close to zero.

This chapter is structured as follows: Section 5.2 provides a detailed literature review on currency momentum strategies. Section 5.3 presents the excess returns, looking separately at developed and emerging markets' currencies. The role of emerging markets in momentum returns is further examined in section 5.4 using a permutation test. Section 5.5 examines the roles of different risk factors. Section 5.6

investigates the impact of transaction costs and examines whether the success of the strategy is time varying. Section 5.7 concludes this chapter.

5.2. LITERATURE REVIEW

Momentum is a strategy of buying winners and selling losers. Numerous studies have examined momentum, finding that abnormal returns can be achieved using this strategy. This is the case not only for currencies but also for other asset classes. For equity markets, Jegadeesh and Titman (1993) show momentum returns of 12% per year in a frequently cited study. Numerous other studies on momentum in equity markets have since confirmed the strategy's excess returns (Rouwenhorst 1998; Asness et al. 2013; Barroso and Santa-Clara 2015b; Fama and French 2012).

The profitability of momentum strategies has also been widely studied for currency markets, with one of the first studies by Okunev and White (2003). Momentum returns differ from carry returns in concerns of crash risk and skewness. Unlike carry returns, momentum returns are positively skewed, and momentum strategies have generated positive returns during the global financial crisis. For example, Burnside et al. (2011b) examine 20 major currencies between 1976 and 2010. They report annual momentum returns of 4.5%, a Sharpe ratio of 0.62, and skewness of 0.08. For comparison, they show the carry excess returns for the same period, which are 4.6%, with a Sharpe ratio of 0.89 and skewness of –0.53.

Menkhoff et al. (2012b) confirm the positive excess returns for momentum but also the different characteristics of carry trades. They examine different settings for the momentum strategy’s holding and formation periods and report annualised excess returns between 1.89% and 9.46%, depending on the momentum strategy setting.

A question of interest concerns the sources or main drivers of momentum returns. Both Menkhoff et al. (2012b) and Burnside et al. (2011b) report that the excess returns cannot be explained by systematic risk factors such as the business cycle, dollar risk factor, or carry risk factor introduced by Lustig et al. (2011). Menkhoff et al. (2012b) find that idiosyncratic volatility influences momentum returns. Additionally, they show that transaction costs matter when exploiting momentum returns.

Orlov (2016) investigates stock market liquidity as a risk factor for momentum returns. He concludes that momentum returns are lower when stock market liquidity is high; conversely, momentum returns are higher when equity market liquidity suffers. His research covers developed and emerging markets from 1976 to 2014 and reveals monthly average excess returns of 1.09% for the momentum strategy.

Lustig et al. (2011) examine 37 currencies between 1983 and 2008. They find an annual excess return of 9.32% and a Sharpe ratio of 0.86. According to Menkhoff et al. (2012b), transaction costs matter and lower performance and the Sharpe ratio to 5.42% and 0.50, respectively.

More recent studies also report positive momentum returns. Zhang (2022) examines 48 currencies and reveals monthly excess returns of 0.42% and an annualised Sharpe ratio of 0.51 between 1976 and 2020. Eriksen (2019), among others, examines the momentum returns for 48 currencies between 1983 and 2016. He reports momentum excess returns of 5.73% per year with positive skewness of 0.18 and a Sharpe ratio of 0.60. Additionally, he implements a dispersion risk factor derived from the excess returns of carry trades. Eriksen (2019) shows that this dispersion risk factor can explain a significant part of momentum returns, from which he deduces that momentum returns are compensation for risk.

Another approach to explaining momentum returns is provided by Filippou et al. (2018), who develop a measure of political risk that provides information about the political environment in the United States and other countries. They regress momentum returns on political risk and other risk factors like exchange rate volatility and liquidity. Their analysis shows that only the slope factor for political risk is significant at the 5% level. However, R^2 is very low, with values close to zero. The momentum returns reported by Filippou et al. (2018) are also positive, with annualised excess returns between 5.67% and 10.18%, depending on the momentum strategy setting. They also confirm the significant influence of transaction costs, which result in net excess returns between 2.39% and 6.29%.

Other researchers investigate the combination of different strategies, such as using carry, value, and momentum strategies together. Asness et al. (2013) focus on momentum and value in eight different markets. They examine 10 industrialised currencies between 1979 and 2011 and report momentum excess returns of 3.5%

with a Sharpe ratio of 0.32. In addition, they find that momentum and value are negatively correlated and that funding risk accounts for momentum excess returns.

Barroso and Santa-Clara (2015a) investigate the joint performance of carry, momentum, and reversal strategies. They construct an optimal currency portfolio that has a better Sharpe ratio than the single strategies. For out-of-sample data from 1996 to 2011, the annualised momentum return is 4.97% with a Sharpe ratio of 0.37, while for the optimal currency portfolio, the Sharpe ratio increases to 1.15.

Existing literature thus provides evidence of momentum excess returns. However, transaction costs play a significant role. As the momentum strategy is constructed using two legs – buying the winners and selling the losers – transaction costs are incurred twice and thus considerably reduce the returns.

5.3. MOMENTUM RETURNS

This section presents the results of momentum returns. As stated in section 1.2, the data cover 27 currencies, 17 from emerging markets and 10 from developed markets. Monthly data are available for 26 years from 1997 to 2022. Since this study focuses on emerging market currencies, momentum is applied to both the entire dataset of 27 currencies and the two subsets of emerging and developed markets' currencies.

The momentum strategy is composed of two portfolios, where one is long and the other is short. Following Menkhoff et al. (2012b), in the first step, the historical excess returns of the last 1, 3, 6, and 12 months are calculated for each currency. The number of months used to calculate excess returns in the past is referred to as the formation period $f \in \{1, 3, 6, 12\}$. Then, n currencies with the highest historical excess returns are assigned to the long portfolio. At the same time, the short portfolio is formed from those n currencies with the worst historical excess returns. The number of currencies in the long and short portfolios is given by n with $n \in \{1, 3, 5\}$. The portfolios are held for one month.

The momentum strategy return thus corresponds to the long portfolio's excess return minus the short portfolio's return. As in the previous chapters, the calculations are based on forward prices. Momentum returns are generated for 12 different settings using four different formation periods f and three different values for the number of currencies n. Thus, the robustness of the results can be assessed.

The results of the momentum strategy for these 12 settings are presented in Table 33.

Table 33: Momentum Returns for All 27 Currencies

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
$n = 1, f = 1$	0.006849	0.004415	1.5513	0.077983	1.4185	0.3
$n = 1, f = 3$	0.012398**	0.00462	2.6835	0.081607	1.9768	0.53
$n = 1, f = 6$	0.009972*	0.004149	2.4035	0.073282	2.2446	0.47
$n = 1, f = 12$	0.006921	0.004475	1.5465	0.079049	1.3716	0.3
$n = 3, f = 1$	0.004809*	0.002058	2.3369	0.03635	1.4053	0.46
$n = 3, f = 3$	0.004262*	0.002138	1.9937	0.037761	1.3376	0.39
$n = 3, f = 6$	0.005962**	0.002295	2.5982	0.040534	1.0609	0.51
$n = 3\ f = 12$	0.003852°	0.002334	1.6508	0.041221	0.8898	0.32
$n = 5, f = 1$	0.003567*	0.001567	2.2764	0.027679	1.019	0.45
$n = 5, f = 3$	0.003403*	0.001538	2.2134	0.02716	0.8412	0.43
$n = 5, f = 6$	0.003047°	0.001619	1.8828	0.02859	0.7479	0.37
$n = 5, f = 12$	0.002378	0.001698	1.4008	0.029987	0.5464	0.27

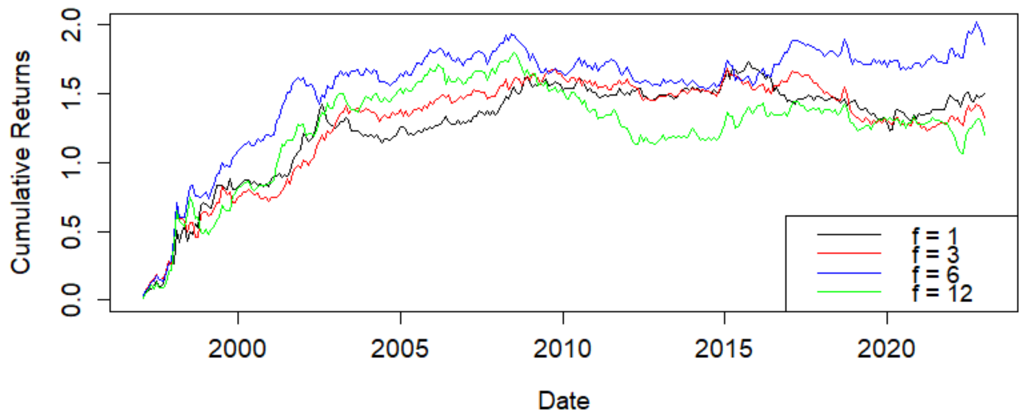
Note. The table shows the momentum strategy's monthly average excess returns. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

The momentum strategy shows positive excess returns for all 12 settings. The average monthly excess return is significant at the 5% level for 7 of 12 settings. One exception is the setting with a formation period of 12 months, for which the results are positive but not significantly different from zero.

The standard error, standard deviation, and skewness decrease as expected with an increasing number of currencies n. Skewness is positive for all settings. In bad times, when foreign currencies suffer from strong depreciation, profits can be made with short positions in the momentum strategy, which results in positive skewness. The Sharpe ratios are between 0.27 and 0.53.

Figure 23 shows the cumulative returns for $n = 3$, that is, three currencies in each of the long and short portfolios. All four settings for the formation period are shown. Momentum returns have been less profitable since the global financial crisis.

Figure 23: Cumulative Returns for $n = 3$



Note. Figure 23 shows the cumulative returns of the momentum strategy for different settings.

The results in Table 33 show solid returns for the momentum strategy. However, the question of interest is whether momentum returns are generated by emerging or developed markets' currencies. As this study focuses on the former, the momentum strategy is also analysed separately for developed and emerging markets' currencies. Table 34 shows the results for the 10 industrialised countries.

Table 34: Momentum Returns for 10 Developed Markets´ Currencies

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
$n = 1, f = 1$	–0.002978	0.001922	–1.5499	0.033944	0.0922	–0.3
$n = 1, f = 3$	–0.00143	0.001983	–0.7209	0.035029	0.8661	–0.14
$n = 1, f = 6$	–0.001883	0.001952	–0.9643	0.034485	0.1403	–0.19
$n = 1, f = 12$	–0.00094	0.001846	–0.5093	0.032602	–0.2911	–0.1
$n = 3, f = 1$	–0.000601	0.001215	–0.4945	0.021462	0.0776	–0.1
$n = 3, f = 3$	–0.001303	0.001201	–1.0853	0.021207	0.2697	–0.21
$n = 3, f = 6$	–0.001129	0.001188	–0.9506	0.02098	–0.4071	–0.19
$n = 3\ f = 12$	–0.000147	0.001303	–0.1129	0.023023	–0.0223	–0.02
$n = 5, f = 1$	0.0002	0.0009	0.2223	0.015892	0.4482	0.04

$n = 5, f = 3$	–0.001373	0.000884	–1.5536	0.015609	0.4667	–0.3
$n = 5, f = 6$	–0.000708	0.000843	–0.8397	0.014888	–0.1436	–0.16
$n = 5, f = 12$	–0.000385	0.00088	–0.4378	0.015539	0.0579	–0.09

Note. The table shows the monthly average excess returns for the momentum strategy applied to 10 developed market currencies. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

If the momentum strategy is only applied to the industrialised countries' currencies, no excess returns are observed; the returns are close to zero and are predominantly negative. For all 12 settings, the returns are not significantly different from 0%. The results in Table 34 are a first indication that the momentum returns for a broad set of currencies are driven by emerging markets' currencies. To further verify this, Table 35 reports the momentum returns specifically for emerging markets' currencies.

Table 35: Momentum Returns for 17 Emerging Markets' Currencies

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
$n = 1, f = 1$	0.010809*	0.004419	2.4458	0.07806	1.5738	0.48
$n = 1, f = 3$	0.011838*	0.004726	2.5048	0.083478	2.0168	0.49
$n = 1, f = 6$	0.01055*	0.004158	2.5372	0.073446	2.1622	0.5
$n = 1, f = 12$	0.007445°	0.004451	1.6725	0.078624	1.3858	0.33
$n = 3, f = 1$	0.00681**	0.002124	3.2064	0.037515	1.1878	0.63
$n = 3, f = 3$	0.005934**	0.002208	2.6869	0.039008	1.2507	0.53
$n = 3, f = 6$	0.006634**	0.002217	2.9922	0.03916	1.2501	0.59
$n = 3\ f = 12$	0.003646	0.002335	1.5613	0.04125	1.1024	0.31
$n = 5, f = 1$	0.005812***	0.001572	3.6972	0.027767	0.8508	0.73
$n = 5, f = 3$	0.004501**	0.001586	2.8379	0.028013	0.98	0.56
$n = 5, f = 6$	0.004054*	0.001593	2.5451	0.028136	0.8987	0.5
$n = 5, f = 12$	0.001987	0.001585	1.2532	0.028	0.6279	0.25

Note. The table shows the monthly average excess returns applying the momentum strategy to 17 emerging market currencies. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

The monthly average excess return is positive for all 12 settings. For the formation periods of 1, 3, and 6 months, the return is significant at the 5% level. The

Sharpe ratio can be further increased up to 0.73 compared to applying the strategy to all currencies.

One possible reason for the success of the momentum strategy could be autocorrelations. Under the momentum strategy, those currencies that have performed best in the past are bought and those currencies that have performed worst are sold. Therefore, the success of the strategy lies in the fact that currencies that have performed best (worst) in the past will also perform well (poorly) in the future. Currencies that meet this condition are expected to exhibit autocorrelation. As presented in Table 5 on page 50, a buy-and-hold strategy does not lead to statistically significant, positive returns. In contrast, there are statistically significant excess returns when the momentum strategy is applied, as shown in this section. This indicates that the excess returns of the individual currencies are autocorrelated. To further investigate this, Table 36 presents the excess returns` autocorrelation coefficients of order 1 to 7, denoted by ρ_1 to ρ_7. The p-values of the Ljung-Box test for 12 lags are also reported.

Table 36: Autocorrelations and Ljung-Box Test

	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	p-value
Emerging Markets								
INR	0.092	–0.093	0.044	–0.105	0.051	0.148	–0.045	0.0114*
KRW	–0.043	–0.044	0.118	–0.038	0.044	0.067	–0.136	0.3622
RUB	0.163	0.055	–0.067	–0.216	0.032	–0.011	–0.108	0.0001***
BRL	0.069	0.184	0.033	0.019	0.024	–0.027	–0.102	0.1154
IDR	0.231	–0.058	–0.088	0.123	0.150	0.116	–0.084	0.0000***
MXN	0.053	–0.052	–0.002	–0.068	0.006	–0.011	–0.064	0.7413
TRY	0.149	0.085	0.053	0.016	0.009	0.099	0.092	0.0041**
ZAR	0.005	0.044	–0.006	0.000	–0.055	–0.031	0.008	0.7789
CLP	–0.100	0.072	–0.077	0.015	0.019	0.019	–0.062	0.101
COP	–0.018	0.024	–0.095	0.027	0.038	0.066	–0.102	0.3651
PLN	0.075	–0.016	0.084	–0.066	–0.026	0.041	–0.076	0.1728
CZK	0.034	0.032	0.063	–0.070	–0.027	0.088	–0.124	0.2967
HUF	0.014	0.012	0.068	–0.103	0.050	0.044	–0.056	0.3158
PHP	0.080	0.015	0.140	–0.012	0.019	0.052	–0.051	0.0762
TWD	0.142	–0.020	0.016	–0.029	–0.106	0.060	–0.090	0.239
THB	0.148	–0.075	0.072	–0.040	0.097	0.056	–0.184	0.0035**
PEN	–0.067	0.032	0.035	0.071	0.002	0.013	–0.168	0.1743

Developed Markets								
EUR	0.044	0.006	0.083	–0.053	–0.003	0.092	–0.090	0.3814
GPB	0.023	0.066	0.082	0.032	–0.070	0.061	–0.192	0.0455*
JPY	0.002	0.096	–0.012	0.002	–0.145	0.000	–0.082	0.0470*
CHF	–0.072	–0.030	0.063	–0.100	–0.011	0.027	–0.042	0.2505
AUD	0.029	–0.017	0.070	0.023	0.013	0.084	–0.072	0.6902
CAD	–0.068	0.025	–0.080	0.143	–0.013	–0.013	–0.058	0.0501
ILS	–0.002	–0.051	0.118	–0.001	0.064	–0.067	–0.076	0.2923
NZD	–0.010	–0.015	0.164	–0.059	–0.024	0.104	–0.045	0.2256
NOK	0.017	0.010	0.010	–0.036	0.012	0.098	–0.050	0.6816
SEK	0.046	0.006	0.062	0.055	0.044	0.090	–0.085	0.464

Note. Table 36 shows the autocorrelation coefficients of each currency's excess returns and the p-values of the Ljung-Box test with 12 lags. *, **, and *** indicate significance at the 5%, 1%, and 0.1% levels, respectively.

The table shows that autocorrelations are evident for some currencies. The absolute highest value is reached for $\rho_1 = 0.231$ for the Indonesian rupiah (IDR), and the second highest absolute value is for $\rho_4 = -0.216$ for the Russian rouble (RUB). In addition, Table 36 reports the p-values of the Ljung-Box test for 12 lags, corresponding to a 12-month period. For the emerging markets, the null hypothesis of no autocorrelation is rejected for 5 out of 17 currencies. For the developed currencies, this is the case for 2 out of 10 currencies.

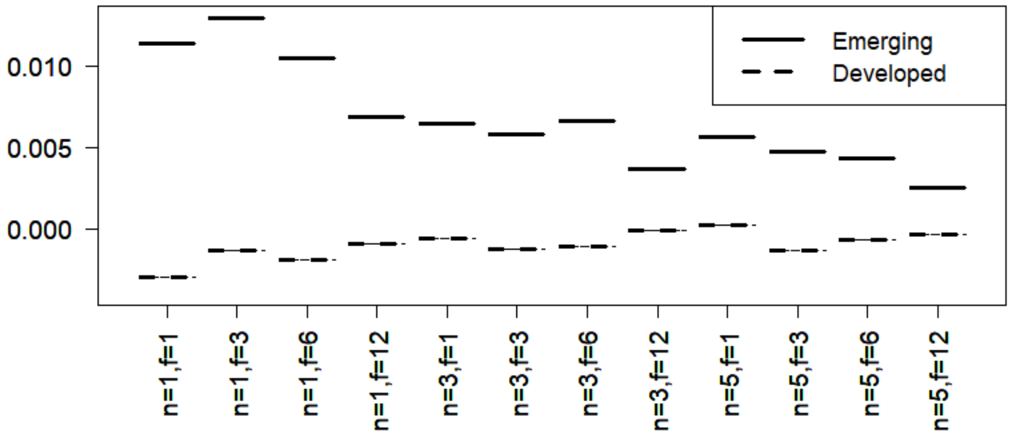
The autocorrelation is thus more pronounced for emerging market currencies than for currencies of industrialised countries. As a consequence, momentum returns can be observed for emerging market currencies, while the momentum returns for industrialised market currencies are limited.

5.4. PERMUTATION TESTS

In section 5.3, momentum returns were calculated for both emerging and developed markets. The results show that there are no momentum returns for developed markets, while the returns for emerging markets are statistically significant. The results indicate that developed countries have no impact on momentum strategies applied to a bundle of both emerging and developed markets' currencies. The impact of emerging markets on momentum returns is, therefore, further investigated using a permutation test.

Figure 24 shows that emerging markets' momentum returns dominate developed markets' returns. The illustration plots the average monthly momentum returns for the different formation period settings *f* and number of currencies *n*.

Figure 24: Emerging and Developed Markets' Momentum Returns



Note. Figure 24 shows the momentum strategy's average monthly excess returns for different formation period settings and number of currencies for emerging and industrialised markets' currencies.

The emerging markets' momentum returns in all settings of *f* and *n* are higher than the developed countries' returns. This suggests that the returns for a broad set of currencies are due to emerging markets' currencies. This hypothesis is further examined below using a permutation test (Efron and Tibshirani 1997).

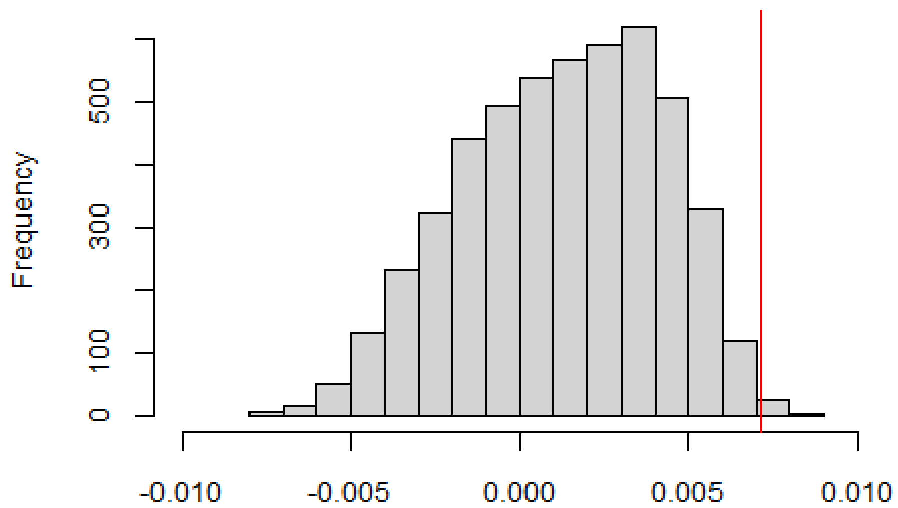
Data are available for 27 currencies, of which 17 belong to emerging markets and 10 to industrialised countries. The permutation test compares two groups, assigning 17 currencies to one group and the remaining 10 currencies to the other group. The hypothesis is that for excess returns, it does not matter what groups the currencies are in. The alternative hypothesis is that a specific assignment of the 27 currencies to homogeneous groups, that is, assigning all emerging market currencies to the same group, significantly impacts the excess returns.

The principle of the permutation test is as follows: of the 27 currencies, 17 are randomly assigned to the first group, A. The remaining 10 currencies are assigned to the second group, B. In the next step, momentum returns are calculated for both groups. So far in this research, momentum returns have been calculated for 12 different settings for *n* and *f*. For convenience, this is not the case in the permutation test; only the momentum returns for three currencies ($n = 3$) and a formation period of three months ($f = 3$) are used. After calculating the momentum returns for the two groups, A and B, their average monthly returns are compared. The difference in the returns of both groups constitutes the test statistic in Eq. (40)

$$\theta = r_A - r_B \tag{40}$$

with r_A as group A's monthly average momentum returns and r_B as group B's momentum returns. This process is repeated 5,000 times, generating a distribution with 5,000 values. This distribution represents the differences between the momentum returns of groups A and B. Figure 25 illustrates the distribution for 5,000 permutations.

Figure 25: Results of the Permutation Test



Note. The figure illustrates the return differences between the two groups generated by the permutation test. The red line marks the difference when all emerging market currencies are assigned to Group A.

The research question is whether a specific allocation of currencies to one of the two groups leads to abnormal returns. The specific case of interest here is when all 17 emerging market currencies are in group A, and all 10 developed market currencies are in group B. According to the null hypothesis, how the 27 currencies are allocated to the two groups should have no effect on the excess returns, as in Eq. (41):

$$H_0 : \theta = 0 \tag{41}$$

The excess return for the case where all emerging market currencies are in one group and all developed market currencies are in the other group has already been determined in section 5.3, as shown in Table 34 and Table 35 on pages 146 and 147. For a formation period of three months ($f = 3$) using three currencies ($n = 3$), the monthly momentum return is 0.005831 for emerging markets' currencies and –0.001303 for developed markets' currencies. The difference between these two groups is 0.007134. In addition, this value represents the result of one possible permutation and is referred to as $\hat{\theta}$.

According to the null hypothesis, the value for θ is 0. The null hypothesis is rejected if 95% of all possible permutations $\hat{\theta}^*$ have momentum returns smaller than $\hat{\theta}$. The star representation gives the value for a single permutation, while $\hat{\theta}$ denotes the particular case when all emerging market currencies are in group A. Conversely, the p-value can be derived by putting the number of cases in which $\hat{\theta}^*$ is greater than $\hat{\theta}$ in proportion to the total number of permutations using Eq. (42):

$$p - value = \#\{\hat{\theta}^* \geq \hat{\theta}\} \,/\, 5000 \tag{42}$$

The p-value thus indicates the probability that the return difference between groups A and B is greater than the difference between the groups in the specific case when all emerging market currencies are assigned to group A, see Eq. (43):

$$p - value = Prob_{H_0}\{\hat{\theta}^* \geq \hat{\theta}\} \tag{43}$$

If 17 of 27 currencies need to be assigned to one group and the remaining 10 currencies to another group, there are a total of approximately 8.4 million different possible combinations, which can be computed using the binomial coefficient shown in Eq. (44):

$$\binom{27}{17} = \frac{27!}{17! \cdot (27 - 17)!} \tag{44}$$

Due to the high number of possible assignments of the currencies to groups, a Monte Carlo permutation test with 5,000 repetitions is employed. Applying Eq. (42), the p-value for the null hypothesis is

$$p - value = 18/5000 = 0.0036 \tag{45}$$

The condition that $\hat{\theta}^*$ is greater than $\hat{\theta} = 0.007134$ is fulfilled in only 18 of the 5,000 permutations. Thus, the null hypothesis is rejected at the 1% significance level. Using emerging markets' currencies for the momentum strategy leads to significant outperformance. If all emerging markets' currencies are assigned to group A, the difference in momentum returns is significant.

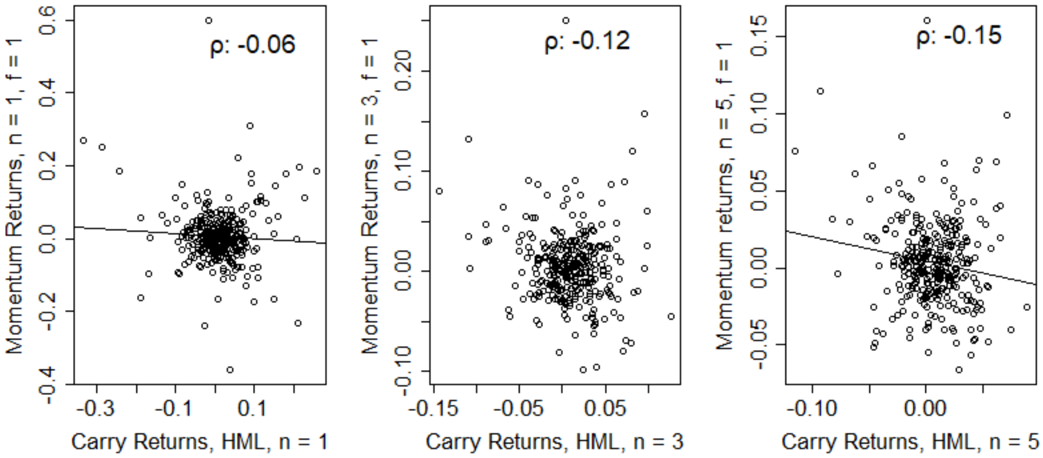
The permutation test underlines the relevance of emerging markets' currencies for the momentum strategy: the strategy's payoff is connected to emerging markets' currencies. The results of the permutation test are in line with the findings in Table 34 and Table 35 on pages 146 and 147. In these tables, the momentum strategy is calculated separately for emerging and developed markets' currencies, with the result that the returns of the former dominated the latter.

5.5. RISK FACTORS

The momentum strategy's excess returns correlate only poorly with those of the carry strategy. Depending on the settings of the two strategies, the correlation coefficient is between –0.15 and 0.12. Thus, it is also conceivable that momentum returns have different risk factor loadings than carry returns. In fact, as presented in this section, the momentum strategy has significantly positive loadings on the VOL risk factor, while carry trades load negatively on VOL. Furthermore, market risk factors, such as equities or commodities, do not play a role in momentum returns but do affect carry returns.

To illustrate the relationship between momentum and carry returns, Figure 26 plots the carry trade returns (x-axis) and momentum returns (y-axis). The left graph shows the strategies when the number of currencies in each portfolio is 1, while on the right-hand side n = 5. The formation period for the momentum strategy is one month.

Figure 26: Correlation of Carry and Momentum Returns



Note. The figure illustrates the momentum and carry strategy returns for $n = 1$, 3, and 5. The regression lines and correlation coefficients are also plotted.

Figure 26 reveals the lack of correlation between momentum and carry returns. Consequently, the two currency strategies could have different relevant risk factors. For momentum returns, the relevant risk factors for currencies – the DOL, VOL, and market risk factors – are therefore examined. Further explanations of the risk factors can be found in section 2.7.

DOL is predominantly significant for momentum returns, but R^2 is low. Table 37 shows the results of the linear regression of momentum returns on the DOL risk factor. To distinguish between emerging and industrialised market currencies, three different settings for the momentum returns are shown. MOM^{ALL} represents the momentum returns when all 27 currencies are used. MOM^{EM} (MOM^{IND}) refers to the momentum returns when only emerging (industrialised) market currencies are considered in the strategy. For convenience reasons, only the formation periods with $f = 3$ and $f = 6$ are given. Tables with all settings for n and f are presented in the Appendix D1.

Table 37: Momentum Returns and DOL Risk Factor

	Constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
MOM^{ALL}					
$n = 1, f = 3$	0.0122**	–0.523798*	0.209933	–2.495	0.0197

$n = 1, f = 6$	0.009733*	–0.632401***	0.186984	–3.382	0.0356
$n = 3, f = 3$	0.004204*	–0.154966	0.097716	–1.586	0.008
$n = 3, f = 6$	0.005788**	–0.460611***	0.102014	–4.515	0.0617
$n = 5, f = 3$	0.003354*	–0.130289°	0.070178	–1.857	0.011
$n = 5, f = 6$	0.002944°	–0.273509***	0.07264	–3.765	0.0437
MOM^{EM}					
$n = 1, f = 3$	0.011662*	–0.465519*	0.215275	–2.162	0.0149
$n = 1, f = 6$	0.010296*	–0.674025***	0.186948	–3.605	0.0402
$n = 3, f = 3$	0.005873**	–0.160766	0.100939	-1.593	0.011
$n = 3, f = 6$	0.00644**	–0.514498***	0,097458	–5.279	0.0825
$n = 5, f = 3$	0.004453**	–0.125497°	0.072432	–1.733	0.0096
$n = 5, f = 6$	0.003942*	–0.296605***	0.071136	–4.17	0.0531
MOM^{IND}					
$n = 1, f = 3$	–0.001482	–0.139052	0.090668	–1.534	0.0075
$n = 1, f = 6$	–0.001922	–0.105215	0.089399	–1.177	0.0044
$n = 3, f = 3$	–0.001311	–0.021099	0.055086	–0.383	0.0005
$n = 3, f = 6$	–0.001153	–0.064824	0.054385	–1.192	0.0046
$n = 5, f = 3$	–0.001388	–0.040197	0.040491	–0.993	0.0032
$n = 5, f = 6$	–0.000073	–0.058305	0.03854	–1.513	0.0073

Note. The table presents results for the single linear regression of the momentum returns on DOL. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The DOL risk factor has negative, predominantly significant loadings on MOM^{ALL} and MOM^{EM}. However, R^2 remains low with maximum values of 0.0825 for all settings of n and f. For the carry returns, the DOL loadings were consistently positive, as presented in Table 27 on page 128.

For the VOL risk factor, momentum returns are also the opposite of carry returns. Momentum returns load positively on the risk factor, while carry returns have negative loadings. Table 38 shows the results of the regression of momentum returns on the VOL risk factor. Again, tables with all settings for n and f are presented in the Appendix D2.

Table 38: Momentum Returns and VOL Risk Factor

	Constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
MOM^{ALL}					
$n = 1, f = 3$	–0.057761***	2.624805***	0.296615	8.849	0.2017

$n = 1, f = 6$	–0.044018***	2.019877***	0.27515	7.341	0.1481
$n = 3, f = 3$	–0.021961***	0.981074***	0.143149	6.854	0.1316
$n = 3, f = 6$	–0.019376***	0.947959***	0.155851	6.082	0.1066
$n = 5, f = 3$	–0.014076***	0.653929***	0.104055	6.284	0.113
$n = 5, f = 6$	–0.012124***	0.567605***	0.111745	5.079	0.0768
MOM^{EM}					
$n = 1, f = 3$	–0.058379***	2.626941***	0.305051	8.611	0.193
$n = 1, f = 6$	–0.043181***	2.010188***	0.2761	7.281	0.146
$n = 3, f = 3$	–0.021253***	1.017117***	0.147795	6.882	0.1325
$n = 3, f = 6$	–0.020487***	1.014656***	0.14851	6.832	0.1309
$n = 5, f = 3$	–0.014376***	0.706222***	0.106661	6.621	0.1239
$n = 5, f = 6$	–0.013231***	0.646673***	0.108403	5.965	0.103
MOM^{IND}					
$n = 1, f = 3$	–0.002699	0.047489	0.142469	0.333	0.0004
$n = 1, f = 6$	–0.0019	0.00216	0.140282	0.015	0
$n = 3, f = 3$	–0.001998	0.026004	0.086255	0.301	0.0003
$n = 3, f = 6$	–0.002395	0.047379	0.085302	0.555	0.0001
$n = 5, f = 3$	–0.002091	0.026855	0.063478	0.423	0.0006
$n = 5, f = 6$	–0.001342	0.023714	0.060549	0.392	0.0005

Note. The table shows statistics for the single linear regression of momentum returns on the currency VOL risk factor. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

Analogous to DOL, VOL has no significant impact on momentum returns when only industrialised market currencies considered. Contrary, the slope coefficient of the VOL risk factor is positive for all settings of n and f and significant at the 1% level when the strategy is applied to emerging markets. The R^2 ranges between 0.103 and 0.193. An increase in currency volatility thus tends to be accompanied by positive momentum strategy returns, which is the reverse of the carry strategy. A rational explanation is that the momentum strategy´s short position performs well in crises when volatility is high.

The role of market risk factors for momentum returns is shown in Table 53, which presents the results of the single linear regression in Eq. (46):

$$r_t^{MOM} = \alpha + \beta RF_t + \varepsilon_t \tag{46}$$

with r_t^{MOM} as the momentum strategy's excess return, that is, the long portfolio's return minus the short portfolio's return, and RF as the specific market risk factor.

The latter include the MSCI World index return, INT represents the change in yield of 10-year US government bonds, COM covers the Bloomberg Commodity Total Return index, and VIX is the equity market volatility index of the Chicago Board of Trade. Further descriptions of the indices are given in section 2.7. The table is limited in terms of the settings for *f* and *n*, but the tables in the Appendix D3 include all settings.

Table 39: Regression of Momentum Returns on Market Risk Factors

	MSCI	COM	INT	VIX
MOM^{ALL}				
f = 1, *n* = 3	–0.1063	–0.158	–1.1094	0.0142
	(–1.057), [0.004]	(–1.596), [0.008]	(–0.606), [0.001]	(0.646), [0.001]
n = 1, *f* = 6	–0.0781	–0.1699°	0.1075	0.0049
	(–0.864), [0.002]	(-1.914), [0.012]	(0.065), [0]	(0.251), [0]
n = 3, *f* = 3	–0.0316	–0.0211	–0.3464	–0.0021
	(–0678), [0.001]	(-0.458), [0.001]	(–0.409), [0.001]	(–0.207), [0]
n = 3, *f* = 6	–0.0734	–0.0723	–0.3999	0.0037
	(–1.472), [0.007]	(-1.469), [0.007]	(–0.44), [0.001]	(0.337), [0]
n = 5, *f* = 3	–0.0476	–0.0137	–0.2757	0.0028
	(–1.424), [0.006]	(-0.414), [0.001]	(–0.453), [0.001]	(0.384), [0]
n = 5, *f* = 6	–0.0422	–0.0253	–0.0815	0.0022
	(–1.199), [0.005]	(–0.727), [0.002]	(–0.127), [0]	(0.289), [0]
MOM^{EM}				
f = 1, *n* = 3	–0.0857	–0.1136	–1.6132	0.0081
	(–0.833), [0.002]	(–1.119), [0.004]	(–0.862), [0.002]	(0.36), [0]
n = 1, *f* = 6	–0.0781	–0.1471°	–0.314	–0.0047
	(–0.862), [0.002]	(–1.651), [0.008]	(–0.191), [0]	(–0.239), [0]
n = 3, *f* = 3	–0.0389	–0.0083	–0.9144	0.0046
	(–0.808), [0.002]	(–0.174), [0]	(–1.047), [0.004]	(0.437), [0.001]
n = 3, *f* = 6	–0.1033*	–0.0828°	–0.5832	0.0076
	(–2.152), [0.015]	(–1.743), [0.01]	(–0.664), [0.001]	(0.718), [0.002]
n = 5, *f* = 3	–0.037	–0.0025	–0.6106	0.0017
	(–1.071), [0.004]	(–0.073), [0]	(–0.973), [0.028]	(0.0231), [0]
n = 5, *f* = 6	–0.0556	–0.0438	–0.607	0.0047
	(–1.607), [0.008]	(–1.28), [0.005]	(–0.963), [0.003]	(0.624), [0.001]
MOM^{IND}				
f = 1, *n* = 3	–0.0864*	–0.0732°	0.8074	0.0077

	(–2.011), [0.013]	(–1.723), [0.009]	(1.029), [0.003]	(0.82), [0.002]
$n = 1, f = 6$	–0.0714°	–0.018	0.3252	0.01273
	(–1.685), [0.009]	(–0.428), [0.001]	(0.421), [0.001]	(1.375), [0.006]
$n = 3, f = 3$	–0.0492°	–0.0232	0.0552	0.0075
	(–1.889), [0.011]	(–0.898), [0.003]	(0.116), [0]	(1.322), [0.006]
$n = 3, f = 6$	–0.0509*	–0.0071	–0.056	0.007
	(–1.978), [0.012]	(–0.278), [0]	(–0.119), [0]	(1.244), [0.005]
$n = 5, f = 3$	–0.0356°	–0.0249	0.0524	0.0045
	(–1.86), [0.011]	(–1.313), [0.006]	(0.15), [0]	(1.065), [0.004]
$n = 5, f = 6$	–0.0265	–0.0029	–0.1284	0.0034
	(–1.446), [0.007]	(–0.157), [0]	(–0.385), [0]	(0.846), [0.002]

Note. The table presents slope coefficients for the single linear regressions of momentum excess returns on four different market risk factors. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. Values in parentheses indicate the slope coefficients´ t-values, and values in brackets show the regressions´ R^2.

Momentum returns have different patterns than carry returns with respect to risk factors. Commodities, interest rates and the VIX are not significant at the 5% level, and R^2 is close to 0 for all settings. MSCI is also not significant at the 5% level for most settings. The pattern is similar for both currency groups, emerging and industrialised markets.

Overall, the risk factors examined play different roles for momentum returns than for carry returns. Momentum returns have positive loadings on the VOL risk factor; for carry returns, the loadings are negative. The DOL risk factor has a negative slope coefficient for momentum returns, while it is positive for carry returns. Market risk factors have no significance for the momentum strategy.

5.6. ARBITRAGE LIMITS

Historically, the momentum strategy has produced abnormal returns. However, the calculations so far have been based exclusively on bid prices. To implement the momentum strategy in practice, existing positions must be regularly closed, and new positions opened. The bid-ask spread is incurred, as transaction costs reduce momentum returns.

Bid-ask spreads are higher for emerging markets' currencies than for developed markets' currencies. The mean spread for the former (latter) is 0.20% (0.07%).

Because emerging markets' currencies contribute strongly to the momentum strategy's success, the bid-ask spread should have a relevant impact on momentum returns. Therefore, the momentum strategy´s return is examined by considering bid and ask prices. Table 40 presents the momentum returns for all 27 currencies.

Table 40: Momentum Returns for all 27 Currencies with Bid and Ask Prices

	mean return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
$n = 1, f = 1$	0.001548	0.004328	0.3576	0.076446	0.7586	0.07
$n = 1, f = 3$	0.005185	0.004293	1.208	0.075825	1.5616	0.24
$n = 1, f = 6$	0.003477	0.00385	0.90316	0.068	1.9044	0.18
$n = 1, f = 12$	0.000615	0.00434	0.14173	0.076663	1.061	0.03
$n = 3, f = 1$	0.000304	0.002009	0.15111	0.035488	0.5889	0.03
$n = 3, f = 3$	0.000743	0.002111	0.35212	0.037291	0.984	0.07
$n = 3, f = 6$	0.001059	0.002092	0.50643	0.036947	0.9923	0.1
$n = 3, f = 12$	–0.000537	0.002206	–0.2434	0.038963	0.699	–0.05
$n = 5, f = 1$	–0.000729	0.00153	–0.47689	0.027018	0.6934	–0.09
$n = 5, f = 3$	–0.000382	0.001481	–0.25786	0.026162	0.4565	–0.05
$n = 5, f = 6$	–0.000294	0.00155	–0.18973	0.027383	0.4533	–0.04
$n = 5, f = 12$	–0.001805	0.001622	–1.1131	0.028642	0.2294	–0.22

Note. Table 40 presents momentum returns when bid-ask spreads are applied. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels respectively. The Sharpe ratio is annualised.

The results in Table 40 demonstrate the importance of bid-ask spreads. A positive return can be achieved for only 7 of the 12 different settings. No return is different from zero at the 5% significance level; the bid-ask spreads completely dissipate momentum strategy returns.

The momentum strategy, which involves buying the currencies with the best recent performance and selling those with the worst recent performance, is transaction cost intensive. In this strategy, transaction costs are incurred twice: once when buying the long portfolio and again when selling the short portfolio.

The data source for the bid and ask prices is Refinitiv Eikon, and the quotes are indicative rather than traded prices. In practice, traded spreads are lower than quoted spreads (Lyons 2001); Mancini et al. (2013) report that the effective bid-ask spread is half the bid-ask quote. Moreover, transaction costs can be reduced substantially by rolling forward contracts with swaps (Gilmore and Hayashi 2011).

According to Menkhoff et al. (2012b) and Barroso and Santa-Clara (2015a), to adequately consider the bid-ask spread, momentum returns are calculated using half the bid-ask spread. Table 41 shows the results of the momentum strategy when 50% of the transaction costs are used in the calculation.

Table 41: Momentum Returns with Halved Spreads, All Currencies

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
$n = 1, f = 1$	0.004198	0.004336	0.9682	0.076592	1.1179	0.19
$n = 1, f = 3$	0.008792*	0.004346	2.0229	0.076768	1.7913	0.4
$n = 1, f = 6$	0.006724°	0.003892	1.7275	0.068755	2.1597	0.34
$n = 1, f = 12$	0.003768	0.004275	0.88134	0.075516	1.2394	0.17
$n = 3, f = 1$	0.002556	0.002012	1.2703	0.035547	1.0011	0.25
$n = 3, f = 3$	0.002503	0.002102	1.1909	0.037122	1.1949	0.23
$n = 3, f = 6$	0.003511	0.002163	1.6233	0.038202	1.0562	0.32
$n = 3, f = 12$	0.001658	0.002235	0.74168	0.039479	0.8108	0.15
$n = 5, f = 1$	0.001419	0.001539	0.92211	0.02718	0.8584	0.18
$n = 5, f = 3$	0.001511	0.001495	1.018	0.0264	0.649	0.2
$n = 5, f = 6$	0.001377	0.00156	0.88225	0.027563	0.6328	0.17
$n = 5, f = 12$	0.000287	0.001637	0.17512	0.028907	0.4292	0.03

Note. The table presents momentum returns with halved bid-ask spreads. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

If only half the bid-ask spread is used, positive momentum returns emerge for all 12 settings; however, only one case has a return that is significant at the 5% level. The Sharpe ratio reaches a maximum value of 0.4.

Considerable differences can be observed when the momentum strategy with halved spread is applied exclusively to both currency groups. Table 42 presents excess returns, when only emerging market currencies are used.

Table 42: Momentum Returns with Halved Spreads, Emerging Markets

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
n = 1, *f* = 1	0.007893°	0.004354	1.8128	0.076906	1.2757	0.36
n = 1, *f* = 3	0.008656°	0,004436	1.9512	0.078357	1.7982	0.38
n = 1, *f* = 6	0.00764°	0.003904	1.957	0.068957	2.1407	0.38
n = 1, *f* = 12	0.003601	0.004265	0.84418	0.075339	1.2354	0.17
n = 3, *f* = 1	0.003791°	0.002064	1.8371	0.036452	0.8952	0.36
n = 3, *f* = 3	0.003563°	0.00215	1.657	0.037978	1.2054	0.32
n = 3, *f* = 6	0.004287*	0.002099	2.0426	0.037072	1.2859	0.4
n = 3, *f* = 12	0.001434	0.002238	0.6409	0.039525	0.9865	0.13
n = 5, *f* = 1	0.003169*	0.001536	2.0632	0.027128	0.7889	0.4
n = 5, *f* = 3	0.002245	0.001548	1.4507	0.02734	0.8551	0.28
n = 5, *f* = 6	0.001893	0.001552	1.22	0.027406	0.9108	0.24
n = 5, *f* = 12	–0.000283	0.00156	–0.1814	0.02755	0.5847	–0.04

Note. The table presents momentum returns for emerging markets´ currencies with halved bid-ask spreads. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

The monthly average excess returns are statistically significant for two settings out of twelve settings at the 5% significance level. In seven cases, the returns are significant at the 10% level.

Momentum returns, when exclusively applied to industrialised market currencies, were predominantly negative and close to zero when transaction costs were excluded, as shown in Table 34. Thus, when transaction costs are considered, the monthly average excess return is negative for all settings for *n* and *f*, presented in Table 43.

Table 43: Momentum Returns with Halved Spreads, Industrialised Markets

	return	standard error	t-value	standard deviation	skew-ness	Sharpe ratio
$n = 1, f = 1$	–0.003705°	0.001917	–1.9312	0.033865	0.0762	–0.38
$n = 1, f = 3$	–0.001982	0.001982	–1.0004	0.035001	0.8634	–0.2
$n = 1, f = 6$	–0.002568	0.001925	–1.3337	0.034006	0.1362	–0.26
$n = 1, f = 12$	–0.001227	0.001839	–0.6672	0.03249	–0.337	–0.13
$n = 3, f = 1$	–0.001465	0.001222	–1.1992	0.021577	0.0639	–0.24
$n = 3, f = 3$	–0.002152	0.001199	–1.7954	0.021172	0.2643	–0.35
$n = 3, f = 6$	–0.002004	0.001175	–1.7053	0.020753	–0.451	–0.33
$n = 3, f = 12$	–0.001057	0.001289	–0.8204	0.022765	–0.047	–0.16
$n = 5, f = 1$	–0.000565	0.00089	–0.6343	0.015723	0.4035	–0.12
$n = 5, f = 3$	–0.002025*	0.000878	–2.3055	0.015517	0.4383	–0.45
$n = 5, f = 6$	–0.00128	0.000836	–1.5311	0.014762	–0.169	–0.3
$n = 5, f = 12$	–0.001177	0.000876	–1.3441	0.015473	–0.013	–0.26

Note. The table presents momentum returns for industrialised markets´ currencies with halved bid-ask spreads. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

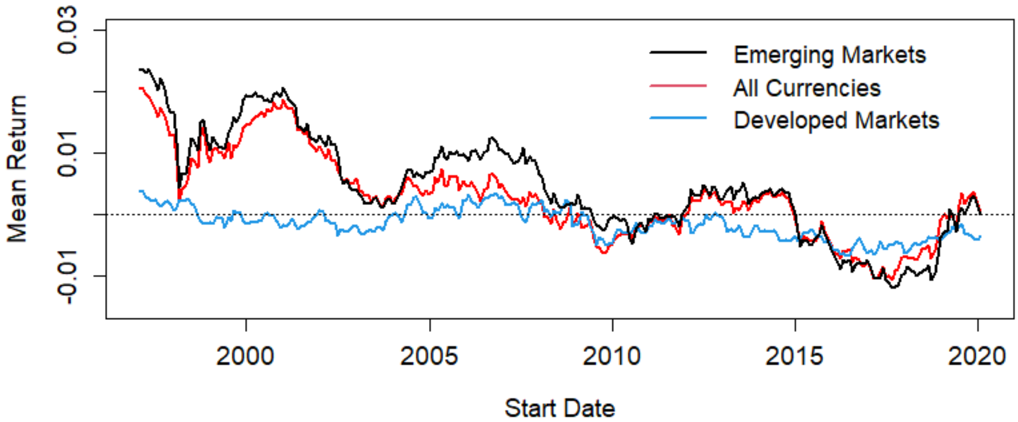
Momentum returns are negative when the strategy is only applied to industrialised market currencies. In contrast, momentum returns are positive and at least significant at the 10% level when emerging market currencies are used.

Overall, the research conducted shows that transaction costs have a significant impact on momentum returns. These findings are in line with Menkhoff et al. (2012b) and Barroso and Santa-Clara (2015a). The latter suggest combining the momentum strategy with other strategies, which can reduce transaction costs.

Another possible limitation of using the momentum strategy in practice is time-varying returns. The more stable the returns are over time, the more interesting the strategy is for investors. Risk premiums and returns in foreign exchange markets are, however, time varying (Londono and Zhou 2017; Sarno et al. 2012). To measure the momentum strategy's stability over time, the momentum returns are examined using a rolling 36-month investment horizon, following Menkhoff et al. (2012b).

The rolling returns shown in Figure 27 are for the momentum setting with a formation period of three months ($f = 3$) and a holding period of three months ($n = 3$).

Figure 27: Rolling Returns with a 36-month Investment Horizon



Note. The figure presents monthly average rolling returns with an investment horizon of 36 months. No transaction costs are considered.

Until the global financial crisis, investors could achieve positive returns with currency momentum; however, in recent years, rolling returns have been predominantly negative. For developed currencies, the rolling returns are close to zero for the entire period.

There are relevant arbitrage limits when implementing the momentum strategy in practice. The bid-ask spread is essential and has a significant impact on momentum returns; in addition, the returns are not stable over time. In recent years, momentum has not been a high-yielding strategy with abnormal returns.

5.7. CHAPTER CONCLUSION

This chapter examines momentum strategy excess returns for 27 currencies between 1997 and 2022. The results show that currency momentum leads to abnormal returns. The monthly average returns range between 0.24% and 1.24%, with annualised Sharpe ratios between 0.27 and 0.53, depending on the strategy setting.

However, the returns are time varying and occurred mainly from 1997 to the global financial crisis. Moreover, transaction costs play a crucial role in exploiting momentum strategy returns. If the full bid-ask spread is considered, momentum returns are completely eliminated. When transaction costs are halved, excess returns still exist but are largely no longer statistically significant at the 5% level.

In this study, the focus is on emerging markets´ currencies, the momentum strategy is applied to both emerging and developed markets' currencies. Using only emerging markets' currencies, the Sharpe ratio can be increased up to 0.73. For industrialised countries' currencies, the picture is the opposite. If the momentum strategy is applied exclusively to these currencies, negative returns can be observed for almost all settings of the formation period and number of currencies.

These results suggest that the momentum strategy's success is driven by emerging market currencies. To further verify this, a permutation test is conducted. In the test, two groups are formed, and the 27 currencies are randomly assigned to one of the two groups. The momentum returns for these groups are then calculated, and the difference between the returns of the two groups is obtained. When all emerging markets' currencies are in one group and the industrialised countries' currencies are in the other group, an abnormal return differential exists. The null hypothesis that randomly assigning the currencies to one of the groups does not lead to a difference in returns must be rejected at the 1% significance level. The permutation test reinforces that emerging markets' currencies drive momentum returns.

The risk factors of momentum returns have different characteristics than those of carry returns. Momentum returns have positive loadings on the VOL risk factor. Increasing volatility is thus a good environment for the momentum strategy, while the opposite is true for carry returns. For the DOL risk factor, the loadings of the momentum returns are contrary to those of carry returns, too. The DOL slope coefficient is negative for momentum returns and positive for carry returns. Market risk factors like equity or commodity risk factors do not play a role in the momentum strategy.

VI – CURRENCY VALUE EXCESS RETURNS

VI -CURRENCY VALUE EXCESS RETURNS

6.1. CHAPTER INTRODUCTION

Currency value is the intrinsic or fundamental value of a currency (Menkhoff et al. 2017). A common method for measuring this intrinsic value is purchasing power parity (PPP). The simple idea behind PPP is that equal products should trade at the same price across different countries (Rogoff 1996). As different countries have their own currencies and thus different price levels, the nominal exchange rate compensates for the countries' different price levels, so that Eq. (47) applies:

$$P_{i,t} = Sp_t P_{i,t}^{*} \tag{47}$$

$P_{i,t}$ is the domestic price for a given good in country i at time t, $P_{i,t}^{*}$ is the price of that good in foreign currency, and Sp_t is the nominal exchange rate expressed as the US dollar price for one unit of foreign currency.

Absolute PPP means that the purchasing power of citizens in their home country is the same abroad as at home, even after accounting for the exchange rate (Balassa 1964). That is, the price of a good abroad converted at the spot rate is the same as the price at home, as indicated in Eq. (47).

Relative purchasing power parity states that the change in the nominal exchange rate offsets the price changes in the two countries (Balassa 1964), as shown in Eq. (48):

$$\frac{Sp_{t+1}}{Sp_t} = \frac{P_{t+1} \;/\; P_{\mathrm{t}}}{P_{t+1}^{*} \;/\; P_t^{*}} \tag{48}$$

The nominal exchange rate or spot price is given by Sp. The domestic price level is given by P and the foreign price level by P^{*}. It follows from Eq. (48) that if relative PPP holds, the nominal exchange rate of a foreign currency falls if inflation in that country is higher than inflation in the base currency country.

Absolute PPP is not a necessary condition for relative PPP, but relative PPP is fulfilled if absolute PPP holds over time. The real exchange rate (RER) is used to measure the purchasing power between two countries. This corresponds to the quotient of the domestic price and foreign price multiplied by the nominal exchange rate, as shown in Eq.(49):

$$RER_t = \frac{P_t}{P_t^* \times Sp_t} \tag{49}$$

The RER is mathematically related to the weak form of PPP. A time series with a constant RER means that the change in the nominal exchange rate offsets the inflation differences, thus fulfilling the relative form of PPP. Furthermore, if absolute PPP holds, the RER equals 1.

According to macroeconomic theory, RER depends on the countries' productivities. Balassa (1964) shows that differences in productivity between two countries lead to different PPP values. The higher a country's productivity, the higher its purchasing power. In a small economy, higher productivity does not lead to lower prices for traded goods, as prices are determined by international markets (Demir and Razmi 2022). Rather, higher productivity increases wages in the traded goods sector, which impacts the prices of non-traded goods. Workers in the non-traded goods sector will also demand higher wages, leading to higher inflation (Sarno and Taylor 2002). Since traded goods' prices are determined by international markets and thus have no impact on the nominal exchange rate, purchasing power increases due to higher inflation in the non-traded goods sector. This relationship is known as the Balassa-Samuelson effect. However, empirical evidence of the validity of this effect is mixed (Sarno and Taylor 2002).

The Balassa-Samuelson effect is important for the RER. An increase in a country's productivity could lead to higher purchasing power and thus to appreciation of the RER. As a result, the RER time series is possibly non-stationary. This is important, as the common tests for PPP validity are unit root tests.

Trade barriers, like tariffs, transportation costs, or nontariff barriers such as taxes or costs of information, are an important aspect in studying the RER with respect to PPP (Rogoff 1996). These aspects lead to the fact that price differences, which may result from the nominal exchange rate's over- or undervaluation, cannot be arbitrated. Deviations from PPP are thus normal to a certain extent, since the costs to exploit these arbitrage opportunities are higher than the value of the arbitrage opportunity itself (Dumas 1992). This creates a transition band where the RER follows a random walk. Outside the transition band, the RER tends to reduce the over- or undervaluation due to arbitrage activities until it is back within the transition band.

As a result, a common way to measure PPP is through threshold autoregression models (TAR), which can determine the thresholds at which a currency is over- or undervalued. These thresholds can be used to derive a currency value strategy in which undervalued currencies are bought and overvalued currencies are sold. The currency value strategy presented in this study achieves annual excess returns between 2.34% and 3.92% from 1997 to 2022, depending on the setting, with a Sharpe ratio of up to 0.36. The results of this currency value strategy are presented in detail later.

This chapter is structured as follows: Section 6.2 reviews the currency value literature, in particular, the literature regarding the RER and PPP. Section 6.3 provides unit root tests for the RER. As noted earlier, a mean reversion in the RER could potentially arise only if the currency under- or overvaluation is large enough. Consequently, a transition band emerges in which the RER follows a random walk. The band is marked by two thresholds, which allow using TAR models to describe the RER process. Section 6.4 investigates the RER using a self-exciting TAR. Building on these results, section 6.5 examines currency value excess returns. A strategy is implemented in which those currencies that are considered undervalued are bought and those that are overvalued are sold. Section 6.6 examines which risk factors could account for currency value returns, section 6.7 discusses the arbitrage limits, and section 6.8 concludes.

6.2. LITERATURE REVIEW

Since the 1973 collapse of Bretton Woods, PPP has been a popular target of academic studies. Isard (1977) was among the first studies in the post-Bretton Woods era. He examines various traded goods and finds strong evidence that the law of one price (LOP) is violated.

The early PPP studies in the 1980s and 1990s tested for a unit root in RER time series. Meese and Rogoff (1988), among others, incorporate the Dickey-Fuller test and are unable to reject the null of a unit root for the RER. However, the unit root tests suffer from lack of power, as mentioned by Froot and Rogoff and Lothian and Taylor (1997). As a result, the null hypothesis of a unit root is not rejected because of the small sample size, even if the RER is mean reverting.

Consequently, researchers have executed long-term studies spanning more than 100 years. Edison (1987) studies PPP from 1890 to 1978 and, using an error correction approach, confirms that PPP holds. Lothian and Taylor (1996) study the British pound and French franc vis-à-vis the US dollar from 1791 to 1990. Using autoregressive models, they show that the RER is stationary.

Other researchers have used panel data instead of long time series to investigate the RER's stationarity. Frankel and Rose (1996) and Oh (1996) find evidence for PPP, while Papell (1997) shows that evidence against the unit root is more robust when large panels rather than small ones are used. However, mixed results are found in the literature when panel data are used. Alba and Papell (2007) examine PPP for different regions and find that it holds for European and Latin American countries but not for Asian and African countries.

Dŏganlar et al. (2021) also come to mixed conclusions. They examine industrialised, emerging, and frontier markets between 1993 and 2018 with different results. Using Fourier quantile unit root tests, they show the validity of PPP in 8 out of 10 industrialised, 11 out of 20 emerging, and 7 out of 15 frontier markets. Bahmani-Oskooee and Ranjbar (2016) also use quantile unit root tests to test PPP in 23 OECD countries and find support that PPP holds in 16 out of 23 countries. Additionally, when they apply standard unit root tests, they find that PPP only holds in 6 out of 23 countries.

According to Rogoff (1996), the reasons for the deviations from PPP can be found in price stickiness. While currencies are volatile and subject to large fluctuations in a short amount of time, price adjustments occur only slowly. It follows that, in the short run, PPP does not hold and convergence to the PPP equilibrium is slow. These aspects are referred to as the PPP puzzle. In fact, Rogoff (1996) shows that PPP deviations have a half-life between three and five years, which means that it takes three to five years for half a currency's over- or undervaluation to be eliminated. Besides Rogoff (1996), price stickiness is reported by several researchers as a major reason for long-term deviations from PPP (Burstein et al. 2005; Steinsson 2008; Devereux and Yetman 2010; Engel 2019).

A second reason for deviations from PPP is how it is measured. As mentioned previously, a common way to test for PPP validity is to verify if the RER time series is stationary. However, the Balassa Samuelson effect suggests that the RER is not necessarily a stationary process, as it is expected to appreciate when a country's productivity improves structurally over the long run (Balassa 1964). Different findings about this aspect can be found in the literature. Berka et al. (2018) examine data from 1995 to 2009 and construct their own index for the RER. They find that an increase in traded goods productivity leads to appreciation of the RER. An increase in productivity in non-traded goods negatively impacts the RER.

Wang et al. (2016) analyse emerging and developed markets and find that higher productivity leads to appreciation in the real exchange rate, although they find no evidence for this in developed markets. Lothian and Taylor (2008) examine long-term data between 1820 and 2001 for the US dollar (USD) against the British pound (GPB) and the French franc (FRF) against the British pound. They find evidence of non-linear mean reversion of the RER for GBP-USD. However, they find a shifting RER equilibrium for GBP-FRF.

The RER and PPP literature thus shows no clear results that the null hypothesis of a unit root in the RER can be rejected. Chong et al. (2012) point out that the RER should not be considered a fixed average value but rather a moving target.

A possibly non-stationary RER makes it difficult to measure currency value. If the time series is not stationary, then it is hardly possible to find whether a currency is over- or undervalued compared to its past. This is a critical aspect when defining an investment approach based on PPP deviations or RER mean reversion.

Regardless, the RER is usually used to derive currency value strategies. Asness et al. (2013) examine various asset classes in terms of value and momentum. A currency’s over- or undervaluation is measured by observing the RER development over the last five years. Three portfolios are then formed, with portfolio 1 containing the third of the currencies whose RER has risen the most in the last five years; that is, currencies that are overvalued. In portfolio 3, they sort the third of the currencies whose RER has lost the most in the last five years; these currencies are undervalued. The HML strategy, which buys the currencies in portfolio 3 and sells those in portfolio 1, results in an annual excess return of 3.3% with a Sharpe ratio of 0.35.

Menkhoff et al. (2017) examine quarterly data between 1970 and 2014 for 22 currency pairs. Analogous to Asness et al. (2013), they form different portfolios and assign the currencies to one of the portfolios according to their fundamental over- and undervaluation. The HML portfolio achieves an annual excess return of 3.89% with a Sharpe ratio of 0.44. The authors also show that RERs are adjusted by fundamentals such as productivity, output gaps, or net foreign assets, which further improve the results. Menkhoff et al. (2017) further find that value and carry strategies are independent of each other.

Barroso and Santa-Clara (2015a) examine several strategies, including carry, momentum, and value, and additionally provide a portfolio approach. They report an average annual excess return of 3.09% with a Sharpe ratio of 0.36 for the value strategy from 1976 to 1996. For out-of-sample data from 1996 to 2011, the average annual return is 1.69% with a Sharpe ratio of 0.18. However, if transaction costs are applied, the return is zero.

Kroencke et al. (2014) examine the value, momentum, and carry strategies using 30 different currencies from 1981 to 2011. They report an annual excess return of 4.18% for the value strategy with a Sharpe ratio of 0.62. Transaction costs do not have as large an impact in their sample as they do in Barroso and Santa-Clara (2015a); after transaction costs, the Sharpe ratio falls from 0.62 to 0.57. In addition, they report that a combined strategy of carry, momentum, and value outperforms all three single strategies in terms of excess returns and Sharpe ratios, the latter achieving values of 1.14.

The literature on value strategies thus shows abnormal excess returns, as it does for carry and momentum. However, the value strategy returns seem to be smaller than those of the carry and momentum strategies.

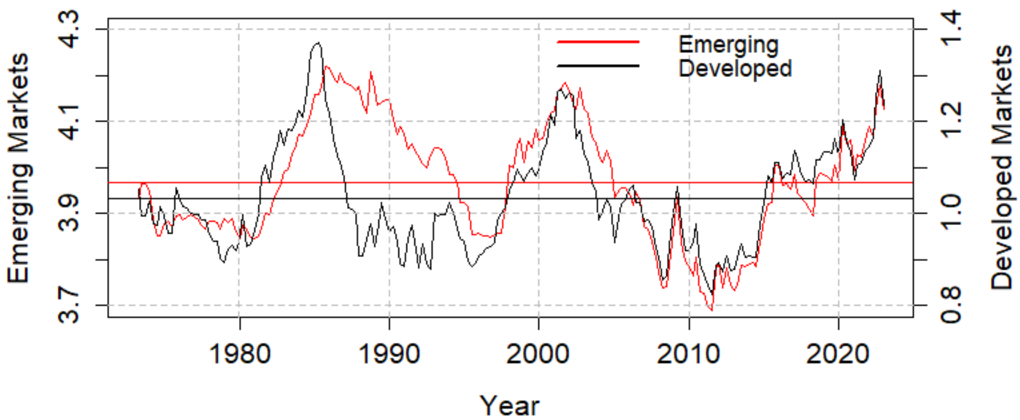
6.3. RER UNIT ROOT TESTS

The RER reflects a currency's development after adjusting for inflation. Relative PPP holds when the RER time series is stationary. The basic idea behind a stationary RER is that currency over- and undervaluation are arbitrated in the long run. If the RER is substantially above its long-term average, the domestic currency's purchasing power abroad is very high, and the foreign currency is relatively weak. As a result, the demand for foreign products will increase; at the same time, foreign demand for domestic products will decrease. Both affect the supply and demand for the foreign currency. Higher demand for foreign goods coincides with higher demand for foreign currency. Consequently, the RER is mean reverting in the long run since currency over- and undervaluation affects supply and demand for traded goods.

Sarno and Taylor (2002) state that, due to trading thresholds, tariffs, and non-tariff barriers, this arbitrage effect will only begin when a currency's over- or undervaluation is sufficient. Consequently, a band is created around the RER mean in which the costs to exploit arbitrage opportunities are greater than the benefits. Only when the RER is above or below the band will market participants take advantage of the over-/undervaluation. Consequently, this behaviour could result in a stationary RER time series.

Figure 28 presents the RER time series for a basket of 17 emerging and 10 developed market currencies against the US dollar. The RERs are calculated as shown in Eq. (49) on page 168. A rising exchange rate indicates real appreciation of the US dollar, which means that US citizens enjoy their currency's high purchasing power abroad. Nominal exchange rates adjusted for consumer prices are used for the calculation.

Figure 28: Real Exchange Rates



Note. The time series shows the real exchange rates of emerging and developed market currencies against the US dollar. The horizontal lines indicate mean values.

The figure also plots the mean values for the RERs, which are indicated by the two horizontal lines. For both the emerging and developed countries, the figure shows that significant over- and undervaluation were corrected in the following years. However, periods of over- or undervaluation can be persistent.

Note that the values for the RERs in Figure 28 are given in log form. Thus, the scale in Figure 28 does not indicate a US citizen's de facto purchasing power abroad. In addition, the consumer price index (CPI) used to calculate the RER is not an absolute price but an indexed price, and the basket of goods used to calculate the CPI varies from country to country. The focus in Figure 28 is, therefore, on the change in the time series, not on the absolute levels.

A currency value strategy can be derived from RERs if the time series is mean reverting. Such a time series is possibly, but not necessarily, stationary. The Augmented Dickey-Fuller and Phillips-Perron tests are applied to measure the stationarity of the RERs. Table 44 shows the results of the two tests for the individual currencies against the US dollar. The data are obtained from the International Monetary Fund, which provides quarterly data. Maximum available data are used for the unit root test, starting from the first quarter of 1973 at the earliest. Calculations for the period from January 1997 to December 2022 are additionally shown in the Appendix E1.

Table 44: Real Exchange Rate Unit Root Tests

	ADF t-statistic	ADF p-value	Phillips-Perron test statistic	Phillips-Perron p-value	observations
Emerging Markets					
INR	–1.492615	0.5355	–1.538936	0.5119	200
KRW	–2.6191	0.0908*	–2.599512	0.0947*	200
RUB	–2.732193	0.0716*	–2.730462	0.0719*	119
BRL	–2.536471	0.1087	–2.601013	0.0947*	171
IDR	–1.410483	0.5766	–1.272041	0.6425	200
MXN	–3.331845	0.0147**	–3.42004	0.0114**	200
TRY	–1.356833	0.6027	–1.356833	0.6027	200
ZAR	–1.520603	0.5213	–1.613748	0.4737	200
CLP	–2.849182	0.0534*	–3.5687	0.0072***	200
COP	–1.098487	0.7165	–1.254712	0.6504	200
PLN	–2.051265	0.2649	–1.996949	0.2881	171
CZK	–1.848045	0.3558	–1.790397	0.3837	119

HUF	–1.47992	0.5418	–1.454524	0.5545	187
PHP	–2.725664	0.0715*	–2.538191	0.108	200
TWD	–2.132742	0.2322	–2.174259	0.2164	200
THB	–1.718296	0.4205	–1.678534	0.4406	200
PEN	–1.352466	0.6048	–1.352466	0.6048	200
Developed Markets					
EUR	–2.690187	0.0775*	–2.967431	0.0398**	200
GPB	–2.532449	0.1093	–2.769239	0.0646*	200
JPY	–1.933891	0.3163	–2.248030	0.1902	200
CHF	–3.525733	0.0083***	–3.693808	0.0049***	200
AUD	–2.220187	0.1998	–2.220187	0.1998	200
CAD	–1.783719	0.3878	–1.885034	0.3389	200
ILS	–2.800834	0.0599*	–2.870674	0.0506*	200
NZD	–2.434318	0.1337	–2.720037	0.0724*	200
NOK	–2.134514	0.2315	–2.134514	0.2315	200
SEK	–1.189275	0.6792	–1.34974	0.6061	200

Note. Table 44 presents the results of the Augmented Dickey-Fuller and Phillips-Perron tests. *, **, and *** indicate rejection of the null hypothesis of a unit root at the 10%, 5%, and 1% significance levels, respectively. Bayesian information criterion is used for Augmented Dickey-Fuller test.

The results of applying Augmented Dickey-Fuller and Phillips-Perron tests for unit roots are mixed. For the 17 emerging markets currencies, the null of a unit root can be rejected at the 5% level only in two cases, and in 6 of 17 cases, the null is rejected at the 10% level. For the 10 developed country currencies, in two (five) cases the null is rejected at the 5% (10%) level.

If the RER is examined for the two currency baskets, the results also offer no clear evidence that the null hypothesis of a unit root can be rejected.

Table 45: Unit Root Tests for Baskets

	ADF t-statistic	ADF p-value	Phillips-Perron test statistic	Phillips-Perron p-value	observations
EM	–1.606189	0.4775	–1.71714	0.4211	200
IND	–2.222919	0.1989	–2.627173	0.0892*	200

Note. The table shows the results of Augmented Dickey-Fuller and Philips-Perron tests for emerging markets (EM) and industrialised markets (IND) currencies. *, **, and *** indicate rejection of the null of a unit root at the 10%, 5%, and 1% significance levels, respectively.

The time series of the currency baskets` RERs show no stationarity. This makes it difficult to derive a currency value strategy from an RER time series. In fact, section 6.5 shows the excess returns of currency value strategies are slightly positive but predominantly not significant.

However, stationarity is not a mandatory prerequisite for identifying a currency's over- and undervaluation. As shown by Sarno and Taylor (2002), fundamental mispricing of a currency is only arbitrated when it is large enough. Thus, two thresholds emerge for the RER. One indicates the value above which a currency is overvalued, and the other threshold indicates below which value a currency is undervalued. Between the thresholds, the costs of arbitrage are higher than the benefits of the arbitrage opportunities. Consequently, the RER may follow a random walk within the thresholds and is, therefore, not necessarily stationary.

TARs have been used by various analysts to model the non-linearity of currencies (Firat 2017; Allen et al. 2016; Jiang et al. 2016). The following section, therefore, examines the RER using a self-exciting TAR.

6.4. SELF-EXCITING THRESHOLD AUTOREGRESSION

This section examines the importance of thresholds for the RER. The basic idea is that an overvalued currency tends to depreciate, and an undervalued currency tends to appreciate. Therefore, two thresholds appear that mark over- and undervaluation. The RER time series under the influence of two thresholds can be characterised as shown in Eq. (50):

$$y_t = \begin{pmatrix} \phi_1 y_{t-1} + \varepsilon_t, & if\ y_{t-1} < \lambda_1 \\ \phi_2 y_{t-1} + \varepsilon_t, & if\ \lambda_1 < y_{t-1} < \lambda_2 \\ \phi_3 y_{t-1} + \varepsilon_t, & if\ \lambda_2 < y_{t-1} \end{pmatrix} \quad (50)$$

with y_t as the RER, two unknown thresholds λ_1 and λ_2, three AR(1) parameters ϕ_1, ϕ_2, and ϕ_3, and ε as an i.i.d $(0,\sigma^2)$ error term.

The log RER thus follows a first-order autoregressive process with different values for ϕ depending on the regime the currency is exposed to. The thresholds λ_1 and λ_2 define the neutral band's lower and upper ends. If the RER is within this range, then there is only minor or no exchange rate mispricing. The cost of exploiting this mispricing is then greater than the benefit of the mispricing itself. Within this neutral range, the RER may therefore follow a random walk.

If the RER is too strong and above λ_2, then ϕ_3 should be less than 1. The overvaluation is reduced when $\phi_3 < 1$; that is, in this regime, the RER tends to fall. If the RER is too weak and below λ_1, then ϕ_1 is expected to be greater than 1. In this regime, $\phi_1 > 1$ tends to cause the RER to rise until it is within the neutral band between λ_1 and λ_2 again.

A self-exciting TAR model (SETAR) is used to investigate the RER threshold behaviour (Tong 1990). The SETAR model is applied to the real effective exchange rate (REER), which represents the inflation-adjusted exchange rate vis-à-vis a country's most important trading partners. The REER thus differs from the RER in Eq. (49) on page 168, which shows the inflation-adjusted exchange rate of a single currency pair. The advantage of the REER is that a currency is not quoted against a single currency, such as the US dollar, but against several currencies that are important for the country's foreign trade. Thus, the REER mitigates the base currency´s idiosyncratic risk. Another advantage of REER is that the data are available on a monthly basis, whereas the data for the RER are for some currencies only available on a quarterly basis.

In the following, the log REER is analysed based on data from the Bank for International Settlements. A SETAR model is used, as specified in Eq. (50). The results are shown in Table 46. Since the REER is not quoted against a single currency but reflects a currency's value against different currencies as an index, a time series for the REER is also available for the US dollar. Thus, 28 currencies are available for further analysis.

Table 46: Self-Exciting TAR with Three Regimes

	ϕ_1	ϕ_2	ϕ_3	ann. mean reversion ϕ_1	ann. mean reversion ϕ_3
Emerging Markets					
INR	1.000872	1.00001	0.999008	1.05%	1.19%
KRW	1.002422	1.000008	0.99884	2.91%	1.39%
RUB	1.003332	1.000786	0.998957	4.00%	1.25%
BRL	1.00146	0.999763	0.998596	1.75%	1.68%
IDR	1.00179	0.99976	0.998009	2.15%	2.39%
MXN	1.001459	0.999177	0.99984	1.75%	0.19%
TRY	0.999568	1.000879	0.999005	-0.52%	1.19%
ZAR	1.001803	0.998163	0.999628	2.16%	0.45%
CLP	1.001185	0.99989	0.999138	1.42%	1.03%
COP	1.000435	0.999697	0.998424	0.52%	1.89%
PLN	1.000988	0.998841	0.999661	1.19%	0.41%
CZK	1.00059	1.001507	0.999811	0.71%	0.23%
HUF	1.00098	1.000163	0.9934	1.18%	7.92%
PHP	1.000987	0.999904	0.999219	1.18%	0.94%
TWD	1.00056	0.999845	0.999098	0.67%	1.08%
THB	1.000512	1.000019	0.998654	0.61%	1.62%
PEN	1.000526	0.999984	0.999282	0.63%	0.86%
Developed Markets					
USD	1.00016	1.000549	0.999884	0.19%	0.14%
EUR	1.000716	0.999925	0.999234	0.86%	0.92%
GPB	1.001309	0.999324	0.999985	1.57%	0.05%
JPY	0.999943	1.000591	0.999167	-0.68%	1.00%
CHF	1.000107	1.000705	0.999509	0.13%	0.59%
AUD	1.000268	1.001421	0.999467	0.32%	0.64%
CAD	1.000097	1.00063	0.999728	0.12%	0.33%
ILS	1.000438	1.000059	0.999259	0.53%	0.89%
NZD	1.000512	0.999794	0.998757	0.61%	1.49%
NOK	0.999894	1.000647	0.999342	-0.13%	0.79%
SEK	1.000345	0.998965	0.999735	0.41%	0.32%

Note. Table 46 shows the results of the SETAR for the log REER of 28 currencies. The last two columns show the annualised speed of mean reversion.

All 28 currencies have a ϕ_3 of less than 1. This means that if the threshold λ_2 exceeds a certain value, the currency's overvaluation is reduced by following the process $y_t = \phi_3 y_{t-1} + \varepsilon_t$ with $\phi_3 < 1$; that is, the estimated value for $\hat{y}_t$ is smaller than y_{t-1}. Note that high values for the REER indicate a strong currency against the currencies of the country's major trade partners.

Table 46 also shows that for most currencies, ϕ_1 is greater than 1. This means that if y_{t-1} falls below a certain threshold λ_1, then the estimated $\hat{y}_t$ is greater than y_{t-1}; in other words, currency appreciation can be expected.

However, the speed of mean reversion varies and is very low. Emerging market currencies depreciate at an annual average rate of 1.44%, while currencies from industrialised countries depreciate at an average rate of 0.50% per year. The annualised mean reversion is calculated by $(\phi_1 - 1) \times 12$ and $(1 - \phi_3) \times 12$, respectively. The low speed of mean reversion suggests that excess returns may be limited under a currency value strategy.

The results of the SETAR allow conclusions that differ from the results of the ADF and PP tests in the previous section. The PP test concludes that the null hypothesis of a unit root cannot be rejected for most of the 27 currencies examined. The SETAR results demonstrate that, outside the thresholds λ_1 and λ_2, the REER follows mean reversion for most currencies. The results reinforce Sarno and Taylor's (2002) findings. Within the neutral band, where the costs to exploit arbitrage are higher than the benefits of the arbitrage opportunity, the REER follows a random walk. Therefore, in the ADF and PP tests, the null of a unit root cannot be rejected for most currencies. However, SETAR indicates that the REER no longer follows a random walk when the thresholds λ_1 and λ_2 are passed.

The mean reversion of the REER is a crucial prerequisite when implementing a currency value strategy. This chapter has shown that beyond thresholds, currencies are over- and undervalued and tend towards their long-term equilibriums. However, the conversion rate is very low, averaging 0.12% per month for emerging markets and 0.04% per month for developed markets. This suggests that the excess returns of a currency value strategy should be limited.

6.5. CURRENCY VALUE EXCESS RETURNS

The basic idea of a value strategy is to buy undervalued currencies and sell overvalued currencies. This section presents the excess returns for a currency value strategy.

The excess return calculations are based on the approach used by Menkhoff et al. (2017) and Asness et al. (2013). Two portfolios are formed; the long portfolio consists of n currencies that are undervalued, and the short portfolio contains n currencies that are overvalued with $n \in \{1, 3, 5\}$. The average performance of the log REER over the last 60 months is used to measure over- and undervaluation. Those n currencies with the highest REER average performance are sold, and simultaneously those n currencies with the lowest REER average performance in the last 60 months are bought.

The impulse to buy or sell a currency is thus generated based on the REER. The monthly data are provided by the Bank for International Settlements and cover January 1997 to December 2022. The value strategy buys n currencies against the US dollar and sells n currencies against the US dollar. The strategy is, therefore, dollar neutral.

Table 47 reports the performance of the long and short portfolios for the currency value strategy. Since the currencies are bought in the long portfolio and sold in the short portfolio, the excess return for the long minus short (LMS) strategy is the difference between the two portfolios' returns.

Table 47: Performance of the Currency Value Strategy

	mean return	standard error	t-value	standard deviation	skewness	Sharpe ratio
$n = 1$, long	0.00164	0.003342	0.4907	0.056621	–0.7717	0.10
$n = 1$, short	–0.000834	0.002419	–0.3448	0.040985	–1.9294	–0.071
$n = 1$, LMS	0.002474	0.003805	0.6502	0.064469	–0.0766	0.133
$n = 3$, long	0.001827	0.001929	0.947	0.032679	-0.3248	0.194
$n = 3$, short	–0.001441	0.001582	–0.9114	0.026795	–0.9723	–0.186
$n = 3$, LMS	0.003268°	0.001859	1.7579	0.031497	0.1744	0.359
$n = 5$, long	0.000997	0.001710	0.5826	0.028977	–0.2277	0.119

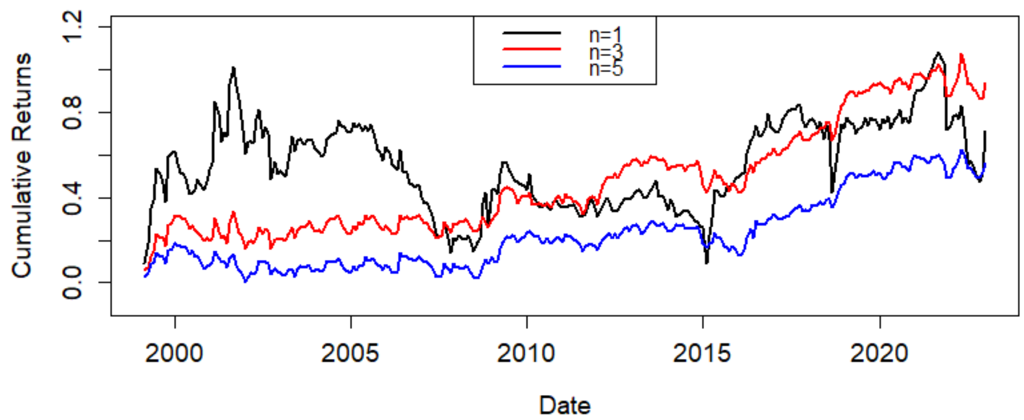
n = 5, short	–0.000955	0.001408	–0.6781	0.023851	–1.2064	–0.139
n = 5, LMS	0.001951	0.00142	1.374	0.024059	0.3409	0.281

Note. Table 47 presents the returns for the currency value strategy. The t-values refer to the null hypothesis of mean return = 0. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

The long portfolios achieve positive excess returns for all three settings of n, while the excess returns for the short portfolios are negative. Consequently, the excess returns are the greatest in the LMS portfolios. However, the results are not significant at the 5% level. Only the LMS portfolio with $n = 3$ shows a positive excess return that is significant at the 10% level. Sharpe ratios range between 0.13 and 0.36 for the LMS portfolios.

The results in Table 47 show that the currency value strategy excess returns are limited. Although an investment in undervalued currencies and a short position in overvalued currencies leads to an excess return, it is not significant. Graphically, the cumulative excess returns of the currency value strategy for the three different settings are presented in Figure 29:

Figure 29: Cumulative Currency Value Returns



Note. The figure illustrates the currency value strategy's cumulative excess returns.

In contrast to the carry and momentum strategies, the returns remain limited until the financial crisis. Afterwards, however, there is a noticeable increase in cumulative returns.

One question of interest is what impact emerging markets currencies have on the success of a currency value strategy. To investigate this, the excess returns are calculated separately for the two currency groups of emerging and developed markets. Table 48 provides the results for the former.

Table 48: Currency Value Excess Returns for Emerging Markets

	mean return	standard error	t-value	standard deviation	skewness	Sharpe ratio
n = 1, long	0.00167	0.003434	0.4863	0.058168	–0.8138	0.099
n = 1, short	–0.000739	0.002449	–0.3017	0.041491	–1.9676	–0.062
n = 1, LMS	0.002409	0.00379	0.6355	0.064211	–0.1286	0.13
n = 3, long	0.000843	0.002024	0.4163	0.034297	–0.3298	0.085
n = 3, short	–0.000327	0.001624	–0.2016	0.027516	–1.1553	–0.041
n = 3, LMS	0.001170	0.001945	0.6015	0.032959	0.0727	0.123
n = 5, long	0.001183	0.00176	0.6723	0.029813	–0.1758	0.137
n = 5, short	–0.000565	0.001411	–0.4004	0.023896	–1.3562	–0.082
n = 5, LMS	0.001748	0.001445	1.2095	0.024483	0.2316	0.247

Note. The table presents the currency value strategy returns if applied only to emerging market currencies. The t-values are given for mean return = 0. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

The excess returns are positive for the long portfolio and negative for the short portfolio for all settings. Thus, undervalued currencies tend to rise, while overvalued currencies tend to fall. However, the LMS portfolio excess returns are not significant.

The currency value strategy excess returns for industrialised countries are summarised in Table 49.

Table 49: Currency Value Excess Returns for Developed Markets

	return	standard error	t-value	standard deviation	skewness	Sharpe ratio
n = 1, long	–0.000156	0.001713	–0.0913	0.029012	0.0089	–0.019
n = 1, short	–0.000127	0.001643	–0.0775	0.027833	–0.4761	–0.016
n = 1, LMS	–0.000029	0.001888	–0.0154	0.031974	0.4378	–0.003
n = 3, long	0.000435	0.001547	0.2819	0.026205	–0.0239	0.058

n = 3, short	0.000124	0.001422	0.087	0.024095	–0.2792	0.018
n = 3, LMS	0.000312	0.001208	0.2581	0.020457	0.1807	0.053
n = 5, long	0.000211	0.001515	0.1393	0.025659	0.1496	0.028
n = 5, short	–0.000314	0.00136	–0.2312	0.023045	–0.4828	–0.047
n = 5, LMS	0.000525	0.000911	0.5766	0.01544	0.3778	0.118

Note. The table shows the returns for the currency value strategy if applied only to developed market currencies. t-values are given for mean return = 0. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The picture for industrialised countries is different from that for emerging markets. The long portfolio has positive excess returns in only two out of three cases, and the short portfolio has negative excess returns in two out of three cases. The results are also very close to zero; the LMS portfolio using n = 1 even has a negative excess return.

The analyses in the previous tables show that although currency value generates positive excess returns, they are only weakly or not significant. The Sharpe ratio is worse than that for the carry or momentum strategies. Furthermore, excess returns seem to be driven by emerging market currencies.

The latter aspect is further examined using single linear regressions. The excess returns for a value strategy using all currencies are regressed on the excess returns for the strategies using emerging and developed markets' currencies:

$$VAL_t = \alpha + \beta VAL^{EM/IND} + \varepsilon_t \quad (51)$$

The currency value strategy's excess return is indicated with VAL, and the excess returns of the respective sub-strategies are indicated with VAL^{EM} for emerging markets and VAL^{IND} for industrialised countries. Subsequently, the results of both regressions are compared.

Table 50: Excess Returns Regression

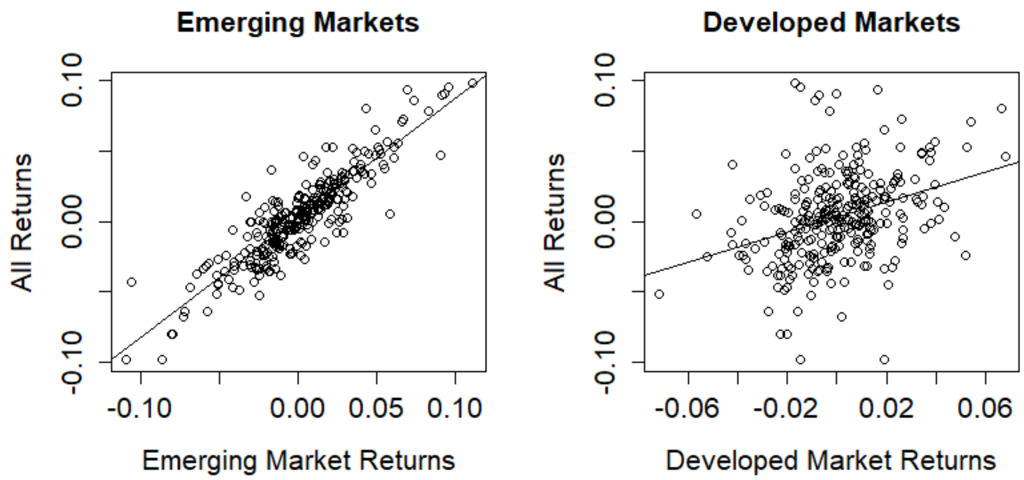
	α	VAL^{EM}	R^2	α	VAL^{IND}	R^2
$n = 1$	0.000236	0.929147***	0.8564	0.002482	0.274949*	0.0186
$n = 3$	0.002273**	0.850603***	0.7922	0.0031°	0.539119***	0.1226
$n = 5$	0.000497	0.832001***	0.7168	0.001581	0.704362***	0.2042

Note. The table shows the results from the regression in Eq. (51). The regression is calculated once with VAL^{EM} and once with VAL^{IND} as independent variables. °, *, **, and *** indicate significance the 10%, 5%, 1%, and 0.1% levels, respectively.

Table 50 shows that emerging markets are the engine driving the excess returns under the currency value strategy. The R^2 for emerging markets is between 0.7168 and 0.8564, while for industrialised countries, it is only between 0.0186 and 0.2042. The slope coefficient for emerging market currencies is close to 1, while it is only between 0.27 and 0.70 for industrialised countries.

Figure 30 also graphically shows the linear regressions from Eq. (51). The currency value strategy's excess returns are shown for all currencies included (y-axes) and if only emerging market and developed market currencies are included (x-axes). In the version shown, the number of currencies n in the long and short portfolios is 3 each.

Figure 30: Regressions of Excess Returns with $n = 3$



Note. The figure plots the currency value strategy excess returns if applied to all currencies (y-axis) and if applied to emerging and developed market currencies, respectively (x-axis). The regression lines are also shown.

The evaluations in this section show that although the currency value strategy leads to positive excess returns, they are not significant at the 5% level. Overvalued currencies, measured by their REER performance over the last 60 months, tend to depreciate, while undervalued currencies tend to appreciate. A long portfolio of undervalued currencies generates positive excess returns, and overvalued currencies generate negative returns. Therefore, a short position in these currencies also leads to positive excess returns. Furthermore, the currency value strategy's excess returns largely depend on emerging market currencies.

The calculations in this section are based on bid prices. Section 6.7 examines the influence of transaction costs on the currency value strategy's excess returns. First, section 6.6 examines the relevance of different risk factors for value returns.

6.6. RISK FACTORS

As in the previous chapters, the impact of various risk factors on value returns is analysed in this section. The results indicate that none of the risk factors can explain value returns, as R^2 is close to zero for all settings. In this respect, currency value returns appear to have a different risk profile than carry and momentum returns.

Table 51 shows the regression of the value returns on the DOL risk factor as introduced by Lustig et al. (2011). The relevance of the DOL risk factor as examined for the value strategy is compiled by emerging market currencies (LMS^{EM}), industrialised country currencies (LMS^{IND}), and all 27 currencies (LMS^{ALL}). LMS refers to the return of the long minus short portfolios.

Table 51: Value Returns and DOL Risk Factor

	constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
$n = 1$					
LMS^{ALL}	0.002435	0.134785	0.178213	0.756	0.002
LMS^{EM}	0.002375	0.11561	0.177546	0.651	0.001
LMS^{IND}	–0.00002	–0.09202	0.08831	–1.042	0.004
$n = 3$					
LMS^{ALL}	0.003271°	–0.008766	0.087154	–0.101	0
LMS^{EM}	0.001172	–0.007287	0.091199	–0.08	0

LMS^{IND}	0.000319	–0.026322	0.056584	–0.465	0.001
$n = 5$					
LMS^{ALL}	0.001954	–0.008463	0.066573	–0.127	0
LMS^{EM}	0.001751	–0.011559	0.067744	–0.171	0
LMS^{IND}	0.000533	–0.02478	0.042689	–0.58	0.001

Note. The table shows regression results for the DOL risk factor. Significant values are marked with °, *, **, and ***, indicating significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

The slope coefficient is close to zero and predominantly negative, and the risk factor is not significant for any setting. Contrary to carry and momentum returns, the DOL risk factor plays no role in the currency value strategy's excess returns.

The same picture emerges for the VOL risk factor. The results of regressing the value returns on the VOL risk factor are given in Table 52.

Table 52: Value Returns and VOL Risk Factor

	constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
$n = 1$					
LMS^{ALL}	0.004674	–0.469489	2.497327	–0.188	0
LMS^{EM}	–0.004271	1.42545	2.486051	0.573	0.001
LMS^{IND}	–0.001853	0.389236	1.23847	0.314	0
$n = 3$					
LMS^{ALL}	0.002189	0.2304	1.220096	0.189	0
LMS^{EM}	–0.003741	1.047892	1.275286	0.822	0.02
LMS^{IND}	–0.000407	0.153385	0.79243	0.194	0
$n = 5$					
LMS^{ALL}	0.002158	–0.044023	0.932042	–0.047	0.002
LMS^{EM}	0.002026	–0.059365	0.948454	–0.063	0
LMS^{IND}	0.000466	0.012787	0.598002	0.021	0

Note. The table presents statistics for the single linear regression of value returns on the VOL risk factor. Values marked with °, *, **, and *** are significant at the 10%, 5%, 1%, and 0.1% levels, respectively.

The slope coefficient of the VOL risk factor is not significant for any setting of n for either the emerging markets or developed markets' currencies. The R^2 is close to zero.

In a further step, the impact of market risk factors are analysed. Analogous to the assessments in the previous chapters, four markets risk factors are examined: the MSCI World index (MSCI), the CBOE volatility index (VIX), the Bloomberg Commodity Total Return index (COM), and the monthly change in the 10-year US government bond yield (INT). The regression´s results are shown in Table 53.

Table 53: Regression of Value Returns on Market Risk Factors

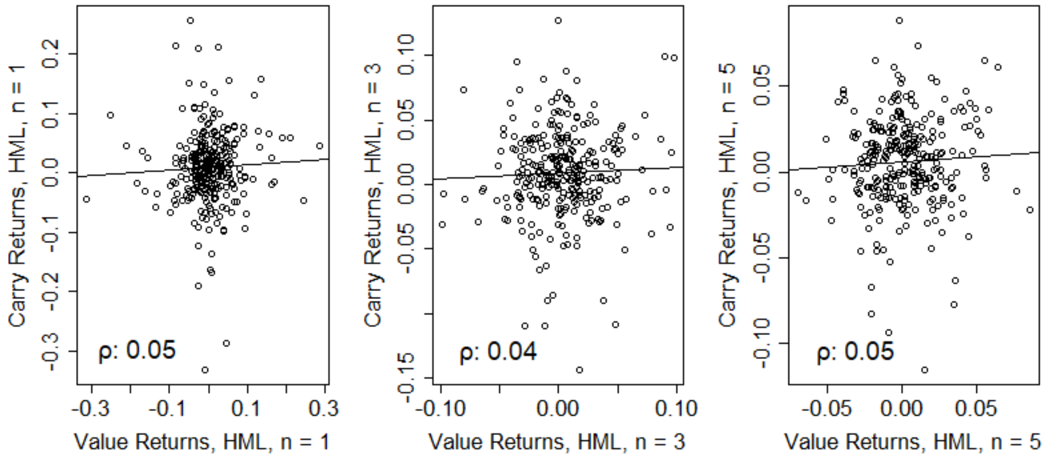
	MSCI	COM	INT	VIX
$n = 1$				
LMS^{ALL}	0.0281	0.0246	2.9199°	–0.0151
	(0.249), [0]	(0.304), [0]	(1.956), [0.013]	(–0.836), [0.002]
LMS^{EM}	0.0146	–0.0309	3.3418*	–0.0223
	(0.175), [0]	(–0.385), [0.001]	(2.252), [0.017]	(–1.248), [0.005]
LMS^{IND}	–0.0891*	–0.0122	–0.0211	0.0144
	(–2.171), [0.016]	(–0.305), [0]	(–0.028), [0]	(1.613), [0.009]
$n = 3$				
LMS^{ALL}	–0.0365	–0.0215	1.4213°	–0.0006
	(–0.879), [0.003]	(–0.545), [0.001]	(1.948), [0.013]	(–0.074), [0]
LMS^{EM}	–0.0293	–0.0312	1.6974*	–0.0048
	(–0.686), [0.002]	(–0.757), [0.002]	(2.228), [0.017]	(–0.518), [0.001]
LMS^{IND}	–0.012	–0.0159	0.0197	0.0099°
	(–0.455), [0.001]	(–0.619), [0.001]	(0.041), [0]	(1.741), [0.011]
$n = 5$				
LMS^{ALL}	–0.0289	–0.0096	0.8943	0.0015
	(–0.929), [0.003]	(–0.317), [0]	(1.601), [0.009]	(0.216), [0]
LMS^{EM}	–0.0165	–0.0126	0.9044	–0.0019
	(–0.521), [0.001]	(–0.411), [0.001]	(1.591), [0.009]	(–0.277), [0]
LMS^{IND}	–0.0082	–0.0116	–0.2877	0.0077°
	(–0.411), [0.001]	(–0.602), [0.001]	(–0.8), [0.002]	(1.787), [0.011]

Note. The table presents slope coefficients for the single linear regressions of currency value excess returns on four different market risk factors. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. Values in parentheses indicate the slope coefficients´ t-values, and values in brackets show the regressions´ R^2.

The risk factors´ impact is low and predominantly not significant at the 5% level. Interest rate risk, measured by the 10-year US government bond yield, has some impact on LMS^{ALL} and LMS^{EM}. However, R^2 remains close to zero for the market risk factors.

The analyses in this chapter show that the currency value strategy excess returns have no loadings on currency markets´ common risk factors, such as the DOL, VOL, or market risk factors. In addition, currency value returns are not correlated with the returns of the carry and momentum strategies. Figure 31 plots the excess returns of the currency value and carry trade strategies, that is, the LMS portfolio, for each.

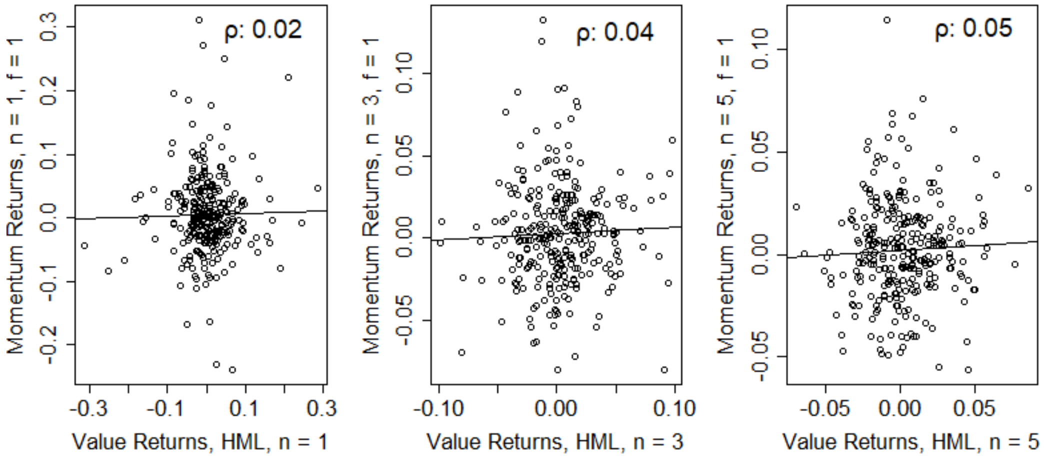
Figure 31: Correlation of Currency Value and Carry Trade Returns



Note. The figure illustrates the correlation between carry and value returns. The regression lines and correlation coefficients are also plotted.

There is no correlation between the value and carry returns. This is also the case for value and momentum returns, as shown in Figure 32.

Figure 32: Correlation of Currency Value and Momentum Returns



Note. The figure presents correlations of currency value and momentum returns and includes the correlation coefficients and regression lines.

There is also no correlation between the returns of the currency value and currency momentum strategies, as the correlation coefficients are close to zero. Overall, the returns of the three currency strategies – carry, momentum, and value – are different. In addition, the DOL, VOL, and market risk factors have different impacts on the three strategies.

6.7. ARBITRAGE LIMITS

Section 6.5 showed that the currency value strategy generates positive returns, although they are not significant. The currency value returns are mainly driven by emerging market currencies, while the excess return of a value strategy based on developed market currencies is zero. As transaction costs are higher for emerging market currencies than for developed market currencies, the currency value strategy may be affected by the bid-ask spread.

Whether transaction costs are substantial depends on whether new foreign currency positions must be opened or existing positions can be rolled. Gilmore and Hayashi (2011) show that transaction costs can be significantly reduced if existing positions are prolongated by currency swaps. For the value strategy with five currencies, that is, $n = 5$, about 87% of all transactions can be swapped. This means that in most cases, an existing currency position is rolled and not closed. For these positions, the excess return is calculated based on bid prices. If a new position must be opened for the long portfolio in the value strategy, a currency's excess return is calculated with bid and ask prices, as in Eq. (52):

$$r_{t+1} = sp_{t+1}^{BID} - fw_t^{ASK} \quad (52)$$

The excess return of a new position to be opened in the short portfolio is calculated with Eq. (53):

$$r_{t+1} = sp_{t+1}^{ASK} - fw_t^{BID} \quad (53)$$

Table 54 shows the currency value strategy's excess return when bid and ask prices are considered.

Table 54: Performance of the Value Strategy with Bid and Ask Prices

	mean return	standard error	t-value	standard deviation	skewness	Sharpe ratio
n = 1, long	0.001228	0.003362	0.36533	0.05696	–0.7843	0.075
n = 1, short	–0.000205	0.002507	–0.08159	0.04246	–1.1443	–0.017
n = 1, LMS	0.001433	0.003866	0.3706	0.0655	–0.2161	0.076
n = 3, long	0.001421	0.001931	0.73587	0.03272	–0.3236	0.15
n = 3, short	–0.001012	0.001599	–0.6333	0.02709	–0.8652	–0.129
n = 3, LMS	0.002434	0.001868	1.3032	0.03164	0.0125	0.266
n = 5, long	0.000734	0.001712	0.42844	0.02901	–0.2150	0.088
n = 5, short	–0.00067	0.001413	–0.47443	0.02394	–1.1854	–0.097
n = 5, LMS	0.001404	0.001427	0.98384	0.02417	0.272	0.201

Note. Table 54 presents the currency value strategy returns with bid and ask prices. The t-values refer to the null of mean return = 0. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

The excess returns in the three long portfolios are positive even after considering transaction costs. The excess returns in the short portfolios remain negative. Thus, a positive excess return can be measured for the LMS portfolio for all three settings of n, even after considering transaction costs. However, the returns are not significant. A similar pattern emerges when the value strategy is complied by emerging market currencies, as shown in Table 55.

Table 55: Value Strategy incl. Transaction Costs, Emerging Markets

	mean return	standard error	t-value	standard deviation	skewness	Sharpe ratio
n = 1, long	0.001239	0.003452	0.3591	0.058476	–0.8203	0.073
n = 1, short	–0.000108	0.002538	–0.0427	0.042995	–1.2037	–0.009
n = 1, LMS	0.001348	0.003855	0.3497	0.065301	–0.2612	0.072
n = 3, long	0.000445	0.002021	0.2203	0.03424	–0.3194	0.045
n = 3, short	0.000073	0.001647	0.0441	0.027896	–0.9513	0.009
n = 3, LMS	0.000373	0.001954	0.1908	0.033096	–0.0849	0.04
n = 5, long	0.000966	0.001754	0.5509	0.029719	–0.2078	0.113
n = 5, short	–0.000263	0.00142	–0.18523	0.024054	–1.2767	–0.038
n = 5, LMS	0.001229	0.001449	0.8482	0.024556	0.1281	0.173

Note. The table shows the currency value strategy returns with bid and ask prices for emerging market currencies. The t-values refer to the null of mean return = 0. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

The returns of the LMS value strategy remain positive for all settings for *n* when transaction costs are considered. The Sharpe ratio is a maximum of 0.173 for *n* = 3. Table 56 shows the strategy´s returns when applied to industrialised market currencies only.

Table 56: Value Strategy incl. Transaction Costs, Industrialised Markets

	mean return	standard error	t-value	standard deviation	skewness	Sharpe ratio
n = 1, long	–0.00025	0.001711	–0.1484	0.028978	–0.0022	–0.03
n = 1, short	0.000046	0.001643	0.0279	0.027834	–0.4777	0.006
n = 1, LMS	–0.0003	0.001884	–0.159	0.031922	0.4354	–0.033
n = 3, long	0.000337	0.001548	0.2179	0.026227	–0.0267	0.045
n = 3, short	0.000196	0.001422	0.1378	0.024095	–0.278	0.03
n = 3, LMS	0.000141	0.001208	0.1171	0.020462	0.1171	0.02
n = 5, long	0.000156	0.001514	0.103	0.025654	0.1503	0.02
n = 5, short	–0.000247	0.001360	–0.1858	0.023044	–0.4832	–0.037

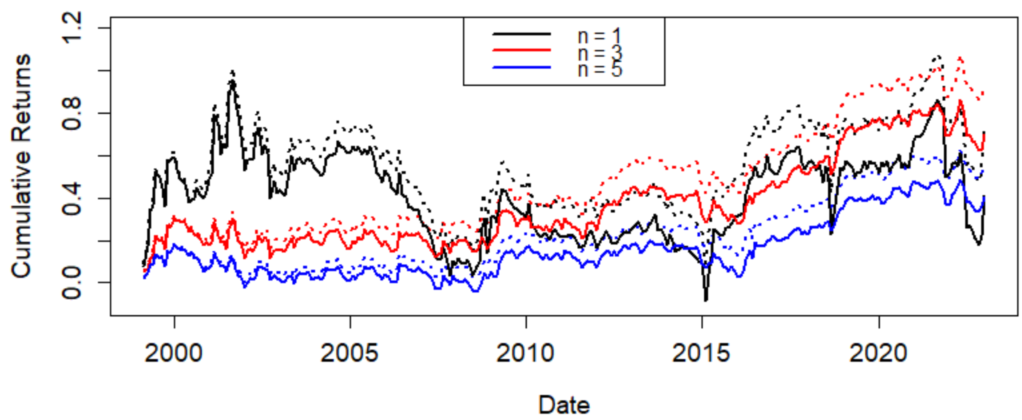
n = 5, LMS	0.000403	0.000911	0.4429	0.01544	0.3836	0.09

Note. Table 56 presents the currency value strategy returns with bid and ask prices. The t-values refer to the null of mean return = 0. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. The Sharpe ratio is annualised.

Transaction costs do not play a major role for the value strategy with industrialised countries´ currencies. However, the returns are close to zero.

Finally, the cumulative currency value excess returns considering transaction costs are shown graphically in Figure 33. In addition, the cumulative returns without transaction costs are shown with dashed lines.

Figure 33: Cumulative Currency Value Returns with Bid and Ask Prices



Note. The figure illustrates the currency value strategy's cumulative excess returns considering bid and ask prices. Additionally, cumulative returns without transaction costs are shown as dashed lines.

The use of bid and ask prices reduces cumulative excess returns, but they remain positive. For n = 3 and n = 5, the idiosyncratic currency risk is mitigated, which lowers volatility compared to n = 1. Furthermore, the strategies for n = 3 and n = 5 performed best after the global financial crisis, which is a pattern opposite that of the carry and momentum returns.

6.8. CHAPTER CONCLUSION

This chapter examines the currency value strategy's excess returns. The basis for this strategy is PPP and the RER. The strong form of PPP claims that goods in different countries should trade at the same price, and inflation differentials are offset by the nominal exchange rate. This results in an RER that follows a mean reversion.

However, the literature does not unconditionally confirm this theoretical assumption. RERs partially exhibit a unit root and thus are not stationary. The studies in this chapter confirm this point. The Augmented Dickey-Fuller and Philipps-Perron tests show that the null hypothesis of a unit root cannot be rejected for most currencies.

This chapter also shows, however, that for most currencies, the RERs follow a mean reversion outside certain thresholds. A SETAR model is applied to demonstrate this and shows that for all currencies in a regime with currency overvaluation, the expected value for $\hat{y}_t$ is smaller than y_{t-1}. In addition, in the case of currency undervaluation, in 25 out of 28 cases, the expected value for $\hat{y}_t$ is higher than y_{t-1}. However, the speed of mean reversion is very low. The average mean reversion for emerging market currencies is 1.44% per year, while for industrialised market currencies, it is only 0.50% per year. The speed of mean reversion of the RER is an important condition for generating excess returns using a currency value strategy. The unsatisfactory speed is an indicator that the currency value strategy's excess returns should be limited.

In fact, further research in this chapter shows that a currency value strategy leads to positive but limited returns. These are consistent with the assumption that undervalued currencies tend to appreciate and overvalued currencies tend to depreciate. However, the excess returns are not significant at the 5% level. Depending on the currency value strategy's setting, the excess returns are between 0.195% and 0.329% per month, and the annualised Sharpe ratio ranges between 0.13 and 0.36. These returns are consistent with the speed of mean reversion measured using the SETAR model. Currencies tend to revert only slightly to their long-term equilibrium, which results in insufficient excess returns.

Furthermore, this chapter shows that emerging markets are responsible for the currency value strategy's excess returns. Currencies from industrialised countries make a less important contribution. Depending on the currency value strategy's setting, emerging market currencies account for up to 85% of the strategy´s success. Currencies from industrialised markets explain only a maximum of 20% of the excess returns.

Contrary to the carry strategy, common risk factors in the currency market, such as the DOL, VOL, or market risk factors like equities, have no loadings on the currency value strategy´s excess returns. Thus, currency value would be a candidate for optimising the risk-return profile of a currency portfolio.

Transaction costs are shown to impact the value strategy’s success. However, despite the transaction costs, excess returns can still be achieved, although they are not significant.

VIII – CONCLUSIONS AND LIMITATIONS

VII - CONCLUSION AND LIMITATIONS

This research demonstrates that emerging market currencies are essential for generating currency excess returns. For the three main currency strategies – carry, momentum, and value – emerging market currencies are the main source of excess returns, while developed market currencies have limited impact.

For the carry strategy, the average monthly excess return for emerging markets' currencies from January 1997 to December 2022 ranges between 0.58% and 1.08%, with a Sharpe ratio between 0.56 and 0.96, depending on the strategy's setting. In contrast, the carry strategy's excess return for industrialised countries' currencies is between 0.08% and 0.21%, with a Sharpe ratio between 0.16 and 0.21. Bootstrap analyses show that the values for emerging and developed markets are significantly different, some even at the 0.1% level, depending on the setting.

Analyses of the carry strategy also show that the returns are negatively skewed. However, if the strategy is applied only to emerging market currencies, the skewness is less pronounced and, in some settings, even positive. This indicates that carry trades with emerging market currencies are less exposed to crash risk.

For momentum returns, the same pattern evolves. If the strategy is applied only to emerging market currencies, the average monthly excess return for a formation period of one month ranges between 0.58% and 1.08%. The annualised Sharpe ratio is between 0.48 to 0.73. For the momentum strategy applied to industrialised market currencies, the return is predominantly negative and close to zero. The hypothesis that emerging market currencies drive momentum returns is reinforced by a permutation test. The results are significant at the 1% level.

The currency value strategy also produces positive returns, but they are not significant at the 5% level. However, the same pattern as that of the carry and momentum returns can be seen here. The currency value strategy's returns are predominantly determined by emerging market currencies, while industrialised countries' currencies have a distinctly smaller impact. The strategy delivered an average monthly excess return between 0.12% and 0.24% for emerging markets' currencies between January 2000 and December 2022. The annual Sharpe ratio ranges between 0.12 and 0.25. For the value strategy based on developed market currencies, the excess return is between 0% and 0.05% with a maximum Sharpe ratio of 0.12. However, the returns are not significant at the 5% level for either emerging or industrialised markets' currencies. The currency value strategy's lack of success is not surprising. Unit root tests of the RERs show that not every exchange rate time series is stationary. Consequently, for the currency value strategy, it is challenging to determine the values at which a currency is over- or undervalued.

In addition, the thesis shows that a straightforward buy-and-hold currency strategy is not successful. Interestingly, this is true for both currency groups. A buy-and-hold strategy covering only the emerging markets delivers a monthly average excess return of –0.03% between 1997 and 2022. A currency basket that only includes the currencies of industrialised countries has a return of –0.06%. However, the negative skewness for emerging markets is more pronounced at –0.64 than for industrialised countries at –0.13.

The fact that a buy-and-hold strategy delivers similar results for both currency groups contrasts with the findings for the carry, momentum, and value strategies. This indicates that emerging markets' currencies unfold their potential under the three currency strategies rather than through the buy-and-hold strategy. The fact that emerging markets' currencies are the key driver of the currency strategies´ returns also shows that emerging markets' currencies may be more predictable than currencies from industrialised countries.

The currency excess returns are possible since UIP does not hold over the whole period. UIP states that interest rates and spot rate changes are in equilibrium. The UIP research in this study reveals different pictures for emerging and industrialised markets' currencies. A basket of currencies consisting of industrialised markets' currencies has a slope coefficient of –1.69 in the UIP regression, which deviates from unity at the 5% significance level. For a basket of emerging markets' currencies, the slope of 1.04 is close to unity, so UIP holds. This is consistent with the results of the buy-and-hold strategy, which yielded an average monthly excess return of –0.03% for emerging markets' currencies. The interest rate advantage of emerging markets' currencies is thus eroded by currency depreciation. The failure of UIP for industrialised countries' currencies, on the other hand, must be evaluated in light of the low interest rate differentials, which are only 0.01% per month on average. The negative slope coefficient of –1.69 in the UIP regression becomes less important due to the nearly non-existent interest rate difference.

However, further research on UIP has shown that the UIP regression's slope coefficient is regime dependent and subject to structural breaks. The Bai-Perron test for structural breaks clearly shows that the slope coefficient's sign changes for both individual currencies and currency baskets. This means that the slope is negative in some periods and positive in others. Further analyses using the Markov regime switching model additionally show that the UIP regression slope coefficient is regime dependent and above unity, especially in times of crisis, while it is negative in stable market environments.

Overall, this thesis shows that emerging market currencies are the key element for the three currency strategies of carry, momentum, and value. The implication for further research is to more thoroughly enhance appreciation of this characteristic by examining emerging market currencies more individually. For practitioners, the implications of this research are, on the one hand, to focus on emerging markets' currencies when implementing currency strategies. On the other hand, it is necessary to optimise transaction costs.

The results are subject to limitations. Currency markets represent a large field of research, and this dissertation cannot cover the full breadth of the field. Instead, the focus is the impact of emerging markets' currencies on currency excess returns. Consequently, various aspects that are examined in the literature are not considered here. This includes, for example, the importance of monetary policy, as investigated by many researchers, including Devereux and Engel (2003) and Gürkaynak et al. (2021). Furthermore, this dissertation focuses on nominal interest rates. An extension could demonstrate the role of real interest rates, as Byrne and Nagayasu (2010) did.

A further condition of this work is the selection of the 17 emerging market and 10 developed market currencies. These 27 currencies are determined according to MSCI's definition of developed and emerging markets. In principle, however, other definitions are also conceivable. Furthermore, the group of frontier markets is omitted, which would also be an exciting group for research, as shown by Dŏganlar et al. (2021).

This dissertation uses data from January 1997 to December 2022. The focus on emerging markets' currencies restricts the start date, as data for most of these currencies are only available from 1997 onwards. In other studies that focus exclusively on currencies from industrialised countries, the period generally starts in the 1980s and sometimes the 1970s.

Next, excess returns are calculated using currency forwards. An alternative approach would be to use money market rates. Under CIP, the interest rate differential between two currencies is equal to the difference between the forward and spot prices. However, studies show that CIP does not always hold (Du et al. 2018; Cerutti et al. 2021). Nevertheless, using forward prices is correct and consistent, as discussed in section 1.3. However, it is possible that using money market rates instead of forward prices would yield somewhat different results.

VIII – REFERENCES

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IX – APPENDIX

IX - APPENDIX

Appendix A. Chapter I Annex

Appendix A1: Refinitiv Eikon Identifiers

	Spot rate	Forward rate 1 month	Poll
Emerging Markets			
INR	INR=	INR1MV=	INR1MP=
KRW	KRW=	KRW1MV=	KRW1MP=
RUB	RUB=	RUB1MV=	RUB1MP=
BRL	BRL=	BRL1MNDFOR=	BRL1MP=
IDR	IDR=	IDR1MV=	IDR1MP=
MXN	MXN=	MXN1MV=	MXN1MP=
TRY	TRY=	TRY1MV=	TRY1MP=
ZAR	ZAR=	ZAR1M=*	ZAR1MP=
CLP	CLP=	CLP1MNDF=*	CLP1MP=
COP	COP=	COP1MNDF=*	COP1MP=
PLN	PLN=	PLN1MV=	not available
CZK	CZK=	CZK1MV=	CZK1MP=
HUF	HUF=	HUF1MV=	HUF1MP=
PHP	PHP=	PHP1MV=	PHP1MP=
TWD	TWD=	TWD1MV=	TWD1MP=
THB	THB=	THB1MV=	THB1MP=
PEN	PEN=	PEN1MNDF=*	PEN1MP=
Developed Markets			
EUR	EUR=	EUR1MV=	EUR1MP=
GBP	GPB=	GBP1MV=	GBP1MP=
JPY	JPY=	JPY1MV=	JPY1MP=
CHF	CHF=	CHF1MV=	CHF1MP=
AUD	AUD=	AUD1MV=	AUD1MP=
CAD	CAD=	CAD1MV=	CAD1MP=
ILS	ILS=	ILS1MV=	not available
NZD	NZD=	NZD1MV=	NZD1MP=
NOK	NOK=	NOK1MV=	NOK1MP=
SEK	SEK=	SEK1MV=	SEK1MP=

Note. The table shows the Refinitiv Eikon identifiers used in this study. For currency forward rates annotated with *, the forward rate is calculated by the spot rate plus the swap rate.

Appendix B. Chapter II Annex

Appendix B1: Correlation Matrix

	EUR	GBP	JPY	CHF	AUD	CAD	ILS	NZD	NOK	SEK	INR	KRW	RUB	BRL	IDR	MXN	TRY	ZAR	CLP	COP	PLN	CZK	HUF	PHP	TWD	THB	PEN
EUR	1,00	0,64	0,29	0,81	0,64	0,50	0,50	0,65	0,76	0,86	0,38	0,57	0,26	0,29	0,19	0,33	0,28	0,41	0,49	0,47	0,75	0,87	0,83	0,26	0,53	0,31	0,35
GBP	0,64	1,00	0,14	0,50	0,52	0,48	0,42	0,53	0,59	0,63	0,31	0,42	0,21	0,22	0,11	0,34	0,18	0,31	0,37	0,38	0,56	0,58	0,56	0,22	0,43	0,26	0,33
JPY	0,29	0,14	1,00	0,40	0,21	0,10	0,17	0,22	0,20	0,27	0,11	0,25	-0,09	0,02	0,18	-0,04	-0,03	0,17	0,16	0,17	0,16	0,23	0,18	0,16	0,35	0,21	0,18
CHF	0,81	0,50	0,40	1,00	0,51	0,33	0,49	0,57	0,62	0,71	0,35	0,53	0,17	0,20	0,18	0,23	0,15	0,36	0,38	0,37	0,60	0,69	0,64	0,22	0,52	0,26	0,27
AUD	0,64	0,52	0,21	0,51	1,00	0,71	0,51	0,84	0,68	0,70	0,53	0,64	0,35	0,51	0,24	0,51	0,41	0,60	0,62	0,63	0,66	0,60	0,65	0,36	0,57	0,36	0,45
CAD	0,50	0,48	0,10	0,33	0,71	1,00	0,48	0,62	0,62	0,59	0,39	0,48	0,36	0,47	0,20	0,48	0,32	0,51	0,52	0,57	0,56	0,49	0,52	0,27	0,43	0,30	0,38
ILS	0,50	0,42	0,17	0,49	0,51	0,48	1,00	0,49	0,44	0,49	0,37	0,42	0,24	0,29	0,34	0,39	0,21	0,35	0,34	0,36	0,50	0,47	0,46	0,30	0,44	0,28	0,25
NZD	0,65	0,53	0,22	0,57	0,84	0,62	0,49	1,00	0,62	0,69	0,48	0,63	0,30	0,43	0,27	0,46	0,36	0,54	0,54	0,56	0,64	0,59	0,66	0,38	0,55	0,39	0,40
NOK	0,76	0,59	0,20	0,62	0,68	0,62	0,44	0,62	1,00	0,81	0,41	0,54	0,32	0,40	0,22	0,45	0,30	0,49	0,56	0,59	0,70	0,74	0,73	0,25	0,51	0,32	0,41
SEK	0,86	0,63	0,27	0,71	0,70	0,59	0,49	0,69	0,81	1,00	0,42	0,60	0,30	0,36	0,21	0,41	0,31	0,43	0,50	0,52	0,75	0,80	0,75	0,26	0,56	0,33	0,41
INR	0,38	0,31	0,11	0,35	0,53	0,39	0,37	0,48	0,41	0,42	1,00	0,49	0,26	0,39	0,20	0,49	0,34	0,44	0,44	0,46	0,44	0,33	0,44	0,35	0,45	0,27	0,31
KRW	0,57	0,42	0,25	0,53	0,64	0,48	0,42	0,63	0,54	0,60	0,49	1,00	0,23	0,34	0,43	0,44	0,26	0,52	0,43	0,52	0,62	0,54	0,55	0,50	0,70	0,50	0,43
RUB	0,26	0,21	-0,09	0,17	0,35	0,36	0,24	0,30	0,32	0,30	0,26	0,23	1,00	0,28	0,17	0,41	0,21	0,29	0,24	0,42	0,34	0,32	0,29	0,05	0,27	0,13	0,25
BRL	0,29	0,22	0,02	0,20	0,51	0,47	0,29	0,43	0,40	0,36	0,39	0,34	0,28	1,00	0,34	0,50	0,44	0,40	0,55	0,64	0,40	0,33	0,32	0,34	0,32	0,32	0,37
IDR	0,19	0,11	0,18	0,18	0,24	0,20	0,34	0,27	0,22	0,21	0,20	0,43	0,17	0,34	1,00	0,30	0,19	0,24	0,34	0,50	0,14	0,19	0,19	0,44	0,31	0,53	0,26
MXN	0,33	0,34	-0,04	0,23	0,51	0,48	0,39	0,46	0,45	0,41	0,49	0,44	0,41	0,50	0,30	1,00	0,30	0,45	0,50	0,60	0,55	0,40	0,46	0,28	0,37	0,30	0,39
TRY	0,28	0,18	-0,03	0,15	0,41	0,32	0,21	0,36	0,30	0,31	0,34	0,26	0,21	0,44	0,19	0,30	1,00	0,33	0,32	0,41	0,33	0,25	0,34	0,21	0,17	0,17	0,18
ZAR	0,41	0,31	0,17	0,36	0,60	0,51	0,35	0,54	0,49	0,43	0,44	0,52	0,29	0,40	0,24	0,45	0,33	1,00	0,56	0,59	0,50	0,40	0,49	0,25	0,44	0,29	0,38
CLP	0,49	0,37	0,16	0,38	0,62	0,52	0,34	0,54	0,56	0,50	0,44	0,43	0,24	0,55	0,34	0,50	0,32	0,56	1,00	0,56	0,52	0,44	0,48	0,40	0,44	0,37	0,49
COP	0,47	0,38	0,17	0,37	0,63	0,57	0,36	0,56	0,59	0,52	0,46	0,52	0,42	0,64	0,50	0,60	0,41	0,59	0,56	1,00	0,56	0,48	0,52	0,42	0,51	0,41	0,52
PLN	0,75	0,56	0,16	0,60	0,66	0,56	0,50	0,64	0,70	0,75	0,44	0,62	0,34	0,40	0,14	0,55	0,33	0,50	0,52	0,56	1,00	0,81	0,83	0,29	0,55	0,31	0,45
CZK	0,87	0,58	0,23	0,69	0,60	0,49	0,47	0,59	0,74	0,80	0,33	0,54	0,32	0,33	0,19	0,40	0,25	0,40	0,44	0,48	0,81	1,00	0,81	0,22	0,52	0,30	0,36
HUF	0,83	0,56	0,18	0,64	0,65	0,52	0,46	0,66	0,73	0,75	0,44	0,55	0,29	0,32	0,19	0,46	0,34	0,49	0,48	0,52	0,83	0,81	1,00	0,25	0,50	0,30	0,35
PHP	0,26	0,22	0,16	0,22	0,36	0,27	0,30	0,38	0,25	0,26	0,35	0,50	0,05	0,34	0,44	0,28	0,21	0,25	0,40	0,42	0,29	0,22	0,25	1,00	0,38	0,58	0,35
TWD	0,53	0,43	0,35	0,52	0,57	0,43	0,44	0,55	0,51	0,56	0,45	0,70	0,27	0,32	0,31	0,37	0,17	0,44	0,44	0,51	0,55	0,52	0,50	0,38	1,00	0,50	0,42
THB	0,31	0,26	0,21	0,26	0,36	0,30	0,28	0,39	0,32	0,33	0,27	0,50	0,13	0,32	0,53	0,30	0,17	0,29	0,37	0,41	0,31	0,30	0,30	0,58	0,50	1,00	0,35
PEN	0,35	0,33	0,18	0,27	0,45	0,38	0,25	0,40	0,41	0,41	0,31	0,43	0,25	0,37	0,26	0,39	0,18	0,38	0,49	0,52	0,45	0,36	0,35	0,35	0,42	0,35	1,00

Note. The table presents the correlation matrix for currency excess returns.

Appendix B2: Monthly Excess Returns, base currency = GBP

	mean	standard error	t-statistics ($\mu = 0$)	standard deviation	skew-ness	kurto-sis	Sharpe ratio
Emerging Markets							
INR	0.002238	0.001483	1.5086	0.026202	0.0579	3.4083	0.30
KRW	0.000206	0.001904	0.1082	0.030757	0.6017	8.9989	0.02
RUB	0.003242	0.003035	1.0679	0.050246	0.6194	12.461	0.22
BRL	0.002144	0.003206	0.66861	0.052492	–0.5158	6.3392	0.14
IDR	0.001011	0.003852	0.2626	0.068036	–1.9582	27.578	0.05
MXN	0.003191	0.001966	1.6236	0.033356	–0.2122	4.6975	0.33
TRY	–0.00866**	0.003007	–2.8806	0.05312	–1.458	9.73	–0.56
ZAR	0.00208	0.002571	0.80918	0.045411	–0.2129	4.2207	0.16
CLP	0.001611	0.002353	0.68457	0.035525	0.1009	3.2346	0.16
COP	0.000856	0.002656	0.32239	0.038951	0.0668	3.8791	0.08
PLN	0.002968°	0.001748	1.6981	0.030872	–0.6053	4.5685	0.33
CZK	0.00171	0.001605	1.0653	0.028346	–0.1594	4.315	0.21
HUF	0.001786	0.0018	0.99232	0.031791	–0.8301	8.6849	0.19
PHP	0.000967	0.001679	0.57587	0.029649	–0.2609	4.3222	0.11
TWD	–0.000520	0.001427	–0.36446	0.023272	0.3586	4.1077	–0.08
THB	–0.000017	0.001961	–0.008604	0.034631	–0.4726	12.815	0.00
PEN	0.00273	0.001746	1.5634	0.025897	0.2793	4.6929	0.37
Developed Markets							
EUR	–0.000404	0.00127	–0.31812	0.02244	1.023	9.0211	–0.06
USD	0.000806	0.0014	0.57565	0.02472	0.3328	4.4191	0.11
JPY	–0.001619	0.002047	–0.79096	0.036154	1.0112	6.8107	–0.16
CHF	0.000316	0.001533	0.20636	0.027071	1.1274	9.4668	0.04
AUD	0.001563	0.00175	0.89351	0.030908	0.0845	4.4733	0.18
CAD	0.000787	0.001424	0.5524	0.025157	0.0511	3.9151	0.11
ILS	0.001744	0.00166	1.0505	0.026296	0.174	3.6251	0.23
NZD	0.002087	0.001797	1.1612	0.031742	0.1013	5.1727	0.23
NOK	–0.000082	0.001543	–0.05289	0.027249	–0.0561	3.2902	–0.01
SEK	–0.0011	0.00142	–0.77448	0.025077	0.4127	3.7957	–0.15

Note. The table shows the summary statistics of the excess returns of 27 currencies against the British pound. The Sharpe ratio is the quotient of the mean × 12 and the standard deviation × √12. Additionally, t-statistics for mean = 0 are reported. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

Appendix C. Chapter III Annex

Appendix C1: Beta Factors for Two Different Time Periods

	β_{P1}	se (β_{P1})	n	β_{P2}	se (β_{P2})	n
Emerging Markets						
INR	0.4348	0.4106	133	–0.204	0.7338	176
KRW	–4.8492***	1.0477	92	3.0895°	1.0981	169
RUB	2.0826**	0.3444	179	–1.4698***	0.5437	95
BRL	–0.0049***	0.2369	131	–0.0538	1.2007	137
IDR	–2.1937*	1.5342	52	–1.7846***	0.5875	260
MXN	–0.8955**	0.5484	234	7.4348	4.4996	54
TRY	–8.298***	1.8613	42	0.57	0.5166	173
ZAR	–1.6962	1.6411	60	–4.0444*	1.6359	252
CLP	–17.8994*	7.7528	51	0.3034	1.3153	177
COP	–4.4778*	2.5756	39	1.096	1.1148	176
PLN	1.2361	0.5071	139	1.8077	1.8028	173
CZK	1.191	0.8353	138	1.582	1.6491	174
HUF	–0.1934	0.8800	46	–1.4939**	0.8074	266
PHP	2.2104	1.7466	46	–0.7835***	0.5229	266
TWD	–0.401°	0.7794	223	3.0428	2.6956	43
THB	2.0198	1.1800	47	0.4273***	0.0988	265
PEN	0.9814	0.4649	138	–3.8765***	1.3147	82
Developed Markets						
EUR	–4.9067**	1.7962	144	2.2306	2.0333	168
GPB	–5.556*	2.5391	86	0.5065	1.6441	226
JPY	–1.5324	1.9308	126	4.3536*	1.3723	186
CHF	–3.317*	1.7057	175	2.4482	1.9839	138
AUD	–7.2468***	2.2603	86	0.1942	1.5187	226
CAD	–4.1777*	2.1661	172	4.5045	2.5211	140
ILS	0.3745	1.0458	76	2.1737	1.4796	175
NZD	3.2322	3.1677	46	–0.2378	1.5076	266
NOK	–4.1259***	1.3533	77	1.6696	1.6163	235
SEK	–5.7537***	1.7310	107	1.2981	1.6359	205

Note. The table shows the slope coefficient and standard error for the regression of the spot rate change on the forward discount. β values marked with °, *, **, and *** deviate from 1 at the significance levels of 10%, 5%, 1%, and 0.1%, respectively. The number of observations in the respective period is given by n.

Appendix C2: Beta Factors for Four Different Time Periods

	β_{P1}	n	β_{P2}	n	β_{P3}	n	β_{P4}	n
Emerging Markets								
INR	0.115°	65	–0.97*	110	–5.108*	56	0.241	81
	(0.449)		(0.98)		(2.753)		(0.816)	
KRW	–2.555	42	–8.096***	50	3.489°	87	–3.834	82
	(2.785)		(1.737)		(1.295)		(3.886)	
RUB	1.553*	129	11.184***	50	–3.048°	54	–1.53**	41
	(0.225)		(2.169)		(2.041)		(0.728)	
BRL	–0.046**	45	1.373	86	3.832	50	–1.969*	87
	(0.318)		(0.665)		(3.096)		(1.359)	
IDR	–2.194*	52	–1.625**	124	0.684	49	–4.368**	87
	(1.544)		(0.835)		(2.74)		(1.704)	
MXN	–1.173***	79	5.687°	43	–6.763**	109	7.543	57
	(0.511)		(2.391)		(2.531)		(4.514)	
TRY	–8.298***	42	1.873	89	12.629*	32	0.028	52
	(1.879)		(1.827)		(4.882)		(0.85)	
ZAR	–1.696	60	–3.091°	86	–23.774***	59	–0.392	107
	(1.652)		(2.195)		(6.154)		(4.42)	
CLP	12.713°	58	–1.743	34	–6.28	48	0.34	88
	(6.927)		(1.7)		(6.412)		(1.927)	
COP	–4.478*	39	1.808	75	–3.095	68	3.792	33
	(2.6)		(1.252)		(2.666)		(3.622)	
PLN	–1.022	46	0.331	52	10.866**	48	0.82	166
	(1.232)		(1.568)		(3.631)		(1.685)	
CZK	–0.319	46	–1.035	92	–3.656	81	2.258	93
	(1.199)		(2.009)		(4.746)		(1.4)	
HUF	–0.193	46	–1.077	88	–27.052**	46	–0.303	132
	(0.886)		(1.267)		(8.18)		(1.106)	
PHP	2.21	46	–2.209*	47	1.682	46	–3.56***	173
	(1.758)		(1.196)		(2.139)		(1.09)	
TWD	–0.004	100	10.348	46	5.79°	63	–0.482	57
	(0.974)		(9.623)		(2.522)		(1.764)	
THB	1.955	52	0.233***	80	0.705*	64	2.384	116
	(1.117)		(0.129)		(0.146)		(1.203)	
PEN	2.773*	43	–2.248**	60	–1.34*	35	–3.88***	82
	(0.859)		(1.048)		(0.915)		(1.327)	

Developed Markets								
EUR	–6.646**	84	3.668	57	–11.022°	67	4.55	104
	(2.28)		(2.482)		(6.272)		(2.322)	
GPB	–4.253*	95	8.929*	46	–13.343*	97	1.095	74
	(2.232)		(3.18)		(5.779)		(3.523)	
JPY	3.978	61	–3.589*	65	3.4	55	4.961°	131
	(5.793)		(1.989)		(1.79)		(2.262)	
CHF	–1.242	61	–14.624*	46	–0.274	68	2.448	137
	(3.203)		(5.923)		(3.057)		(1.997)	
AUD	–7.247***	86	5.174	59	11.523	46	2.672	121
	(2.275)		(4.253)		(7.809)		(2.219)	
CAD	–0.892	72	–0.894	58	–19.055*	46	4.516	136
	(2.151)		(3.098)		(8.525)		(2.59)	
ILS	–0.89*	66	15.897**	61	–11.318*	37	–0.421	87
	(0.939)		(4.739)		(4.989)		(2.327)	
NZD	–4.515**	100	15.92*	48	–15.647*	59	1.768	105
	(1.825)		(5.663)		(6.428)		(2.261)	
NOK	–3.611**	80	–3.683	48	13.969°	46	0.829	138
	(1.423)		(3.482)		(6.974)		(2.277)	
SEK	–5.754***	107	2.235	100	16.498***	46	–1.309	59
	(1.742)		(2.627)		(3.828)		(3.235)	

Note. The table shows the slope coefficient and its standard error in parentheses for the regression of the spot rate change on the forward discount. β values marked with °, *, **, and *** deviate from 1 at the significance levels of 10%, 5%, 1%, and 0.1%, respectively. The number of observations in the respective period is given by n.

Appendix C3: Beta Factors for Two Different Time Periods for Baskets

	Emerging Markets	Developed Markets
First period [n]	01/1997 – 10/2000 [46]	01/1997 – 12/2004 [96]
α	–0.01715 (0.01278)	0.00058 (0.00197)
β	–0.62162 (1.46481)	–4.76682*** (1.38361)
R^2	0.004	0.112
Second period [n]	11/2000 – 12/2022 [266]	01/2005 – 12/2022 [216]
α	0.00094° (0.00246)	–0.0011 (0.00163)
β	0.88475 (0.70728)	1.38684 (1.67108)
R^2	0.006	0.003

Note. The table shows the regression of the spot rate change on the forward discount. Standard errors are given in parentheses, and the number of observations n in the respective period is given in brackets. β (α) values marked with °, *, **, and *** deviate from 1 (0) at the significance levels of 10%, 5%, 1%, and 0.1%, respectively.

Appendix C4: Beta Factors for Four Different Time Periods for Baskets

	Emerging Markets	Developed Markets
First period [n]	01/1997 – 10/2000 [46]	01/1997 – 12/2004 [96]
α	–0.01715 (0.01278)	0.00058 (0.00197)
β	–0.62162 (1.46481)	–4.76682*** (1.38361)
R^2	0.004	0.112
Second period [n]	11/2000 – 07/2008 [93]	01/2005 – 11/2008 [47]
α	0.00416° (0.00212)	–0.00358 (0.00358)
β	0.40497 (0.56133)	4.28029 (3.36355)
R^2	0.006	0.035
Third period [n]	08/2008 – 01/2018 [114]	12/2008 – 09/2012 [46]
α	0.00699 (0.00816)	0.02752** (0.01)
β	3.35747 (2.48467)	29.73239* (11.61404)
R^2	0.016	0.13
Fourth period [n]	02/2018 – 12/2022 [173]	10/2012 – 12/2022 [123]
α	–0.0037 (0.00503)	–0.00325 (0.00203)
β	0.61823 (1.49423)	1.9209 (2.10066)
R^2	0.003	0.007

Note. The table shows the regression of the spot rate change on the forward discount. Standard errors are given in parentheses, and the number of observations n in the respective period is given in brackets. β (α) values marked with °, *, **, and *** deviate from 1 (0) at the significance levels of 10%, 5%, 1%, and 0.1%, respectively.

Appendix D. Chapter V Annex

Appendix D1: Regression on DOL Risk Factor for All Settings for n and f

	constant	β	standard error for β	t–statistics (β = 0)	R^2
MOM^{ALL}					
n = 1, f = 1	0.006642	–0.546937**	0.200221	–2.732	0.0235
n = 1, f = 3	0.0122**	–0.523798*	0.209933	–2.495	0.0197
n = 1, f = 6	0.009733*	–0.632401***	0.186984	–3.382	0.0356
n = 1, f = 12	0.006644	–0.733404***	0.201117	–3.647	0.0411
n = 3, f = 1	0.004713*	–0.25543**	0.093323	–2.737	0.0236
n = 3, f = 3	0.004204*	–0.154966	0.097716	–1.586	0.008
n = 3, f = 6	0.005788**	–0.460611***	0.102014	–4.515	0.0617
n = 3, f = 12	0.003698	–0.408363***	0.104558	–3.906	0.0469
n = 5, f = 1	0.003481*	–0.228624**	0.070734	–3.232	0.0326
n = 5, f = 3	0.003354*	–0.130289°	0.070178	–1.857	0.011
n = 5, f = 6	0.002944°	–0.273509***	0.07264	–3.765	0.0437
n = 5, f = 12	0.002265	–0.300476***	0.07602	–3.953	0.048
MOM^{EM}					
n = 1, f = 1	0.010587**	–0.586729**	0.20006	–2.933	0.027
n = 1, f = 3	0.011662*	–0.465519*	0.215275	–2.162	0.0149
n = 1, f = 6	0.010296*	–0.674025***	0.186948	–3.605	0.0402
n = 1, f = 12	0.007198	–0.653241**	0.200883	–3.252	0.033
n = 3, f = 1	0.006718**	–0.243254*	0.096488	–2.521	0.0201
n = 3, f = 3	0.005873**	–0.160766	0.100939	-1.593	0.011
n = 3, f = 6	0.00644**	–0.514498***	0,097458	–5.279	0.0825
n = 3, f = 12	0.003496	–0.398407***	0.10476	–3.803	0.0446
n = 5, f = 1	0.00573***	–0.218881**	0.071066	–3.08	0.0297
n = 5, f = 3	0.004453**	–0.125497°	0.072432	–1.733	0.0096
n = 5, f = 6	0.003942*	–0.296605***	0.071136	–4.17	0.0531
n = 5, f = 12	0.001885	–0.268321***	0.071136	–3.772	0.0439
MOM^{IND}					
n = 1, f = 1	–0.002966	0.033809	0.088172	0.383	0.0005
n = 1, f = 3	–0.001482	–0.139052	0.090668	–1.534	0.0075
n = 1, f = 6	–0.001922	–0.105215	0.089399	–1.177	0.0044
n = 1, f = 12	–0.001017	–0.2041*	0.08391	–2.432	0.0324
n = 3, f = 1	–0.000639	–0.101252°	0.055467	–1.825	0.0106

$n = 3, f = 3$	–0.001311	–0.021099	0.055086	–0.383	0.0005
$n = 3, f = 6$	–0.001153	–0.064824	0.054385	–1.192	0.0046
$n = 3, f = 12$	–0.000194	–0.125241*	0.059394	–2.109	0.0141
$n = 5, f = 1$	0.000167	–0.079664°	0.041043	–1.941	0.012
$n = 5, f = 3$	–0.001388	–0.040197	0.040491	–0.993	0.0032
$n = 5, f = 6$	–0.000073	–0.058305	0.03854	–1.513	0.0073
$n = 5, f = 12$	–0.000412	–0.069878°	0.040179	–1.739	0.0097

Note. The table presents results for the single linear regression of the momentum returns on DOL. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

Appendix D2: Regression on VOL Risk Factor for All Settings for n and f

	constant	β	standard error for β	t–statistics ($\beta = 0$)	R^2
MOM^{ALL}					
$n = 1, f = 1$	–0.038250***	1.687249***	0.302412	5.579	0.0913
$n = 1, f = 3$	–0.057761***	2.624805***	0.296615	8.849	0.2017
$n = 1, f = 6$	–0.044018***	2.019877***	0.27515	7.341	0.1481
$n = 1, f = 12$	–0.029706**	1.37028***	0.312007	4.392	0.0586
$n = 3, f = 1$	–0.018552***	0.873995***	0.139288	6.275	0.1127
$n = 3, f = 3$	–0.021961***	0.981074***	0.143149	6.854	0.1316
$n = 3, f = 6$	–0.019376***	0.947959***	0.155851	6.082	0.1066
$n = 3, f = 12$	–0.013109**	0.634578***	0.163764	3.875	0.0462
$n = 5, f = 1$	–0.012639***	0.606327***	0.107202	5.656	0.0935
$n = 5, f = 3$	–0.014076***	0.653929***	0.104055	6.284	0.113
$n = 5, f = 6$	–0.012124***	0.567605***	0.111745	5.079	0.0768
$n = 5, f = 12$	–0.007158*	0.35676**	0.120291	2.966	0.0276
MOM^{EM}					
$n = 1, f = 1$	–0.041222***	1.946588***	0.297677	6.539	0.1212
$n = 1, f = 3$	–0.058379***	2.626941***	0.305051	8.611	0.193
$n = 1, f = 6$	–0.043181***	2.010188***	0.2761	7.281	0.146
$n = 1, f = 12$	–0.027272**	1.298821***	0.311215	4.173	0.0532
$n = 3, f = 1$	–0.017846***	0,92243***	0.143335	6.435	0.1179
$n = 3, f = 3$	–0.021253***	1.017117***	0.147795	6.882	0.1325
$n = 3, f = 6$	–0.020487***	1.014656***	0.14851	6.832	0.1309
$n = 3, f = 12$	–0.014281**	0.670696	0.163422	4.104	0.0515

$n = 5, f = 1$	–0.01147***	0.64653***	0.10682	6.052	0.1057
$n = 5, f = 3$	–0.014376***	0.706222***	0.106661	6.621	0.1239
$n = 5, f = 6$	–0.013231***	0.646673***	0.108403	5.965	0.103
$n = 5, f = 12$	–0.007544*	0.356567**	0.112088	3.181	0.0316
MOM^{IND}					
$n = 1, f = 1$	–0.001804	–0.043951	0.13806	–0.318	0
$n = 1, f = 3$	–0.002699	0.047489	0.142469	0.333	0.0004
$n = 1, f = 6$	–0.0019	0.00216	0.140282	0.015	0
$n = 1, f = 12$	0.001602	–0.095111	0.132514	–0.718	0.0017
$n = 3, f = 1$	0.000991	–0.059597	0.087243	–0.683	0.0015
$n = 3, f = 3$	–0.001998	0.026004	0.086255	0.301	0.0003
$n = 3, f = 6$	–0.002395	0.047379	0.085302	0.555	0.0001
$n = 3, f = 12$	0.001109	–0.046991	0.093618	–0.502	0.0008
$n = 5, f = 1$	–0.000108	0.011537	0.064646	0.178	0.0001
$n = 5, f = 3$	–0.002091	0.026855	0.063478	0.423	0.0006
$n = 5, f = 6$	–0.001342	0.023714	0.060549	0.392	0.0005
$n = 5, f = 12$	0.000551	–0.035039	0.063182	–0.555	0.001

Note. The table shows statistics for the single linear regression of momentum returns on the currency VOL risk factor. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively.

Appendix D3: Regression of Momentum Returns on Market Risk Factors

	MSCI	COM	INT	VIX
MOM^{ALL}				
$n = 1, f = 1$	–0.2331*	–0.191	–1.2405	0.056**
	(–2.444), [0.019]	(–2.023), [0.013]	(–0.71), [0.002]	(2.7), [0.023]
$n = 1, f = 3$	–0.1063	–0.1581	–1.1094	0.0142
	(–1.057), [0.004]	(–1.596), [0.008]	(–0.606), [0.001]	(0.646), [0.001]
$n = 1, f = 6$	–0.0781	–0.1699°	0.1075	0.0049
	(–0.864), [0.002]	(-1.914), [0.012]	(0.065), [0]	(0.251), [0]
$n = 1, f = 12$	–0.0149	–0.0087	–0.8706	–0.0164
	(–0.152), [0]	(–0.09), [0]	(–0.491), [0.001]	(–0.77), [0.002]
$n = 3, f = 1$	–0.1491***	–0.1187	–0.9463	0.0286**
	(–3.383), [0.036]	(–2.711), [0.023]	(–1.163), [0.004]	(2.959), [0.027]
$n = 3, f = 3$	–0.0316	–0.0211	–0.3464	–0.0021
	(–0.678), [0.001]	(-0.458), [0.001]	(–0.409), [0.001]	(–0.207), [0]

$n = 3, f = 6$	–0.0734	–0.0723	–0.3999	0.0037
	(–1.472), [0.007]	(-1.469), [0.007]	(–0.44), [0.001]	(0.337), [0]
$n = 3, f = 12$	–0.0488	–0.0411	–1.0285	–0.0013
	(–0.96), [0.003]	(–0.819), [0.002]	(–1.114), [0.004]	(–0.113), [0]
$n = 5, f = 1$	–0.1176***	–0.0854*	–0.537	0.0201**
	(–3.508), [0.038]	(–2.557), [0.021]	(–0.866), [0.002]	(2.734), [0.024]
$n = 5, f = 3$	–0.0476	–0.0137	–0.2757	0.0028
	(–1.424), [0.006]	(-0.414), [0.001]	(–0.453), [0.001]	(0.384), [0]
$n = 5, f = 6$	–0.0422	–0.0253	–0.0815	0.0022
	(–1.199), [0.005]	(–0.727), [0.002]	(–0.127), [0]	(0.289), [0]
$n = 5, f = 12$	–0.0443	–0.0216	–0.9457	–0.0014
	(–1.2), [0.005]	(–0.592), [0.001]	(–1.41), [0.006]	(–0.175), [0]
MOM^{EM}				
$n = 1, f = 1$	–0.2392*	–0.201*	–0.4642	0.0591**
	(–2.507), [0.02]	(–2.128), [0.014]	(–0.265), [0]	(2.846), [0.025]
$n = 1, f = 3$	–0.0857	–0.1136	–1.6132	0.0081
	(–0.833), [0.002]	(–1.119), [0.004]	(–0.862), [0.002]	(0.36), [0]
$n = 1, f = 6$	–0.0781	–0.1471°	–0.314	–0.0047
	(–0.862), [0.002]	(–1.651), [0.008]	(–0.191), [0]	(–0.239), [0]
$n = 1, f = 12$	0.0371	0.0282	0.0673	–0.0251
	(0.382), [0]	(0.295), [0]	(0.038), [0]	(–1.19), [0.005]
$n = 3, f = 1$	–0.1396**	–0.0928*	–0.902	0.0278**
	(–3.059), [0.029]	(–2.043), [0.013]	(–1.074), [0.004]	(2.783), [0.024]
$n = 3, f = 3$	–0.0389	–0.0083	–0.9144	0.0046
	(–0.808), [0.002]	(–0.174), [0]	(–1.047), [0.004]	(0.437), [0.001]
$n = 3, f = 6$	–0.1033*	–0.0828°	–0.5832	0.0076
	(–2.152), [0.015]	(–1.743), [0.01]	(–0.664), [0.001]	(0.718), [0.002]
$n = 3, f = 12$	–0.0536	–0.0444	–1.8243*	–0.0014
	(–1.054), [0.004]	(–0.884), [0.003]	(–1.984), [0.013]	(–0.126), [0]
$n = 5, f = 1$	–0.1494***	–0.078*	–0.5477	0.0241**
	(–4.499), [0.061]	(–2.325), [0.017]	(–0.88), [0.002]	(3.278), [0.034]
$n = 5, f = 3$	–0.037	–0.0025	–0.6106	0.0017
	(–1.071), [0.004]	(–0.073), [0]	(–0.973), [0.028]	(0.0231), [0]
$n = 5, f = 6$	–0.0556	–0.0438	–0.607	0.0047
	(–1.607), [0.008]	(–1.28), [0.005]	(–0.963), [0.003]	(0.624), [0.001]
$n = 5, f = 12$	–0.0513	–0.0069	–0.7997	0.0048
	(–1.489), [0.007]	(–0.203), [0]	(–1.277), [0.005]	(0.634), [0.001]
MOM^{IND}				

$n = 1, f = 1$	–0.0212	–0.0157	–0.5113	0.0091
	(–0.507), [0.001]	(–0.38), [0]	(–0.672), [0.001]	(1.001), [0.003]
$n = 1, f = 3$	–0.0864*	–0.0732°	0.8074	0.0077
	(–2.011), [0.013]	(–1.723), [0.009]	(1.029), [0.003]	(0.82), [0.002]
$n = 1, f = 6$	–0.0714°	–0.018	0.3252	0.01273
	(–1.685), [0.009]	(–0.428), [0.001]	(0.421), [0.001]	(1.375), [0.006]
$n = 1, f = 12$	–0.0544	–0.0382	0.1649	0.0094
	(–1.356), [0.006]	(–0.963), [0.003]	(0.225), [0]	(1.07), [0.004]
$n = 3, f = 1$	–0.0646*	–0.0771**	–0.3621	0.1223*
	(–2.461), [0.019]	(–2.99), [0.028]	(–0.753), [0.002]	(2.143), [0.015]
$n = 3, f = 3$	–0.0492°	–0.0232	0.0552	0.0075
	(–1.889), [0.011]	(–0.898), [0.003]	(0.116), [0]	(1.322), [0.006]
$n = 3, f = 6$	–0.0509*	–0.0071	–0.056	0.007
	(–1.978), [0.012]	(–0.278), [0]	(–0.119), [0]	(1.244), [0.005]
$n = 3, f = 12$	–0.0487°	–0.017	–0.0274	0.0005
	(–1.72), [0.009]	(–0.607), [0.001]	(–0.053), [0]	(0.087), [0]
$n = 5, f = 1$	–0.0482*	–0.0573**	–0.2849	0.0082°
	(–2.479), [0.019]	(–3.003), [0.028]	(–0.8), [0.002]	(1.924), [0.012]
$n = 5, f = 3$	–0.0356°	–0.0249	0.0524	0.0045
	(–1.86), [0.011]	(–1.313), [0.006]	(0.15), [0]	(1.065), [0.004]
$n = 5, f = 6$	–0.0265	–0.0029	–0.1284	0.0034
	(–1.446), [0.007]	(–0.157), [0]	(–0.385), [0]	(0.846), [0.002]
$n = 5, f = 12$	–0.0366°	–0.0142	–0.3251	0.0025
	(–1.921), [0.012]	(–0.75), [0.002]	(–0.934), [0.003]	(0.587), [0.001]

Note. The table presents slope coefficients for the single linear regressions of momentum excess returns on four different market risk factors. °, *, **, and *** indicate significance at the 10%, 5%, 1%, and 0.1% levels, respectively. Values in parentheses indicate the slope coefficients´ t-values, and values in brackets show the regressions´ R^2.

Appendix E. Chapter VI Annex

Appendix E1: Real Exchange Rate Unit Root Tests, Q1 1997 to Q4 2022

	ADF t-statistic	ADF p-value	Phillips-Perron test statistic	Phillips-Perron p-value	observations
Emerging Markets					
INR	–1.413443	0.5731	–1.376107	0.5913	104
KRW	–3.251624	0.0198**	–3.239006	0.0205*	104
RUB	–1.744756	0.4058	–1.684167	0.4362	104
BRL	–1.825251	0.3665	–1.825666	0.3663	104
IDR	–3.403189	0.013*	–3.033096	0.0351*	104
MXN	–1.967723	0.3006	–1.821295	0.3684	104
TRY	–0.898291	0.7853	–0.761733	0.8253	104
ZAR	–2.084801	0.2512	–2.119897	0.2374	104
CLP	–1.999589	0.2867	–1.91958	0.3222	104
COP	–1.291372	0.6315	–1.148141	0.6943	104
PLN	–2.144997	0.2278	—1.967984	0.3005	104
CZK	–1.510766	0.5244	–1.407812	0.5758	104
HUF	–1.672654	0.4421	–1.58944	0.4844	104
PHP	–2.062898	0.2601	–2.211033	0.2037	104
TWD	–3.299905	0.0174*	–3.281879	0.0182*	104
THB	–2.681774	0.0806°	–2.681774	0.0806°	104
PEN	–1.417729	0.5709	–1.523907	0.5177	104
Developed Markets					
EUR	–1.732614	0.412	–1.779913	0.3886	104
GPB	–1.426955	0.5664	–1.477004	0.5414	104
JPY	–0.854622	0.7988	–0.91246	0.7808	104
CHF	–2.065252	0.2591	–1.958388	0.3048	104
AUD	–1.491371	0.5342	–1.611836	0.473	104
CAD	–1.401091	0.5791	–1.401091	0.5791	104
ILS	–2.56225	0.1042	–2.56225	0.1042	104
NZD	–1.703858	0.4264	–1.860146	0.3499	104
NOK	–1.398017	0.5806	–1.358892	0.5996	104
SEK	–1.557005	0.5009	–1.723721	0.4164	104

Note. °, *, **, and *** indicate rejection of the null hypothesis of a unit root at the 10%, 5%, 1%, and 1% significance levels, respectively.