GRA 19703

Master Thesis

Currency fundamentals, implied volatility, and FX
investment strategies as NOK determinants

Navn:	Morten Mehle Aabelvik, Dane Cekov

Master Thesis:

Currency fundamentals, implied volatility, and FX investment strategies as NOK determinants

Campus:
BI Oslo

Examination code and name:
GRA 19702 Master Thesis

Programme:
Master of Science in Finance

Supervisor:
Professor Dagfinn Rime

<u>Abstract</u>[*]

We study which factors determine the Norwegian krone at the weekly frequency. We show the existence of a relation between the EURNOK depreciation rate and changes in oil prices, implied volatility indices, and the excess returns on carry trade and value FX investment strategies. In particular, our findings suggest that the Norwegian krone is exposed to global risks proxied by the implied volatility indices and carry trade factor, is not exposed to the momentum factor, and has a risk discount as proxied by the value factor.

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<u>Acronyms</u>

CBOE: Chicago Board Options Exchange

CIP: Covered Interest Parity

DB: Deutsche Bank

EUR: Euro

EURIBOR: Euro Interbank Offered Rate

FX: Foreign Exchange

G10: Group of Ten currencies

IBOR: Interbank Offered Rate

NIBOR: Norwegian Interbank Offered Rate

NOK: the Norwegian krone

OECD: Organisation for Economic Co-operation and Development

PPP: Purchasing Power Parity

RER: Real exchange rate

UIP: Uncovered Interest Parity

USD: United States Dollar

VIX: Chicago Board Options Exchange Volatility Index

1. Introduction

We study which factors determine the Norwegian krone (NOK) at the weekly frequency. In particular, we focus on the Norwegian exchange rate measured against the Euro (EURNOK[2]) and examine its connection with 1) interest rates, 2) oil prices, 3) implied volatility indices, and 4) excess returns on three well diversified forex investment strategies.

Previous studies find that the exchange rate of commodity export-based economies is linked to commodity prices (e.g., Chen & Rogoff, 2003). For Norway the commodity of importance is oil. It has been shown that oil prices have predictive ability for the Norwegian krone at the daily frequency (e.g., Ferraro, Rogoff & Rossi, 2015). Even though there is substantial empirical evidence that oil prices are important periodical determinants of movements in the Norwegian krone, this is not always the case; see Figure 1. For example, from mid-2017, oil prices have risen, while EURNOK has reach historically low values not seen since the finical crisis.

Figure 1: Oil prices and EURNOK
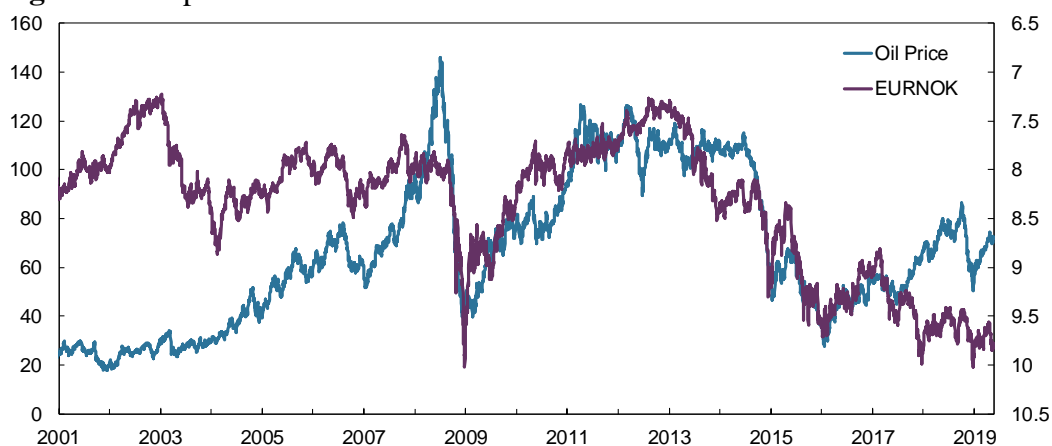
Notes: The figure above shows the development of the EURNOK spot exchange rate (right axis, inverted) and USD-denominated Brent oil price (left axis). Sample period is 01.01.2001 – 17.05.2019. Figure 1 shows that developments in the Brent crude oil price corresponds very well with EURNOK in some periods, however, this relationship is not consistent over the full sample.

When reading about the Norwegian krone in the news, a recurring question asked over the past few years has been why the krone remains so weak when oil prices have increased and the outlook of the Norwegian economy has improved. The novelty of our approach is to examine risk factors which might address this shortcoming.

The value of the Norwegian krone is determined on the international financial market. Since foreign exchange is an asset class, the value of the

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[2] EURNOK is defined as the amount of Norwegian kroner one has to pay to acquire one Euro.

Norwegian krone will be influenced by risks. Currencies, like other assets, should be priced to adequately compensate investors for the risk factors which they expose them to. More risk should imply a lower value, and vice versa.

Previous studies show that the Norwegian krone is affected by international financial volatility (e.g., Bernhardsen & Røisland, 2000; Flatner, 2009). With this in mind, we seek to investigate if variables that proxy for international financial volatility convey information about movements in the Norwegian exchange rate (i.e., depreciation rate). Widely used to proxy for financial uncertainty are implied volatility indices such as Chicago Board Options Exchange Volatility Index (VIX). In addition, we use implied volatility indices derived from options on currency markets such as JPMorgan Global FX Volatility Index and Barclays Emerging Markets FX Risk Index.

Moreover, recent literature shows that FX investment strategies such as carry trade, value, and momentum capture risk premia in foreign exchange rates (e.g., Lustig, Roussanov & Verdelhan, 2011; Menkhoff, Sarno, Schmeling & Schrimpf, 2012b, 2016). We investigate if the excess returns from these three well diversified FX investment strategies convey information relevant for movements of the Norwegian exchange rate.

We take an asset pricing approach and estimate price impact regressions. Further, we investigate the stability of our results by using rolling regressions due to the time-varying nature of risk premia.

In general, we find empirical evidence that there is a relation at the weekly frequency between the Norwegian krone and 1) oil prices, 2) implied volatility indices, and 3) the carry trade and value risk factors. In particular, our findings suggest that the Norwegian krone is exposed to global risks proxied by the implied volatility indices and carry trade factor, not exposed to currency-specific risks as proxied by momentum, and has a risk discount as proxied by value. Further, we find that the implied volatility indices, carry trade and value factors are consistent in explaining variations in the EURNOK depreciation rate, while momentum's explanatory power is ephemeral, appearing only in some subsamples of the data.

Our results suggest that the Norwegian krone has, besides with oil prices, relations to risk premia conveyed by the implied volatility indices and excess returns on carry trade and value, demonstrating that these additional factors have explanatory power for variations in the EURNOK depreciation rate.

Our findings should be of interest to financial entities such as banks and hedge funds, which undertake speculative positions in forex markets. Better understanding of the factors that affect the Norwegian krone could enable these financial entities to improve their currency hedging strategies. In particular, the insight into which factors convey most information about movements in the Norwegian exchange rate is of value to the many analysts who follow the krone closely, as it may aide them to improve their analyses.

2. Review of literature

In this section we review the relevant literature about exchange rate determination and previous studies pertaining to the Norwegian krone. Further, we review literature related to carry, value, and momentum, and give a brief explanation of these FX investment strategies' connection to currency risk premia.

2.1 Exchange rate determination

In general, our thesis is related to the vast literature on exchange rate determination using fundamental macroeconomic variables. We start with one of the simplest theories; Uncovered Interest Rate Parity (UIP). According to UIP any difference in interest rates between two countries will be offset by the relative change in the countries' currency exchange rates over the same period.[3] It has empirically been shown that UIP does not hold as surveyed for example by Hodrick (1987), Froot and Thaler (1990), and Engel (1996, 2014). More specifically, Fama (1984) decomposes the forward premium into two components and shows that a rejection of the unbiasedness hypothesis implies time-varying risk premia.

More recently, Bussiere, Chinn and Ferrara (2018) re-examine Fama (1984) and find that the Fama regression coefficient is positive and large in the period after the global financial crisis for multiple currencies, in contrast to earlier empirical findings.[4] However, the Norwegian krone is an exception to this finding as its coefficient is still negative in the aftermath of the financial crisis, in violation of UIP. Examining Norway in particular, Akram and Mumtaz (2016) show that the correlations between money market rates and nominal exchange rates have steadily fallen towards zero.

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[3] The Appendix contains a detailed explanation of UIP.

[4] The Fama coefficient is β from the regression $s_t = \alpha + \beta(i_t^{NO} - i_t^{EU}) + u_t$. Many previous studies have found that that this coefficient is negative.

This thesis is also connected to the literature that uses fundamentals such as commodity prices to determine exchange rates. For a small open economy which mostly exports commodities, the exchange rate is expected to reflect movements in the prices of the country's major commodity export (Ferraro et al., 2015). Norway is a small open economy with crude oil as its main export, accounting for approximately 40% of total exports in 2018 (Norsk Petroleum, 2019). Further, Norway is a price-taker on the international oil market since it produces relatively small quantities compared to other oil-producing countries. For example, in 2017, Norway produced approximately two percent of the total global oil demand (Norsk Petroleum, 2019). Most of Norway's oil production is exported, however, the country accounts for a minor part of overall global oil exports. Due to this, any major changes in oil prices may act as observable and exogenous terms-of-trade shocks for Norway's economy, in line with Chen and Rogoff (2003). This is corroborated by Akram and Mumtaz (2016) who show that oil price shocks have contributed to sizable volatility in the macroeconomic variables for Norway since the early 1980s.

In particular, Ferraro et al. (2015) show the existence of a short-term relationship between changes in prices of a country's major commodity export and its nominal exchange rate. By studying several oil exporting countries' nominal exchange rates, they find that oil prices have the ability to contemporaneously predict movements of nominal exchange rates, among them the Norwegian (USDNOK) exchange rate.

It is possible that the relation between oil prices and exchange rates occurs due to a portfolio rebalancing effect, where investors simultaneous move into (out of) commodity markets and high-yielding currencies during risk-on (risk-off) episodes. This is possible because foreign exchange rates, crude oil contracts, and other financial securities are traded on the international financial market. Hau and Rey (2004, 2005) find evidence that portfolio rebalancing is an important source of exchange rate movements. When unhedged investors rebalance their global equity portfolios to limit their exchange rate exposure, this rebalancing of portfolios initiates forex order flow, which in turn leads to exchange rate movements. Further, Camanho, Hau and Rey (2018) find that a high level of global FX volatility reinforces the rebalancing behaviour of international equity funds, triggering larger rebalancing toward domestic assets compared to periods of low FX volatility. In this context, it could be that portfolio rebalancing effects are the cause of the short-

term relationship between changes in commodity prices and exchange rates, which previous studies have found.

Kohlscheen, Avalos and Schrimpf (2016) extend the framework of Ferraro et al. (2015) and find that commodity prices explain a significant part of variation in exchange rates that is not comparable to global risk, as proxied by VIX. This finding suggests that portfolio rebalancing effects are not the cause of the short-term relationship between commodity prices and exchange rates. Hence, this finding indicates that commodity prices and implied volatility indices contain different information which is relevant for movements of exchange rates.

Our thesis is related to Ferraro et al. (2015) and Kohlscheen et al. (2016) in terms that we examine the importance of oil prices for the exchange rate. However, we differ by focusing on the Norwegian krone and additionally consider multiple (risk) factors. Moreover, we use Brent as the crude oil benchmark, while Ferraro et al., 2015 use West Texas Intermediate (WTI). The use of WTI is less suitable for Norway relative to Brent because the two benchmarks represent the value of oil from different geographical locations and with different chemical characteristics, which results in a price difference between the two. The price spread between Brent and WTI is not constant, as shown for example by Chen, Huang and Yi (2015) who find a structural break in the spread around 2010. Hence, we use Brent since it is the superior crude oil benchmark for Norway.

Studies looking into the Norwegian krone and oil prices show that model specifications are important. Both Akram (2004) and Ter Ellen (2016) find evidence of a non-linear relationship between the NOK and oil prices, with the size of correlation varying with the level and trend of oil prices. However, we use linear models in this analysis since they are found supreme among the model specifications considered in the literature, according to Rossi (2013). In addition, linear models are widely used in the asset pricing literature (Cochrane, 2005).

2.2   Risk premia, implied volatility & FX investment strategies

The examination of currency risk premia connects this thesis to the asset pricing literature. Because exchange rates are asset prices whose future risk affects their current value, relatively riskier countries have more depreciated exchange rates (Farhi & Gabaix, 2015). Fama (1984) was one of the first to argue the existence of risk premia in foreign exchange rates. These risk premia vary over time and are likely to be high at the bottom of a recession, and vice versa (Cochrane,

2011). This indicates according to Cochrane (2011) that cyclical variables should work as predictors of expected returns. Sarno, Schneider and Wagner (2012) show that deviations from UIP can almost entirely be explained by currency risk premia and provide empirical evidence that these risk premiums are closely related to variables that proxy for 1) global risk aversion, 2) US business cycles, and 3) traditional exchange rate fundamentals.

Previous studies show that the Norwegian krone is affected by uncertainty and global risk events. Bernhardsen and Røisland (2000) find that NOK is affected by financial risks in the short run. Flatner (2009) investigates the characteristics of NOK during times of high market turmoil and finds that it cannot be regarded as a safe haven currency.[5] Lund (2011) shows that liquidity of Norwegian kroner is adversely affected during periods characterised by high global financial volatility. Kohlscheen et al. (2016) use VIX as a proxy of uncertainty and global risk events. VIX is derived from option prices on the S&P 500 index and widely used as a measure of U.S. equity market volatility. In addition to VIX, we use Barclays Emerging Markets FX Risk Index and JPMorgan Global FX Volatility Index because these two are derived from option prices on foreign exchange.

Finance theories tie risk premiums to broad return-based factors (Cochrane, 2011). In empirical asset pricing, the three-factor model of Fama and French (1993) and the extention by Carhart (1997) use factors such as value, size and momentum to explain returns in equity market. In this way empirical asset pricing boils down pricing anomalies to a small set of large-scale systematic risks that generate rewards (Cochrane, 2011). Riskier currencies should bear larger exposure to systematic risk factors, such as carry trade (e.g., Lustig et al., 2011; Menkhoff et al., 2012a), momentum (e.g., Menkhoff et al., 2012b) and value (e.g., Menkhoff et al., 2016). In this thesis, we relate the time-varying risk premia of the Norwegian krone to covariances with these pricing factors and portfolio returns from the FX investment strategies, and seek to find how much of the EURNOK depreciation rate these factors explain.

Note, we assume that excess returns from the three FX investment strategies embody currency risk premia. This assumption is important because there are there are opposing views in the literature, for example, Burnside, Eichenbaum and

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[5] Safe haven currencies are defined as those that provide a hedge for a reference portfolio of risky assets, conditional on shocks to global risk aversion (e.g., De Bock and Carvalho Filho, 2015).

Rebelo (2011) argue that profits from carry trade and momentum do not compensate investors for risks.

2.3.1 Carry Trade

Carry trade is an investment strategy where one buys currencies with high interest rates and funds this investment by selling (shorting) currencies with low interest rates. The net return to an investor who engages in carry trade should be zero if UIP holds because any profits generated by the interest rate differential will be equally offset by the change in the exchange rate.[6] However, many previous studies have shown that carry trade does make significant excess returns.

An investment is considered risky if it yields low returns in bad times when its return matters the most, i.e. when investors have high marginal utility of consumption. In the literature, investors that engage in carry trade are thought to be compensated for consumption growth risk (e.g., Lustig & Verdelhan, 2007), global risk (e.g., Lustig et al., 2011), crash risk (e.g., Brunnermeier, Nagel & Pedersen, 2008), illiquidity risk (e.g., Abankwa & Blenman, 2015) and volatility risk (e.g., Menkhoff et al., 2012a), amongst other.

The carry trade factor we use is closely related to Lustig et al. (2011) who identify a slope-factor ("high minus low" factor) in exchange rates. This factor, which they construct from currency portfolios, can explain the variation in country-level returns, where high interest currencies load positively and low interest currencies negatively. According to Lustig et al. (2011), currency risk premiums are determined by a home risk premium, and a carry trade risk premium which compensates investors for global (common) risk. Lustig et al. (2011) find that the exposure to global risk explains a major part of the excess return generated by carry trade. Further, Menkhoff et al. (2012a) build on Lustig et al. (2011) and find that global FX volatility is key to explain the risk premia of carry trade excess returns. Menkhoff et al. (2012a) find a negative comovement between high interest rate currencies and global FX volatility innovations, while low interest rate currencies provide a hedge against unexpected volatility changes.

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[6] UIP assumes that investors are rational and risk-neutral. Additionally, transactions costs in the foreign exchange and money markets have to be negligible in order for UIP to hold.

2.3.2 Momentum

A momentum strategy involves buying currencies in upwards trends (appreciating) and selling currencies in downwards trends (depreciating) due to the anticipation that these trends will continue further. Although studies about momentum have mainly focused on equity markets, momentum has been documented in currency markets as well. The most relevant study is by Menkhoff et al. (2012b) who relate momentum returns to currency-specific characteristics. In particular, Menkhoff et al. (2012b) find that significantly positive excess returns are found in the currencies of countries with 1) high past idiosyncratic volatility, 2) high country-specific risk, and 3) high exchange rate (in)stability risk. All these three currency-specific characteristics prevent FX market participants from conducting arbitrage strategies, leading to the high excess returns. Additionally, Menkhoff et al. (2012b) argue that the excess returns from currency momentum strategies and carry trades are very different.

2.3.3 Value

Value strategies are derived from measures of currency valuation which attempt to identify overvalued and undervalued currencies, using the framework of real exchange rates (RER) and Purchasing power parity (PPP) to measure intrinsic value.[7] A currency is fairly valued if there is no possibility of tradable goods arbitrage. Engel and West (2005) demonstrate that the real exchange rate can be derived into a present-value formulation which shows its close connection to currency risk premia. Menkhoff et al. (2016) find that real exchange rates have predictive power for currency excess returns and that the information content in these RER is different from those embedded in carry and momentum strategies. In addition, Menkhoff et al. (2016) show that 1) there may exist a risk premium for high inflation countries (relative to USA) and 2) that strong (highly valued) currencies tend to earn low risk premiums going forward. Additionally, Menkhoff et al. (2012b) argue that the excess returns from currency value strategies are different from carry trades or currency momentum strategies, meaning that investors who combine all three FX strategies in their portfolios can benefit from increased diversification.

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[7] See the appendix for more information about RER and PPP.

3. Research theory and methodology

In this section we present the methodology we use in our empirical analysis. We estimate price impact regressions to explore contemporaneous relations between changes in the spot log exchange rate (i.e., depreciation rate) and different factors. We consider multiple specifications and estimate both univariate and multivariate regressions (see Table 3 for estimation results of all models).

In general, the reduced form specifications of the regression models we estimate are subsumed in (i) below:

$$s_t = \alpha_i + \beta_i(f_{i,t}) + u_t \quad \text{(i)}$$

where $s_t = s_t - s_{t-1}$ stands for the one-week depreciation rate in the spot log EURNOK exchange rate, $f_{i,t}$ stands for variable or factor i such as the interest rate differential between Norway and the Euro area $(i_t^{NO} - i_t^{EU})$, one-week change in log USD-denominated Brent price (oil_t), one-week change in JPMorgan's Global FX Volatility Index $(fxvix_t)$, one-week change in CBOE's Volatility Index (vix_t), one-week change in Barclays Emerging Markets FX Risk Index $(emvix_t)$, one-week returns on Deutsche Bank's G10 Carry (car_t), Value (val_t) and Momentum (mom_t) Indices. The small letters represent natural logarithms of the variables. α is the constant term, β_i is the estimated slope coefficient of variable i, and u_t denotes the error term.

In particular, the first specification (1) we estimate is given by the Fama regression:

$$s_t = \alpha + \beta_1(i_t^{NO} - i_t^{EU}) + u_t \quad \text{(1)}$$

The second specification is the fundamentals model with interest rate differential and oil prices:

$$s_t = \alpha + \beta_1(i_t^{NO} - i_t^{EU}) + \beta_2(oil_t) + u_t \quad \text{(2)}$$

Then we build on (2) with the implied volatility indices. Note that we consider one volatility index at a time to examine their relative performance. For example, specification (3) considers JPMorgan's Global FX Volatility Index $(fxvix_t)$:

$$s_t = \alpha + \beta_1(i_t^{NO} - i_t^{EU}) + \beta_2(oil_t) + \beta_3(fxvix_t) + u_t \quad \text{(3)}$$

Specifications (4) and (5) are with CBOE's Volatility Index (vix_t) and Barclays Emerging Markets FX Risk Index $(emvix_t)$, respectively. The slope coefficient on

the volatility indices measures the price impact of changes in expected volatility, i.e., a volatility impact coefficient.

In turn, we investigate the importance of excess returns to carry trade, value, and momentum for explaining movements in the depreciation rate. Continuing, we build on (2) with each factors excess return separately. For example, specification (6) considers the carry trade factor:

$$s_t = \alpha + \beta_1(i_t^{NO} - i_t^{EU}) + \beta_2(oil_t) + \beta_3(car_t) + u_t \quad (6)$$

Specifications (7) and (8) are with the excess returns of value and momentum, respectively. The last specification, (9) includes excess returns from all three FX investment strategies as explanatory variables. In this setting, the depreciation rate is determined by the exposure of the Norwegian krone to different factors, where excess returns on carry trade, value, and momentum represent the price of risk which these factors embody.

Note that the approach we have chosen is related to empirical asset pricing, since we seek to explain variations in the depreciation rate (s_t) by its exposure to a number of factors. In asset pricing, factors which proxy for marginal utility growth are used to express the expected return of assets (Cochrane, 2005). Assets must give investors higher returns (have low prices) if they have a good payoff in times that are good, and have bad payoffs in times which are bad, as measured by the factors. In this case, general specification (i) can be considered a linear factor pricing model, where expected returns are linearly dependent on the betas of the factors. As stated by Cochrane (2005), these regressions are not about predicting returns from variables seen ahead of time, but to measure contemporaneous relations or risk exposures. After estimating these regressions, the betas can be interpreted as the amount of exposure EURNOK has to the risks proxied by each factor f_i.

Further, note that we do not consider any specification with both the implied volatility indices and these three factors. Both the implied volatility indices and excess returns from the FX investment strategies contain information which is relevant for movements in the exchange rate, as outlined in section 2.2. We assume that these variables contain information which overlaps and hence are mutually exclusive. This assumption is reasonable given the literature we have reviewed and therefore, we do not consider a mixed specification model.

In addition, note that we include the oil price in all specifications, except the first. The oil price is included as it likely is a good factor that proxies well for

marginal utility growth in Norway. One of the goals of our thesis is to examine if the additional risk factors convey relevant information for movements in the Norwegian exchange rate beyond the information attributed to oil prices. To do this, we consider specifications with oil prices alone and together with the additional factors.

A likely question would now be why we choose to estimate a regression model with all three factors included? This is because these strategies are found to offer a set of excess returns that are largely independent from one another. For example, Menkhoff et al. (2012b, 2016) argue that carry, momentum, and value capture largely unrelated dimensions of currency risk premia (see sections 2.3.2 and 2.3.3). This means that these factors provide relevant information for movements in the depreciation rate which is unique from one factor to another. By estimating a regression with all three excess returns, we attempt to establish a superior model that will explain more of the variation in the depreciation rate.

After estimating all the regressions, coefficients can be evaluated by a t-test. If the null hypothesis; $\beta_i = 0$ is rejected, then this signals that factor i contains useful information for fluctuations in the exchange rate over the full sample. Further, all the regression intercepts α_i should be zero.

4. Data description

The main focus of our empirical analysis is on the Norwegian nominal spot exchange rate. First, when looking into the Norwegian krone (NOK), we find that it has a sufficient long history of market values to be analysed; NOK has been a market-based free-floating exchange rate since the 1990s when Norges Bank altered its monetary policy regime from exchange rate management to inflation targeting (Alstadheim, 2016). According to the latest Triennial Central Bank Survey of foreign exchange markets, the most liquid currency pair involving the NOK is measured against the Euro with 14.8 billion USD daily average spot turnover in April 2016.[8] This is why we focus on the EURNOK spot exchange rate in our analysis.

In our empirical analysis we use several financial time series which are available from the Bloomberg Terminal. The variables we use are 1) one week Norwegian Interbank Offered Rate, 2) one week Euro Interbank Offered Rate, 3) the USD-denominated Brent crude oil price, 4) JPMorgan Global FX Volatility Index, 5) Chicago Board Options Exchange Volatility Index (VIX), 6) Barclays Emerging Markets FX Risk Index, and 5) Deutsche Bank G10 Carry Index, 6) Deutsche Bank G10 Value Index, and 7) Deutsche Bank G10 Momentum Index.[9]

As is standard in the literature, we take natural logarithms of all the variables and use first differences since most of the financial time series (prices) we use are non-stationary. A common way to transform these non-stationary variables into stationary is to take the first difference (Brooks, 2014). After the transformation, the stationary series (returns) exhibit the required properties for the regression analyses.

All variables are sampled at end-of-week, following the convention that all information is priced into markets at the end of each business week. The sample period starts in September 2001 and ends in May 2019. The beginning of our sample is specified to correspond with Norges Bank's decision to officially alter its monetary policy regime from exchange rate management to inflation targeting. Descriptive statistics can be seen in Table 1. Note that we exclude the period of the

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[8] The daily average spot turnover is presented on a net-on-net basis, for more see the survey. This survey is from December 2016 and is conducted by the Bank for International Settlements.
[9] The appendix contains graphical representations of the variables.

financial crisis (July 2008 to June 2009) in the first part of the analysis as it represents a black swan event.[10]

Table 1: Descriptive statistics

	Mean	Median	Std. Dev.	Skew.	Kurt.
s_t	0.38	-3.05	48.85	0.64	5.32
$(i_t^{NO} - i_t^{EU})$	1.37	1.37	0.91	0.52	3.30
oil_t	8.90	20.60	221.30	-0.62	5.21
$fxvix_t$	-0.10	-0.24	4.55	0.83	7.50
vix_t	-0.03	-0.84	13.83	0.63	5.71
$emvix_t$	-0.04	-0.48	6.53	1.07	7.78
car_t	3.68	6.88	59.88	-0.74	5.92
val_t	1.53	0.61	50.19	-0.41	6.05
mom_t	0.21	2.05	56.01	-0.49	5.12

Notes: This table reports descriptive statistics for the depreciation rate (s_t), interest rate differentials between Norway and the Euro area $(i_t^{NO} - i_t^{EU})$, USD-denominated Brent price (oil_t), JPMorgan's Global FX Volatility Index $(fxvix_t)$, CBOE's Volatility Index (vix_t), Barclays Emerging Markets FX Risk Index $(emvix_t)$, and one-week excess returns on Deutsche Bank's G10 Carry (car_t), Value (val_t) and Momentum (mom_t) Indexes. All values represent first differences of the natural logarithms of the variables, measured in percent and annualised. The sample period is 18.09.2000 – 13.05.2019 and contains 922 end-of-week observations, excluding the financial crisis period (July 2008 to June 2009). Std. Dev., Skew. and Kurt. denote standard deviation, skewness and kurtosis, respectively.

To construct the weekly Norway - Euro Area interest rates differential data, we subtract one week EURIBOR from one week NIBOR. Oil prices are represented by the first Brent futures contract because the Brent crude benchmark is the most appropriate representation for the value of oil extracted from the Norwegian continental shelf.

In order to proxy for international financial volatility and uncertainty (risk-on and risk-off events), we use implied volatility indices such as VIX, JPMorgan's Global FX Volatility Index, and Barclays Emerging Markets FX Risk Index. Table 2 shows that changes in these indices are not perfectly correlated. We conjecture this is because the indices are derived from options with different underlying securities; JPMorgan's Global FX Volatility Index is based on G10 currencies, CBOE's VIX is based on the S&P 500 Index for equities, and Barclays Emerging Markets FX Risk Index is based on the currencies of emerging market countries.

To represent the financial performance of carry, value, and momentum we use three Exchange Traded Funds (ETFs) from Deutsche Bank which can be easily

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[10] A black swan is an extreme and unpredictable event with a very low probability.

traded by investors.[11] Deutsche Bank's *Carry* Index is based on the carry trade strategy. This index is built of long futures contracts on the top-three G10 currencies with highest interest rates and is short futures of the bottom-three G10 currencies with lowest interest rates.

The *Value* Index is based on the PPP theory. Using PPP values calculated by OECD, G10 currencies are ranked by how over- or undervalued they are relative to their fair PPP value. This *Value* Index is constructed of long futures of the three most undervalued currencies and shorts the three most overvalued currencies.

The *Momentum* Index is based on the momentum strategy and describes the short- or some mid-term tendencies in the currency price movement trends. First, G10 currencies are ranked by their change over the past 12 months. Then, the *Momentum* Index consists of long futures contracts on the top-three best performing and shorts the futures of the three worst performing G10 currencies. The decision of which currencies to be long and short in is reassessed every three months for the Carry and Value Index, and each month for the Momentum Index (Baig et al., 2007).

Table 2: Correlation Matrix

	s_t	r_{diff}	oil_t	car_t	val_t	mom_t	$fxvix_t$	vix_t	$emvix_t$
s_t	**1.00**								
r_{diff}	0.01	**1.00**							
oil_t	-0.25	-0.03	**1.00**						
car_t	-0.34	0.03	0.22	**1.00**					
val_t	0.41	-0.01	-0.15	0.09	**1.00**				
mom_t	-0.08	0.04	-0.01	0.23	-0.08	**1.00**			
$fxvix_t$	0.26	0.00	-0.13	-0.50	0.09	-0.09	**1.00**		
vix_t	0.25	0.00	-0.17	-0.38	0.09	-0.04	0.49	**1.00**	
$emvix_t$	0.30	0.01	-0.13	-0.40	0.18	-0.13	0.65	0.38	**1.00**

Notes: Table 2 shows the correlation matrix for the depreciation rate (s_t), interest rate differentials between Norway and the Euro area (r_{diff}), USD-denominated Brent price (oil_t), JPMorgan's Global FX Volatility Index ($fxvix_t$), CBOE's Volatility Index (vix_t), Barclays Emerging Markets FX Risk Index ($emvix_t$), and one-week excess returns on Deutsche Bank's G10 Carry (car_t), Value (val_t) and Momentum (mom_t) Indexes. All values represent first differences of the natural logarithms of the variables, measured in percent and annualised. The sample period is 18.09.2000 – 13.05.2019 and contains 922 end-of-week observations, excluding the financial crisis period (July 2008 to June 2009).

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[11] For example, the PowerShares DB G10 Currency Harvest Fund (symbol: DBV) which replicates the Deutsche Bank Carry index, has been listed on the NYSE since 18 September 2006 (Lustig and Verdelhan, 2008).

5. Empirical analysis

This section presents our main empirical findings. Table 3 show results from price impact regressions estimated over the whole sample, excluding the period of the financial crisis. Here we present the results from regressing the EURNOK depreciation rate on different combinations of interest rates, oil prices, implied volatility indices, and the carry trade, value and momentum factors.

Table 3: Price Impact Regressions

This table reports estimation results from price impact regressions. The dependent variable is the one-week change in log EURNOK spot exchange rate (i.e., depreciation rate), measured as a yearly return in percentage points. For each regression we report corresponding slope coefficients for the repressors, the Wald F-statistic and adjusted R^2. Below the estimated coefficients, Newey and West (1987) standard errors are reported in brackets. The sample *excludes* the period of the financial crisis. Negative estimates of slope coefficients imply an appreciation of the Norwegian krone for higher values of the regressor, and vice versa, positive estimates imply a depreciation.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
α	-0.08	1.05	1.10	0.86	1.20	0.99	0.05	0.84	-0.07
	(2.62)	(2.53)	(2.63)	(2.57)	(2.55)	(2.73)	(2.38)	(2.54)	(2.43)
r_{diff}	0.34	-0.13	-0.03	-0.02	-0.22	0.49	0.11	0.04	0.81
	(1.58)	(1.57)	(1.60)	(1.58)	(1.57)	(1.65)	(1.52)	(1.56)	(1.46)
oil_t		-0.06***	-0.05***	-0.05***	-0.05***	-0.04***	-0.04***	-0.06***	-0.02***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$fxvix_t$			2.44***						
			(0.45)						
vix_t				0.77***					
				(0.12)					
$emvix_t$					2.02***				
					(0.29)				
car_t						-0.25***			-0.30***
						(0.04)			(0.03)
val_t							0.38***		0.42***
							(0.04)		(0.04)
mom_t								-0.07	0.03
								(0.05)	(0.03)
F-stat	0.05	17.99***	21.93***	23.39***	28.53***	21.92***	44.12***	12.49***	58.63***
Adj. R^2	0.00	0.06	0.11	0.11	0.13	0.15	0.21	0.07	0.33

Notes: The sample period is 18.09.2000 – 13.05.2019 and contains 922 end-of-week observations, *excluding* the financial crisis period (July 2008 to June 2009). r_{diff} denotes the interest rate differential. The other variables are the one-week changes of log USD-denominated Brent oil price (oil_t), JPMorgan Global FX Volatility Index ($fxvix_t$), CBOE's Volatility Index (vix_t), and Barclays Emerging Markets FX Risk Index ($emvix_t$). car_t, val_t, mom_t denote one-week returns of Deutsche Bank's G10 Carry, Value and Momentum Indexes, respectively. All variables are annualised and measured in percent. The F-statistic refers to the joint null hypothesis that all slope coefficients are equal to zero. The robust Wald F-statistic is computed based on robust coefficient covariance estimators. Statistical significance at the 10, 5 and 1 percent levels are denoted by "*", "**" and "***", respectively.

5.1 Fundamentals

Consistent with many earlier studies, we find that interest rates account for little of the variation in the depreciation rate. As we can see from column (1) in Table 3, the beta of regressor is insignificant and the adjusted R^2 is practically zero. This Fama-regression tests the validity of the uncovered interest rate parity. If UIP holds, relative interest rate changes will be the sole driver of currency movements and we would find that $\hat{\alpha} = 0, \hat{\beta} = 1$, and a very high R^2. These findings show that that UIP does not hold at the weekly frequency for EURNOK.

When we extend the previous model and include the oil price, this fundamentals model performs better given the improvement in adjusted R^2. Further, column (2) in Table 3 shows that the estimated slope coefficient on oil prices is negative and statistically significant at the 1 percent level. A higher oil price is estimated to coincide with an appreciation of the krone, and vice versa. The economic significance is however modest; a one percent increase in the oil price is estimated to correspond with 0.06 percent appreciation of NOK over the sample.

The first possible explanation behind our findings pertaining to oil prices is the terms of trade channel. In the short run, higher oil prices will lead to increased export revenues for Norway. Since crude oil is traded in foreign exchange (U.S. dollars), more inflow of foreign currency will need to be exchanged into Norwegian kroner and this higher demand for Norwegian kroner should appreciate the currency. In the medium to long run, higher oil prices might lead to more foreign direct investment, thereby enhancing the positive effect for the Norwegian krone. In addition, sustained higher oil prices improve the outlook for Norway's economy and this could make investors demand a lower excess return to invest in Norwegian kroner, leading to an appreciation of the exchange rate.

Moreover, higher oil prices will increase revenues for oil firms operating on the Norwegian continental shelf, improving their outlook. This could lead to appreciations of the krone through two additional channels. First, international investors will have to expose themselves to Norwegian kroner first, before they can purchase stocks of oil companies listed on the Oslo stock exchange.[12] Second, higher revenues will in turn lead to higher taxes that need to be paid to the Norwegian state. Since all oil transactions are denominated in U.S. dollars and taxes

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[12] Note that what we have outlined here are portfolio investments, not foreign direct investments.

need to be paid in Norwegian kroner, oil firms will need to increase their krone purchases.[13] In turn this should lead to an appreciation of the krone, ceteris paribus.

Lastly, we cannot rule out that the oil prices act as macroeconomic news announcements; they could simply be good predictors of monetary policy decisions by the Norwegian central bank. Norges Bank's goal is stable inflation, high and stable output and employment levels. Oil prices are important to Norges Bank because they affect inflation directly, and indirectly through output and employment. Thus, new information about these variables could immediately affect the exchange rate due to changes in expectations pertaining to future interest rates.

5.2   Implied volatility indices

Starting with JPMorgan's Volatility Index, column (3) in Table 3 shows a positive estimate of the volatility impact coefficient that is both highly statistically and economically significant. This means that higher expected volatility coincides with a depreciation of the krone. We conjecture the intuition behind this finding is that investors demand higher returns to take exposure in relatively illiquid currencies at times of great financial uncertainty. However, portfolio investments could have an effect as well since international investors would likely reduce their exposure to NOK (foreign) denominated assets during risk-off events.

Overall, this model has improved explanatory power, as evident by the increase in adjusted R^2. This finding is consistent with the notion that implied volatility indices contain relevant information for variations in the depreciation rate.

Further, comparing specification (3) with specifications (4) and (5), we see similar results with significant and positive coefficients for all three volatility indices. In addition, these results show that JPMorgan's Volatility Index is most economically significant, VIX is least economically significant, and that Barclays Risk Index is relatively better at explaining variations in the depreciation rate.

We surmise that these slightly differing results arise due to differences in the underlying options of the indices; JPMorgan's Volatility Index is based on G10 currencies, VIX is based on the S&P 500 Index, and Barclays Risk Index is based on the currencies of emerging market countries. It is possible that Barclays Risk Index has slightly higher explanatory power for variations in the EURNOK

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[13] This could happen through a direct transaction in USDNOK, or more common in FX markets through transactions in the most liquid crosses of the currencies. The latter would be conducted first through a transfer in USDEUR and then EURNOK, thereby leading to lower transaction costs.

depreciation rate because NOK resembles characteristics attributed to emerging market currencies; many are predominantly commodity export-based economies.

5.3   Currency risk premia

Going forward, we turn to the excess returns (i.e., currency risk premiums) of carry trade, value, and momentum.

Specifications (6) and (9) show a statistically and economically significant slope-factor coefficient on carry trade, which is estimated to be negative. Higher excess return on carry trade are estimated to coincide with appreciations of the Norwegian krone, and vice versa. In line with the argument of Lustig et al. (2011), this finding implies that kroner load positively on the carry trade slope-factor. This means that the Norwegian krone was a high interest rate currency, in our sample. Currencies which load positively on this slope-factor are considered risky, as argued by both Lustig et al. (2011) and Meinkhoff et al. (2012a). The carry trade risk premium compensates investors because high interest rate (investment) currencies tend to depreciate and low interest rate (funding) currencies tend to appreciate when global volatility is high. In addition, this is confirmed by the specifications with the implied volatility indices; we found that higher expected volatility coincides with depreciation of the Norwegian krone, and vice versa. These findings suggest that the Norwegian krone appreciates during times when excess returns on carry trade are high, which is during periods of low global uncertainty, i.e., when there is more risk appetite among investors in financial and currency markets.

Specifications (7) and (9) show a statistically and economically significant coefficient on value, which is estimated to be positive. Further, the regression intercepts α_i is insignificant and close to zero. Higher excess return on value are estimated to coincide with depreciations of the Norwegian krone, i.e., NOK loads negatively on the value risk premium. Menkhoff et al. (2016) argue that value embodies a risk premium for currencies of high inflation countries relative to the United States. We surmise that because Norway is not a country with high inflation, the Norwegian krone has a risk discount possibly because it is considered a low and stable-inflation currency, relative to the U.S.

Furthermore, note that value invests in the most undervalued currencies and short sells the most overvalued. One simple but popular metric of currency value is the Economist's Big Mac index, which consistently reports the Norwegian krone

among the most overvalued currencies in the world; see Table B1 in the appendix. Hence, our finding is in accord with Menkhof et al. (2016) who show that highly valued currencies (such as the Norwegian krone) tend to earn low risk premiums forward.

Regarding momentum, specifications (8) and (9) show a negative and a positive coefficient, respectively. Moreover, both coefficients are statistically and economically insignificant. Interpreting this pattern requires care. Given our assumption that momentum embodies currency risk premia, these results imply that the Norwegian krone does not load on this risk factor.[14] According Menkhoff et al. (2012b), momentum compensated for currency-specific risks which prevent FX market participants from conducting arbitrage strategies. We surmise that the Norwegian krone is not exposed to such currency-specific risks.

Moreover, comparing specifications (8) to (2), we see that the momentum factor does not materially improve the overall explanatory power of the regression. In contrast, comparing specifications (7) to (2) shows that the value-extension to the fundamentals model provides substantially more explanatory power than any other variable. Further, the carry trade factor also conveys relevant information that is beneficial for explaining variations in the depreciation rate, as can be seen from the adjusted R^2 statistic in specification (6).

To conclude, we find that carry trade and value factors convey information relevant for explaining fluctuations in the depreciation rate, while the momentum factor lacks explanatory power. Moreover, we find that carry and value factors have more explanatory power relative to specifications with the implied volatility indices and oil prices. Our results suggest that the Norwegian krone is exposed to global risks proxied by carry trade, in line with our finding from the implied volatility indices. In contrast, the Norwegian krone is not exposed to currency-specific risks as proxied by momentum. Finally, NOK has a risk discount as proxied by value, possible because Norway is not a country with high inflation relative to the U.S.

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[14]Alternatively, this result could simply be because momentum's excess returns are not actually currency risk premia, as argued by Brunside et al. (2011).

6. Robustness analysis – whole sample

Table 4 show results from the price impact regressions estimated over the whole sample, including the period of the financial crisis (July 2008 to June 2009). We note that after adding the observations from this period with substantial financial uncertainty, the effects on the slope coefficients are insignificant. Moreover, we see minor improvements in some specifications explanatory power. However, these results have no substantial implications for our previous discussions. To conclude, our prior results are robust when we include the 51 weekly observations which were previously removed from the sample.

Table 4: Price Impact Regressions - Whole Sample

This table reports estimation results from price impact regressions. The dependent variable is the one-week change in log EURNOK spot exchange rate (i.e., depreciation rate), measured as a yearly return in percentage points. For each regression we report corresponding slope coefficients for the repressors, the Wald F-statistic and adjusted R^2. Below the estimated coefficients, Newey and West (1987) standard errors are reported in brackets. The sample *includes* the period of the financial crisis. Negative estimates of slope coefficients imply an appreciation of the Norwegian krone for higher values of the regressor, and vice versa, positive estimates imply a depreciation.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
α	-0.44	1.22	1.33	1.18	1.60	1.23	0.02	1.07	-0.21
	(2.70)	(2.56)	(2.63)	(2.58)	(2.56)	(2.68)	(2.39)	(2.56)	(2.42)
r_{diff}	1.08	0.09	0.07	0.11	-0.22	0.35	0.11	0.23	0.56
	(1.81)	(1.66)	(1.65)	(1.64)	(1.61)	(1.65)	(1.56)	(1.66)	(1.50)
oil_t		-0.07***	-0.06***	-0.06***	-0.06***	-0.05***	-0.05***	-0.07***	-0.03***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$fxvix_t$			1.90***						
			(0.53)						
vix_t				0.73***					
				(0.12)					
$emvix_t$					1.77***				
					(0.28)				
car_t						-0.19***			-0.23***
						(0.04)			(0.04)
val_t							0.36***		0.38***
							(0.04)		(0.04)
mom_t								-0.04	-0.04
								(0.03)	(0.04)
F-stat	0.36	20.14***	21.10***	28.81***	31.66***	22.86***	57.49***	13.21***	50.18***
Adj. R^2	0.00	0.09	0.12	0.12	0.14	0.15	0.21	0.09	0.30

Notes: The sample period is 18.09.2000 – 17.05.2019 and contains 973 end-of-week observations, *including* the financial crisis period (July 2008 to June 2009). All variables are annualised and measured in percent. The F-statistic refers to the joint null hypothesis that all slope coefficients are equal to zero. The robust Wald F-statistic is computed based on robust coefficient covariance estimators. Statistical significance at the 10, 5 and 1 percent levels are denoted by "*", "**" and "***", respectively.

7. Robustness analysis – alternative specifications

We assumed that implied volatility indices and factors from the FX investment strategies contained similar information for the variations in the depreciation rate. Table 5 shows that this assumption was reasonable, considering that none of the specifications with the three factors and implied volatility indices substantially improve upon the explanatory power of specification (9).

Table 5: Price Impact Regressions - Alternative Specifications

This table reports estimation results of in-sample fit regressions. The dependent variable is the one-week change in log EURNOK spot exchange rate (i.e. depreciation rate), measured as a yearly return in percentage points. For each regression we report corresponding slope coefficients for the repressors, the Wald F-statistic and adjusted R^2. Below the estimated coefficients, Newey and West (1987) standard errors are reported in brackets. The sample *excludes* the period of the financial crisis. Negative estimates of slope coefficients imply an appreciation of the Norwegian krone for higher values of the regressor, and vice versa.

	(9)	(9a)	(9b)	(9c)
α	-0.07	0.03	-0.12	-0.05
	(2.43)	(2.41)	(2.43)	(2.43)
r_{diff}	0.81	0.71	0.79	0.79
	(1.46)	(1.45)	(1.45)	(1.46)
oil_t	-0.02***	-0.02***	-0.02***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.01)
$fxvix_t$				0.35
				(0.36)
vix_t			0.26**	
			(0.11)	
$emvix_t$		0.60***		
		(0.23)		
car_t	-0.30***	-0.27***	-0.28***	-0.29***
	(0.03)	(0.03)	(0.03)	(0.03)
val_t	0.42***	0.41***	0.42***	0.42***
	(0.04)	(0.04)	(0.04)	(0.04)
mom_t	0.03	0.03	0.03	0.03
	(0.03)	(0.03)	(0.03)	(0.03)
F-stat	58.63***	50.01***	49.52***	50.00***
Adj. R^2	0.326	0.331	0.330	0.327

Notes: The sample period is 18.09.2000 – 13.05.2019 and contains 922 end-of-week observations, *excluding* the financial crisis period (July 2008 to June 2009). r_{diff} denotes the interest rate differential. The other variables are one-week changes of log USD-denominated Brent oil price (oil_t), JPMorgan Global FX Volatility Index $(fxvix_t)$, CBOE's Volatility Index (vix_t), and Barclays Emerging Markets FX Risk Index $(emvix_t)$. car_t, val_t, mom_t denote one-week returns of Deutsche Bank's G10 Carry, Value and Momentum Indexes, respectively. All variables are annualised and measured in percent. The F-statistic refers to the joint null hypothesis that all slope coefficients are equal to zero. The robust Wald F-statistic is computed based on robust coefficient covariance estimators. Statistical significance at the 10, 5 and 1 percent levels are denoted by "*", "**" and "***", respectively.

8. Robustness analysis – rolling regressions

We conduct stability analysis by estimating rolling-window regressions with sample window-sizes of 52, 260, and 520 weeks, which correspond to 1, 5, and 10 years. The step size is always 1 week ahead. We do this because risk premia are time-varying, and to find out how consistent the contemporaneous relations are between changes in the depreciation rate and the explanatory variables. In this section we report only figures from regressions with the 52 week rolling-windows estimates. However, results from some regressions with sample window-sizes of 260 and 520 weeks can be found in Appendix C.[15] Finally, note that estimates are saved end-of-sample for each roll.

8.1 Fundamentals

Concerning the first specification, figure 2 shows a coefficient that is insignificant over time and estimated to be both negative and positive. Furthermore, figure C17 shows the adjusted R^2 statistic frequently to be negative. These results indicate that interest rates do poorly at explaining variations in the depreciation rate over time.

Figure 2: Rolling-window coefficients, rdiff (52 weeks)
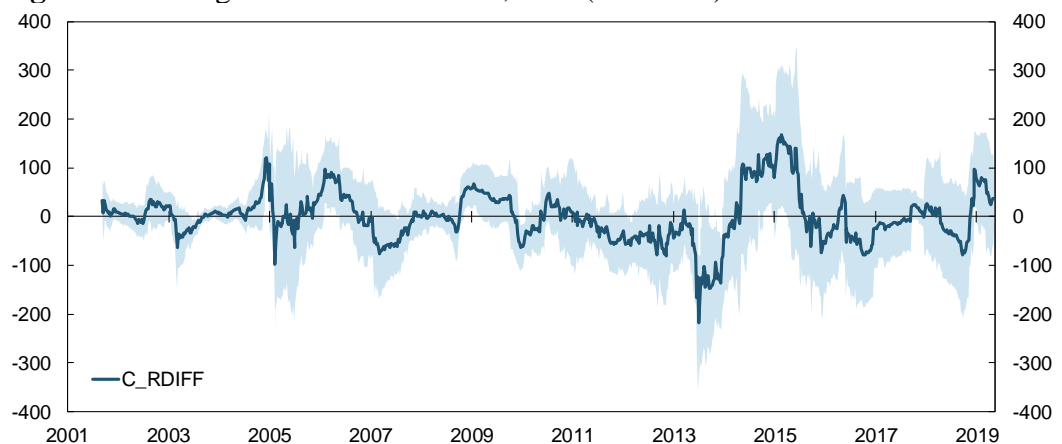
Notes: The figure above shows rolling-window estimates of the coefficient ($\beta_{t,rdiff}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + u_t$, where window size is 52 weeks and step size is 1 week. Estimates are saved end-of-sample for each roll. The shaded light blue area corresponds approximately to a 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

Figure 3 shows that rolling-window coefficients of oil prices are often statistically significant over time. Looking at the entire timeframe, we see estimates

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[15] Note that all figures with C can be found in Appendix C. Additionally, note that we show results for one coefficient from each rolling regression. Results are available for all rolling-window coefficients from the specifications in Table 4, however, we report only one coefficient since these results represent the rest of the findings adequately.

mostly being negatively significant and sometimes insignificant. Further, figure 4 shows an adjusted R^2 statistic which is periodically high, indicating that oil prices have explanatory power for fluctuations in depreciation rate often, but not always. These findings suggests that oil prices are important for movements in the Norwegian krone, but not consistently at all times.

However, the figures in appendix C show that the coefficients stabilize and become significantly negative when we consider window-sizes of 260 and 520 weeks. These results suggest that higher (lower) oil prices do indeed correspond with an appreciation (depreciation) of the Norwegian krone over time. This is expected given our previous discussion of how oil prices affect the exchange rate.

Figure 3: Rolling-window coefficients, oil price (52 weeks)
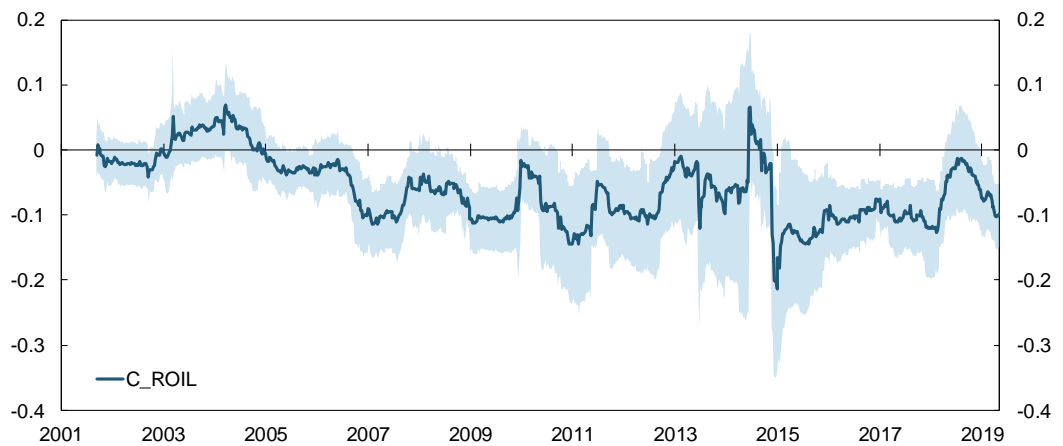
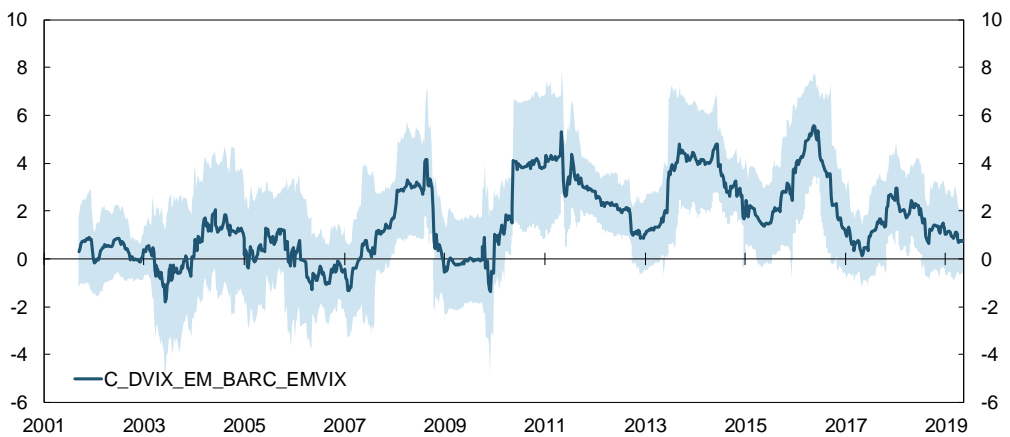*Notes:* The figure above shows rolling-window estimates of the coefficient ($\beta_{t,oil}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + u_t$, where window size is 52 weeks and step size is 1 week. Estimates from each roll are saved end-of-sample. The shaded light blue area corresponds approximately to a 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 13.05.2019.

Figure 4: Adjusted R^2 statistics, specification (2)
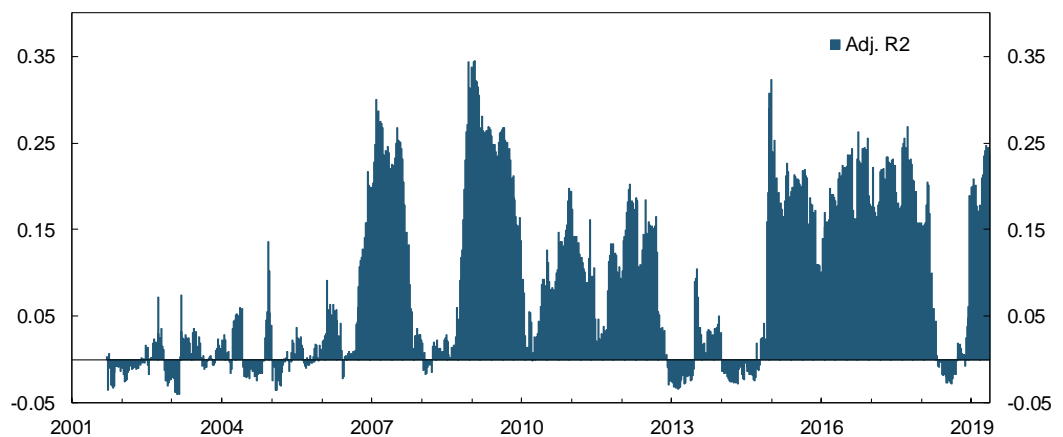
Notes: The figure above shows the adjusted R^2 statistics from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + u_t$, where window size is 52 weeks and step size is 1 week. Estimates from each roll are saved end-of-sample. The sample period is 18.09.2000 – 13.05.2019.

8.2 Volatility indices

Figures 5, 6 and 7 show estimates of rolling-window volatility impact coefficients corresponding to the three implied volatility indices. All three figures show coefficients which are often significantly positive, however, for some periods we find negative estimates as well, mostly before the year 2010. The finding of negative coefficients indicates that higher (lower) expected volatility corresponded with appreciation (depreciation) of the Norwegian krone. In contradiction with Flatner (2009), these results suggests that the Norwegian krone had characteristics that are attributed to safe haven currencies, in some periods of our data.

However, figures 5, 6 and 7 provide little consistent evidence that the Norwegian krone was in fact was a safe haven currency. Comparing the three figures, we only see significantly negative coefficients against JPMorgan Global FX Volatility Index, in the period between 2004 and 2006. All other negative coefficients are statistically insignificant and have moreover modest economic significance too.

In contrast, after the period of the financial crisis, we find almost no negative volatility impact coefficients. In fact, the three figures show positive coefficients which are often statistically and economically significant. These results suggest that the Norwegian krone is not a safe haven currency, but a risky asset, which is adversely affected by higher financial uncertainty and volatility.

Figure 5: Rolling-window coefficients, JPM Volatility Index (52 weeks)
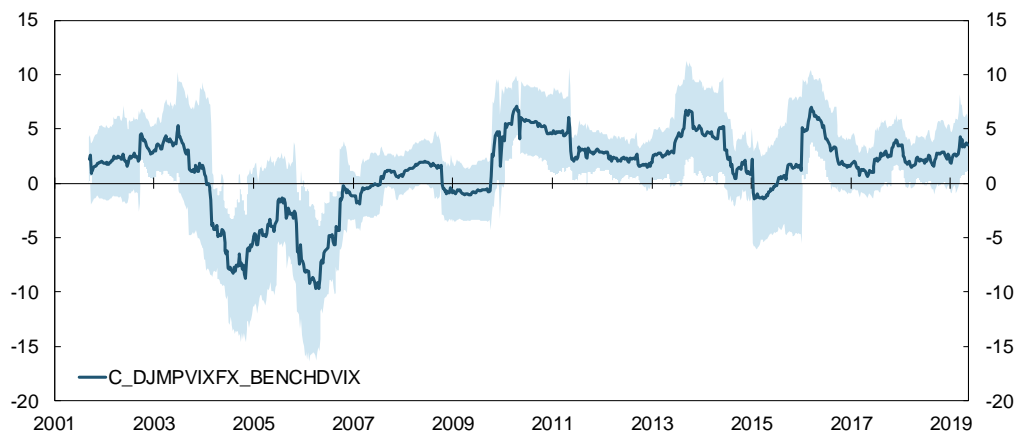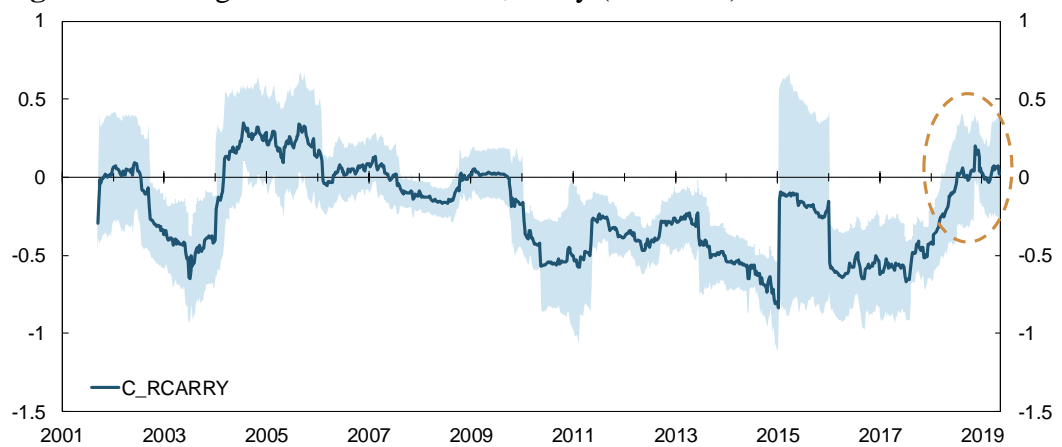

Notes: The figure above shows rolling-window estimates of the volatility impact coefficient ($\beta_{t,fxvix}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,fxvix}(fxvix_t) + u_t$, where $fxvix_t$ stands for JPMorgan's Global FX Volatility. The window size is 52 weeks and step size is 1 week. Estimates from each roll are saved end-of-sample. The shaded light blue area corresponds approximately to a 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 13.05.2019.

Figure 6: Rolling-window coefficients, VIX (52 weeks)
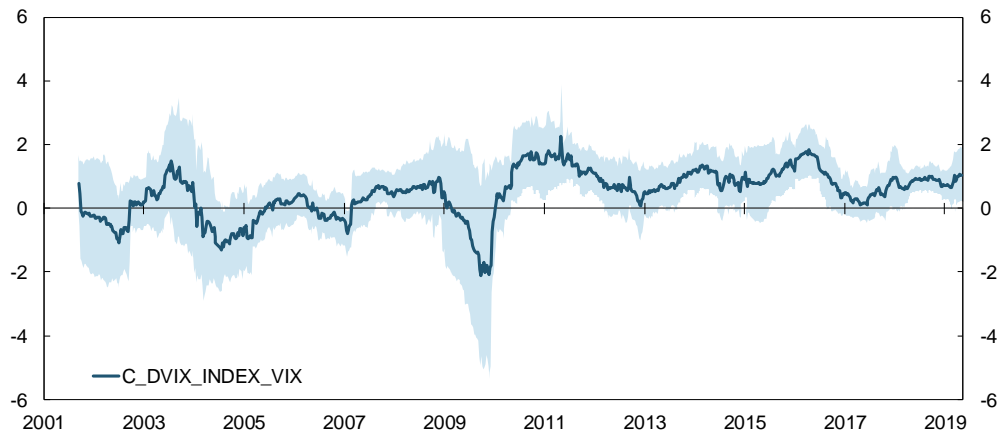
Notes: The figure above shows rolling-window estimates of the volatility impact coefficient ($\beta_{t,vix}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,emvix}(vix_t) + u_t$, where vix_t stands for CBOE's Volatility Index. The window size is 52 weeks and step size is 1 week. Estimates from each roll are saved end-of-sample. The shaded light blue area corresponds approximately to a 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 13.05.2019.

Figure 7: Rolling-window coefficients, Barclays Risk Index (52 weeks)
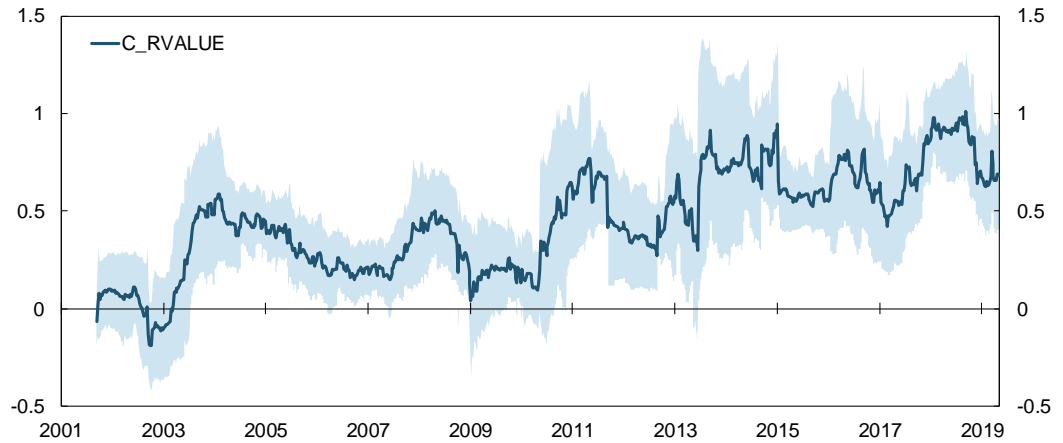

Notes: The figure above shows rolling-window estimates of the volatility impact coefficient ($\beta_{t,emvix}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,emvix}(emvix_t) + u_t$, where $emvix_t$ stands for Barclays Emerging Markets FX Risk Index. The window size is 52 weeks and step size is 1 week. Estimates from each roll are saved end-of-sample. The shaded light blue area corresponds approximately to a 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 13.05.2019.

8.3   Currency risk premia

Figure 8 shows that carry trade slope-factor coefficients were often significantly negative over the sample period, especially after 2010. These findings imply that NOK has mostly loaded positively on the slope-factor over time, suggesting that the krone was a high interest rate currency during these periods. The findings presented here affirm the previous, that the Norwegian krone appreciates when excess returns on carry are high and expected volatility is low, i.e., when there is more risk appetite among investors in financial and currency markets.

However, note that there are some periods when the Norwegian krone does not load on this slope-factor; for example, the last period which is marked in figure 8. We surmise that these results appear because it is unlikely that the Norwegian krone was allocated to the long portfolio of carry trade towards the end of our sample. The reason for this is that three other G10 currencies have had higher interest rates during this last period; these are the currencies of the United States, Canada and New Zealand (e.g., Lomholt, 2019). The Norwegian krone is unlikely to be influenced by carry trade at current interest rate levels since it is not allocated to the corner portfolios of this strategy (e.g., Lomholt, 2019; Skarsgård, 2019). Due to this, a slope-factor coefficient near zero is to be expected.

Figure 8: Rolling-window coefficients, Carry (52 weeks)

Notes: The figure above shows the rolling-window estimates of the slope-factor coefficient ($\beta_{t,car}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,car}(car_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019. The dashed orange oval marks the latest period, where the slope-factor coefficient is near zero.

In addition, notice that information from carry slope-factors frequently overlap with the information from implied volatility indices. This can for example be seen by comparing figures 5 and 8; estimates of negative carry slope-factors frequently coincide with positive volatility impact coefficients, and vice versa. In particular, note that the carry trade slope-coefficients are highly positive in the same period when JPMorgan's volatility impact coefficients are statistically negative. This additionally suggests that the Norwegian krone displayed characteristics attributed to safe haven currencies, in the period between 2004 and 2006.

Figure 9 shows that coefficients from rolling regressions on value are mostly significantly positive. When considering larger window-sizes, the estimates become more positively significant, see figures C15 and C16 in the appendix.
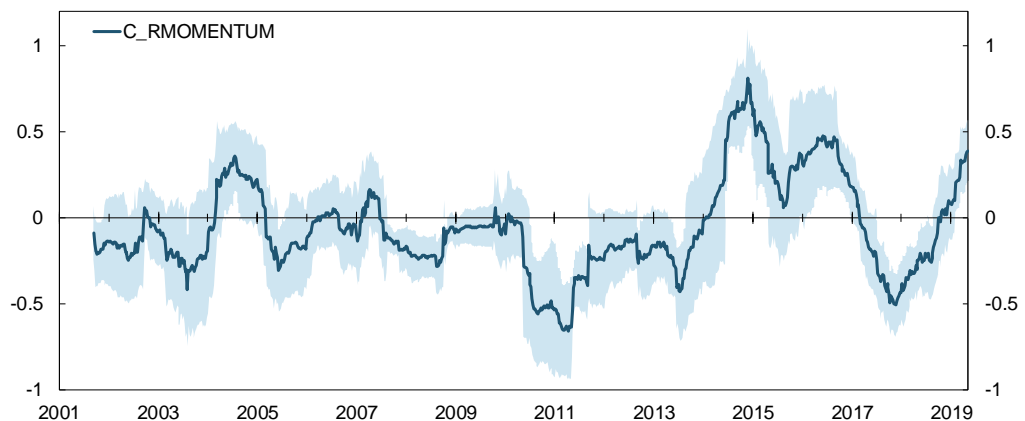
Figure 9: Rolling-window coefficients, Value (52 weeks)

Notes: The figure above shows rolling-window estimates of the slope coefficient ($\beta_{t,val}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,val}(val_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 13.05.2019.

Figure 10 shows that momentum's estimated coefficients are at times both highly statistically and economically significant. In addition, it is noticeable that these coefficients often switch signs. When considering larger window-sizes, the coefficients from regressions with windows of 260 weeks also switch signs, see figure C13. Only when we estimate regressions with a window-size of 520 weeks do we see that estimated coefficients are mostly negative; see figure C14. As evident by the slope coefficients and adjusted R^2 statistic (figure C20), momentum's explanatory power is ephemeral, appearing in some subsamples of the data.

Figure 10: Rolling-window coefficients, Momentum (52 weeks)

Notes: The figures below show rolling-window estimates of the slope coefficient ($\beta_{t,mom}$) from the rolling regression $s_t = \alpha_t + \beta_{t,rdiff}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,mom}(mom_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 13.05.2019.

9. Conclusion

In this thesis, we have studied which factors determine the movements in the Norwegian exchange rate (i.e., depreciation rate) at the weekly frequency. In particular, we examined the importance of 1) interest rates, 2) oil prices, 3) implied volatility indices, and 4) excess returns on three well diversified forex investment strategies; carry trade, value and momentum. In general, our findings show the existence of relations at the weekly frequency between the EURNOK deprecation rate and 1) oil prices, 2) implied volatility indices, and 3) the carry trade and value risk factors.

Consistent with earlier studies, we find that interest rates account for little of the variation in the depreciation rate, while in contrast, oil prices have periodically high explanatory power.

Further, our findings suggest that the Norwegian krone is adversely affected by international financial volatility and uncertainty, as proxied by the implied volatility indices. However, we do identify a period when the opposite seems to hold; the Norwegian krone displayed characteristics attributed to safe haven currencies especially in the period around the years 2004 and 2006.

In particular, we find that Barclays Emerging Markets FX Risk Index conveys marginally better information for the variation in the depreciation rate, relative to VIX or JPMorgan Global FX Volatility Index, possibly due to this index containing information more relevant for commodity exporting currencies.

Concerning the FX investments strategies, we find that the carry trade and value factors are consistent in explaining variations in the EURNOK depreciation rate, above that conveyed by the implied volatility indices and oil prices, while momentum's explanatory power is ephemeral, appearing only in some subsamples of the data.

Moreover, we find that the Norwegian krone covaries positively with carry trade (i.e., is a risky currency). In our data, we find that the Norwegian krone often appreciates during times of low global uncertainty, when there is more risk appetite among investors in financial and currency markets. In addition, the rolling regressions suggest that for the last period in our data, NOK was likely not affected by carry trade. This implies that no price impact arises from this forex investment strategy for the Norwegian krone, at current interest rate levels.

Overall, our findings suggest that the Norwegian krone is exposed to global risks, proxied by both the implied volatility indices and carry trade factor. In contrast, the Norwegian krone is not exposed to currency-specific risks, as proxied by momentum. Further, NOK has a risk discount as proxied by value, possible because Norway is not a country with high inflation relative to the U.S. Moreover, our findings suggest that the Norwegian krone has, besides with oil prices, relations to risk premia proxied by the implied volatility indices and excess returns on carry trade and value, demonstrating that these additional variables have explanatory power for variations in the EURNOK depreciation rate. Lastly, the implied volatility indices and carry trade factor convey similar information; however, specifications with the latter are superior. This finding is relevant for practitioners because it identifies an easily available variable which is a relatively better proxy than the more widely used implied volatility indices.

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Appendix A. – Theory

This appendix provides a review of theory related to Uncovered Interest Rate Parity and Purchasing Power Parity. Both of these theories are based on no-arbitrage conditions and assume that agents are homogenous, have full information, and that spot exchange prices are determined in equilibrium. However, one important difference among the theories is that PPP is based on trade of goods, while UIP are based on capital flows between countries.

A1. Review of Uncovered Interest Rate Parity

The following explanation is based on Burnside (2018). Suppose that the interest rate in the home country, which in this case is Norway, is given by i_t for a NOK denominate deposit from period t until period $t + 1$. Furthermore, suppose that the foreign interest rate (for example in the Euro Area) is given by i_t^* for a EURO denominated deposit between t and $t + 1$. Investing 1 NOK in Norway would give an investor a gross return of $1 + i_t$. Alternatively, the same investor could convert the 1 NOK into $1/S_t$ euros, where S_t represents the spot exchange rate at period t expressed as NOK per EUR. By doing so and investing these euros for one period in the EU an investor will earn a gross return of $1 + i_t^*$. After exchanging back the euros into NOK at the future spot rate S_{t+1} the investor will be left with a gross return of $S_{t+1}(1 + i_t^*)/S_t$. If investors are rational and risk neutral, the expected returns on these two alternative investments should be the same when expressed in a common currency. Given investors' expectations at time t we have that the no-arbitrage condition is:

$$1 + i_t = E_t \left[(1 + i_t^*) \frac{S_{t+1}}{S_t} \right] \tag{1}$$

Equation (1) states the UIP no-arbitrage condition mathematically. For the equality to hold, any changes to the interest rate i_t by Norges Bank will need to be offset by a change in the spot exchange rate S_t assuming that i_t^* and $E_t(S_{t+1})$ are left unaffected. For the equality in equation (1) to hold, an increase in i_t demands a appreciation of NOK relative to EUR (lower S_t), and respectively, a decrease of i_t would demand an depreciation of NOK relative to the euro (higher S_t),.

Alternatively, an investor could sell EUR forward for NOK at the forward rate F_t. Doing so he is certain to receive a gross NOK return of $F_t(1 + i_t^*)/S_t$. Substituting S_{t+1} in equation (1) with F_t we get the *covered interest rate parity* (CIP) no-arbitrage condition:

$$1 + i_t = (1 + i_t^*)\frac{F}{S_t} \tag{2}$$

Equations (1) and (2) are equal when the forward rate is an unbiased predictor of the future spot rate, meaning: $F_t = E_t[S_{t+1}]$

This means that if UIP and CIP hold, we can simply use the forward rates which are traded in the market as predictors of the future sport rates. Empirically, UIP has been shown not to hold and this literature together with the corresponding "forward premium puzzle" has been surveyed by for example Hodrick (1987), Froot and Thaler (1990), Engel (1996, 2014) and Sarno (2005).

A2. Review of Purchasing Power Parity

The following explanation is based on pages 101 – 110 from Levi (2009). According to the Purchasing power parity (PPP), exchange rates adjust so that a country's currency has the same purchasing power both home and abroad if frictions (transportation costs, sale restrictions, etc.) do not exist. This is because consumers otherwise can earn a riskless profit from arbitrage trades between the countries. The role of the exchange rate is thus to eliminate arbitrage opportunities between similar consumption goods across countries, yielding the following relationship:

$$P^H * S = P^F \leftrightarrow S(F/H) = \frac{P^F}{P^H}$$

Where S is the spot exchange rate, P^H is the price level of consumption basket in home country and P^F is the price level of consumption basket in foreign country. The spot exchange rate is fairly valued when the above equation is satisfied. In reality however, PPP will not hold exactly because of the existence of market imperfections.

The real exchange rate (RER) is closely connected to PPP and regarded as a common measure of currency intrinsic value. RER can be defined in the following way:

$$Q_t = \frac{P_t}{S_t P_t^*}$$

Where Q is the RER at time t, S denotes to the nominal exchange rate measured in home currency per unit of foreign, and P denotes to price levels in home and foreign (*) countries. A fairly valued currency will have its RER equaling one. Any movements away from unity capture the deviation of a currency's value consistent with PPP.

Appendix B. - Tables

Table B1: Big Mac Index

Year	Top 3 overvalued countries	NOK overvaluation
2019	1) Switzerland 2) **Norway** 3) Sweden	5 %
2018	1) Switzerland 2) **Norway** 3) Sweden	18.2 %
2017	1) Switzerland 2) **Norway** 3) Sweden	12 %
2016	1) Switzerland 2) Sweden 3) **Norway**	5.8 %
2015	1) Switzerland 2) **Norway** 3) Denmark	31.5 %
2014	1) **Norway** 2) Switzerland 3) Sweden	68.6 %
2013	1) **Norway** 2) Switzerland 3) Sweden	79.6 %
2012	1) Switzerland 2) **Norway** 3) Sweden	61.7 %
2011	1) **Norway** 2) Switzerland 3) Sweden	104.5 %
2010	1) **Norway** 2) Switzerland 3) Denmark	96.2 %
2009	1) **Norway** 2) Switzerland 3) Denmark	72.1 %
2008	1) **Norway** 2) Sweden 3) Switzerland	120.6 %
2007	1) **Norway** 2) Switzerland 3) Denmark	111.2 %
2006	1) **Norway** 2) Switzerland 3) Denmark	127.3 %
2005	1) **Norway** 2) Switzerland 3) Denmark	98.1 %
2004	1) **Norway** 2) Switzerland 3) Denmark	78.7 %

Notes: This table shows the top three overvalued currencies each year according to the Big Mac Index during the past 15 years, constructed by The Economist. Even though the Big Mac Index is not meant as an exact science, it may gauge general perceptions about currency valuation. USD is always used as the base currency, thus under- and overvaluation is relative to USD. The third column shows the degree of overvaluation of NOK versus USD.

The raw data is extracted from the following website:
https://www.economist.com/news/2019/01/10/the-big-mac-index

Appendix C. - Figures

Figure C1: Implied volatility indexes
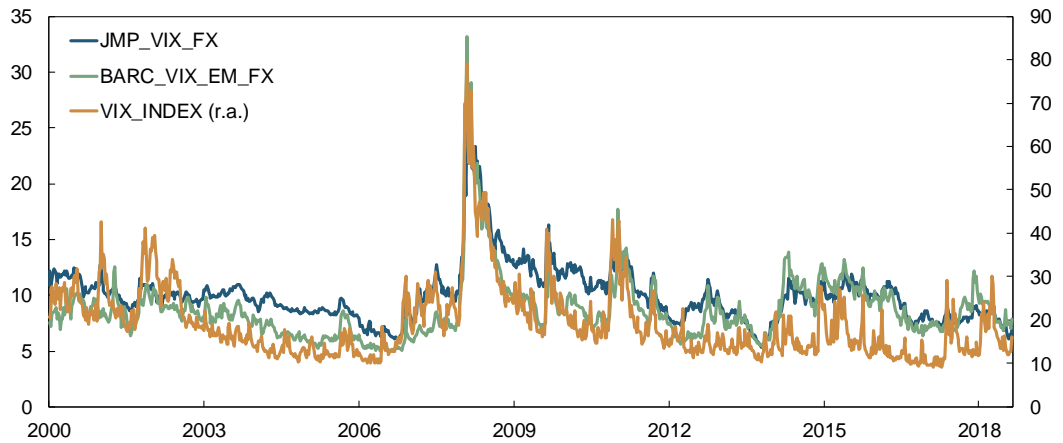
Notes: The figure above plots the development of CBOE's Volatility Index (right axis), JPMorgan's Global FX Volatility Index, and Barclays Emerging Markets FX Risk Index. The data is sampled weekly from 18.09.2000 to 13.05.2019.

Figure C2: Implied volatility and EURNOK
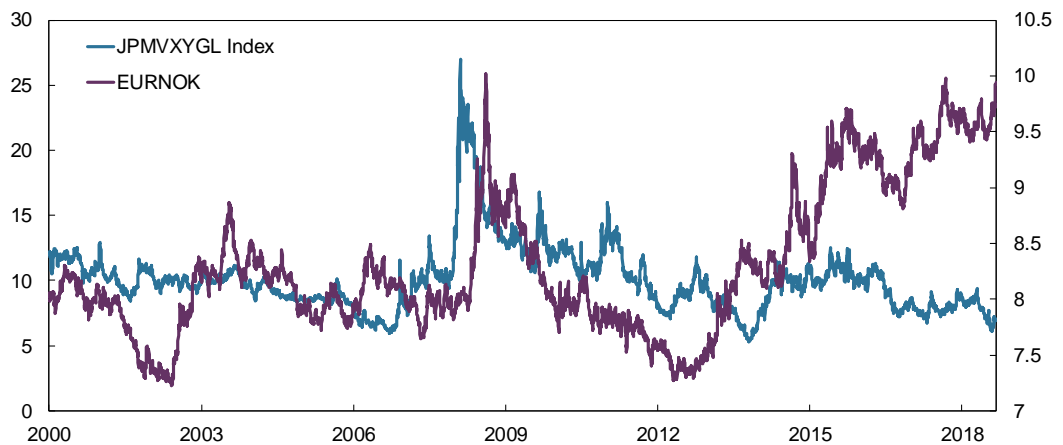
Notes: The figure above shows the development of EURNOK spot exchange rate (right axis) and JPMorgan's Global FX Volatility Index (left axis). Sample period is 18.09.2000 – 17.05.2019.

Figure C3: Carry index and EURNOK
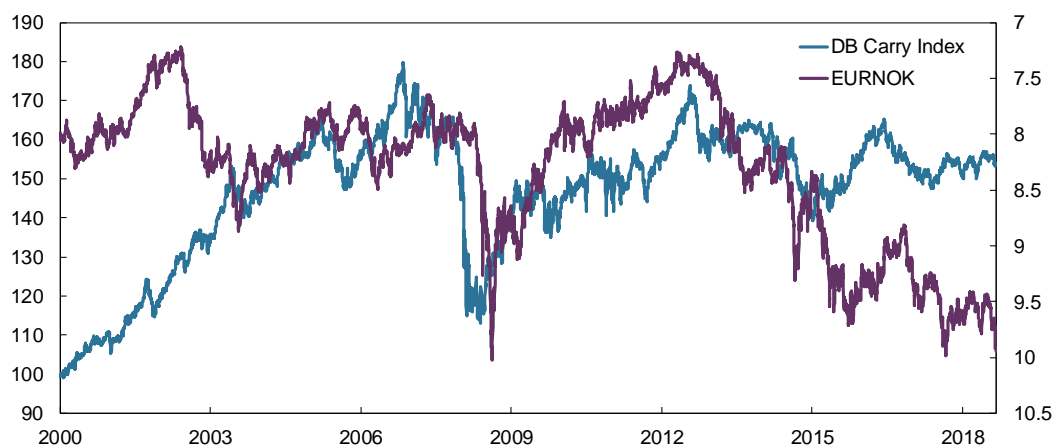
Notes: The figure above shows the development of EURNOK spot exchange rate (right axis, inverted) and Deutsche Bank's G10 Carry Index (left axis). Sample period is 18.09.2000 – 17.05.2019.

Figure C4: Value index and EURNOK
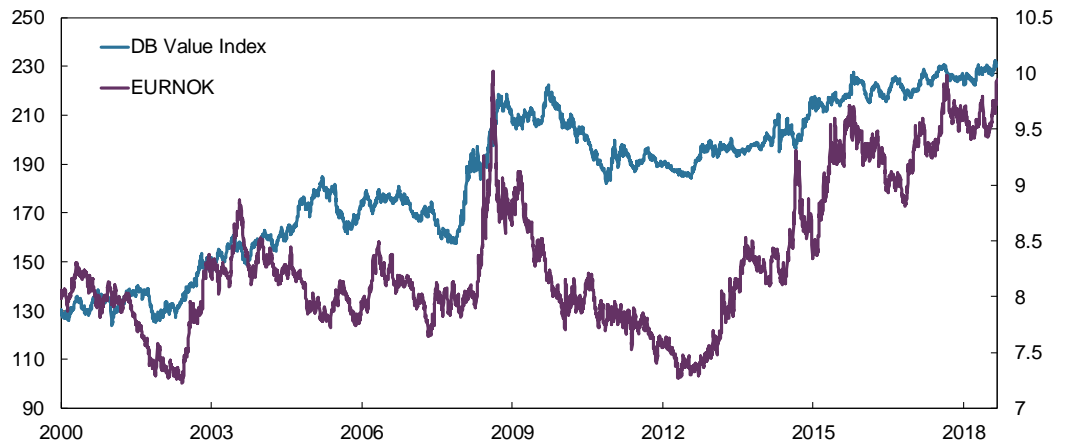
Notes: The figure above shows the development of EURNOK spot exchange rate (right axis) and Deutsche Bank's G10 Value Index (left axis). Sample period is 18.09.2000 – 17.05.2019.

Figure C5: Momentum index and EURNOK
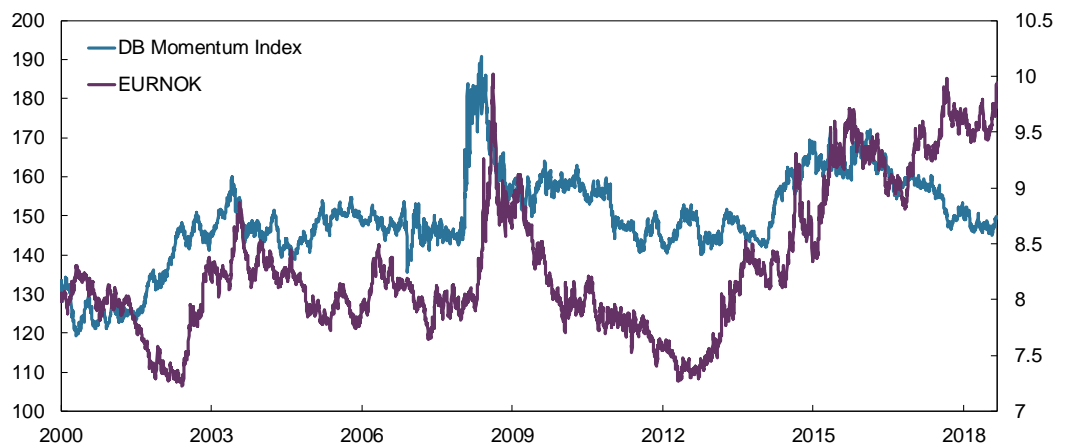
Notes: The figure above shows the development of EURNOK spot exchange rate (right axis) and Deutsche Bank's G10 Momentum Index (left axis). Sample period is 18.09.2000 – 17.05.2019.

Figure C6: Rdiff and EURNOK
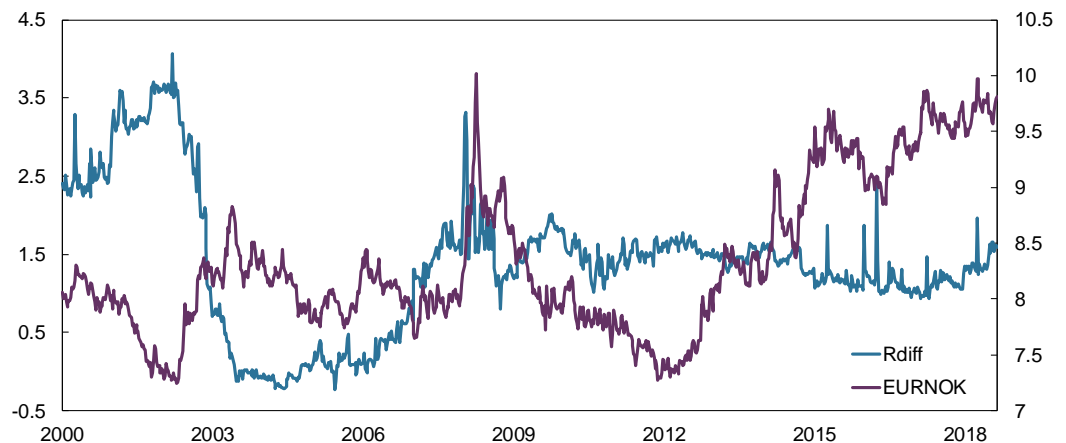
Notes: The figure above shows the development of EURNOK spot exchange rate (right axis) and one-week interest rate differential between Norway and the Euro area (left axis, in percent). Sample period is 18.09.2000 – 17.05.2019.

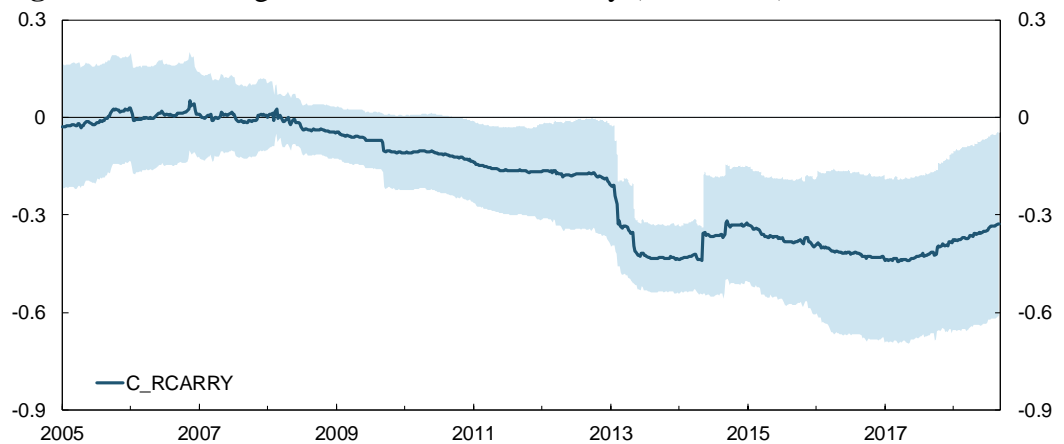**Figure C7:** Rolling-window coefficients, rdiff (260 weeks)
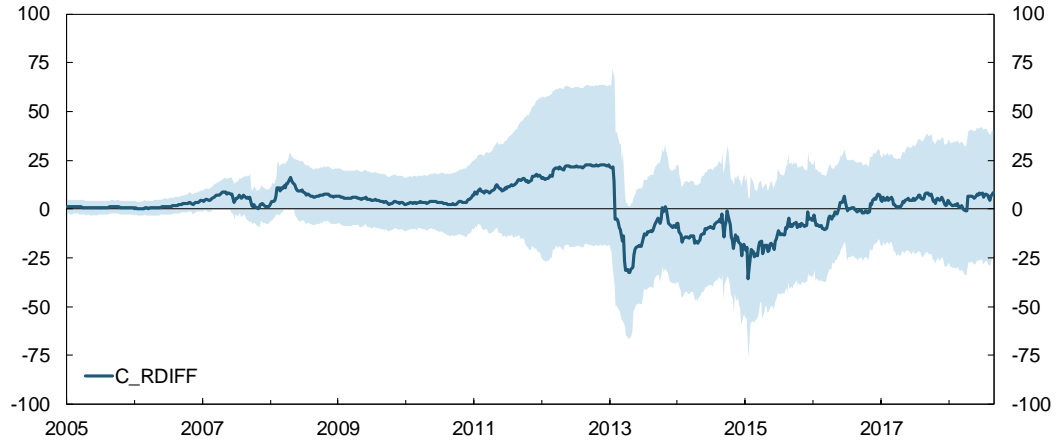
Notes: The figure above shows rolling-window estimates of the slope coefficient ($\beta_{t,uip}$) from the rolling regression $s_t = \alpha_t + \beta_{t,uip}(i_t^{NO} - i_t^{EU}) + u_t$, where window size is 260 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

Figure C8: Rolling-window coefficients, rdiff (520 weeks)
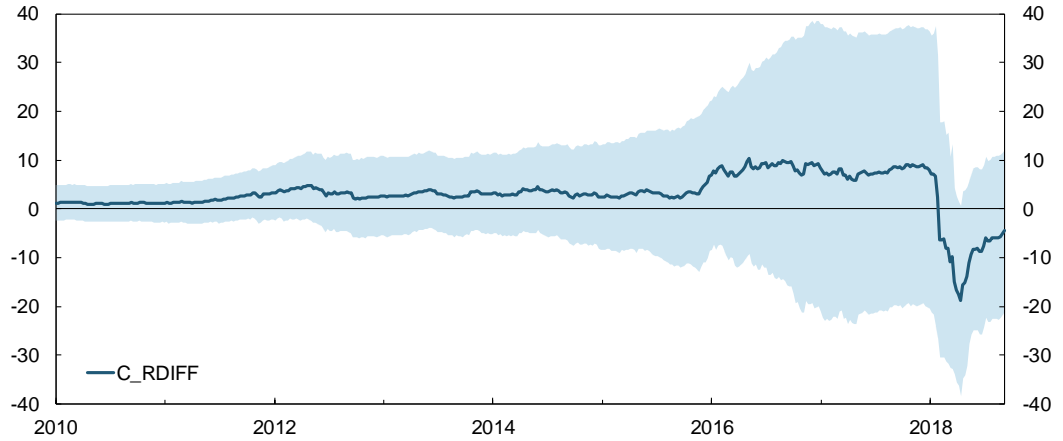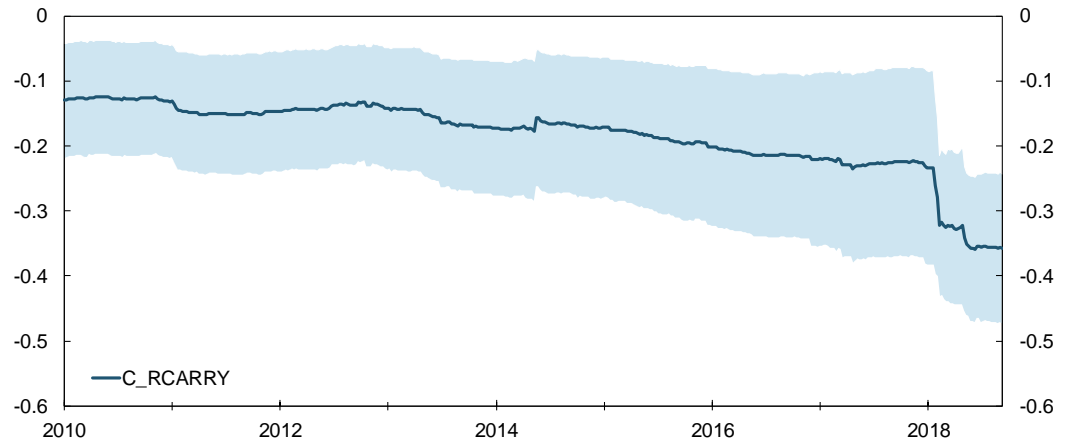

Notes: The figure above shows rolling-window estimates of the slope coefficient ($\beta_{t,uip}$) from the rolling regression $s_t = \alpha_t + \beta_{t,uip}(i_t^{NO} - i_t^{EU}) + u_t$, where window size is 520 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

Figure C9: Rolling-window coefficients, oil price (260 weeks)
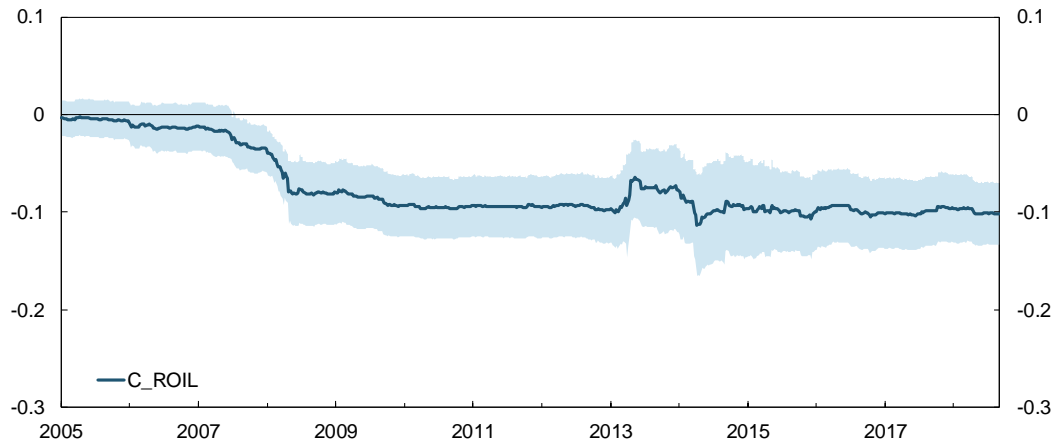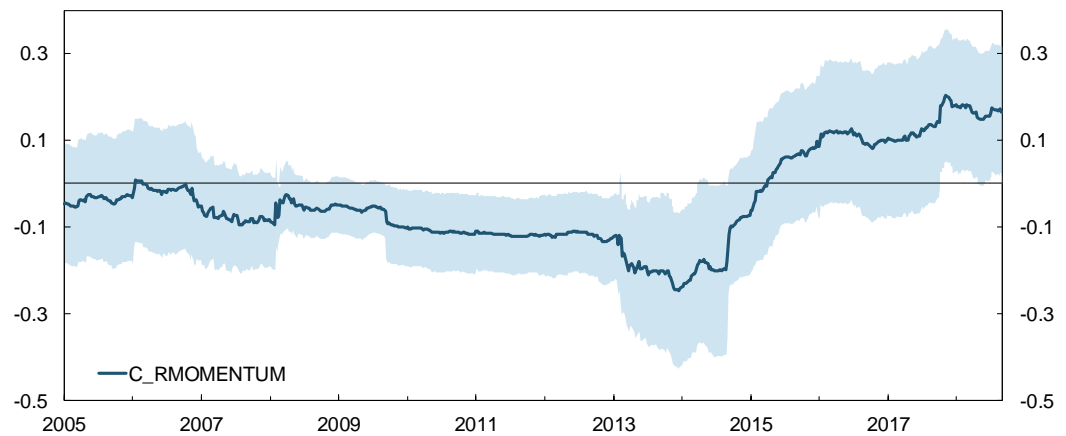

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Notes: The figure above shows rolling-window estimates of the slope coefficient $(\beta_{t,oil})$ from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + u_t$, where window size is 260 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

Figure C10: Rolling-window coefficients, oil price (520 weeks)
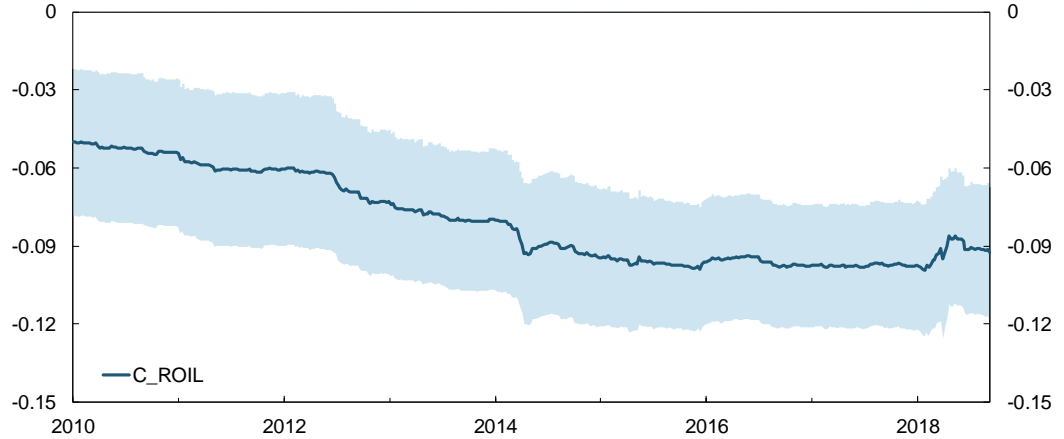
Notes: The figure above shows rolling-window estimates of the slope coefficient $(\beta_{t,oil})$ from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + u_t$, where window size is 520 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

Figure C11: Rolling-window coefficients, carry (260 weeks)
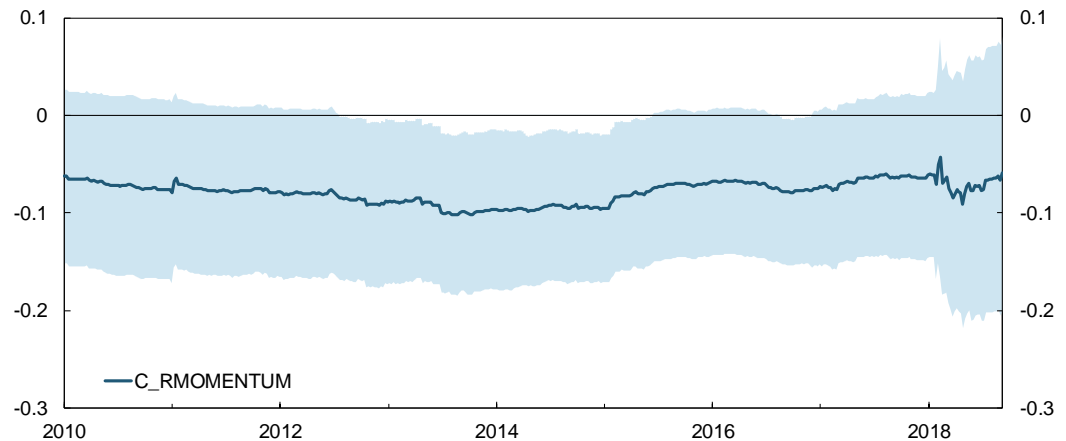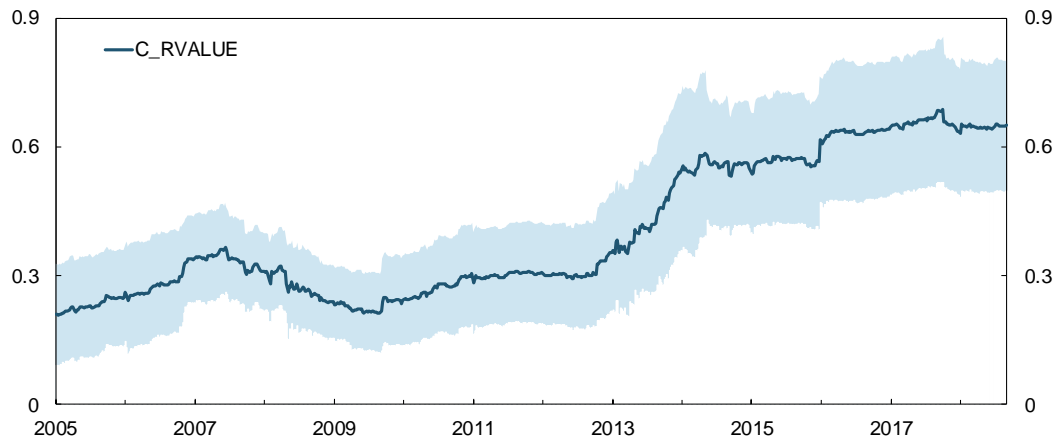

Notes: The figure above shows rolling-window estimates of the coefficient $(\beta_{t,car})$ from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,car}(car_t) + u_t$, where window size is 260 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\,SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

Figure C12: Rolling-window coefficients, carry (520 weeks)

Notes: The figure above shows rolling-window estimates of the coefficient ($\beta_{t,car}$) from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,car}(car_t) + u_t$, where window size is 520 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

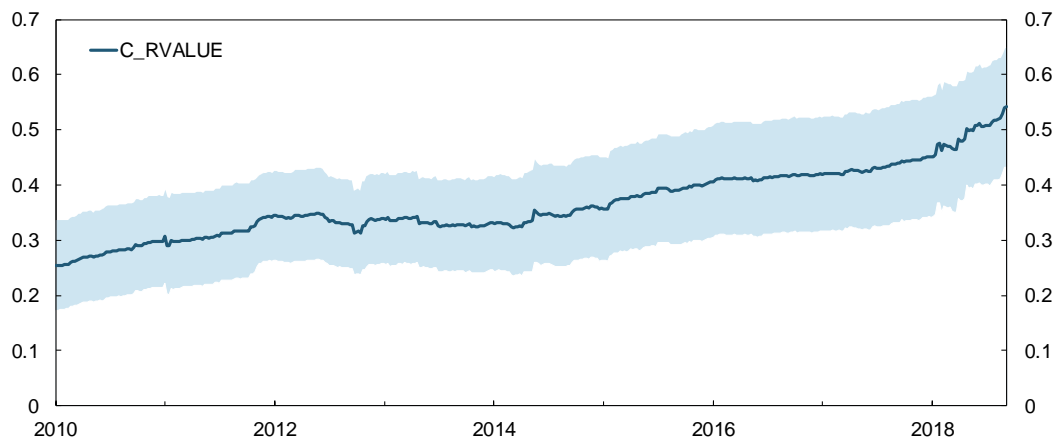**Figure C13:** Rolling-window coefficients, momentum (260 weeks)

Notes: The figure above shows rolling-window estimates of the coefficient ($\beta_{t,mom}$) from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,mom}(mom_t) + u_t$, where window size is 260 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

**Figure C14:** Rolling-window coefficients, momentum (520 weeks)

Notes: The figure above shows rolling-window estimates of the coefficient $(\beta_{t,mom})$ from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,mom}(mom_t) + u_t$, where window size is 520 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

**Figure C15:** Rolling-window coefficients, value (260 weeks)

Notes: The figure above shows rolling-window estimates of the coefficient $(\beta_{t,val})$ from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,val}(val_t) + u_t$, where window size is 260 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

Figure C16: Rolling-window coefficients, value (520 weeks)

Notes: The figure above shows rolling-window estimates of the coefficient $(\beta_{t,val})$ from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,val}(val_t) + u_t$, where window size is 520 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. The shaded light blue area corresponds approximately to 95% confidence interval constructed with $\pm 2\ SE$ estimated according to Newey and West (1987). Sample period is 18.09.2000 – 17.05.2019.

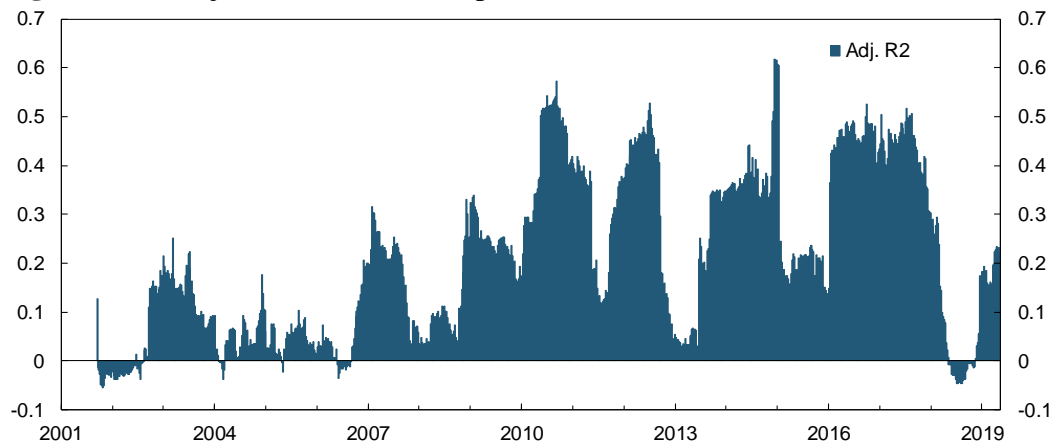**Figure C17:** Adjusted R^2 statistics, specification (1)
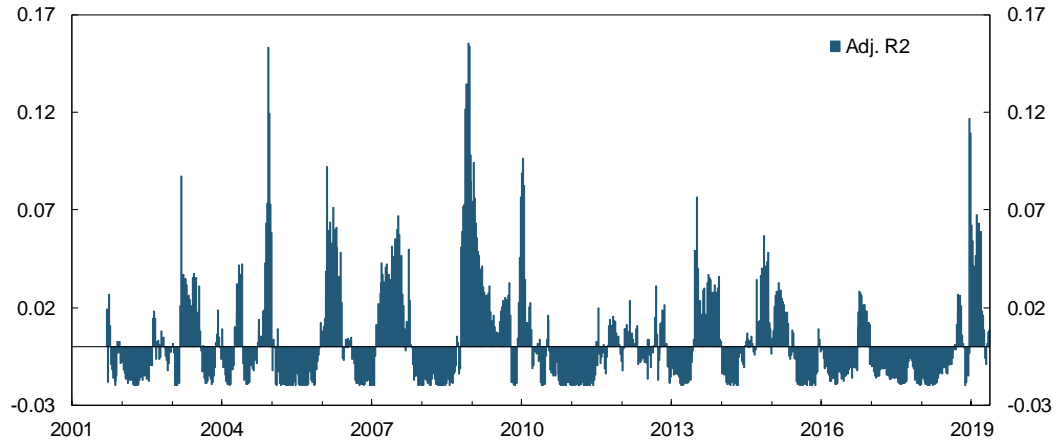
Notes: The figure above shows adjusted R^2 from the rolling regression $s_t = \alpha_t + \beta_{t,uip}(i_t^{NO} - i_t^{EU}) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. Sample period is 18.09.2000 – 17.05.2019.

Figure C18: Adjusted R^2 statistics, specification (3)
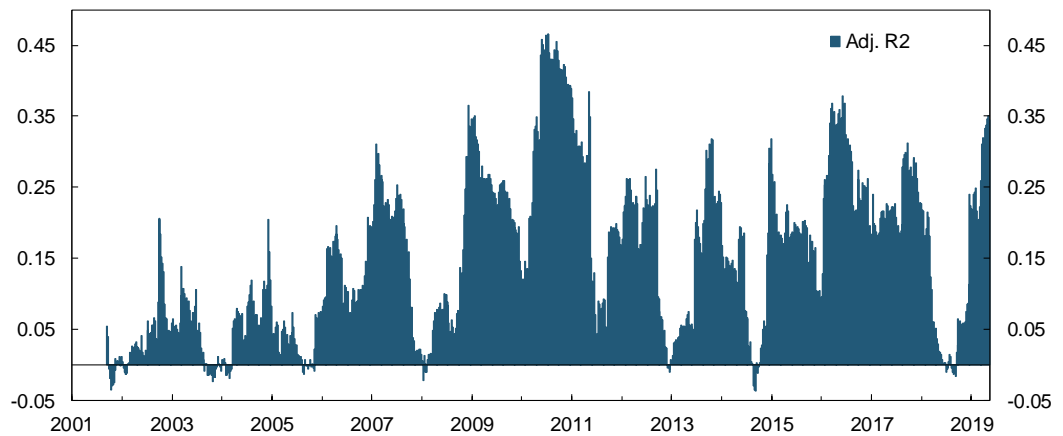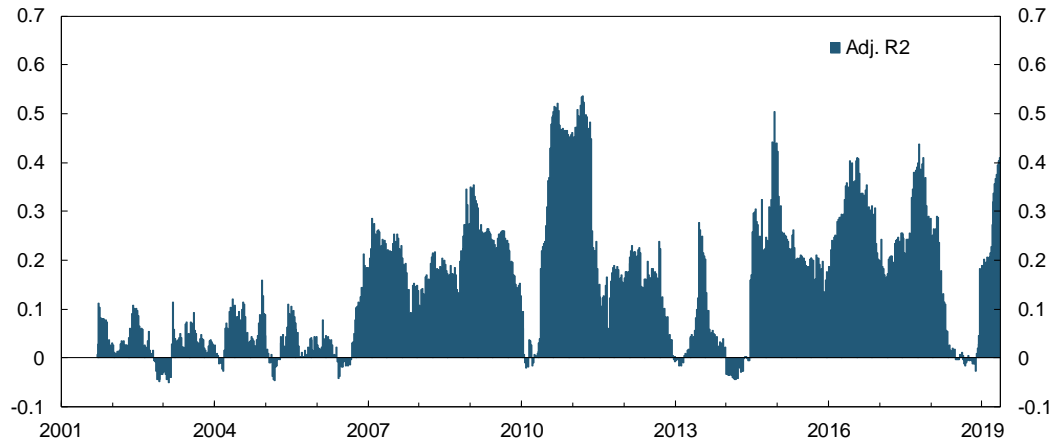

Notes: The figure above shows adjusted R^2 from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,vix}(fxvix_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. Sample period is 18.09.2000 – 17.05.2019.

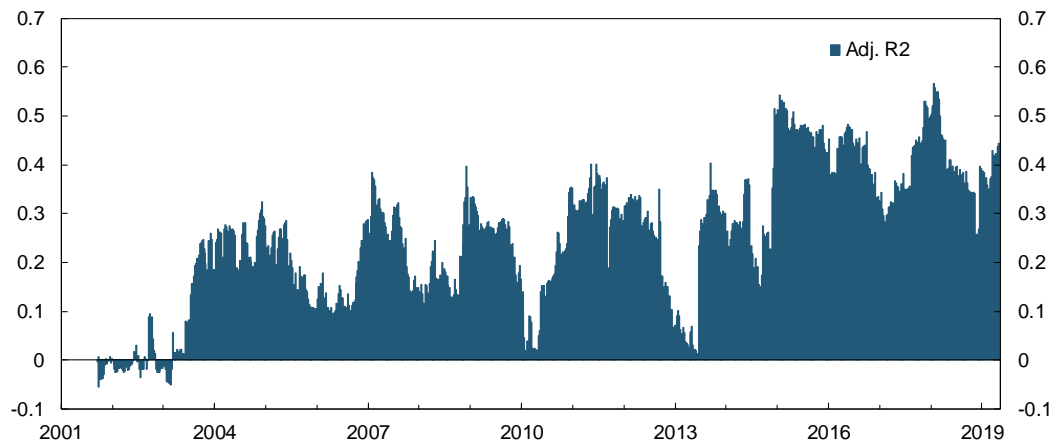**Figure C19:** Adjusted R^2 statistics, specification (6)

Notes: The figure above shows adjusted R^2 from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,car}(car_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. Sample period is 18.09.2000 – 17.05.2019.

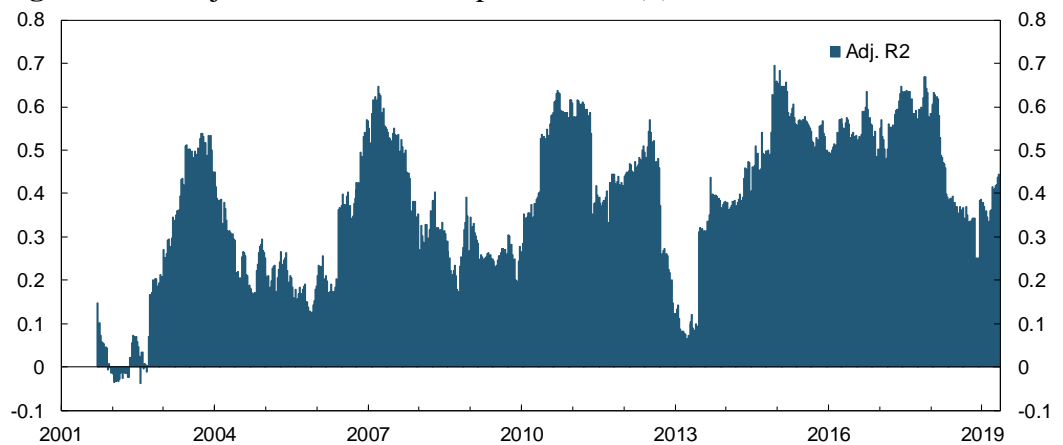**Figure C20:** Adjusted R^2 statistics, specification (8)

Notes: The figure above shows adjusted R^2 from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,mom}(mom_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. Sample period is 18.09.2000 – 17.05.2019.

Figure C21: Adjusted R^2 statistics, specification (7)

Notes: The figure above shows adjusted R^2 from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,val}(val_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. Sample period is 18.09.2000 – 17.05.2019.

Figure C22: Adjusted R^2 statistics, specification (9)

Notes: The figure above shows adjusted R^2 from the rolling regression $s_t = \alpha_t + \beta_{t,1}(i_t^{NO} - i_t^{EU}) + \beta_{t,oil}(oil_t) + \beta_{t,car}(car_t) + \beta_{t,mom}(mom_t) + \beta_{t,val}(val_t) + u_t$, where window size is 52 weeks and step size is 1 week. For each roll, estimates are saved end-of-sample. Sample period is 18.09.2000 – 17.05.2019