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A contemporary study of safe haven currencies

By

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Written within the specialization area financial economics,
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Abstract

This thesis provides contemporary insight into the safe haven phenomenon. We separately examine three characteristic periods; the years 2001 to 2007, 2007 to 2010, and 2010 to 2016. Our focus is to examine currency portfolio rebalancing in times of increased risk aversion and identify any periodical changes in behavior pre and post financial crisis.

Using an autoregressive distributed lag (ADL) model, we study the high-frequency movements of eight nominal effective exchange rates against three measures of risk aversion. The purpose of the ADL model is to examine the safe haven behavior on an average basis. We later expand this baseline model to an interactive dummy model, which allows us to explore the more conditional behavior during crisis episodes. To the best of our knowledge, the literature has yet to explore this topic in a similar fashion, especially for the recent years 2010 to 2016.

We document that the Japanese Yen (JPY), Swiss Franc (CHF) and U.S. Dollar (USD) tend to appreciate when there is an increase in *i)* stock volatility; *ii)* forex volatility; *iii)* composite financial volatility. In recent years, the JPY shows significantly stronger safe haven tendencies, whereas the CHF portrays weaker properties post financial crisis. The USD has experienced a noteworthy shift in status, and shows strong signs of being a safe haven currency post financial crisis compared to the years 2001 to 2007, where it behaved more pro-cyclically with financial markets.

The New Zealand Dollar (NZD) and Australian Dollar (AUD) tend to depreciate when risk aversion increases. Here, the AUD shows stronger non safe haven tendencies than the NZD. Interestingly, the Norwegian Krone (NOK) shows relatively stronger non safe haven tendencies for the recent period 2010 to 2016. On the other hand, results for the Euro (EUR) and British Pound (GBP) are overall inconclusive.

We also identify a tendency of stronger quantitative impacts of the JPY during risk episodes compared to ordinary days. The safe haven phenomenon is however not contingent upon these specific episodes. On average, the quantitative impacts and explanatory powers are at their highest for all findings during the years of the financial crisis, 2007 to 2010. Furthermore, the years 2010 to 2016 show far more powerful safe haven flows than 2001 to 2007.

Foreword

This thesis represents the end of our M.Sc. studies in financial economics at the Norwegian School of Economics (NHH).

The theme of this thesis is motivated by the authors' mutual interest in financial markets, risk aversion, and business cycle analysis. The specific choice of investigating safe haven currencies has been influenced by courses and topics that appealed to our empirical curiosity. Furthermore, the scarcity of research on the safe haven phenomenon in the literature motivated us to contribute with contemporary insight.

The research process has been demanding. First, there is relatively little established empirical and theoretical foundation on the topic. This made it difficult to gather a broad base of relevant literature. Second, the methodological approach was initially hard to pin down, and to some degree based on trial and error and continuous improvements. Given the magnitude of variables we have chosen to investigate, we have run hundreds of regressions and diagnostics. This has been extremely time consuming, yet rewarding.

The data gathering process has as well been challenging. This included choosing the most robust option among data alternatives and synchronizing all the daily data to ensure coherent regression analysis and validity. This challenge was however alleviated by access to legitimate and reliable data sources through terminals at NHH.

Working with the thesis has been educational and interesting. It has prompted us to apply our theoretical knowledge from NHH, work closely as a team, and efficiently employ our individual strengths. We have also learned to independently resolve complex problems where the right choice is far from obvious. Progress has therefore at times demanded tough decisions and trade-offs. In total, our experiences and new insight into the mechanics of currency markets gained from producing this thesis will be highly valuable for our future professional careers.

Acknowledgement

We wish to express our gratitude to Professor Jan Tore Klovland for inspiring us in the choice of topic through his many interesting M.Sc. courses at NHH. Our meetings throughout the research process have been both productive and helpful. His knowledge on the topic and overall feedback has been instrumental. We also want to thank Professor Gernot Doppelhofer, who helped us during the initial stages of the research process. His critical questions regarding our methodology helped us specify our baseline model and make progress early on. Any mistakes and inadvertences are the result of our own doing.

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1. Introduction

The extent of empirical research on "safe haven" currencies is remarkably scarce, particularly when considering the frequent media coverage this topic receives in the financial press. The past decade's increase in economic, environmental, geopolitical, technological and societal risk factors, epitomized by incidents such as the recent financial crisis, the sovereign debt crisis, the slow-down of the Chinese economy, the structural crisis and price shock in the oil and gas sector, as well as the large-scale unrest in the Middle East, has made discussions around safe haven assets even more relevant. Global risk factors are believed to have a significant impact on risk aversion among market participants. In times of market stress, risk aversion increases, and participants tend to rebalance their portfolios towards "safe haven" assets.

The study of carry trade strategies, contrary to safe haven studies, is relatively more well-established in terms of empirical research. These studies largely show that returns on low-yield interest rates tend to be negatively correlated with global risk aversion, while returns on high-yield interest rates tend to be positively correlated with increases in global risk aversion (Brunnermeier, Nagel, & Pedersen, 2008). This shows a systematic deviation from the Uncovered Interest Parity (UIP) theory, as low-yield interest rate currencies under-perform in bull markets when perceived risk is low, while over-performing in bear markets when perceived risk is high. However, this leads to the misconception that empirical regularity of carry trade properties is identical to safe haven properties. As Habib & Stracca (2011) point out in their study; *"the two concepts overlap only insofar as, and to the extent which, traders pursue carry trade strategies"*.

There are several definitions of a "safe haven" asset in the literature. The most prevailing definition, in our opinion, is formulated by Ranaldo & Söderlind (2007). In their research paper, a safe haven currency is defined as an asset that is generally characterized by a negative risk premium. The reason why we consider this definition to be most prevailing, is because it covers both the *traditional meaning* of a safe haven currency – i.e. the unconditional lack of or negative correlation with its reference asset, and the more *rigorous meaning* – i.e. the lack of or negative correlation conditional on losses in the reference portfolio. In other words, a safe haven currency is defined as an asset that either provides benefits on average or in times of particular stress.

This paper will investigate the relationship between short term currency movements and increased volatility in three global risk indicators; the Chicago Board Volatility Index (VIX), the Global Risk Index (GRI), and the Macro Risk Indicator (MRI). We will focus on understanding the daily short run movements of exchange rates, rather than the long term movements. Our independent variables, VIX, GRI and MRI, have therefore been chosen based on a focus on financial factors rather than macro factors such as interest rates, inflation, income growth and money supply. The availability of high-frequency macro data is limited, and even if this existed, a vast majority of empirical studies have shown that macroeconomic fundamentals are not well-equipped to explain the short term movements in exchange rates.

An emerging literature argues that deviations from UIP can be rationalized by the covariation of exchange rate changes with risk factors. Hence, through our three global risk indicators, we want to thoroughly investigate and quantify these deviations in relation to the safe haven phenomenon.

1.1 Contribution to the literature

In contrast to existing literature, our study will include recent periods and risk episodes that have not been thoroughly examined yet, especially the period after the financial crisis, and in particular the years 2012-2016. In addition, our focus is on global risk indicators rather than returns on assets such as equity and bonds, albeit we believe these to be strongly inter-connected. Furthermore, our study has a particular emphasis on the impact of the financial crisis, and whether this has caused recent safe haven tendencies to deviate from what previous research has shown.

Additionally, we will use Nominal Effective Exchange Rates (NEER) as our dependent variables, instead of a set of currencies against a base currency which has been the norm in previous research. The justification for choosing NEER is mainly twofold. First, it is related to the problem certain researchers have encountered while using the USD as a base currency. In some of the findings, they questioned whether it was the dollar, rather than its counter currency, that determined the results. Second, Flatner (2009) and other research articles have suggested that the USD may have experienced significant change in safe haven properties during the past decade, which also may disturb our results. Hence, by applying NEER, we eliminate such disturbances caused by the USD or other major currencies that are usually eligible for being a base currency.

1.2 Research Question

Our paper will mainly address two questions; first, which currencies can be considered as safe haven assets in our sample period, and second, has safe haven behavior changed after the financial crisis. In answering these two questions, we also intend to capture what is considered to be two important safe haven drivers. First, we want to capture the unconditional slow-moving currency effects of gradual erosions of risk willingness. Second, we want to capture the conditional and potentially fast-moving currency effects of risk episodes that are extreme and sudden.

In summary, the main questions this thesis seeks to answer can be outlined in the following research question (RQ) and two sub-research questions (SRQ):

RQ: Which currencies can be regarded as safe haven or non safe haven assets in the period 2001-2016?

- **SRQ #1:** Has the financial crisis or other recent developments in the world economy and financial markets caused a shift in safe haven behavior?
- **SRQ #2:** Is the behavior stronger during episodes of extreme and sudden risk compared to the behavior on an average basis?

Our study will focus on three periods within the sample data. First, we will investigate the period 02.01.2001 – 29.12.2006. Relative to the other periods we are examining, we expect this to be a period of stability in terms of safe haven behavior, and we expect that our findings will align with previous research on the same period. Second, we will study the erratic period 02.01.2007 – 31.12.2009, to isolate any safe haven tendencies during the financial crisis. Here, we expect the quantitative impacts of volatility on short term currency movements to be relatively large. Lastly, we will investigate the more recent period 04.01.2010 – 01.09.2016, allowing us to identify potential changes in safe haven tendencies after the financial crisis. In order to capture the extreme effects of increased volatility on currency movements, related to SRQ #2, we will add a second model where we include dummy variables for extreme risk episodes.

1.3 Disposition

In the following sections of this paper, we will first discuss the *background* for the topic we have chosen to investigate. This includes a literature review and discussion of financial developments that we believe are relevant to our study. In our second section, we will describe the properties of our *data*. This section will present and justify the choice of currencies, risk indicators, and risk-off episodes. The third section will outline the *methodology* for the paper, i.e. our choice of econometric models and statistical assumptions that must hold for our models to be considered valid. The fourth section will contain the *results and analysis*, where we will present and attempt to explain our findings for each currency. The fifth section discusses the *diagnostics and robustness* of our results. The last section will be a *conclusion* on our overall findings, as well as a general discussion on the limitations of our study and fruitful avenues for further research.

2. Background

Between 2001-2007, in the years prior to the financial crisis, a broad portion of the established literature has identified the JPY and CHF as safe haven currencies, while the Australian dollar (AUD) and New Zealand dollar (NZD) are widely regarded as non safe haven currencies. First, supported by empirical research, this section will outline the traditional view on the flight-to-quality phenomenon. Second, we will describe some significant events and world developments in our sample period that lead us to believe our findings may provide some new insight into the topic of safe haven currencies.

2.1 Literature review

In their extensive and highly regarded study of high-frequency exchange rate movements in the period 1993-2006, Ranaldo & Söderlind (2007) find that the CHF shows the strongest safe haven effects. It appreciates significantly against other cross currencies in the same situations as it appreciates against the USD in times of negative S&P returns, increased U.S. bond prices, and currency market volatility. The effects were found to be visible on horizons spanning from 3 hours to 4 days after a crisis episode. Overall, Ranaldo & Söderlind suggest two main points in their findings. First, currency, equity, and bond markets seem to be inter-connected even at high frequencies. As an example, their findings show that a 1 per cent increase in the S&P is associated with a four basis points depreciation of the CHF, and a 1 per cent increase in Treasury notes with a thirty basis points appreciation. Second, risk in the currency market seems to be priced into the value of CHF at any time granularity. Overall, this indicates that the CHF has a genuine character of being a safe haven asset.

Grisse & Nitschka (2013) conduct a study on bilateral exchange rate returns in an asset pricing framework to evaluate the safe haven characteristics of the CHF. Their study reveals interesting results regarding the CHF against the two currencies that are widely regarded as non safe haven currencies, the AUD and NZD. For instance, they show that a 1 per cent increase in the VIX index is associated with 0.04 per cent CHF appreciation against the AUD. Around the time of the Lehman Brother collapse, the quantitative impact increased significantly. The VIX index change was associated with a 0.2 per cent appreciation against the AUD. As for the analysis of the CHF against the USD, JPY, and GBP, results showed a depreciation. In other words, their results highlight that the CHF is a safe haven relative to many, but not all currencies. In this study, the USD, JPY and GBP appear to have a relatively stronger safe haven status compared to the CHF. On the other hand, the NZD and AUD show a clear inferiority in terms of safe haven status against the CHF.

Botman et al. (2012) investigate currency movements during risk-off episodes, in what they call the "Curious Case of the Yen as a Safe Haven Currency". Their findings lead to some noteworthy conclusions regarding the safe haven mechanisms of the JPY. Their paper supports the common interpretation of the JPY as a currency with significant safe haven characteristics. However, they emphasize the fact that these effects work differently compared to other safe haven currencies. In quite strong contrast to the CHF, JPY risk-off episodes appear to be unrelated to capital inflows and the relative stance of monetary policies. Botman et al. present evidence that portfolio rebalancing through the use of offshore derivative transactions occurs simultaneously to JPY risk-off appreciations. The authors suggest the JPY risk-of appreciation could either be caused by a causal effect of the portfolio rebalancing, or by the workings of self-fulfilling prophecies leading to both a JPY appreciation and portfolio rebalancing. Overall, their findings contribute to the literature in documenting that exchange rates may be volatile even if capital flows and interest rate differentials are not, implying that offshore and complex financial transactions may be key transmission mechanisms.

Habib & Stracca (2011) attempt to establish the fundamentals of safe haven currencies, i.e. which factors are robustly associated with a safe haven status. The authors put forwards three possible explanations of a safe haven status. The first explanation is related to risk aversion among investors. In their second possible explanation, they investigate whether the size and liquidity of a country's financial market may support a safe haven status. Third, they test whether financial openness and globalization is a significant determinant. Their results are ambiguous, which is not surprising given the large literature on the exchange rate disconnect. The exchange rate disconnect puzzle refers to the weak short-run relationship between the exchange rate and its macroeconomic fundamentals. In other words, underlying fundamentals such as output, inflation rates and interest rates are not well-equipped to explain the short-term movements of exchange rates.

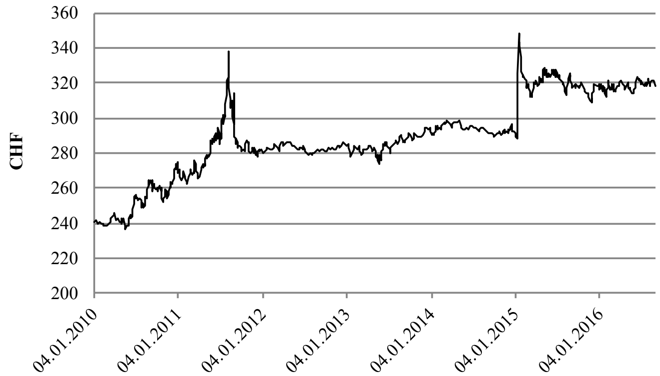
Habib & Stracca do however find a small number of variables to be statistically significant, and not surprisingly, more so for advanced countries than for emerging countries. Most notably, the net foreign asset position, an indicator of country risk and external vulnerability, and to a lesser extent, the absolute size of the stock market, an indicator of liquidity, seem to be the most significant fundamentals. Nonetheless, even variables that were found to be statistically significant, had a rather small quantitative impact on exchange rate behavior. In general, their results support the view that the interest rate differential is not a fundamental driver of safe haven flows.

Flatner (2009) investigated currency movements during the financial crisis, in the period 2007-2009. The commentary examined various currencies to identify those that appear to have been safe haven currencies since the start of the financial turmoil in the summer of 2007. Flatner compares 16 currencies, including the USD, JPY, CHF, AUD, NZD, NOK and GBP, with indicators of financial market turmoil and developments in the U.S. equity market. His findings show that the JPY and CHF have clear safe haven tendencies throughout the period, while the AUD and NZD appear to react in the opposite direction. The commentary also identifies an interesting change of behavior regarding the USD. Before the collapse of Lehman Brothers in September 2008, the currency had been showing a non safe haven tendency for quite a while. However, after the bankruptcy, results indicate that it served as a safe haven currency. Other findings by Flatner point towards clarifying the misconception that the NOK is a safe haven currency due to Norway's strong financial and economical position. The paper concludes that it is difficult to find empirical evidence that supports such a view, largely due to a small and illiquid market for the NOK.

2.2 Switzerland's Currency Peg

In 2011, a time of financial turmoil around the world, demand for the CHF was extremely high due to the Swiss currency's status as a safe haven asset (The Economist, 2015). This caused a significant increase in its value relative to the Euro (EUR), which is not an ideal situation for a country that is heavily reliant on exports to the Euro-zone. Exports of goods and services represent more than 70 per cent of the Swiss GDP. To bring down its value, the Swiss National Bank (SNB) introduced a currency peg at 1.2 CHF per EUR. To actuate the fixed exchange rate system, the SNB printed more money and used them to buy EUR, which led to a considerable increase in the supply of the CHF relative to the EUR. The SNB were successful in ensuring that 1 EUR was worth 1.2 CHF. By 2014, the policy had led to an accumulation of about $480 billion worth of foreign currency. To put this in context, this equals about 70 per cent of Switzerland's GDP.

Figure 1: SNB's successful implementation of a currency peg



Note: Data retrieved from Bloomberg Terminal

Figure 1 shows the CHF's 'bathtub shape' in the years when the currency was pegged. On January 15th, 2015, in a surprising and unpredictable move, the SNB announced that it would unwind the currency peg, and allow free floating of the CHF. The reaction in equity and currency markets was dramatic, as shown in the figure, causing the Swiss stock market to collapse, and the CHF to soar in value. In one day, CHF per EUR went from 1.2 CHF to just 0.85 CHF. There were several reasons for the SNB's unwinding of the fixed exchange rate scheme. First of all, it was the somewhat unfounded fears of hyperinflation due to the large-scale printing of the CHF. Swiss inflation was at the time very low due to a persistent deflationary pressure, hence hyperinflation was quite unlikely. Political pressure did however force through this argument. Second, the European Central Bank (ECB) was about to introduce quantitative easing (QE), which eventually would push down the value of the EUR, hence increasing the relative value of the CHF. This would force the SNB to amass even larger foreign exchange reserves in order to maintain the currency peg. Third, the EUR had depreciated against other major currencies, and as a result, because of the currency peg, the CHF had depreciated as well. As an example, the CHF had lost around 12 per cent of its value against the USD in 2014. This made a strong case for not continuing to weaken the value of the CHF.

Switzerland's introduction of a currency peg and the following dismantling is relevant to our study for several reasons. First, investors and market participants may have changed their perception of Switzerland's status as a safe haven asset due to many of the sudden actions by the SNB related to the currency peg. In the world of central banking, where slow and predictable decisions are highly valued by stakeholders, sudden actions often create panic in the markets. For instance, when the peg was unexpectedly removed, a number of hedge funds across the world incurred tremendous losses. This, together with the overall Swiss situation spanning from around 2011 to 2015, may have caused a change in preferences and behavior among investors. Second, the currency peg will underwhelm the quantitative impacts in our results. Although investors may flee to the CHF in times of distress or on average, which isolated will lead to an appreciation, we may not detect these appreciations as strongly due to the SNB's counteraction of maintaining a fixed exchange rate.

2.3 Deflationary Pressure in Japan

In the past decades, Japan has been extremely prone to deflation and rolling recessions. Many argue that the term "quantitative easing (QE)", i.e. the buying of private assets to recapitalize businesses and increase inflation, was born in Japan. Starting in 2001, and lasting five years, the country attempted to stimulate the economy and boost inflation through wide-spread QE (The Guardian, 2016). This proved to be unsuccessful, and became a lesson that gave rise to critics during QE efforts in the U.S., Great Britain and the Euro-zone after the financial crisis.

The Bank of Japan's (BoJ) most recent QE efforts began in April 2013, as BoJ Governor Haruhiko Kuroda launched a $ 1.4 trillion QE plan to buy large amounts of government bonds each month using electronically created money. The policies were aimed at tackling a worrying deflationary pressure and low consumer spending. The plan was part of an overall policy strategy termed as "Abenomics", inspired by the name of Japan's Prime Minister, Shinzo Abe. A "weak yen" policy was also an important part of this plan. A depreciation of the JPY would increase the amount of imported inflation, hence helping prop up prices, allowing the BoJ to approach their inflation target.

QE failed to work as intended, and there was little evidence of real growth. In 2015, there was a growing concern that the BoJ was approaching a shortage of Japanese government bonds for the central bank to buy (Markets, 2016). In other words, the central bank was reaching the quantitative limits of quantitative easing. Furthermore, Japan's real debt burden, including private debts, was around 449 per cent relative to its GDP. The large debt servicing cost this entails has a disturbing effect on the potential for savings or investments, which reduces current returns and limits the potential for future economic growth.

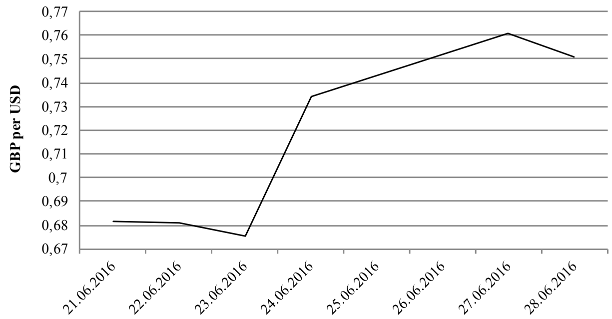
The expansive monetary policies in Japan, exemplified by interest rate manipulation and accumulation of huge fiscal deficits, has had little effect. As a last desperate measure, the BoJ announced negative interest rates in January 2016 (The Telegraph, 2016). Governor Haruhiko Kuroda pushed through negative rates even though there were strong protests by half the BoJ voting members. The main argument for the move was to increase inflation by weakening the JPY. This proved to unsuccessful, as the JPY appreciated by 9 per cent against the USD in only one month. Analysts believe that there is little the BoJ can do to stop the inflows of money into the country. Any direct intervention to devalue the JPY and increase competitiveness relative to other countries would violate an accord amongst G20 countries. This accord prohibits the use of QE for exchange rate purposes, and any action otherwise might trigger accusations of currency warfare.

The situation in Japan might impact or explain some of our results in this safe haven study. First, the dire situation of the Japanese economy, together with the BoJ's unpredictability and unsuccessful policy measures, may have changed investors' perception of the currency's safe haven status. Second, the implications of BoJ's expansive monetary policies may impact our regression results. For instance, lower yields on Japanese government bonds through QE might lead to portfolio rebalancing and increased investments in alternative assets that might generate higher yields, such as currencies. Third, our study allows us to examine the quantitative effects of Japan's "weak yen" policy, and whether or not our findings indicate that this policy has suppressed safe haven appreciations in the JPY. Most financial analysts suggest it has not so, and in fact only gained more momentum as a safe haven currency in the past 4-5 years.

2.4 Brexit

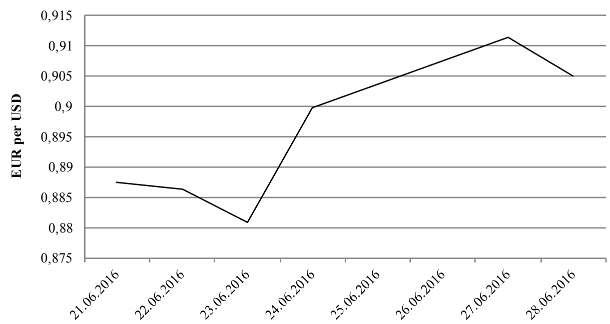
On June 23rd, 2016, four decades of Euroscepticism eventually culminated in Britain's exit from the European Union (EU). There were several reasons for why the referendum showed a 52 % to 48 % win for leaving the EU. First, polling suggests that a large disgruntlement with increased migration to the UK was one of the biggest factors. Second, there was a wide movement within the UK that claimed Brussels and the EU had too much power. Eurosceptic movements branded the EU and Brussels officials as political elites that were not democratically voted by the British people. Third, the referendum may have never taken place if not Prime Minster David Cameron had called for the referendum due to the rise of political and public traction towards Nigel Farage and the rival party Ukip.

Figure 2: Brexit effects on the GBP



Note: Data retrieved from Bloomberg Terminal

Figure 3: Brexit effects on the EUR

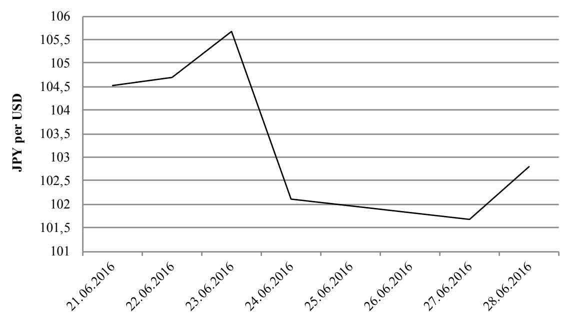


Note: Data retrieved from Bloomberg Terminal

In the days following the Brexit vote, the pound fell to a 30-year low, depreciating 10 per cent against the USD. The EUR, also strongly affected by the worries of the impacts Brexit will have on the EU economy, dropped sharply against the USD. This is shown in figure 2 and 3 above, where the two currencies against the USD portray remarkably similar deprecations in the days encompassing Brexit.

As for the JPY, shown on the next page in figure 4, Brexit fears caused a strong appreciation, further complicating Japan's efforts to manage deflation. The JPY appreciated heavily against the USD, GBP and EUR. The appreciation prompted the BoJ to hold emergency meetings in order to formulate a strategy that would counteract the undesired appreciations. Although Japan has struggled through decades of sluggish growth and deflationary pressure, as mentioned in section 2.3, the Brexit effects indicate that its wealthy society and lack of external debt has maintained its status as a safe haven for investors who are experiencing increased risk aversion. This leads to us believe that our findings may show stronger safe haven tendencies for JPY in the recent years of our sample period.

Figure 4: Brexit effects on the JPY



Note: Data retrieved from Bloomberg Terminal

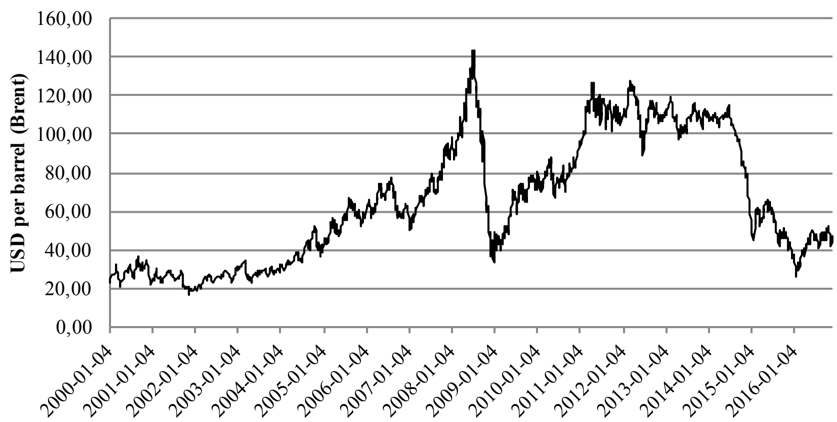
As of October 2016, the UK economy appears to have withstood the initial shocks of the Brexit vote. Although the value of the GBP has reached record low levels, opinions regarding the long term effects are widely divided. Several major firms in the UK, such as Easyjet and John Lewis, have suggested that the drop in the GBP is forcing them to incur larger costs (BBC, 2016). Moreover, Britain has lost its AAA credit rating, causing the cost of government borrowing to increase. On the other side, stock markets have recouped and share prices have recovered from the dramatic, initial slump following the referendum. Currently, both the FTSE 100 and the broader FTSE 250 index show higher levels of trading than before the Brexit vote. However, due to economic indicators pointing towards a downturn in the British economy, the Bank of England (BoE) cut interest rates in half, from 0.5 per cent to 0.25 per cent, hoping to counter recession and stimulate investments.

The Brexit vote and the aftereffects are highly relevant to our research question. Several analysts claim that Brexit has intensified the safety attraction of traditional safe haven currencies, such as the JPY and CHF. Our study allows us to investigate the overall currency movements and risk aversion effects of the period encompassing Brexit, i.e. 2010-2016. Moreover, the examination of risk-off episodes such as Brexit through the use of our interactive dummy model may provide valuable insight into risk aversion mechanisms.

2.5 Structural Crisis in the Oil and Gas Industry

After a decade-long booming period in the oil and gas industry, companies are now facing a major structural crisis. In June 2014, oil prices peaked at almost $116 per barrel, before they plummeted by more than 60 per cent over the next seven months. In mid January 2015, Brent had dropped to a record-low $47 per barrel. This development is shown in figure 5, where we also see that the persistent price increase was disrupted by the financial crisis, but swiftly recouped.

Figure 5: Brent oil price development (2000-2016)



Note: Data retrieved from the U.S. Energy Information Administration

The relentless price drop forced major international oil companies and small independents to cancel billion dollar projects for the years 2015 and 2016, and carry out cost reductions through massive lay-offs. There were mainly three deciding factors that led to a drastic shift in the industry.

First, many claim that an inevitable decline in global oil consumption was strongly influential in causing prices to drop. In retrospect, 2005 was the peak year for oil consumption in advanced economies. A major contributor to the following decline in oil consumption were the many laws and government regulations put in place by advanced economies in the period between 2004 and 2014. These laws and regulations, such as the U.S.' Energy Policy Act in 2005, promoted energy conservation and cut demand for expensive imported oil. Between 2005 and 2013, consumption of refined products in the U.S. declined by more than 2 million barrels per day, i.e. roughly 12 per cent. This decline took place in the same period as the U.S. population increased by more than 20 million, and real economic output grew by 10 per cent.

Second, the U.S. shale boom was a key contributor to the sharp price decline. The high prices prior to the crisis were a key catalyst for the shale revolution. The period between 2013 and 2014 experienced the fastest growth in oil production in history, causing a large oversupply of oil in the market. This was further exacerbated by the unpredictable increases in production in the Middle East and Africa, as a result of war, unrest and sanctions. The oversupply in the market was met by a strong price correction.

Third, a market rebalancing due to growing inefficiency was almost inevitable. Due to the high prices and booming period prior to the crisis, oil production was becoming increasingly more expensive and inefficient. Investment trends in the industry were more concerned with a "nice to have" rather than "need to have" mentality. This eventually lead to an inevitable adjustment for the industry, forcing industry participants to cut drilling and production, improve efficiency and cut costs to reduce the breakeven price for new wells, while at the same time maintaining production in an environment of lower prices.

There are mainly three reasons for why the structural crisis in the oil and gas sector is relevant to our study of safe haven assets. First, the export and import of oil and gas is influenced by exogenous variables that can have a huge impact on the fiscal and monetary policy in an economy. In general terms, an oil exporting country will be negatively affected by a low oil price, as it will reduce national oil revenues and tax incomes. Unemployment will also be strongly affected if the country's workforce is heavily concentrated in oil and gas sectors. This will weaken the outlook for economic growth, and may cause the country to launch an expansionary monetary policy through a reduction in interest rates. In contrast, oil importing countries will reap the benefits of a lower oil price trough reduced import costs and improved balances. This may result in increased economic growth, leading to a more contractionary monetary approach by the central bank.

Although our study on safe haven assets is not focused on the relationship between currencies and macroeconomic fundamentals rooted in economic policy, the effects of the structural crisis on monetary policy may still be influential in our results. Market participants put emphasis on the financial situation and policy predictability in a country when rebalancing portfolios towards safe haven assets. The effect of the oil and gas crisis on policy unpredictability can be exemplified through the current situation in Norway. The Norwegian Central Bank's reduction in interest rates to counter the negative effects of the oil crisis has intentionally caused the NOK to depreciate. This has created a "two-way" economy in Norway, where traditional export sectors are experiencing high growth due to a competitive currency, at the same as the large oil and gas industry in the country is in a crisis. Furthermore, the Norwegian Central Bank's commitment to bolster financial stability means the monetary policy must also, to some degree, address the problem of soaring house prices and household debt. This divided nature of the Norwegian economy has lead to more uncertainty and unpredictability in regard to monetary policy, which may affect the willingness to invest in the NOK.

Second, the structural oil and gas crisis may be relevant to our study on safe haven assets due to the conception of oil itself as a financial asset, and that its price reacts to and influences other assets in financial markets. A growing literature studying the link between oil prices and individual markets for financial assets has provided evidence that the oil prices affect individual asset prices at a monthly data frequency, e.g. the U.S. stock markets as shown by Killian & Park (2009). Several major companies in large stock exchanges worldwide operate in the oil and gas industry, where fluctuations in oil prices affects the outlook for future earnings and dividends, causing equity prices to react accordingly. This is especially the case for Norway and the Oslo Stock Exchange, where oil companies such as Statoil and others heavily influence the overall index returns.

Fratzscher et. al (2014) identify a causality between currencies and oil prices that runs in both directions. A 10 per cent increase in the oil price led to a deprecation of the USD effective exchange rate by 0.28 per cent on impact, whilst a 1 per cent depreciation of the USD caused oil prices to rise by 0.73 per cent. There are several plausible explanations for this two-way causality. One explanation is that oil exporters may change their price setting and production to induce a rise in oil prices due do budgetary pressures caused by a depreciation in the USD. Another explanation may be that oil can be used as a hedge against a depreciation of the USD, since oil is expressed in dollars, hence propping up the demand for oil as a financial asset. Furthermore, a rise in oil prices may cause a depreciation in the USD if it leads to intensified petro-dollar recycling towards important demand of goods and services from other regions, e.g. Europe.

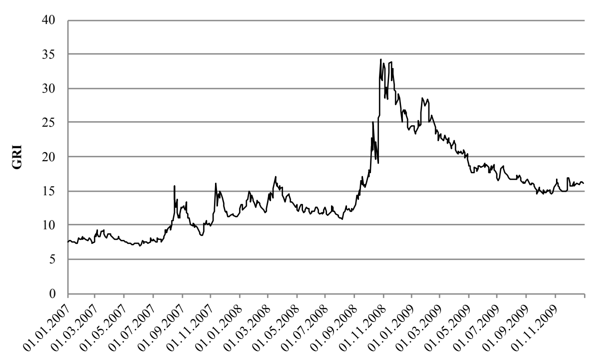
Third, the price fluctuations and overall industry situation in our sample period is highly relevant to our study due to the empirical link between oil prices and global risk indicators. As mentioned in the second point, oil prices and equity prices are highly connected, thus creating a link between oil prices and our global risk indicators VIX and MRI. A sharp decline in the oil price may induce negative index returns in the S&P500, which then increases VIX volatility values. Furthermore, oil prices affecting commodity currencies may as well have an impact on GRI. High volatility in oil prices in the periods we are examining may therefore provide interesting insight to recent safe haven mechanisms due to its effect on global risk indicators and perceived risk among market participants.

2.6 The Financial Crisis and its impact on Foreign Exchange

The aftereffects of the recent financial crisis, considered by many economists as the worst financial crisis since the Great Depression of the 1930s, are still present today. The bankruptcy of Lehman Brothers in September 2008 nearly caused the world's financial system to collapse, and was followed by a sovereign debt crisis that has lasted for several years.

A major factor in the crisis was the bursting of the U.S. housing bubble and the high default rate in the subprime home mortgage sector. A fragile bank solvency, declines in credit availability, and low investor confidence had a huge impact on global financial markets. The study of causal factors and the lead-up to the financial crisis in the U.S. and Euro-zone is relatively well-established in the literature. This part will therefore not discuss this area in detail. Instead, this subsection will focus on empirical evidence on developments in the foreign exchange markets in the period surrounding the financial crisis. Figure 6 and 7 show the development in the risk indicators GRI and VIX, representing foreign exchange (forex) and stock volatility.

Figure 6: Forex volatility during the financial crisis (2007-2010)



Note: Data retrieved from Bloomberg Terminal

Figure 7: Stock volatility during the financial crisis (2007-2010)

Note: Data retrieved from Bloomberg Terminal

During the crisis, traders around the world experienced a lack of liquidity and volatile fluctuations in currency rates. The index levels surrounding the financial crisis are large, as evident in the figures. In a commentary published by the Reserve Bank of New Zealand, Wallis (2010) examines the trends in the global and NZD foreign exchange markets over the financial crisis period defined as the years 2007 to 2010. During this period, increased volatility and risk aversion in financial markets led to alterations in the nature of currency trading. The variety of instruments traded, the volume of transactions, as well the types of investors trading, all experienced significant change. The strained market liquidity and increased focus on counterparty risk forced investors to reassess trades that were popular in the years between 2004 and 2007, the period leading up to the crisis.

Table 1: Percentage of daily average forex turnover divided by currency

	2001	**2004**	**2007**	**2010**
USD	89.9	88.0	85.6	84.9
EUR	37.9	37.4	37.0	39.1
GBP	13.0	16.5	14.9	12.9
JPY	23.5	20.8	17.2	19.0
AUD	4.3	6.0	6.6	7.6
NZD	0.6	1.1	1.9	1.6

Note: Table adapted from Wallis (2010)

Table 1 shows daily average forex turnovers in the period 2001-2010. In general, Wallis finds that the foreign exchange turnover continued to increase, but at a slower rate than the period before the crisis. Reduced risk appetite caused large foreign exchange positions to be scaled back, and more focused towards liquid currencies that were perceived to have a safe haven status. The study identified an increase in popularity for the USD as a safe haven currency, which is in line with the findings of Flatner (2009) The EUR and JPY also showed increasing popularity as standard transactional and intermediary currencies from 2007 to 2010. The USD's turnover market share has therefore, to some extent, been replaced by the EUR and JPY. On the other hand, the NZD has experienced diminishing shares of total trading turnovers. Prior to this, the NZD turnover had been increasing steadily since 1998. This signals a tremendous shift in preferences. Carry trade strategies seem to have declined in popularity during the financial crisis due to reduced risk willingness, causing the NZD and other currencies with similar properties to experience reduced demand.

Markets began to recover in March 2009, as central banks all over the world introduced large-scale policy measures that provided additional liquidity and eased financial markets. This caused increasing worry over sovereign debt levels. The European Union and the International Monetary fund (IMF) introduced the European Financial Stability Fund (EFSF) to aid European economies that were experiencing liquidity crunches, one of the most extreme examples being Greece.

The developments during the recent financial crisis, as well as the aftereffects, are highly relevant to our study on safe haven currencies. First, as we intend to examine the 2007-2010 period in detail, we will be able to empirically confirm or add new insight into currency rebalancing preferences during the financial crisis. Second, the inclusion of dummy variables for news events during the financial crisis period, such as when Lehman Brothers filed for Chapter 11 bankruptcy protection on September 15, 2008, might provide interesting results regarding safe haven behavior on a more conditional basis. Third, we will examine how the extreme and almost unprecedented nature of the crisis, and its effect on volatility in a wide array of financial assets during the period, has affected safe haven behavior post-crisis. This may for instance allow us to further support the empirical notion that the USD started to show stronger haven tendencies after the financial crisis, and that the JPY has been relatively more prone to larger safe haven flows in recent years.

3. Data

Our data consists of eight nominal effective exchange rates (NEER) and three risk indicators. The baseline sample period is 3956 observations of high frequency daily data from 02.01.2001-01.09.2016. There are three main reasons for why our analysis starts in the beginning of 2001. First, this provides us with a satisfactory number of observations and sample length. Second, it allows us to compare our findings with previous empirical research for the period 2001-2007 and supplement this with our new research for the period 2007-2016, which is relatively more scarce in the literature. Third, this is one year after the de facto introduction of the euro currency, which eliminates some of the data gathering and preparation challenges.

All exchange rates and the three risk aversion indicators have been synchronized in the sample period. Furthermore, all the data besides VIX and MRI is transformed into first difference percentages $\frac{x_t - x_{t-1}}{x_{t-1}}$. The MRI is already quoted in percentage points (0-1), hence only first differencing was needed $x_t - x_{t-1}$. The VIX is also quoted as percentages (1-100), but as we see had to be divided by 100 to fit our data before first differencing. This allows us to interpret all our results as percentage appreciations and depreciations. An alternative to our transformation was using log-transformation. When applied to small values, using log transformation is valid, and the difference between the two methods would be trivial. However, since the values of our indices are generally high due to the fact that we are measuring volatility, the log-results become noticeably different, making it more appropriate to use first differentiated percentages.

Descriptive statistics for all our main variables can be found in appendix A. The exchange rates are measured by *Nominal Effective Exchange Rates (NEER).* Our risk indicators consist of the *CBOE Volatility Index (VIX), Global Risk Indicator (GRI)* and *Citi's Macro Risk Index* (MRI).

3.1 Nominal Effective Exchange Rates (NEER)

The NEER describes the strength of a currency against a basket of other currencies (Klau & Fung, 2006). These baskets are typically trade weighted averages against a country's important trading partners. In simple terms, these weights reflect the relative importance of trade between two countries and is measured by trade flows. An increase in NEER indicates that exports become more expensive and imports become cheaper. In other words, an increase in NEER is a nominal appreciation while a decrease is a nominal depreciation.

After thorough consideration, we have decided to use Barclays's NEER as our expression for exchange rates. First, this gives us complete access to daily effective trade-weighted exchange rate indices for all the currencies we want to investigate. Secondly, our independent variables, i.e. the risk indicators, are based on nominal values. It is therefore appropriate to apply nominal instead of real effective exchange rates (REER), which also was an option we tested at one point. Thirdly, we want to avoid problems associated with using cross-currencies, i.e. crossing all currencies against a single base currency. Flatner (2009) found that the U.S. dollar's status as a safe haven may have changed significantly during our sample period. Moreover, in their cross-currency study of safe haven assets, Ranaldo & Söderlind (2007) encountered a problem while using the USD as a base currency. In some of their findings, they questioned whether it was the dollar, rather than its counter currency, that determined the results. Hence, by applying NEER, we eliminate such disturbances caused by the base currency.

In this paper, we investigate the two currencies CHF and JPY that have been historically regarded as safe haven currencies. In addition, we want to investigate various other currencies that might have safe haven tendencies, namely the GBP, USD, EUR and NOK. Lastly, we also investigate currencies that historically have been regarded as the opposite of safe haven currencies, the NZD and AUD. Our dependent variables and their traditional view are summarized in table 2:

Table 2: Dependent variables

	Safe haven currencies	Non-safe haven currencies	Other candidates
Historical view	JPY and CHF	AUD and NZD	USD, EUR, GBP, NOK

We may also include lags of the dependent variables to examine if past movements in the NEER has any impact on today's NEER.

3.2 Measuring volatility in financial markets

There are several different indices for financial turmoil and risk aversion. However, we have chosen the CBOE Volatility Index (VIX), Global Risk Index (GRI), and Citi's Macro Risk

Indicator (MRI) as our three independent variables. Combined, these indices cover risk aversions in a broad, organized and relevant manner in regard to our research question. Another major advantage is the availability of high frequency daily data for all indices.

The VIX has experienced large media exposure for many years, and also been used frequently within research. The MRI and GRI have mostly been applied within research. Lags for the past two days are also included in the regressions for all indices to investigate if past values of volatility affect present values of NEER.

3.2.1 VIX

The *VIX* is calculated by the Chicago Board Options Exchange and is often known as the "fear index" (CBOE, 2015). VIX is a widely used measure for the 30-day expected volatility of the equity price index S&P500. The VIX is comprised of options, where the price of each option reflects the market's expectation of future volatility. The index is quoted in percentage points.

The calculation of the VIX follows a 3-step procedure. The first step is to select the options to be used in the VIX calculation. The second step is to calculate volatility for both near-term and next-term options. The third step is to calculate the 30-day weighted average of σ^2 and σ_2^2, then take the square root and multiply this by 100 to finally calculate the VIX.

The calculation of VIX employs rules for selecting component options and a formula to calculate index values. It estimates the expected volatility by averaging the weighted prices of S&P500 puts and calls over different sets of strike prices. The generalized formula used to calculate the VIX is given by:

$$\sigma^2 = \frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2} e^{RT}\, Q(K_i) - \frac{1}{T}\left[\frac{F}{K_o} - 1\right]^2 \qquad (1)$$

$$where, \sigma = \frac{VIX}{100} => VIX = \sigma * 100,$$

T = Time to expiration,

F = Forward index level desired from index option prices,

K_0 = First strike below the forward index level, F

K_1= Strike price of the ith out-of-the money option; a call if $K_i > K_0$; and a put if $K_i < K_0$; both put and call if $K_i = K_0$.

ΔK_i = Interval between strike prices – half the difference between the strike on either side of K_i: $\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2}$

R= Risk-free interest rate to expiration

Q(K_i) = The midpoint of the bid-ask spread for each option with strike K_i.

Overall, the VIX is one of the most legitimate indicators for global risk aversion and is commonly found in the literature. It gives a broader interpretation, as researchers have found it to be strongly correlated with more comprehensive measures of increased risk and financial turmoil, such as the Financial Stress Index developed by the Federal Reserve Bank of St. Louis, as well as with bond market indicators, and also spreads on emerging market countries' sovereign bonds. Unlike our two other indicators, it does not use any information from currency markets.

During periods where the index increases, we generally assume that safe haven currencies will appreciate. We therefore expect a positive correlation between VIX and safe haven currencies. We have chosen to calculate the VIX variable as the daily average[1] of open and close returns ($\frac{VIX\ open + VIX\ Close}{2}$). The indices have been extracted from Macrobond.

3.2.2 GRI

The *GRI* is based on the implied volatility derived from the prices of 3-month currency options of the largest and most liquid currency markets (Bernhardsen & Røisland, 2000). These are markets for the USD, EUR and JPY. Unlike the VIX, where values have been directly extracted from Macrobond, we have constructed our own GRI based on the following formula by Bernhardsen and Røisland:

[1] See section 6.2 for discussion on robustness of VIX returns definition

$$(2) \qquad GRI = \frac{2\sigma_{DE}\sigma_{DY}\sigma_{EY}}{\sqrt{(\sigma_{DE}+\sigma_{DY}+\sigma_{EY})(-\sigma_{DE}+\sigma_{DY}+\sigma_{EY})(\sigma_{DE}-\sigma_{DY}+\sigma_{EY})(\sigma_{DE}+\sigma_{DY}-\sigma_{EY})}}$$

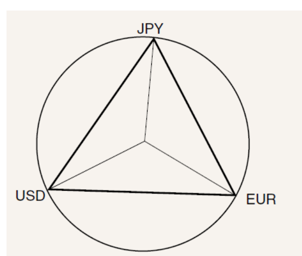
,where $\sigma_{DE} = implied\ volatility\frac{USD}{EUR}$, $\sigma_{DY} = implied\ volatility\frac{USD}{JPY}$ and

$\sigma_{EY} = implied\ volatility\frac{EUR}{JPY}$

The formula can also be explained geometrically, as shown in figure 8. The bold lines show the volatility between the currency pairs. The longer this line is, the larger the volatility between the currencies. In this illustration, the length of the lines is drawn the same for all three variables. Thus, the volatility is also the same across the three currency pairs. If we for instance had drawn the JPY closer to the EUR, the length of the line between EUR/JPY would be relatively shorter than for USD/EUR and USD/JPY. Thus, in this particular example, the volatility between EUR/JPY would be less than the the two other currency pairs, USD/EUR and USD/JPY.

As we have three variables, the GRI is represented by the circle's diameter. The average volatility, on the other hand, is equal to a third of the circumference of the circumcircle of the triangle. This means that the GRI is larger than the average volatility.

Figure 8: Geometrical illustration of GRI



Note: Figure reprinted from Bernhardsen & Røisland (2000)

Even though the GRI is considered to be a superior indicator to for example simple average implied volatility measures, Bernhardsen & Røisland point out that there are some weaknesses. First, as mentioned earlier, the figure is drawn in a symmetrically manner with equal lengths, meaning equal volatility for all three currency pairs. This contradicts with the fact that the three currency pairs in reality differ in nature. This is especially the case for the JPY, which may be argued has too great weight in the formula. Second, although the formula is considered to be theoretically sound, it is not intuitive at first glance.

An increase in the GRI signals increased uncertainty in foreign exchange markets. Our assumption is that an increase in GRI will generally lead to an appreciation in safe haven currencies. We therefore expect a positive correlation between GRI and safe haven currencies. Unlike VIX, the GRI is directly related to the currency market. The implied volatilities used to construct GRI have been extracted from the Bloomberg terminal.

3.2.3 MRI

Lastly, we have also chosen to include *MRI* as an independent variable. This risk indicator can be interpreted as a measure of overall risk aversion among global investors. It is an equally weighted index of emerging market sovereign spreads, U.S. credit spreads, U.S. swap spreads and implied FX, equity and swap rate volatilities (Sugihara, 2010). The advantage of including MRI is due to its nature of being a composite index representing different risk aversion measurements. This encompasses relevant assets, such as bonds, that are considered to be investment substitutions to currency assets.

Thus, MRI allows us to capture the volatility emerging from a wide array of financial assets. The index ranges from 0 (low risk aversion) to 1 (high risk aversion). During periods of high risk aversion, we assume safe haven currencies generally will appreciate. This index is therefore also expected to be positively correlated to safe haven tendencies. The MRI is extracted from Macrobond as the Citi's Long-Term Macro Risk Index.

We were not able to get access to a more in depth methodology behind the MRI index. Neither is this publicly accessible.

3.3 Risk-off Episodes

Our study intends to capture what is considered to be *two* important safe haven drivers. In addition to capturing the slow-moving average currency effects of an increase in risk factors, we also want to capture the potentially fast-moving effects of risk-off episodes that are extreme and sudden.

Risk-off episodes are defined as an investment setting or episode in which price behavior responds to and is driven by changes in investor risk tolerance (De Bock & de Carvalho Filho, 2013). During periods of low perceived risk, investors tend to pursue higher-risk investments, and vice versa. In this paper, we will focus on identifying and examining risk-off episodes in the period 2007-2016, instead of doing so for our entire sample period. This allows us to focus on more recent incidents that have yet to be thoroughly examined in the literature.

Instead of arbitrarily choosing which incidents to focus on, we have chosen to adapt a more methodical, quantitative and real-time definition of risk-off episodes. The method for identification is similar to the one applied by De Bock & de Carvalho Filho, but with certain adjustments that align better with our data properties.

3.3.1 Method for Identifying Risk-off Episodes

The risk-off episodes will be identified through a criteria-based non-linear threshold in VIX. We have defined the start of a risk-off episode as a 10 percentage points difference between VIX and its 50-day backward-looking moving average (MA). In other words, risk-off episodes, according to our definition, start when the VIX is 10 per cent above its 50-day backward looking MA.

(3)

$$MA = \frac{VIX + VIX_{-1} + \cdots + VIX - (n_{-1})}{n} = \frac{1}{n}\sum_{i=0}^{n-1} VIX_{-i}$$

(4)

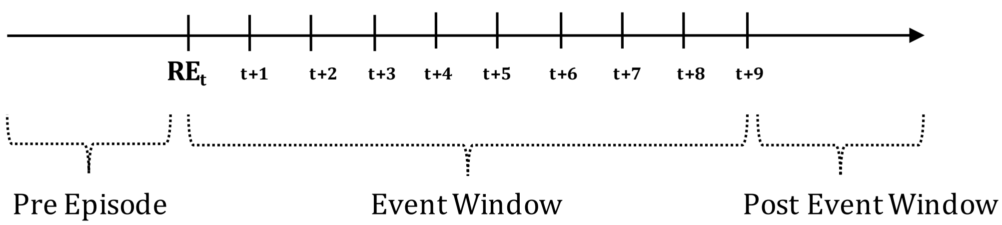
$$RE_t = (VIX_t - MA_t) > 10\ \%$$

$$Where,\quad RE_t = Start\ of\ Risk\ Episode$$

This differs slightly from the method used by De Bock & de Carvalho Filho, who for instance applied a 60-day backward-looking MA. There are mainly two reasons for why we chose a different MA. First, our sample period is slightly shorter than theirs, hence we found it more appropriate to reduce the interval accordingly. Second, we want to impose a stricter criterion for the identification of risk-off episodes. A reduction in the interval implies less smoothening. This preserves more of the volatility in the MA and creates a shorter distance between the 50-day MA and VIX. Consequently, we will capture fewer risk-off episodes with a 50-day MA compared to a 60-day MA, which is indeed the point.

After applying the abovementioned methodology to identify the *start* of a risk-off episode, we also need to define the *end*. We have found it to be quite difficult to pin-point the end, contrary to identifying the beginning. An episode may last from a few days or weeks to several months. The transition from turbulence to more tranquil financial conditions varies in nature depending on the characteristics of the episode. We will therefore not set a certain end date for each risk-off episode, but instead define a generic event window following the days after the start of the episode. As shown in figure 9, our event window will consist of the event day and the subsequent 9 days.

Figure 9: Event window in Risk-off Episodes

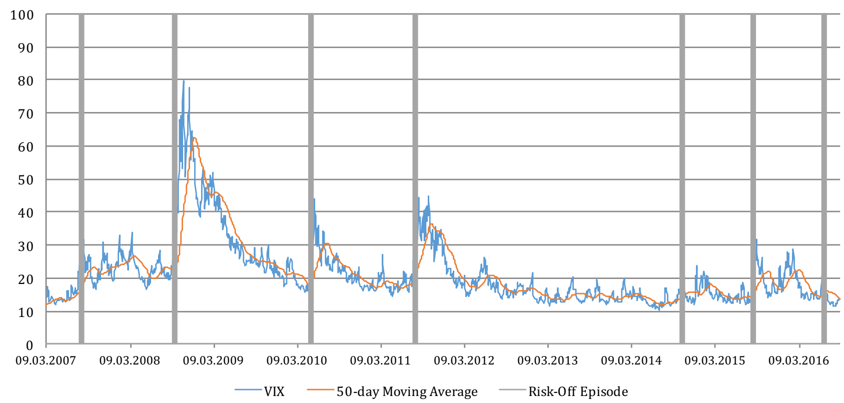


$$Where, \quad RE_t = Start\ of\ Risk\ Episode$$

Our dummy variable model, explained in section 4.2, will be set according to this event window. We have tried different amplitudes of window lengths in order to test whether the results are robust to changes of the event window. Results showed that our event window is sufficiently robust, as significance levels and coefficients did not experience any noteworthy changes.

3.3.2 The Risk-off Episodes

Figure 10: Results from risk-off algorithm



Our method of identifying the start of a risk-off episode, illustrated in figure 10, has provided us with the events presented in table 3. Since our algorithm only gave us the dates, and not a description of what actually happened on these date, we had to perform a thorough review of news paper articles in the period 2007-2016 in order to capture the events that actually took place.

Table 3: Overview of risk-off Episodes

Start Date	**Event**	**Type**
10 August 2007	BNP Paribas freezes $2.2 bln of funds over subprime	Finance
17 September 2008	Lehman Brothers Collapse	Finance
6 May 2010	Greek Debt Crisis	Finance
5 August 2011	US Debt Ceiling Crisis and unrest in the Euro-zone	Finance
15 October 2014	U.S.-led airstrikes in Syria, Hong Kong protests, and Ebola	War/Politics/Nature
21 August 2015	Germany backs thirds bailout for Greece, Greek Prime Minister resigns	Politics/Finance
24 June 2016	Brexit	Finance

Not surprisingly, six out of seven risk-off episodes are triggered by financial incidents, rather than terror, war, nature or politics. These are reasonable findings, since financially rooted triggers are believed to have the most significant impact on financial conditions. It can however be mentioned that there were several incidents related to terror, war, nature or politics that were close to being included, but marginally failed to reach the 10 per cent threshold due to our strict criteria.

4. Methodology

Our first goal is to study how exchange rates are related to different measures of risk aversion on an average basis for the periods 2001-2007, 2007-2010 and 2010-2016. We also intend to compare these periods to identify any changes in behavior. This examination will be conducted through an *Autoregressive Distributed Lag (ADL) model*.

For our second goal, which is to study the potentially fast-moving effects of risk-off episodes that are extreme and sudden, we will employ an *interactive dummy variable ADL model* for the years 2007-2016 in accordance with the risk-off episode methodology described in section 3.3.

4.1 Autoregressive Distributed Lag (ADL)

Our first approach is an Autoregressive Distributed Lag (ADL) model where we test each NEER against a risk indicator. The risk indicator will have two lags included. The model will also include lags of the exchange rate if it proves statistically appropriate. We have tried several different approaches, but landed on the following baseline model:

$$\Delta y_t = \alpha + \sum_{i=1}^{n} \beta_i \Delta y_{t-i} + \sum_{i=0}^{2} \gamma_i \Delta x_{t-i} + \delta_t \qquad (5)$$

$, where\ \Delta\ denotes\ first\ difference, y_{t-i} = \%\ change\ of\ NEER\ in\ time\ t-i,$

$x_{t-i} = \%\ change\ of\ Risk\ indicator\ in\ time\ t-i,\ \alpha = constant\ and\ \ \delta_t =$ residual in time t

$$H_0 : \gamma_i = 0$$

$$H_1 : \gamma_i \neq 0$$

If we fail to reject the null hypothesis, the risk indicator has no effect on the exchange rate. If the null hypothesis is rejected, changes in the risk indicator are associated with significant movements in the exchange rate. We can then assume that there is a correlation between the risk indicator and exchange rate. The optimal lag lengths of the NEERs are decided by the Akaike information criterion (AIC), but also cross checked with Schwarz's Bayesian information criterion (SBIC)

(STATACorp, 2015). Furthermore, we do a last check by investigating the lag length visually, to possibly eliminate non-significant lags.

This baseline regression model is split into three different periods. First we investigate the period 02.01.2001 – 29.12.2006. Our second period is the turbulent years of the financial crisis from 02.01.2007 – 31.12.2009. Third, we investigate the recent years from 04.01.2010 – 01.09.2016 in order to identify any periodical changes in safe haven behavior pre and post financial crisis.

Our focus with this model is on the relationship between exchange rates and risk factors on an average basis, not conditional on extreme and sudden movements in the risk factors. In general, we assume a safe haven currency will appreciate when risk aversion increases, and a non-safe haven currency to depreciate when risk aversion increases.

4.2 Interactive dummy variable ADL model

To gain insight into the fast-moving effects of risk off episodes, we will add an interactive dummy to our baseline model in the years 2007-2016. The dummy is a binary variable that takes the value one (1) or zero (0) depending on whether there is a risk-off episode or not. Identifying the start of a risk-off episode will be based on the methodology outlined in section 3.3. Risk-off episodes will have the value of 1 in the dummy term.

This model will only be applied to our most suitable currency candidate where baseline results are the most promising. Our intention with this model is to study the coefficients results of the dummy variable model relative to the coefficients from the baseline model, which allows us to compare safe haven behavior during average (ordinary) days with more conditional safe haven behavior.

Adding the interactive dummy term gives us the following model:

$$\Delta y_t = \alpha + \sum_{i=1}^{n} \beta_i \Delta y_{t-i} + \sum_{i=0}^{2} \gamma_i \Delta x_{t-i} + \delta_t + \underbrace{\omega D_t + \sum_{i=1}^{n} \mu_i \Delta y_{t-i} D_{t-i} + \sum_{i=0}^{2} \tau_i \Delta x_{t-i} D_{t-i}}_{Additional\ dummy\ and\ interactive\ dummy\ terms} \quad (6)$$

$$, where\ D_t = dummy\ term\ for\ risk\ off\ episode\ in\ time\ t$$

4.3 Best Linear Unbiased Estimator (BLUE)

To retrieve reliable Ordinary Least Squares (OLS) results, we need to satisfy a set of assumptions based on the Gauss-Markov theorem (Wooldridge, 2015). This is to ensure that our model is efficient and has the optimal linear unbiased estimator of the coefficients. If the assumptions presented in table 4 are violated, the regression results may not be trusted unless we correct for these problems.

Table 4: Assumptions based on the Gauss-Markov theorem

Assumption	**Mathematically**
Linear in parameter	See description 4.3.1.
Constant independent variables	$E\ (u_{it} \vert X_{it}) = 0$
Constant variance (homoscedasticity)	$VAR(u_{it} \vert X_{it}) = VAR\ (u_{it}) = \sigma^2$
No serial- or autocorrelation	$COV(u_t, u_s \vert X) = 0, where\ t \neq s$
Normal distribution of residuals	$u_{it} \sim N(O, \sigma^2)$

4.3.1 Linear in Parameter

First, we assume that the model is linear in parameter. This means that the dependent variable is assumed to be a linear function of the variables specified in the model. However, the independent variable can take non-linear forms as long as the parameters are linear.

4.3.2 Constant Independent Variables

The next assumption is that none of the independent variables are constant, and that there is no perfect collinearity among the independent variables. The Zero Conditional Mean-assumption must also hold, known as strict exogeneity. This means that the expected value of the error term is zero for all possible values of x. This assumption is crucial for casual interpretation of OLS.

4.3.3 Constant Variance

We also assume constant variance. The error term must have the same variance given any value of the explanatory variable. This is also known as the assumption of homoscedasticity in the error term. If this is violated, we will encounter problems with heteroscedasticity, which is needed to justify t-, F-tests and confidence intervals.

In STATA, we perform White's and Breusch-Pagan tests for heteroskedasticity. The difference between these two tests is that the former uses squares and cross products of the independent variables. If necessary, we will use heteroskedastic-consistent standard errors (HACSE) to correct for heteroscedasticity.

4.3.4 Serial- or autocorrelation

The last assumption is no serial- or autocorrelation. Violation of this assumption means we have lags of the error term. The consequence of this is unbiased estimates, but that the standard error of this estimate is no longer unbiased. This makes the OLS estimates inefficient and our hypothesis tests can no longer be trusted.

The Durbin-Watson[2] is used to check for problems with autocorrelation. This test ranges from 0 to 4. Values close to 0 indicate strong positive autocorrelation and values close to 4 indicate strong negative autocorrelation. The rule of thumb is that it should be around 2.

4.3.5 Normal distribution of residuals

We will also test for the normal distribution of the residuals. This is not crucial for the validity of the OLS model, but could lead to problems in determining whether the coefficients are significantly different from zero.

4.4 Stationarity

If a time series contains unit roots, it is considered to be non-stationary. A non-stationary process has no simple equilibrium. It has a trend, but each time a shock occurs, there will be a new equilibrium (Wooldridge, 2015). This involves an increasing sample variance over time and this is for instance common when using absolute levels. Non-stationarity leads to strict violations of the homoscedasticity assumption in OLS. This again can lead to spurious results, a situation where two variables are related through their correlation to a third variable. If we find a significant relationship

[2] This test is considered unsuitable for use in regressions that include lags of the dependent variable. For regressions that include lags of NEER, the results must be interpreted with caution.

between x on y, but also want to control for a third variable z, we can include z to make the partial effect of x on y become zero. It is therefore essential to test for stationarity in a time series.

The Augmented Dickey-Fueller (ADF) is a test for the stationarity in a time series. This can be formally done by running the following regression:

$$\Delta X_t = \alpha + \gamma X_{t-1} + \sum_{i=1}^{n} \beta_i \Delta X_{t-1} + \varepsilon_t \tag{7}$$

H_0: Non-stationary process, $\gamma = 0$

We have added a constant. It is also possible to add a trend to adjust for more complex linear relationships, and thus possibly capture a better rejection frequency of the null hypothesis. However, as we are looking into currencies and risk indicators, we find it more appropriate to assume a random walk without a trend. This is contrary to GDP, population growth and other macroeconomic variables where including a trend would be more natural. The optimal lag lengths are again decided by the AIC. This ensures that we capture the lag length that has the least information loss and highest rejection frequency. This also means we have different *n* for each dependent variable X.

If the null hypothesis of the ADF cannot be rejected, then we must conclude that the underlying process is non-stationary. This could make it problematic to continue with our analysis unless the variables are co-integrated. However, as our values are transformed into first differences, we do not expect non-stationarity to be a problem.

5. Results and analysis

In this section, we will present and analyze the results from our econometric analysis. First, we will discuss the results from our baseline regression, i.e. model (1), where the main goal is to identify safe haven tendencies on an average basis and investigate if currency characteristics have changed over time across our sample period. Then, we will expand the baseline model by adding an interactive dummy for risk off episodes, i.e. model (2), where the main goal is to investigate the conditional and potentially large and fast moving safe haven effects in extreme risk-off episodes.

5.1 Model I (baseline)

Each of our eight NEERs are regressed against the risk indicators separately, including any determined lags. For each currency, we therefore have three different regressions, one for each risk indicator. Furthermore, we are investigating three different periods to examine if safe haven behavior has changed over time and to what extent. We therefore have 24 regressions for each period. In total, this is 72 regressions for all the periods combined.

To identify safe haven currencies, we rely on the assumption that they are positively correlated with increases in risk indicators. We therefore expect an appreciation of safe haven currencies if a risk indicator increases. The regression coefficients tell us how the independent variable influences the dependent variable. Safe haven currencies can therefore be identified by interpretation of the risk indicator coefficients. The rule of thumb is that the coefficient needs to be statistically significant and have a positive sign. Non safe haven currencies, on the other hand, are expected to be statistically significant and have a negative sign.

It is not necessarily enough to be positively correlated with only one of the risk indicators. In order for a currency to be considered a reliable safe haven asset, we expect it to be positively correlated and have a statistically significant relationship with at least two of the three risk indicators. Nonetheless, any final conclusions on the label of a currency will be based on theoretical reasoning and our overall impression of the statistical elements.

We report both coefficients and the corresponding t-values. The significance level of the coefficients is based on t-tests, but can more easily be identified by asterisks. If the coefficient has one, two, or three asterisks, it is statistically significant on a 10, 5 or 1 per cent significance level, respectively. If a coefficient does not have an asterisk, it is not statistically different from zero, meaning it has no effect on the NEER. We also report the adjusted coefficient of determination (adjusted r^2) of all our regressions, i.e. the explanatory power.

For each currency, we will first perform a cross-periodical comparison of the results, and then proceed to analyzing the results. The analysis will have a particular emphasis on using empirical research, background material and our own reasoning to explain any cross-periodical change in behavior that we identify. When this is completed, we will present a partial conclusion and overview of our findings from model (1), indicating which currencies our evidence has characterized as safe haven, non safe haven, or inconclusive.

The following tables will show all periodical results for each currency against our three risk indicators VIX (top row), GRI (middle row) and MRI (bottom row). Respectively, these measure S&P500 (stock) volatility, foreign exchange (forex) volatility, and composite financial volatility. Our commentaries will follow the same order. First, we will discuss the results for VIX across all periods, then GRI, then MRI.

5.1.1 The Japanese Yen (JPY)

Table 5: Results from regressing the JPY

JPY	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	**-0.0409***	-	**0.0346****	0.002	-0.0111	0	0.4 %
	(-1.655)	-	(2.414)	(0.146)	(-0.841)	(-0.659)	
2007-2010	**-0.122****	-	**0.234*****	**0.0594****	0.0033	0.0003	23.2 %
	(-2.388)	-	(8.401)	(2.089)	(0.103)	(1.153)	
2010-2016	-	-	**0.218*****	0.0110	**0.0272****	0	20.5 %
	-	-	(12.52)	(0.806)	(2.157)	(0.303)	
JPY	**Y_{t-1}**	**Y_{t-2}**	**GRI**	**GRI_{t-1}**	**GRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	**-0.0569****	-	**0.0837*****	0.0005	0.002	0	7.8 %
	(-2.280)	-	(7.800)	(0.0637)	(0.265)	(-0.450)	
2007-2010	**-0.123*****	-	**0.147*****	**0.0209****	0.0035	0	40.2 %
	(-2.665)	-	(11.80)	(2.006)	(0.360)	(0.285)	
2010-2016	-	-	**0.0767*****	-0.0056	0.0092	0	10.7 %
	-	-	(8.079)	(-0.711)	(1.255)	(0.0553)	
JPY	**Y_{t-1}**	**Y_{t-2}**	**MRI**	**MRI_{t-1}**	**MRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	**-0.0429***	-	**0.0107****	0.0036	**-0.0120****	0	0.7 %
	(-1.732)	-	(2.198)	(0.806)	(-2.569)	(-0.677)	
2007-2010	-	-	**0.0924*****	**0.0283*****	-0.0027	0.0003	9.2 %
	-	-	(8.463)	(2.677)	(-0.235)	(1.072)	
2010-2016	**-0.0577***	-	**0.0524*****	**0.0205*****	**0.0071***	0	13.8 %
	(-1.856)	-	(10.66)	(4.601)	(1.781)	(0.104)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

Cross-periodical comparison of JPY results

Results show that the VIX, i.e. stock volatility, has significant positive coefficients for all three periods. In addition, for the two periods 2001-2007 and 2007-2010, the results show that yesterday's value of the JPY has a significant impact on today's value. Since the interpretation of lagged values of currencies is not our main focus, the paper will not discuss this in any particular detail for any of our results. The constants for all periods are not statistically different from zero, and hence has no impact on the JPY.

The quantitative impact of stock volatility on the JPY in the period 2001-2007 is relatively small, and the explanatory power is similarly weak. In our next period, however, the coefficient shows an enormous increase, as well as moving from a 5 to 1 per cent significance level. In 2001-2007, the coefficient estimates a 0.03 per cent appreciation in JPY when stock volatility increases by 1 per cent. In the period 2007-2010, however, a 1 per cent increase in stock volatility is now associated with a 0.23 per cent appreciation of the JPY. The explanatory power for this period increases accordingly.

As for our more recent period, the years 2010-2016, the stock volatility maintains its high correlation and statistical significance against the JPY, although the quantitative impact and explanatory power are marginally reduced compared to the previous period. Still, the JPY regressed against stock volatility evidently shows vast differences between the initial period of 2001-2007 and the two latter periods that possess a remarkable stronger positive correlation.

Results from the JPY regressed against GRI, i.e. forex volatility, show similar patterns to our previous discussion of the VIX. Forex volatility has a significant impact on the JPY in all three periods, at a 1 per cent significance level. From 2001-2007 to 2007-2010, the explanatory power increases tremendously from 7.8 per cent to 40.2 per cent. The coefficient increases from 0.08 to 0.15 per cent. In our last period, 2010-2016, the GRI's impact on the JPY shows a reversion to lower quantitative impacts and explanatory power, similar to the VIX. In the case of forex volatility, the reversion is larger, but still well above its 2001-2007 levels.

The MRI, measuring composite volatility across several financial assets, shows a similar significant increase in coefficients and explanatory powers from the period 2001-2007 to 2007-2010. The results are weaker than the ones for the VIX and the GRI, but are in total both convincing and highly significant. Interestingly, the explanatory power of the MRI in the recent period 2010-2016 is quite high, in fact higher than the GRI.

Analysis

Overall, our results from regressing the JPY against three different risk indicators and periods clearly suggest that the JPY has strong characteristics of being a safe haven currency. Fluctuations in stock volatility, forex volatility, and composite volatility, had a significant and substantial impact on the value of the JPY in our sample period. This is coherent with older empirical research on safe haven currencies, where the majority of studies present evidence that the JPY has strong safe haven properties (e.g. Ranaldo & Söderlind, 2009; Flatner, 2009; Habib & Stracca, 2011; Grisse & Nitschka, 2013; Botman et al., 2013).

More interestingly, our study identifies a stronger positive correlation in the years 2007-2010 and 2010-2016 compared to the period 2001-2007. In other words, the JPY shows stronger signs of being a safe haven currency in recent years. This is particularly the case for the financial crisis, where coefficients and explanatory powers were at their highest levels.

These findings lead us to one of the more interesting questions of this paper, namely the reasons for this change in behavior. First, we notice that some of the concerns presented in section 2.3 about the macroeconomic situation in Japan has not showed any relevance in our results. The somewhat dire situation of the Japanese economy with strong deflationary pressures in the periods 2007-2010 and 2010-2016, together with e.g. the BoJ's unpredictability and 'weak yen policy', have not affected investors' perception nor weakened the positive correlation. In fact, it has only become stronger.

We believe there are mainly three possible explanations for these findings. First, the *intrinsic risk profile* of Japan may be an explanation. Older research suggests that Japan has relatively less intrinsic risk associated with the country. Naturally, a safe haven asset should be relatively more shielded from global risk incidents. Japan is somewhat isolated in terms of geography, and is perhaps less vulnerable to commodity, political, terror or war related global circumstances compared to for instance the U.S., Great Britain or Europe. The intrinsic risk profile of Japan may therefore be highly attractive to risk averse investors. This effect, and therefore the status of the JPY as a safe haven currency, has only been reinforced in recent times, as we believe there has been a higher rate of market turbulence and risk-off related incidents compared to the period 2001-2007. Thus, the intrinsic risk profile of Japan has increasingly incentivized portfolio rebalancing towards the JPY.

Second, which is somewhat related to the first point, is that countries issuing safe haven currencies are often characterized by large, transparent, open, well-developed and liquid financial markets (Habib & Stracca, 2010). Japan certainly ticks all these boxes. These are characteristics that are highly valued by investors in times of increased global risk aversion and low liquidity. Japan also has a strong net foreign asset position (NFA), which is defined as the value of the assets that Japan owns abroad, minus the value of the domestic assets owned by foreigners. The NFA reflects indebtedness, country risk and external vulnerability.

Third, the unwinding of carry trade positions may have been an influencing factor in explaining the strong JPY appreciations during the financial crisis. Historically, some of the most popular carry trade positions are traditionally held in AUD/JPY and NZD/JPY due to large interest rate differentials. As presented in a commentary by the Reserve Bank of New Zealand, Wallis (2010) finds that the strained market liquidity and increased focus on counterparty risk during the financial crisis forced investors to reassess trades that were popular in the years between 2004-2007. The unwinding of AUD/JPY and NZD/JPY carry trade positions and other similar portfolio rebalancing will have a positive effect on the value of the JPY, as demand for the currency increases. This may also explain why the results for 2007-2010 were stronger than 2010-2016.

5.1.2 The Swiss Franc (CHF)

Table 6: Results from regressing the CHF

CHF	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	**-0.0884*****	-	**0.0859*****	0.0115	0.0078	0	8.9 %
	(-3.314)	-	(9.054)	(1.133)	(0.882)	(0.715)	
2007-2010	-	-	**0.0867*****	0.0135	-0.006	0.0002	13.6 %
	-	-	(7.308)	(1.272)	(-0.493)	(1.002)	
2010-2016	-	-	**0.0587*****	0.0137	0.0220	0.0002	1.9 %
	-	-	(3.557)	(0.674)	(1.367)	(1.292)	
CHF	**Y_{t-1}**	**Y_{t-2}**	**GRI**	**GRI_{t-1}**	**GRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	**-0.0730****	-	**0.0449*****	-0.0008	0.0025	0	7.3 %
	(-2.399)	-	(9.425)	(-0.178)	(0.580)	(0.793)	
2007-2010	-	-	**0.0456*****	-0.0023	-0.0004	0	16.4 %
	-	-	(8.077)	(-0.440)	(-0.0891)	(0.606)	
2010-2016	-	-	**0.0373*****	0.0049	-0.0054	0.0002	3.1 %
	-	-	(2.692)	(0.559)	(-0.983)	(1.231)	
CHF	**Y_{t-1}**	**Y_{t-2}**	**MRI**	**MRI_{t-1}**	**MRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	**-0.112*****	-	**0.0223*****	**0.0127*****	-0.0020	0	6.3 %
	(-3.592)	-	(7.388)	(4.504)	(-0.724)	(0.713)	
2007-2010	-	-	**0.0397*****	**0.0138*****	-0.0015	0.0002	7.2 %
	-	-	(6.578)	(3.053)	(-0.337)	(1.078)	
2010-2016	-	-	**0.0248*****	**0.0043***	-0.0007	0.0002	3.1 %
	-	-	(9.522)	(1.726)	(-0.278)	(1.231)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

<u>*Cross-periodical comparison of CHF results*</u>

According to the results in table 6, the CHF against stock volatility shows signs of significant appreciations for all three periods at a 1 per cent significance level. The results from the periods 2001-2007 and 2007-2010 are very much alike. In both these periods, the coefficient estimates around a 0.09 per cent appreciation of the CHF. The explanatory power is however at 8.9 per cent for the first period, then increases to 13.6 per cent during the years 2007-2010. In the period 2010-2016, the VIX is still statistically significant with increases in stock volatility being associated with an appreciation of the CHF. However, both the quantitative impact and the overall explanatory power are considerably lower for this period compared to the previous two.

Regressions of the CHF against forex volatility also show a positive correlation. Coefficients are positive and statistically significant at a 1 per cent level for all three periods. The GRI indicates around a 0.05 per cent appreciation in the first two periods. The explanatory power is at its highest during the financial crisis, at 16.4 per cent. It it less impressing for 2010-2016, where the explanatory power surprisingly drops to 3.1 per cent, and the coefficient decreases slightly to around 0.04 per cent.

The CHF against composite volatility, i.e. MRI, also shows significant coefficients at a 1 per cent significance level for all periods. All MRI coefficients indicate a positive correlation. Results are weaker than the two other risk indicators in the years up to 2010, but performs on par for the more recent period 2010-2016.

Analysis

Summarizing the CHF results, our final interpretation is that the Swiss currency overall shows significant tendencies of being a safe haven currency in our sample period. There is evidence of a positive correlation against stock volatility, forex volatility and composite volatility in all three periods. Similar to our findings from the JPY, the CHF seems to have gained relatively increased significance as a safe haven asset during the financial crisis. Other research, such as the papers discussed in section 2.1, support this notion and point towards the CHF as a currency with empirically strong hedging properties. This is especially in line with our results for the periods 2001-2007 and 2007-2010.

The most exciting finding from the CHF regressions is however the evidence that coefficients and explanatory powers indicate a weaker positive correlation in the period 2010-2016. Explanatory powers are around 1-3 per cent for all three volatility measures in this period. In other words, the CHF seems to have lost some of its safe haven properties in this period.

The explanation for this change in safe haven behavior is most likely twofold, and related to our initial thoughts expressed in section 2.2. First, it may be the case that investors and other market participants have changed their perception of the Swiss currency's status as a safe haven currency due to many of the unpredictable actions related to the introduction and removal of the currency peg. As the peg was surprisingly removed, a number of market participants across the world incurred large losses. This, together with the overall uneasy currency situation in the period spanning from around 2011 to 2015, may have caused a change in preferences among market participants who anticipate transparent, gradual and predictable actions by a central bank.

Second, the currency peg itself has most likely underwhelmed the quantitative impacts of any portfolio rebalancing towards the CHF. Although investors may flee to the CHF in times of particular distress, or on average, it may have been difficult for our model to capture any appreciations due to SNB's counteraction of maintain a fixed exchange rate. Interestingly, it could be argued the currency peg itself would attract even more risk averse investors, since there is a fixed predictability on the value of the currency. On the other hand, investors had little future information on when the currency peg could potentially be removed. This may have caused such uncertainty that many market participants were reluctant to flee to the CHF, especially compared to their preferences in the relatively more tranquil Swiss currency conditions in the periods 2001-2007 and 2007-2010. Preferences may therefore have been more shifted towards JPY or other perceived safe haven assets such as gold.

5.1.3 The New Zealand Dollar (NZD)

Table 7: Results from regressing the NZD

NZD	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	0.0369	-0.0548**	-0.0441**	-0.0394***	-0.0288**	0.0002	1.8 %
	(1.298)	(-2.171)	(-2.220)	(-2.732)	(-1.971)	(1.529)	
2007-2010	-	-	-0.191***	-0.0647***	0.0174	0	18.6 %
	-	-	(-7.924)	(-2.900)	(0.561)	(0.0740)	
2010-2016	-0.0889***	-	-0.122***	-0.0328***	-0.0036	0.0001	8.6 %
	(-3.662)	-	(-9.242)	(-2.652)	(-0.307)	(0.855)	
NZD	Y_{t-1}	Y_{t-2}	GRI	GRI_{t-1}	GRI_{t-2}	Constant	Adj. R^2
2001-2007	0.0413	-0.0592**	-0.0098	-0.0158*	-0.0071	0.0002	0.5 %
	(1.462)	(-2.299)	(-1.038)	(-1.764)	(-0.815)	(1.518)	
2007-2010	-	-	-0.108***	-0.0112*	-0.001	0.0002	23 %
	-	-	(-11.01)	(-1.751)	(-0.102)	(0.710)	
2010-2016	-0.0578**	-	-0.0561***	0.006	-0.0038	0.0001	7.1 %
	(-2.411)	-	(-8.516)	(1.122)	(-0.704)	(0.990)	
NZD	Y_{t-1}	Y_{t-2}	MRI	MRI_{t-1}	MRI_{t-2}	Constant	Adj. R^2
2001-2007	0.0422	-0.0570**	0.0006	-0.0149***	-0.0070	0.0002	0.9 %
	(1.483)	(-2.219)	(0.115)	(-2.582)	(-1.356)	(1.554)	
2007-2010	-	-	-0.0595***	-0.0281***	-0.0016	0	4.2 %
	-	-	(-6.267)	(-2.788)	(-0.149)	(-0.0499)	
2010-2016	-0.0778***	-	-0.0260***	-0.0122***	-0.0008	0.0001	4.5 %
	(-3.266)	-	(-7.696)	(-3.586)	(-0.250)	(0.938)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

<u>*Cross-periodical comparison of NZD results*</u>

Table 7 shows a significant and negative VIX coefficient for all three periods. Yesterday's value of VIX also has a significant impact in all three periods. The significance level and quantitative impact increases impressively during the financial crisis period compared to the period before. A 1 per cent increase in the VIX is now associated with a 0.19 per cent depreciation of the NZD. The explanatory power increases from 1.8 per cent to 18.6 per cent. In the recent period 2010-2016, the explanatory power and quantitative impacts are reduced by around half compared to the financial crisis, but still at significantly higher levels than in the first period, 2001-2007.

Results from the NZD against the forex volatility indicator, GRI, shows that the coefficient for the period 2001-2007 is not significant. The first lag is significant, but with only a trivial quantitative impact. This suggests a much weaker correlation between forex volatility and NZD in this period compared to our findings above regarding stock volatility. The two other periods, 2007-2010 and 2010-2016, do however show more similar patterns to the VIX. The correlations are highly significant at a 1 per cent level. The explanatory power for forex volatility in 2007-2010 is higher than stock volatility, but more similar for 2010-2016. The quantitative impact associated with a 1 per cent increase in forex volatility is a 0.11 per cent depreciation in 2007-2010 and 0.06 per cent depreciation in 2010-2016.

Similar to forex volatility, today's MRI is not significant in 2001-2007, but the lagged value is. Results for the MRI are weaker in the periods 2007-2010 and 2010-2016 compared to both forex volatility and stock volatility. Although they are significant, the quantitative impacts of composite volatility are lower, at a 0.06 per cent depreciation in 2007-2010 and 0.03 per cent depreciation in 2010-2016. Still, the MRI regressions support the pattern and consistency of our NZD results, as they indicate significant negative correlations and similar periodic changes.

Analysis

In total, our results indicate that the NZD exhibits significant characteristics of being a non safe haven asset. Coefficients are negative almost across the board, meaning a depreciation of the NZD in response to an increase in volatility. Results are weak for the period 2001-2007, which suggests that portfolio rebalancing away from the NZD in response to increased volatility was not as prevalent in this period, perhaps being overshadowed by what investors' perceived to be more important factors at the time. Not to mention, we consider these years to be relatively tranquil with low levels of risk aversion. Thus we expected low statistical strengths for this period in our regressions. Results for the financial crisis are however much stronger. In this period, explanatory powers are around 20 per cent for both stock volatility and forex volatility, and coefficients are at noteworthy levels. For the period 2010-2016, the NZD maintains a relatively strong non safe have tendency compared to the period 2001-2007.

One interesting question in regard to our NZD findings is concerned with potential explanations for the increase in non safe haven behavior during the financial crisis, and the fact that it has been somewhat maintained in the years that followed. We believe there is one prominent reason for the results from the financial crisis. This is related to our discussion surrounding the JPY and the unwinding of carry trade positions. As mentioned, NZD/JPY has traditionally been a popular carry trade position. Historically, the NZD has been a high-yielding currency with relatively high interest rates compared to other developed countries.

Reduced risk appetite during the financial crisis caused such large foreign positions of riskier nature to be scaled back. As shown in section 2.6, the NZD experienced diminishing shares of total trading turnovers during the financial crisis, in stark contrast to the years before where it had been steadily increasing since 1998. The reduced willingness to maintain portfolios in risky position can therefore explain our results for the financial crisis.

It also seems as though the impacts of the financial crisis left lasting scars on market participants, as the non safe haven tendencies continued throughout the recent years of 2010-2016. This is most likely due to the lessons from the financial crisis and the resulting increased preference for liquid currencies in times of market turbulence. During the financial crisis, liquidity in the NZD market became very strained, in turn causing a large widening of bid-ask spreads, particularly around the time of the Lehman Brothers collapse. In situations of increased risk aversion, the illiquidity of the NZD seems to act as a deterrent for investors rebalancing their portfolios.

5.1.4 The Australian Dollar (AUD)

Table 8: Results from regressing the AUD

AUD	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	0.0149	**-0.0615****	**-0.0683*****	**-0.0826*****	**-0.0298***	0.0002	4.9 %
	(0.471)	(-2.184)	(-3.646)	(-4.827)	(-1.911)	(1.065)	
2007-2010	**-0.233*****	-	**-0.261*****	**-0.146*****	0.0201	0.0002	25.6 %
	(-3.571)	-	(-6.783)	(-3.982)	(0.398)	(0.671)	
2010-2016	**-0.105*****	-	**-0.196*****	**-0.0473*****	**-0.0218***	0	20.2 %
	(-4.103)	-	(-13.90)	(-3.285)	(-1.829)	(-0.320)	
AUD	**Y_{t-1}**	**Y_{t-2}**	**GRI**	**GRI_{t-1}**	**GRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	0.0382	**-0.0708****	-0.00217	**-0.0291*****	-0.00837	0.0002	1.2 %
	(1.197)	(-2.500)	(-0.193)	(-3.606)	(-0.924)	(1.059)	
2007-2010	**-0.136****	-	**-0.158*****	**-0.0257****	-0.0101	0.0005	32.4 %
	(-2.573)	-	(-9.554)	(-2.334)	(-0.610)	(1.582)	
2010-2016	**-0.0716****	-	**-0.0843*****	0.0038	-0.005	0	14.7 %
	(-2.538)	-	(-12.80)	(0.602)	(-0.898)	(-0.0367)	
AUD	**Y_{t-1}**	**Y_{t-2}**	**MRI**	**MRI_{t-1}**	**MRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	0.0198	**-0.0707****	-0.0048	**-0.0355*****	**-0.0154*****	0.0001	4.3%
	(0.631)	(-2.536)	(-0.944)	(-6.728)	(-3.095)	(1.074)	
2007-2010	-	-	**-0.0682*****	**-0.0289****	0.0003	0.0001	3.4 %
	-	-	(-5.245)	(-2.291)	(0.0209)	(0.363)	
2010-2016	**-0.104*****	-	**-0.0486*****	**-0.0181*****	**-0.0056***	0	13.1 %
	(-3.648)	-	(-13.91)	(-4.933)	(-1.745)	(-0.110)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

Cross-periodical comparison of AUD results

The VIX coefficients are negative and generally high in all three periods. The large increase in the stock volatility's impact on the AUD across the periods is noteworthy. The quantitative impact increases from a 0.07 per cent depreciation in 2001-2007 to a 0.26 per cent depreciation in 2007-2010. The explanatory power increases accordingly, from 4.9 per cent to 25.6 per cent. The period 2010-2016 shows a slightly lower depreciation, but still at very high levels. The explanatory power also maintains a high level, at 20.2 per cent.

The relationship between the AUD and forex volatility in table 8 shows the same interesting results as stock volatility. The coefficients are negative and indicate a relatively strong depreciation of the AUD when forex volatility increases. The period 2001-2007 must be interpreted with some caution, as only the lagged value of GRI is significant, and the explanatory power and coefficient are very low. For the two other periods, 2007-2010 and 2010-2016, there is a massive increase in both levels. At its highest level across the periods, the explanatory power is 32.4 per cent during the financial crisis, which is higher than the VIX. The coefficient from the VIX is however larger in this period. In the period 2010-2016, we see the same reversion to a smaller explanatory power and quantitative impact after the financial crisis as we have seen in most of the currencies, but still at much higher levels than the years 2001-2007.

In general, the MRI, i.e. financial composite volatility, also support the notion that the AUD depreciates when the risk indicators increase. Only the lagged values of MRI are significant for the years 2001-2007, but at a similar explanatory power as VIX. The MRI model performs relatively poor for the period 2007-2010, but is at a convincing level for the period 2010-2016, with an explanatory power at 13.1 per cent. The composite volatility results support the notion of a negative correlation across all periods for the AUD.

Analysis

Our results show that the AUD displays significant non safe haven characteristics across all three periods. For the period 2001-2007, results are quite similar to the NZD, with low explanatory powers and coefficients. As for the financial crisis, our findings indicate that portfolio rebalancing away from the AUD was stronger than the NZD. Here, the explanatory powers for stock volatility and forex volatility are quite high, at 25.6 per cent and 32.4 per cent, respectively. Coefficients are also at high levels. For the period 2010-2016, we observe that stock, forex and composite volatility all have a convincing explanatory power, especially the VIX that shows a 0.20 per cent depreciation and 20.2 per cent explanatory power.

The previous discussion about the NZD in section 5.1.3 is also relevant in attempting to explain the cross-periodical strengthening of non safe haven tendencies in the AUD. The volatile movements in currency markets seen over the financial crisis significantly reduced the appetite for carry trade investment strategies. We believe investors feared that the amplified risk of sharp currency movements could wipe out any interest rate gains. The unwinding of carry trade positions during the financial crisis, together with investors' increased preference for portfolio rebalancing towards more liquid currencies, has therefore had a similar negative impact on the Australian currency.

The results we have presented for the two non safe haven currencies we have identified so far suggest that the AUD has relatively stronger non safe haven attributes than the NZD, both during the financial crisis and the years that followed. The reason for this is both unclear and rather puzzling, as we expected our results to show the contrary. First, New Zealand has historically had higher levels of interest rates compared to Australia. This means that the interest rate differential has been more favorable in NZD carry trade strategies, causing a relatively larger inflows of capital compared to the AUD. The scaling back of NZD positions during the financial crisis should therefore have been larger than the ones for AUD. Second, the bid-ask spreads of the AUD has historically been below that of the NZD, which indicates a comparatively greater liquidity of the AUD market. These two considerations led us to believe that we would find relatively stronger non safe haven tendencies for NZD in the period 2010-2016, as we expect the scaling back of risky currency positions in times of market turbulence to be most prominent for the most illiquid currencies.

5.1.5 The U.S. Dollar (USD)

Table 9: Results from regressing the USD

USD	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	-	-	0	**0.0296*****	0.0043	0	1 %
	-	-	(0.00459)	(4.086)	(0.611)	(-0.902)	
2007-2010	-	-	**0.0924*****	**0.0280****	-0.0155	0	18.8 %
	-	-	(6.817)	(2.096)	(-1.406)	(-0.547)	
2010-2016	-	-	**0.100*****	0.0086	0.0012	**0.0002****	16.3 %
	-	-	(11.71)	(1.095)	(0.173)	(2.485)	
USD	**Y_{t-1}**	**Y_{t-2}**	**GRI**	**GRI_{t-1}**	**GRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	-	-	**-0.0283*****	0.0015	-0.0025	0	2.9 %
	-	-	(-6.469)	(0.389)	(-0.690)	(-1.121)	
2007-2010	-	-	**0.0368*****	0.0023	-0.0009	-0.0001	11.2 %
	-	-	(6.606)	(0.512)	(-0.201)	(-0.886)	
2010-2016	-	-	**0.0492*****	-0.0041	-0.0021	**0.0002****	16.7 %
	-	-	(14.31)	(-1.343)	(-0.636)	(2.262)	
USD	**Y_{t-1}**	**Y_{t-2}**	**MRI**	**MRI_{t-1}**	**MRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	-	-	-0.0038	**0.0115*****	**0.0059****	0	1.6 %
	-	-	(-1.362)	(4.423)	(2.293)	(-0.892)	
2007-2010	-	-	**0.0179*****	**0.0124*****	-0.0020	0	1.8 %
	-	-	(3.731)	(2.738)	(-0.456)	(-0.400)	
2010-2016	**-0.0473***	-	**0.0294*****	**0.0083*****	-0.0005	**0.0002****	14.9 %
	(-1.808)	-	(15.08)	(4.379)	(-0.293)	(2.412)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

<u>*Cross-periodical comparison of USD results*</u>

The period 2001-2007 seems to show little evidence of a positive correlation between the USD and stock volatility. Only the coefficient for yesterday's value of VIX is significant, but as the explanatory power is very low, and the quantitative impact rather small, there is no strong evidence that an increase in stock volatility is associated with an appreciation nor depreciation of the USD in the years 2001-2007.

As for the two more recent periods, the results for the years 2007-2010 and 2010-2016 are much stronger, showing significant VIX coefficients at a 1 per cent level. The explanatory powers are also much higher, at 18.8 per cent and 16.3 per cent, respectively. Interestingly, the coefficient for the recent period 2010-2016 is the strongest, indicating a 0.10 per cent appreciation in the USD when stock volatility increases by 1 per cent.

The results for the USD against forex volatility are similarly interesting. In the period 2001-2007, an increase in forex volatility is associated with a depreciation of the USD, indicating a negative correlation. The explanatory power is however relatively low for this period. In the periods 2007-2010 and 2010-2016, however, the coefficients change signs, indicating a significant appreciation rather than a depreciation. The explanatory power is also relatively much higher for these two periods. The quantitative impacts on the USD from the GRI are nevertheless smaller than for the VIX.

The USD and composite volatility model, i.e. MRI, shows similar weak results for the first period. In contrast to stock and forex volatility, results for 2007-2010 are much weaker for the composite volatility. The years 2010-2016 are however much more aligned with the other indicators, as we see a relatively high explanatory power at 14.9 per cent.

Analysis

Our findings from regressing the USD against three measures of volatility in financial markets are very interesting. For the period 2001-2007, there are no consistent patters in results for stock, forex, or composite volatility. Explanatory powers are in the area of 1-3 per cent, and the small coefficients show both positive and negative signs. For the years 2007-2016, however, the econometric results are more consistent, significant and powerful. This suggests that the USD has become a stronger safe haven currency in recent years, which is in line with our initial expectations and suggestions from other empirical research. Paradoxically, even though the U.S. triggered the financial crisis and consequently was hit the hardest, interest for the American currency increased during the turmoil.

We would like to put forward two possible explanations for this shift in preference among risk averse investors. The first reason is related to the discussion surrounding reduced risk appetite and preference towards liquid currencies. After the Lehman Brothers' declaration of bankruptcy, it appears as though risk appetite became considerably more important than fundamentals for developments in the forex market. These fundamental factors include the situation in the housing market, which was rather ominous at the time. Fundamentals would furthermore have indicated a rebalancing away from the USD, e.g. because of the fact that monetary policy was expected to be expansionary due to prospects of weaker economic development. Such loosening of policy is not supportive of USD currency positions due to lower yields. As it seems, concern for these fundamental factors was outweighed by reduced risk appetite.

Even though the USD enjoyed a strong liquidity premium amid the market turbulence, several analysts and investors anticipated that it would lose its attractiveness when the full impact of relaxed fiscal and monetary policy hit the country. In the longer term, it was believed that the magnitude of fiscal spending and lack of international capital available to support it would threaten the USD's strength. Our results for 2010-2016 indicate however that increased turbulence and risk aversion in financial markets have continued to boost the buying of USD.

Second, our initial views in section 2.5 about the negative correlation between the USD and oil prices may be be an additional explanation for our results for the period 2010-2016. At present, this is a potential explanatory factor that our model does not include, but we will look into this later. Several studies, such as Fratzscher et al. (2014), have found that an increase in the price of oil is associated with a depreciation of the USD. Oil prices are quoted in USD, making it the transactional standard. A depreciation is likely caused by the fact that increased oil prices reduce the demand for oil, which in turn will reduce the demand for USD. Equally, we believe a reduction in the oil price will be associated with an increase in the demand for USD, causing it to appreciate.

From 2010 to 2014, oil prices were steadily increasing at high levels. From 2014 and onwards, however, oil prices have plummeted. We believe that the magnitude of the oil price plunge in the latter years of the period has had a more dominant effect on our results compared to the oil price increase in the initial years, hence playing some part in explaining the appreciations of the USD in the period 2010-2016 besides our volatility variables. Nonetheless, as the relationship between the oil price and the USD is quite complex, e.g. due to the two-way causality, this explanation should be regarded only as a partial contributor to the appreciations in the USD, rather than a decisive or certain factor.

Worth mentioning is also the fact that volatile fluctuations in the oil price may have had a significant impact on our risk indicators, for instance the VIX. There is strong evidence that oil prices affect individual asset prices at a monthly data frequency (Killian & Park, 2009). Many of the companies in the S&P500 operate in the oil and gas business, meaning that fluctuations in oil prices will affect their earnings and consequently affect equity price movements in a volatile manner, i.e. affecting the VIX. This particular point is more concerned with partially explaining what we believe is a higher occurrence of market turbulence and global risk-off episodes after the period 2001-2007.

5.1.6 The Euro (EUR)

Table 10: Results from regressing the EUR

EUR	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	-	-	**0.0734*****	**-0.0205***	0.0068	0.0002	3.4 %
	-	-	(5.870)	(-1.716)	(0.634)	(1.612)	
2007-2010	-	-	0.0022	-0.0114	0.0042	0.0001	0.07 %
	-	-	(0.208)	(-1.231)	(0.442)	(0.894)	
2010-2016	-	-	**0.0206****	**0.0269*****	-0.0035	0	16.3 %
	-	-	(2.073)	(2.885)	(-0.391)	(0.0307)	
EUR	**Y_{t-1}**	**Y_{t-2}**	**GRI**	**GRI_{t-1}**	**GRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	-	-	**0.0486*****	-0.0018	0.0022	**0.0002***	5.1 %
	-	-	(7.288)	(-0.361)	(0.385)	(1.752)	
2007-2010	-	-	-0.0004	-0.0057	-0.0018	0.0001	0.05 %
	-	-	(-0.105)	(-1.460)	(-0.485)	(1.001)	
2010-2016	-	-	**-0.0098****	**0.0091****	0.0023	0	16.7 %
	-	-	(-1.962)	(2.278)	(0.627)	(0.0098)	
EUR	**Y_{t-1}**	**Y_{t-2}**	**MRI**	**MRI_{t-1}**	**MRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	**-0.0629****	-	**0.0237*****	**0.0090*****	-0.0030	**0.0002***	3.6 %
	(-2.244)	-	(6.177)	(2.661)	(-0.889)	(1.743)	
2007-2010	-	-	**0.0109*****	-0.0008	-0.0029	0.0001	0.4 %
	-	-	(2.695)	(-0.208)	(-0.763)	(0.901)	
2010-2016	-	-	-0.0014	**0.0087*****	0.0024	0	0.9 %
	-	-	(-0.629)	(4.031)	(1.054)	(-0.0105)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

<u>*Cross-periodical comparison of EUR results*</u>

In the period 2001-2007, the EUR has a positive coefficient for stock volatility on a 1 per cent significance level, but with a relatively low explanatory power. During the financial crisis, the years 2007-2010, the VIX regression provide absolutely no result of econometric value. In the last period, the years 2010-2016, the results indicate an appreciation of the EUR when stock volatility increases, also with a quite high explanatory power. This indicates a positive correlation.

In the first period, the forex volatility model initially shows promising results with a coefficient indicating a positive correlation, in line with the results for stock volatility, but at a slightly higher explanatory power. Results from the financial crisis are however not significant. For the period 2010-2016, although the explanatory power is at similar high levels to the VIX, coefficients are small. Furthermore, forex volatility gives us statistical significant coefficients for itself and its first lag with different signs. The VIX and GRI evidently show conflicting correlations for the same period. Based on this, it is hard to draw any consistent conclusion concerning forex volatility and its impact on the EUR in the period 2010-2016.

Similar to the two other risk indicators, and even to a larger extent, the MRI results are unreliable. Explanatory powers are weak, and in the area of 1-3 per cent across all periods. Coefficients range from 0,01 to 0,02 per cent. In total, our results for all three risk indicators present little evidence that the EUR has a strong positive nor negative correlation with increased risk aversion.

Analysis

In general, our EUR findings have not provided us with any new insight, but rather confirmed the empirical notion that the EUR does not exhibit characteristics associated with being a safe nor non safe haven currency. Although the explanatory powers are decent for the period 2010-2016, and show higher levels compared to the years 2001-2007, the quantitative impacts are marginal. Furthermore, the signs in front of the coefficients are not consistent, as the GRI suggests a depreciation for 2010-2016, while the VIX suggests an appreciation for the same period. The EUR is a highly liquid currency that has increased its popularity as an intermediary currency during the years, but our results do not suggest that investors' have strong short term tendencies of portfolio rebalancing towards or away from the EUR in times of increased volatility. Evidently, other factors our model does not capture seem more suited to explain the movements.

5.1.7 The British Pound (GBP)

Table 11: Results from regressing the GBP

GBP	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	-	-	0.0068	-0.001	0.0062	0	0.1 %
	-	-	(0.748)	(-0.114)	(0.683)	(0.578)	
2007-2010	**0.0955***	-	**-0.0458****	-0.0055	-0.0115	-0.0003	2.4 %
	(1.957)	-	(-2.395)	(-0.324)	(-0.745)	(-1.296)	
2010-2016	0.0087	**-0.0399***	-0.0229	-0.0126	0.002	0	0.6 %
	(0.173)	(-1.655)	(-1.210)	(-1.160)	(0.185)	(0.345)	
GBP	Y_{t-1}	Y_{t-2}	**GRI**	GRI_{t-1}	GRI_{t-2}	**Constant**	**Adj. R^2**
2001-2007	-	-	-0.0048	-0.0026	**0.0115****	0	0.2 %
	-	-	(-0.906)	(-0.484)	(2.359)	(0.579)	
2007-2010	**0.0828***	-	**-0.0269*****	0.0006	-0.0056	-0.0002	3.7 %
	(1.747)	-	(-4.417)	(0.115)	(-1.015)	(-1.100)	
2010-2016	0.0121	**-0.0403***	-0.0156	-0.0054	0.0009	0	1.0 %
	(0.249)	(-1.663)	(-1.466)	(-0.689)	(0.142)	(0.417)	
GBP	Y_{t-1}	Y_{t-2}	**MRI**	MRI_{t-1}	MRI_{t-2}	**Constant**	**Adj. R^2**
2001-2007	-	-	0.0047	-0.0027	0.0031	0	0.04 %
	-	-	(1.405)	(-0.905)	(0.959)	(0.583)	
2007-2010	**0.0946***	-	**-0.0125****	-0.0021	0.0029	-0.0003	0.7 %
	(1.928)	-	(-2.099)	(-0.347)	(0.505)	(-1.323)	
2010-2016	-	-	-0.0074	-0.0039	0.0026	0	0.5 %
	-	-	(-1.201)	(-0.934)	(0.883)	(0.371)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

Cross-periodical comparison of GBP results

The relationship between the GBP and stock volatility is weak across all periods. The only result worth mentioning in table 11 is the quantitative impact evident in the period 2007-2010, where a 1 per cent increase in the VIX is associated with close to a 0.05 per cent depreciation of the GBP. The remaining results across the two other periods are not significant.

The GBP against forex volatility shows very similar patterns to stock volatility. The only significant results can be found in the period 2007-2010, at a 1 per cent level, indicating a small depreciation of the GBP when forex volatility increases. The explanatory power for this period is however low. The periods 2001-2007 and 2010-2016 do not reveal any significant quantitative impacts.

The GBP and MRI model performs even poorer than the VIX and GRI, with only a small significant coefficient in the period 2007-2010, and an almost non-existing explanatory power at 0.7 per cent.

Analysis

Concluding on the findings from analyzing the GBP, results are even less convincing than for the EUR. Most of the results were insignificant. There is no evidence that variables related to increased volatility in financial markets are prominent in explaining the short term movements of the GBP. These results are in contrast to e.g. the ones presented by Grisse & Nitschka (2013), who suggest that the GBP shows significant safe haven properties against the CHF. Other research papers have shown the opposite effects, e.g. Flatner (2009). Therefore, in total, we believe our results support the general empirical notion that the GBP is neither a safe nor non safe haven currency, i.e. inconclusive.

5.1.8 The Norwegian Krone (NOK)

Table 12: Results from regressing the NOK

NOK	Y_{t-1}	Y_{t-2}	VIX	VIX_{t-1}	VIX_{t-2}	Constant	Adj. R^2
2001-2007	**0.125*****	**-0.0760*****	**0.0206***	-0.0167	0.0121	0	1.9 %
	(3.804)	(-2.755)	(1.959)	(-1.307)	(1.065)	(0.754)	
2007-2010	-	-	**-0.0595*****	-0.00821	**0.0639*****	0.0001	7.8 %
	-	-	(-3.078)	(-0.476)	(2.639)	(0.488)	
2010-2016	**-0.0544***	-0.0489*	**-0.104*****	**-0.0225****	-0.0142	0	9.2 %
	(-1.853)	(-1.651)	(-9.057)	(-2.420)	(-1.563)	(-0.870)	
NOK	**Y_{t-1}**	**Y_{t-2}**	**GRI**	**GRI_{t-1}**	**GRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	**0.125*****	**-0.0745*****	**0.0133****	-0.0086	0.0071	0	2.2 %
	(3.784)	(-2.682)	(2.168)	(-1.363)	(1.356)	(0.783)	
2007-2010	-	-	**-0.0262*****	0	0.0158	0.0001	3.7 %
	-	-	(-2.770)	(-0.0089)	(1.631)	(0.570)	
2010-2016	-0.0333	**-0.0515***	**-0.0431*****	-0.0003	-0.0084*	0	6.4 %
	(-1.120)	(-1.725)	(-9.690)	(-0.0579)	(-1.767)	(-0.656)	
NOK	**Y_{t-1}**	**Y_{t-2}**	**MRI**	**MRI_{t-1}**	**MRI_{t-2}**	**Constant**	**Adj. R^2**
2001-2007	**0.122*****	**-0.0748*****	**0.0075****	-0.0025	0.0053	0	2.0 %
	(3.701)	(-2.721)	(2.022)	(-0.687)	(1.465)	(0.774)	
2007-2010	-	-	**-0.0266*****	-0.0062	0.0098	0.0001	1.5%
	-	-	(-4.18)	(-0.988)	(1.412)	(0.457)	
2010-2016	**-0.0572****	**-0.0510***	**-0.0262*****	**-0.0092*****	**-0.0060****	0	6.3%
	(-2.050)	(-1.696)	(-9.793)	(-3.393)	(-2.238)	(-0.726)	

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,509 for 2001-2007, 757 for 2007-2010 and 1,681 for 2010-2016.*

Cross-periodical comparison of NOK results

The NOK and stock volatility results from 2001-2007 in the top row of table 12 are weak. They do show some signs of positive correlation, but marginally so, considering the low significance level, quantitative impact and explanatory power. Results for the financial crisis in the years 2007-2010 are stronger and indicate a negative correlation with a depreciation at 0.06 per cent when stock volatility increases by 1 per cent. The explanatory power is higher than in 2001-2007, at 7.8 per cent. During the period 2010-2016, the VIX coefficient estimates a 0.104 per cent depreciation of the NOK. The explanatory power for this period is 9.2 per cent; higher than the financial crisis.

The results concerning forex volatility are much like the VIX regression in the period 2001-2007. The main difference is a higher statistical significance at a 5 per cent significance level and a smaller coefficient. For the financial crisis, the GRI coefficient turns negative, similar to the VIX. These effects become stronger in the third period, in the years 2010-2016, with both a larger quantitative impact and explanatory power.

The MRI results also indicate a small positive correlation during the first period, but with a low explanatory power. Results for the financial crisis show a significant negative correlation, but at low explanatory powers compared to the VIX and GRI. For 2010-2016, composite volatility indicates a significant negative correlation with a decent explanatory power that is on par with forex volatility.

Analysis

Results from analyzing the NOK are quite inconclusive for the first period 2001-2007. It could however to some extent be argued that the NOK has become a relatively stronger non safe haven currency in the years after 2007. The stock volatility results are the most persuading in terms of non safe haven flows during the financial crisis 2007-2010, but, generally, arguments in favor of labelling the NOK as a non safe haven currency for this period are not as strong compared to our highest performing models. For the period 2010-2016, however, all three risk indicators are stronger and more unanimous in their verdict. In this period, the NOK displays in fact stronger non safe haven characteristics than the NZD.

Interestingly, analysts and investors did not completely agree about the NOK’s currency status during the market turmoil in 2007-2010. In fact, many investors were quite public about their positive opinions of the NOK. In march 2009, analysts claimed that it was “the ultimate safe haven currency” (Financial Times, 2009). This was rather surprising as only some months earlier, in December 2008, it had dropped to a record low against the EUR.

Still, analysts at e.g. HSBC said that the NOK was their preferred major currency, and that it was near or at the top of the chart among the world’s ten most traded currencies. The reasons for the

NOK optimism was perhaps related to strong growth at the time, where Norway's economy grew at 1.3 per cent in the fourth quarter of 2008. Investors therefore believed Norway's economic slump following the financial crisis would be of trivial magnitude compared to other currency nations. Furthermore, at the time, monetary policy was quite supportive of the NOK. Norway was among few countries that sensed the market turmoil and commenced their interest rate lift-off relatively early.

Additional factors that may have played into the perception of the NOK's safe haven status was its large current account surplus standing at 5 per cent of GDP. Moreover, the cost of insuring against sovereign default in Norway by the use of credit default swaps was the lowest among the top ten traded currencies. Also, at the time, oil prices were expected to swiftly recoup, which in fact they did, as shown earlier in section 2.5 and figure 5.

On the other hand, there were analysts and investors with more pessimism towards the NOK. First, the fact that it fell strongly against both the USD and EUR during the aftermaths of the Lehman Brothers collapse was a strong argument for this pessimism. Second, there were concerns about the lack of liquidity in the NOK market. Investors and other market participants found it worrying that large trades away from the NOK would impose a substantial depreciation due to the relatively small NOK capital base. Third, investors feared the implications of the NOK's positive correlation with oil prices. Empirical evidence strongly suggest that the NOK depreciates when oil prices drop. Hence, since financial turmoil often is accompanied by a drop in oil prices, it may be argued that the NOK is an unsuitable safe haven candidate.

Overall, the abovementioned discussions are highly relevant to explaining our NOK results. First, in the period 2001-2007, the NOK was relatively more safe haven due to tranquil macro conditions and steadily increasing oil prices. In the period 2007-2010, the NOK was heavily dominated by both safe haven and non safe haven flows, due to the differing views among investors of the NOK's status, as discussed. Considering the negative signs in front of the risk coefficients during the financial crisis, the non safe haven flows seem to have dominated the safe haven flows, but however not that strongly, perhaps due to outlooks for increasing oil prices post financial crisis. The period 2010-2016, however, has been dominated by plummeting oil prices, which seems to have contributed to an overall non safe haven effect on the NOK.

5.1.9 Partial conclusion from model (1)

Table 13 summarizes the overall impression from our regression results. If there is an arrow to the left of the currency, this indicate a periodic strengthening or weakening of the identified tendency.

Table 13: Summary of findings from model (1)

	Safe haven currencies	Non-safe haven currencies	Inconclusive
2001-2007	JPY CHF	AUD NZD	USD EUR GBP NOK
2007-2010	↑ JPY ↑ CHF USD	↑ AUD ↑ NZD	EUR GBP NOK
2010-2016	JPY ↓ CHF and ↑ USD	AUD NZD NOK	EUR GBP

Note: Arrows to the left of a currency indicate a noteworthy strengthening (upward) or weakening (downward) of tendencies from one period to anothe.

The JPY seems to be the strongest safe haven candidate across all periods. The CHF, on the other hand, has experienced significant change in recent years and lost a large extent of its safe haven characteristics, as indicated by the downward arrow for 2010-2016. As for the AUD and NZD, they have in total become relatively more non safe haven currencies in the years 2007-2016 compared to 2001-2007. Here, the AUD exhibits even stronger tendencies than the NZD. In fact, the NZD had such poor explanatory powers for the first period 2001-2007 that we were not sure if it merited the non safe haven label, but we were eventually convinced by the high significance levels and coefficients.

In total, results for the EUR and GBP are inconclusive across all periods, as they correlation-wise perform poorly and inconsistently compared to the models for JPY, CHF, AUD, NZD, and USD. The NOK, on the other hand, shows an interesting shift in safe haven behavior. From being overall inconclusive in the years 2001-2010, the recent years 2010-2016 indicate that it exhibits relatively stronger non safe haven characteristics. This is shown in table 13, where the NOK is inconclusive for the first two periods, but enters the 'non safe haven' column for the last period.

Overall, the majority of the results were in line with our expectations. Based on our previous discussions, we believed for instance that our findings would indicate that the JPY has become more attractive for investors in recent years, while the CHF has lost some of its attractiveness. Also, we were able to confirm our view that the USD has become a significant safe haven currency after the financial crisis. There were however some results that were rather unexpected. First, we did not expect to find that the AUD has developed relatively stronger non safe haven tendencies than the NZD. Second, we were quite unsure what we would find in regard to the NOK, as empirical research and overall investor perceptions regarding its safe haven properties are subject to conflicting views. We were leaning towards an expectation that the NOK would show stronger non safe haven tendencies due to its illiquidity and the oil-induced weakened development in the Norwegian economy.

The overall explanation for many of the changes we have identified post financial crisis is related to what we believe is a higher occurrence and severity of market turbulence in recent years. The turmoil during the financial crisis seems to have left lasting financial scars throughout the period 2010-2016. Combined with the many severe political, nature, war and terror related incidents that have taken place, we believe the difference in tranquility between the periods becomes rather significant. This explains as well why the explanatory powers are generally small for the periods 2001-2007, as we believe risk aversion among investors was quite low at the time.

5.2 Model II (Interactive Dummy Model)

In this model, we have chosen to analyze the JPY against the risk indicators for the period 2007-2016, which allows us to focus on more recent risk-off episodes that have yet to be examined properly in the literature. The JPY has overall displayed the strongest and most reliable safe haven tendencies and is therefore the most suitable candidate for this analysis. The analysis is based on both the expanded Interactive Dummy Model and a comparison with the baseline ADL model for this period.

Based on varsoc results, we have decided to consistently include one lag of the JPY. Removing the lag for JPY where it is insignificant has next to no impact on the regression results. By including it for all regressions, the comparative analysis becomes easier to interpret because of a standardized method. We also continue using two lags of the risk indicators. We still rely on the same assumptions previously stated in the paper.

We hope to catch any extra effects during risk-off episodes by including the dummy to our model. Our assumption is a stronger appreciation during these episodes, which will be captured by the dummy terms. This approach also lets us investigate potential changes in the mutual coefficients from both models.

We will present results for all three risk indicators with a standard ADL Model (1) and an expanded Interactive Dummy Model (2). This gives us two regressions for each risk indicator. In total this is six regressions.

5.2.1 Results and Comparison with Baseline Model

The results for the JPY are presented in table 14. The left column shows results for the VIX, the middle column shows GRI, while the right column shows MRI. The results for model (1) in each column are from the baseline model, and model (2) from the interactive dummy model.

For the VIX, in the left column, the coefficients for model (1) and (2) are remarkably similar. This is evident by the statistical significance and quantitative value of the coefficients for the JPY lag and VIX together with its first and second lag. The difference between the shared coefficients is trivial. Interestingly, the interactive dummy variables do not show any additional effects during risk-off episodes. Despite this the dummy variable does indicate that there is a general appreciation of about 0.002 per cent during these episodes. This quantitative impact is extremely small and should be interpreted carefully. Moreover, the explanatory powers of model (1) and model (2) for VIX are nearly identical. So far, these two discoveries indicate that risk-off episodes. i.e. the conditional effects, have little impact on the short term movement of the JPY in response to stock volatility.

Table 14: JPY Results from model (2)

2007-2016	(1)	(2)	2007-2016	(1)	(2)	2007-2016	(1)	(2)
Constant	0.0001	0	Constant	0	0	Constant	0.0001	0
	(0.981)	(0.569)		(0.344)	(0.0324)		-0.844	(0331)
Y_{t-1}	-0.0657**	-0.0649**	Y_{t-1}	-0.0395	-0.0307	Y_{t-1}	-0.0383	-0.0347
	(-2.222)	(-2.131)		(-1.409)	(-1.099)		(-0.1378)	(-1.204)
VIX	0.2232***	0.2223***	GRI	0.109***	0.105***	MRI	0.0591***	0.0536***
	(14.72)	(13.53)		(14.50)	(12.82)		(13.47)	(14.27)
VIX_{t-1}	0.0356**	0.0337**	GRI_{t-1}	0.0008	-0.0051	MRI_{t-1}	0.0218***	0.0204***
	(2.310)	(1.971)		(0.119)	(-0.781)		(5.275)	(5.451)
VIX_{t-2}	0.0153	0.0186	GRI_{t-2}	0.0066	0.0086	MRI_{t-2}	0.0055	0.0063*
	(0.973)	(1.017)		(1.023)	(1.220)		(1.45)	(1.744)
D	-	0.0021**	D	-	0.0013	D	-	0.0025***
	-	(2.152)		-	(1.645)		-	(2.64)
$D*Y_{t-1}$	-	-0.0399	$D*Y_{t-1}$	-	-0.196	$D*Y_{t-1}$	-	-0.0572
	-	(-0.324)		-	(-1.443)		-	(-0.604)
D*VIX	-	0.0037	D*GRI	-	0.0199	D*MRI	-	0.0748***
	-	(0.0850)		-	(0.928)		-	(3.028)
$D*VIX_{t-1}$	-	0.0131	$D*GRI_{t-1}$	-	0.0557**	$D*MRI_{t-1}$	-	0.0133
	-	(0.352)		-	(2.208)		-	(0.487)
$D*VIX_{t-2}$	-	-0.0290	$D*GRI_{t-2}$	-	-0.0064	$D*MRI_{t-2}$	-	-0.0135
	-	(-0.917)		-	(-0.405)		-	(-0.953)
Adj. R^2	21.5%	21.6%	Adj. R^2	22.2%	22.6%	Adj. R^2	11%	12.3%

*Note: JPY is the dependant variable. Regressions use HACSE. (1) is the ADL-model. (2) is the Interactive Dummy model. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 2,441 for all regressions.*

The shared coefficients continue to show striking similarities for the GRI regressions presented in the middle column. This is solid evidence indicating that our results are *generally* robust, even when adding more variables to the regression. The main discovery by adding the dummy terms is the extra affect indicated by the interaction of the dummy term and the first lag of GRI. Here, the extra effect is an estimated 0.06 per cent appreciation during risk-off episodes when forex volatility increases by 1 per cent. The explanatory power increased marginally from 22.2 to 22.6 per cent by adding dummy terms. Despite the weak increase in explanatory power we have discovered potential extra effects. Additionally, these results are in fact very different from what we saw in the VIX results.

The MRI results in the right column show that the shared coefficients yet again are very similar. This provides us with very strong and consistent support that the effects on ordinary days are correct, this includes our previous regressions in this paper as well. Comparable to the VIX results our MRI model (2) results also indicate that the risk off-episodes lead to a general appreciation of the JPY, as is evident by solely looking at the dummy term. As for the interactive effects the results are promising. We see that MRI during risk off episodes predicts a further 0.07 per cent appreciation.

The quantitative impact of the interactive term is a bit larger than the shared coefficients, making these results even more interesting. It could also be argued that 12.3 per cent for model (2) is acceptable. The interactive coefficient gives us interesting insight into what happens during risk-off episodes, as the MRI results show evidence of positive additional effects.

5.2.2 Partial conclusion from model (2)

The mutual coefficients between the models indicated next to no difference between the models. In general, this is very positive for our study, as this indicates that adding or removing additional variables has little impact on our baseline model. Additionally, the results from both the dummy and interactive dummy terms showed significant extra effects during risk-off episodes.

However, the explanatory powers between the models were essentially equal. Only the MRI regression saw any real increase. The interaction with the GRI first lag is rather unexpected. Instead we would have preferred the interaction term with the GRI to show or at least support this correlation. Besides this, the MRI results proved promising.

Overall, the results from our interactive dummy analysis were far from flawless, but proved promising. There does seem to be some consistent or convincing extra effects during extreme risk-off episodes. There are differences between investors' safe haven behavior on an average basis versus a high-volatility conditional basis. In addition to this insight, including model (2) has strengthened the reliability and robustness of our baseline model.

6. Diagnostics and Robustness

This section will discuss the validity and robustness of our baseline model. We will test its ability to effectively perform while its variables or assumptions are changed. First, we will perform diagnostics tests and discuss whether our regressions satisfy assumptions based on the Gauss-Markov theorem, as well as other considerations in regard to stationarity and model misspecifications. Second, we we will look into the robustness of our variables and periodical division. Third, we will examine the effects of adding additional variables to our baseline model.

6.1 BLUE assumptions and stationarity

To test our model for *misspecification,* we have performed Ramsey's Regression Equation Specification Error Test (RESET) on our regressions. RESET is executed through the ovtest command in STATA. These tests gave mixed results depending on the regressions we investigated. Results for this are shown in table 20 in appendix B. Intuitively. there is little reason to believe that our models should be incorrectly specified. However, we are aware of the concern associated with Omitted-Variable-Bias (OVB). This is however something the RESET has no power in detecting. Furthermore, it is generally hard to detect what we do not observe, as is the case with OVB. On the other hand, our results from the dummy model reduced some of this concern, as there were only minor differences between the shared coefficients. In addition, to address this concern, we have performed measures to investigate this issue even further. This is discussed later in section 6.3.

Table 21 in appendix B presents the most important tests on a select sample of regressions. Here, we address the assumptions of *homoscedasticity, no autocorrelation*, and *normality distributed residuals*. The results for the other currency regressions not included in the table are basically the same. First, we see that the regressions show signs of problems with homoscedasticity, i.e. the error terms are heteroscedastic. We alleviate this problem by running new regressions with HACSE (robust regression in STATA). Since this affects our t-tests, we adjusted the independent variables' lag lengths in the regressions accordingly. Second, we observe that none of our regressions have problems with autocorrelatio*n*. This is evident from the Durbin Watson test results that are consistently centered around 2, regardless if lags of the NEER are included or not. Third, we see that there is a problem with the assumption of normal distributed residuals. As shown in appendix B, the Shapiro Wilk tests on the regression residuals fail.

We have investigated the concern for non-normality further by producing Kernel density graphs of the residuals, as seen in appendix D. These graphs also indicate problems with normal distributions. Optimally the two lines should be aligned. However, these plots also reveal that the problems are minor. The residuals are close to normally distributed. We also want to emphasize that we have sufficiently many observations in our regressions. Furthermore, problems with normal distribution could arguably be expected in a dataset as this, as we are working with high frequent data on daily currency and risk indicator movements.

One solution for dealing with the non-normality is to try and remove extreme outliers in the dataset. The shortcoming is that this would disturb our regressions results, especially since our study is very interested in analyzing such deviations, i.e. volatility. Hence we regard this as a minor concern, given the nature of our data set and that the residuals are very close to being normally distributed.

In regard to the concern for *stationarity*, table 22 in appendix C shows the results from the ADF-tests. The tests prove that all our variables are stationary. First-differenced variables help us avoid problems with non-stationarity.

Multicollinearity posed a problem to our model in the initial stages of this study. Our first suggestion for a baseline model was regressing currencies against all three risk indicators as dependent variables in the same regression. However, when we tested this model for multicollinearity in STATA, results confirmed that the risk indicators, i.e. independent variables, had statistical significant relationship with each other. We therefore modified the model to what became our baseline model, where we test for each risk indicator separately. To some extent there will always be a trade-off between OVB and multicollinearity in our model. Adding more variables, e.g. lags or other financial indicators, will increase the possibility of problems with multicollinearity, whereas not doing so increases the possibility of problems with OVB and misspecification.

In total, our model satisfies all of the crucial assumptions. The first concern was problems with the assumption of constant variance (homoscedasticity). We address this issue by running robust regressions. The second problem, although minor, is that the residuals failed the tests for normal distribution. After closer investigation, we found the residuals to be very close to normality. Therefore, this is only a minor shortcoming considering the characteristics of our data. In total, we feel our OLS models are sufficiently valid given the diagnostics tests we have performed, the properties of our data, and purpose of this study.

6.2 Robustness of variables and periods

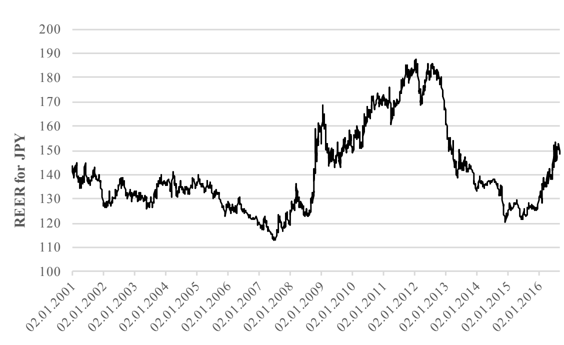
An alternative to applying NEERs as the dependent variables was the use of cross-currency spot rates. The USD would have been the most likely candidate to use as a base currency. However, we wanted to avoid certain problems associated with doing so, e.g. Ranaldo & Söderlind (2007) who in some of their findings questioned whether it was the USD, rather than its counter currency, that determined the results. Moreover, researcher have found that the U.S. dollar's status as a safe haven may have changed significantly during our sample period, which is in line with our own results. By applying NEER, we eliminate such disturbances caused by a change in characteristics of the base currency over time.

We also discussed the possibility of using REERs instead of NEERs, i.e. real effective exchange rates. The advantage of REERs would be that they are adjusted for differences in price levels, which perhaps would have removed the need to consider this as an explanatory variable in our model. However, as our risk indicators are based on nominal values, we chose NEER. As shown in figure 11 and 12, NEER and REER show remarkably similar movements. This is reassuring in terms of the robustness of our choice of dependent variable.

Figure 11: NEER for JPY (2001-2016)

Note: Data retrieved from Bloomberg Terminal

Figure 12: REER for JPY (2001-2016)



Note: Data retrieved from Bloomberg Terminal

One concern associated with NEER is that breaking down the methodology can be difficult. Barclays' exact methodology is unfortunately not publicly accessible either. For this reason, we have experimented with NEER from other sources, such as the ones quoted by the Bank for International Settlements (BIS), where the methodology is publicly available. The NEERs from BIS proved to be basically the same as Barclays'. For this reason, we have no concern with our choice of source.

In order to ensure that the VIX was correctly applied as an independent variable in our model, we had to chose an appropriate measure for the daily values. This is not as easy due to the fact that VIX is quoted twice a day; both open and close, and that there is no norm of calculating daily VIX returns that is common in the literature. We have therefore experimented with several definitions of return, e.g. close-to-close, open-to-close, and open-close-average. Although some regressions showed minor differences when comparing the three definitions, overall results remained quite the same. We finally chose to use open-close-averages. Last but not least, as we have chosen to investigate three risk indicators as independent variables, and not only one, we trust that our measures of risk are broad enough to be a good representation of increased risk aversion among investors, i.e. ensuring that our model is sufficiently robust towards changes in measurement of risk proxies.

We have also controlled for different variances of period division. First, we have attempted to shorten our definition of the financial crisis period from 2007-2010 to 2007-2009. Naturally, the explanatory powers and coefficients increased slightly, as the volatility peeks become more prevalent. However, considering that the differences were only minor, and that we wanted to ensure a satisfactory number of observations for this period, we still believe 2007-2010 is a more suitable choice. We have performed similar control adjustments for the periods 2001-2007 and 2010-2016. Results were again reassuring in regard to the robustness of our periods.

6.3 Adding new variables to the baseline model

In order to test the robustness of our model, and as well dig deeper into further explanatory factors for short term currency movements, we have tried to add new independent variables. This part will discuss the inclusion of three new variables in an attempt to improve our baseline model, i.e. oil price, liquidity, and macroeconomic fundamentals.

Table 15 is an extract of one of these additional tests and shows the results for including the West Texas Intermediate Crude Oil (WTICO) to our USD baseline model in the period 2010-2016. The left column shows stock volatility, middle column shows forex volatility, and the right column shows composite volatility.

Table 15: Adding the WTI oil price to our baseline model for USD (2010-2016)

VIX	**0.100*****	**0.0755*****	**GRI**	**0.0492*****	**0.0395*****	**MRI**	**0.0294*****	**0.0213*****
	(11.71)	(8.931)		(14.31)	(12.21)		(15.08)	(11.55)
VIX_{t-1}	0.0086	0.0011	**GRI_{t-1}**	-0.0041	**-0.0049***	**MRI_{t-1}**	**0.0083*****	**0.0045*****
	(1.095)	(0.142)		(-1.343)	(-1.678)		(4.379)	(2.604)
VIX_{t-2}	0.0012	-0.0015	**GRI_{t-2}**	-0.0021	-0.0027	**MRI_{t-2}**	-0.0005	-0.0015
	(0.173)	(-0.236)		(-0.636)	(-0.88)		(-0.293)	(-0.851)
WTICO	-	**-0.0441*****	**WTICO**	-	**-0.0479*****	**WTICO**	-	**-0.0463*****
		(-10.47)			(-11.54)			(-11)
$WTICO_{t-1}$	-	**-0.018*****	**$WTICO_{t-1}$**	-	**-0.0179*****	**$WTICO_{t-1}$**	-	**-0.0158*****
		(-4.522)			(-4.648)			(-3.987)
$WTICO_{t-2}$	-	-0.001	**$WTICO_{t-2}$**	-	-0.0028	**$WTICO_{t-2}$**	-	-0.00243
		(-0.248)			(-0.749)			(-0.604)
Constant	**0.0002***	**0.0002****	**Constant**	**0.0002***	**0.0002****	**Constant**	**0.0002****	**0.0002****
	(2.485)	(2.452)		(2.262)	(2.303)		(2.412)	(2.315)
Adj. R^2	16.3 %	23.9 %	**Adj. R^2**	16.7	26.2 %	**Adj. R^2**	14.9 %	22.9 %

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,681.*

In our analysis of the USD in part 5.1.5, we put forward a possible alternate explanation for the appreciations that our model did not catch, i.e. that the past years' oil price development has had effects on the USD. The results in table 15 confirm this notion, as we observe significant coefficients for WTICO. The sign in front of the coefficient is also in line with our previous discussions and literature review, as we observe a negative correlation. Compared to our baseline model, the explanatory powers increase by almost 10 per cent for stock, forex and composite volatility when adding WTICO, thus vastly improving the model.

Furthermore, shown in the left column of table 16 on the next page, we added the same oil variable to the NOK-VIX model for 2010-2016. Changes in the oil price appear to have strongly significant coefficients and a positive correlation with changes in the NOK. This is in line with previous research and economic reasoning, where an increase in the oil price is associated with an appreciation of the NOK, as Norway is a relatively oil-income-dependent country. Furthermore, the explanatory power increases by nearly 5 per cent compared to the baseline version, thus overall improving the model.

Table 16: Oil prices added to NOK-VIX and bid-ask spreads added to AUD-VIX (2010-2016)

	Adding oil to NOK-VIX			*Adding bid-ask spreads to AUD-VIX*	
Yt-1	**-0.0544***	**-0.0732****	**Yt-1**	**-0.105*****	**-0.104*****
	(-1.853)	(-2.480)		(-4.103)	(-4.045)
Yt-2	**-0.0489***	**-0.0624****	**Yt-2**	-	-
	(-1.651)	(-2.161)			
VIX	**-0.104*****	**-0.0757*****	**VIX**	**-0.196*****	**-0.196*****
	(-9.057)	(-6.256)		(-13.90)	(-13.71)
VIXt-1	**-0.0225****	**-0.0158***	**VIXt-1**	**-0.0473*****	**-0.0468*****
	(-2.420)	(-1.718)		(-3.285)	(-3.239)
VIXt-2	-0.0142	-0.0093	**VIXt-2**	**-0.0218***	**-0.0224***
	(-1.563)	(-1.044)		(-1.829)	(-1.902)
WTICO	-	**0.0491*****	**spread**	-	**-0.0003****
		(8.109)			(-2.166)
WTICOt-1	-	**0.0202*****	**spread t-1**	-	0
		(3.293)			(-0.554)
WTICOt-2	-	0.0080	**spread t-2**	-	0
		(1.417)			(0.0319)
Constant	0	0	**Constant**	0	0
	(-0.870)	(-0.797)		(-0.320)	(0.422)
Adj. R^2	9.2 %	13.8 %	**Adj. R^2**	20.2 %	20.3 %

*Note: Regressions use HACSE. Only reporting up to 4 decimals. T-values reported in parenthesis. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Number of observations is 1,681.*

Other prominent explanations for our results presented in the analysis included discussions of liquidity, and how investors rebalance their portfolios towards more liquid currencies in times of increased risk aversion. We attempted to add this to our model and measure liquidity by using bid-ask spreads between spot USD and several other cross-currencies, e.g. the NZD, NOK and AUD. The right column of table 16 shows our regression of regressing changes in bid-ask spreads in USD/AUD spot rates against our AUD NEER dependent variable. This had no noteworthy effect on our baseline model. The variable 'spread' shows only a small significant coefficient, and the explanatory power is almost unchanged from 20.2 per cent to 20.3 per cent.

We have tried several different variances of bid-ask spreads against different currencies, but this produced even more unsuccessful results. In fact, the AUD results presented in table 16 were the only significant results. Nonetheless we still believe that investors' preferences for liquidity is a crucial aspect of explaining some of our results. Our unsuccessful attempt can be explained by the fact that measuring liquidity, similar to attempting to measure the unwinding of carry-trades, is relatively difficult. Our particular application of bid-ask spreads was not effective in capturing any relevant information.

One other option in testing the robustness of our model includes macroeconomic variables, or so-called fundamentals. Initial tests for adding interest rate differentials and PPP as additional explanatory variables were unsuccessful, and we chose to not pursue the inclusion of such variables any further. This is very much in line with the empirical view about the previously mentioned exchange rate disconnect puzzle. Ranaldo & Söderlind (2007) found similar insignificant results for interest rate differentials and PPP in their safe haven study. Furthermore, in a highly regarded paper within the study of exchange rates, Meese & Rogoff (1983) found that no macroeconomic model could beat the random walk in out-of-sample short term forecasts. Not only are there measurement problems with short term macroeconomic variables, if even retrievable on a high frequency basis, but they are also poor in explaining the short term currency movements which are the focus of this study.

Overall, adding new variables to our model successfully improved the USD and NOK models in the case of the oil price. The inclusion of new variables was however not successful for liquidity measures and macroeconomic variables. We are mindful of the fact that our model is not capable of explaining a 100 per cent of the short term currency movements. In our most promising results where explanatory powers are up to 40 per cent, there is still around 60 per cent that our model fails to capture. Our model may therefore to some extent suffer from omitted-variable-bias (OVB), where estimated coefficients may gain a larger false quantitative impact due to the omission of other important variables. Nonetheless, the strength of our model is that our methodology and analysis is based on several periods. By applying the same model across three periods, we are able to observe significant changes in safe haven behavior without necessarily putting to much emphasis on the size of the coefficients in a period-isolated sense.

7. Conclusion

Our thesis has investigated the safe haven phenomenon by analyzing the high frequency movements of eight nominal effective exchange rates (NEERs) in response to increased risk aversion in financial markets. Increased risk aversion has been captured through three risk indicators; VIX, GRI and MRI. The VIX represents stock volatility in the S&P500, but has empirically been found to also give a wider interpretation of increased risk aversion. The second risk indicator, GRI, signals uncertainty in foreign exchange markets. The MRI, our third indicator, is a composite measure of volatility in financial markets. Due to our concern for multicollinearity, we chose to regress each risk indicator separately. Overall, the chosen risk indicators have provided us with a broad interpretation of increased uncertainty and risk aversion in financial markets.

Our conclusions from this study are presented below in table 17. *RQ* and *SRQ1* have been answered through applying our baseline model (1), whereas *SRQ2* relates to the results from the interactive dummy model (2).

Table 17: Conclusion on Research Question

RQ: Which currencies can be regarded as safe haven or non safe haven assets in the years 2001 to 2016?			
	2001-2007	**2007-2010**	**2010-2016**
Safe haven:	JPY, CHF	JPY, CHF, USD	JPY, CHF, USD
Non safe haven:	NZD, AUD	NZD, AUD	NZD, AUD, NOK
Inconclusive:	EUR, GBP, USD, NOK	EUR, GBP, NOK	EUR, GBP

SRQ #1: Has the financial crisis or other recent developments in the world economy and financial markets caused a shift in safe haven behavior?	
i)	The JPY shows stronger safe haven tendencies post 2007.
ii)	The CHF shows weaker safe haven tendencies post 2010.
iii)	The AUD and NZD show stronger non safe haven tendencies post 2007; the AUD more so than the NZD.
iv)	The USD shows a significant shift in characteristics towards being safe haven post 2007.
v)	The NOK results indicate relatively stronger non safe haven tendencies post 2010.
vi)	In general, quantitative impacts and explanatory powers are higher for the years 2010-2016 compared to 2001-2007.

SRQ #2: Is the behavior stronger during episodes of extreme and sudden risk compared to the behavior on an average basis?
Analyzing the JPY by using an interactive dummy model showed significant additional effects during risk-off episodes. Hence the behavior on a high-volatility conditional basis deviates from the behavior on an unconditional, average basis, i.e. a somewhat larger quantitative impact.

Overall, we believe our study has contributed to the literature with new insight and contemporary evidence on the safe haven phenomenon. First, we provide an extensive overview of currencies that can be characterized as safe haven, non safe haven, or inconclusive, in our sample. Second, our findings identify significant and noteworthy changes in behavior over time. Third, our evidence suggests that the safe haven effects are stronger on a high-volatility conditional basis, i.e. risk-off episodes, compared to on an average unconditional basis, i.e. ordinary days. The safe haven phenomenon is however not contingent upon these more dramatic episodes.

What is indeed promising for the robustness and validity of our models, is that our findings from the period 2001-2007 are in accordance with previous research and reinforce the traditional views in the literature. This provides further reliability to our results for the more recent period 2007-2016, which is more scarce in the literature. Moreover, the diagnostics tests and discussion surrounding the addition of new variables were reassuring in regard to the robustness of our models.

The majority of changes we identified supported our expectations and initial thoughts. We expected the JPY to show relatively stronger safe haven tendencies than the CHF post financial crisis. Furthermore, we expected the USD to show significant signs of being a safe haven currency in recent years, which is in stark contrast to its inconclusive results from the period 2001-2007 where it moved relatively more pro-cyclically with financial markets.

Furthermore, the EUR and GBP showed little change in behavior and provided us with inconclusive results, partially reinforcing the traditional view of these currencies from previous years. As for the AUD and NZD, our findings strongly suggest that the they have become relatively more non safe haven currencies in the years 2007-2016 compared to 2001-2007. Rather surprisingly, these effects are stronger for the AUD compared to the NZD.

The NOK results were interesting and identified a significant shift in safe haven properties. Results were ambiguous for the periods 2001-2007 and 2007-2010. For the recent years, however, our evidence suggests the NOK is relatively more prone to non safe haven flows in episodes of increased risk aversion.

We believe there are mainly two explanations for the identified changes in safe haven behavior in the years 2001-2016. First, the financial crisis triggered an increase in risk aversion and avoidance of large scaled risky positions among investors. Consequently, concerns for liquidity become more important than concerns for fundamentals. Second, these effects may to some extent have spilled over to the years after the financial crisis. We believe the increased degree of turbulence in financial markets post crisis, e.g. influenced by geopolitical unrest and the oil crisis, can explain the strong quantitative impacts and explanatory powers compared to the years 2001-2007. The highest coefficients and explanatory powers in our results were identified in the two periods 2007-2010 and 2010-2016, while the years 2001-2007 generally had low statistical strengths.

First, we hope the findings in this paper prove to be insightful for financial investors and other market participants. We have provided an updated view on how currency risk premium materializes across a wide array of currencies during a variety of volatility conditions. This may be especially important for risk management and portfolio rebalancing among investors with large currency positions. Second, we believe our findings may be relevant to monetary policy. This relates to the connection between increased risk aversion and financial stability, and also an awareness of how different financial markets are intertwined in episodes of increased risk aversion. Our investigation into the CHF has particularly shown how monetary policy can be highly relevant to the safe haven phenomenon.

7.1 Further research

The main limitation of our study is in fact due to the wide range of variables we have chosen to investigate. We began by examining twelve nominal effective exchange rates as dependent variables, as we were eager to include emerging market currencies in our study. We decided however to reduce the number of currencies to eight in order to improve the focus of our thesis. This paper has examined three risk indicators separately across three different periods that in total cover almost 16 years of daily movements. Consequently, we have not had the capability to thoroughly examine all interesting aspects of our results. However, we believe these aspects are fruitful avenues for further research.

First, it would be interesting to look further into our results for the JPY and CHF, where the JPY shows a stronger safe haven status in recent years, while the CHF shows the opposite trend. An option would be to further investigate the CHF period 2010-2016, and attempt to isolate the effects of the currency peg. Moreover, we are eager to confirm our view of the AUD as a relatively stronger non safe haven currency than the NZD. The USD results were as well quite interesting, and should perhaps be subject to additional research that can further strengthen the notion that it has become a safe haven asset. The same applies for the interesting non safe haven shift identified in the NOK.

Second, we encourage future research to look into any changes in the fundamentals or characteristics of our selected nations in the years 2001-2016, and if this perhaps has contributed to the changes in safe haven behavior. This would for instance involve investigating Japan’s net foreign asset (NFA) position and other fundamentals. Although we have discussed the inclusion of interest rate differentials and PPP, the main purpose of this study has been to identify the safe haven status of a currency and how this has changed over time, not the macro characteristics or fundamentals that explain these patterns. We have attempted to answer some of these questions, but inevitably any confirmation or persuading evidence must be subject to specific empirical research.

Third, we have argued that reasons for the large quantitative impact and explanatory powers in the years 2007-2016 compared to 2001-2007 mainly involve an increased occurrence of risk-off episodes and financial turmoil. The financial crisis and its volatility peeks in the years 2007-2010 speak for themselves. It would however be interesting to compare the two relatively more tranquil periods 2001-2007 and 2010-2016, and investigate which period has contained the most risk-off episodes and market turmoil. Our hypothesis is that the latter period will contain more turbulence due to the lasting effects of the financial crisis and not to mention the large-scale political, war, and terror-related developments of the past 6 years or so.

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9. Appendix

A. Appendix for the description of variables and statistics

Table 18: Data description

Data	Description	Source	Frequency
Main NEERs:			
JPY	*Barclays' Nominal Effective Exchange Rate JPY*	Bloomberg Terminal	Daily
CHF	*Barclays' Nominal Effective Exchange Rate CHF*	Bloomberg Terminal	Daily
NZD	*Barclays' Nominal Effective Exchange Rate NZD*	Bloomberg Terminal	Daily
AUD	*Barclays' Nominal Effective Exchange Rate AUD*	Bloomberg Terminal	Daily
USD	*Barclays' Nominal Effective Exchange Rate USD*	Bloomberg Terminal	Daily
EUR	*Barclays' Nominal Effective Exchange Rate EUR*	Bloomberg Terminal	Daily
GBP	*Barclays' Nominal Effective Exchange Rate GBP*	Bloomberg Terminal	Daily
NOK	*Barclays' Nominal Effective Exchange Rate NOK*	Bloomberg Terminal	Daily
Risk indicators:			
VIX open	*United States, Volatility Indices, CBOE, S&P 500 Volatility Index (VIX), Open*	Macrobond	Daily
VIX close	*United States, Volatility Indices, CBOE, S&P 500 Volatility Index (VIX), Close*	Macrobond	Daily
Vix average	*(VIX close + VIX open)/2*	Formula	Daily
GRI	*Constructed using 3-month implied volatilites (see methodology for details)*	Formula	Daily
3M Vol USD/JPY	*3 Month Volatility Index USD vs JPY*	Bloomberg Terminal	Daily
3M Vol EUR/JPY	*3 Month Volatility Index EUR vs JPY*	Bloomberg Terminal	Daily
3M Vol EUR/USD	*3 Month Volatility Index EUR vs USD*	Bloomberg Terminal	Daily
MRI	*World, Citi, Long-Term Macro Risk Index*	Macrobond	Daily
Risk-off episode	*Dummy variabel indicating risk-off episodes in daily data (see methodology for details)*	Own construction	Daily
Other:	**Data used for graphs, tables or reliability and quality purposes**		
J.P Morgan's NEERs	J.P Morgan's Nominal Effective Broad Exchange Rate Indices (all 8 currencies)	Macrobond	Daily
BIS NEERs B	BIS' Effective Exchange Rate Indices, Broad (all 8 currencies)	Bank for International Settlements	Daily
BIS NEERs N	BIS' Effective Exchange Rate Indices, Narrow (all 8 currencies)	Bank for International Settlements	Daily
BoE REERs	Bank of England's Real Effective Exchange Rate Indicies (all 8 currencies)	Macrobond	Daily
Spot xxx/USD	FX Spot Rates, Macrobond, Currency per USD (all 7 currencies against USD)	Macrobond	Daily
Bid Prices	Bid prices for: AUDJPY, USDCHF, USDNZD, USDAUD, USDEUR, USDGBP, USDNOK	Bloomberg Terminal	Daily
Ask Prices	Ask prices for: AUDJPY, USDCHF, USDNZD, USDAUD, USDEUR, USDGBP, USDNOK	Bloomberg Terminal	Daily
WTICO	Crude Oil Prices - West Texas Intermediate (Spot Price), Dollars per barrel	Federal Reserve Economic Data	Daily
Brent Crude	Crude Oil Prices - Brent Europe (Spot Price), Dollars per barrel	U.S Energy Information Administration	Daily

Table 19: Descriptive statistics

Full sample 2001-2016	JPY	CHF	NZD	AUD	USD	EUR	GBP	NOK	VIX close	VIX open	VIX avg	GRI	MRI
Mean	488.94	248.65	91.75	90.74	275.58	258.63	116.16	112.04	20.35	20.5	20.43	12.64	0.46
Min	394.25	197.83	65.63	63.99	233.62	199.72	93.91	95.18	9.89	9.68	9.87	5.96	0.01
Max	625.06	347.96	111.14	125.53	345.58	293.15	134.67	125.53	80.86	71.06	79.6	34.22	0.99
Std. Dev	54.36	38.37	10.35	11.32	26.62	20.03	11.08	6.69	8.98	9.05	8.99	3.62	0.23
Skewness	0.75	0.6	-0.74	-0.37	0.63	-1.19	-0.2	-0.39	2.12	2.1	2.1	1.88	0.36
Kurtosis	2.63	1.9	2.99	2.41	2.43	4.04	1.5	2.34	9.7	9.48	9.44	9.26	2.28
Number of observations: 3956													

2001-2007	JPY	CHF	NZD	AUD	USD	EUR	GBP	NOK	VIX close	VIX open	VIX avg	GRI	MRI
Mean	465.32	216.41	84.97	80.84	288.4	241.14	126.18	109.7	19.36	19.53	19.45	11.2	0.39
Min	418.15	197.83	65.62	63.99	262.62	199.72	118.92	99.5	9.9	9.68	9.87	6.91	0.054
Max	505.28	229.52	102.16	92.6	317.48	269.29	132.12	120.49	45.08	48.93	45.8	17.36	0.78
Std. Dev	19.56	7.04	10.48	8.32	16.29	20.08	2.82	4.73	7.34	7.47	7.39	1.83	0.16
Skewness	-0.26	-1.01	-0.41	-0.39	0.14	-0.69	-0.14	-0.21	0.94	0.96	0.95	0.94	0.21
Kurtosis	2.08	3.45	1.78	1.51	1.51	1.91	2.48	2.23	3.19	3.26	3.19	4.46	2.32
Number of observations: 1512													

2007-2010	JPY	CHF	NZD	AUD	USD	EUR	GBP	NOK	VIX close	VIX open	VIX avg	GRI	MRI
Mean	471.38	223.6	90.1	91.29	254.96	274.55	115.53	113.54	27.27	27.43	27.35	14.92	0.56
Min	394.25	207.32	71.07	70.22	233.62	257.21	93.91	98.92	9.89	9.99	10.15	6.89	0.052
Max	594.18	243.82	104.69	102.81	287.33	293.15	134.67	121.72	80.86	80.74	79.6	34.22	0.99
Std. Dev	56.3	10.76	7.95	7.82	12.97	9.95	12.2	4.58	13.22	13.31	13.22	6.05	0.27
Skewness	0.36	0.05	-0.64	-0.92	0.25	-0.09	0.03	-0.46	1.46	1.44	1.44	0.96	-0.2
Kurtosis	1.59	1.49	2.43	2.81	2.17	1.63	1.54	2.7	5.08	4.91	4.89	3.48	1.68
Number of observations: 760													

2010-2016	JPY	CHF	NZD	AUD	USD	EUR	GBP	NOK	VIX close	VIX open	VIX avg	GRI	MRI
Mean	518.08	288.9	98.57	99.37	273.37	267.15	107.45	113.47	18.13	18.23	18.18	12.9	0.48
Min	416.03	236.88	85.81	84.54	235.5	246.69	96.82	95.18	10.32	10.4	10.4	5.96	0.01
Max	625.06	347.96	111.14	112.52	345.58	287.36	124.5	125.53	48	47.66	44.85	22.25	0.99
Std. Dev	60.66	22.92	5.98	6.99	31.74	8.63	6.94	8.23	5.92	5.92	5.88	2.64	0.25
Skewness	0.11	-0.24	0.04	-0.24	-0.09	-0.09	0.79	-0.75	1.72	1.71	1.69	-0.01	0.21
Kurtosis	1.63	2.67	2.1	1.95	2.07	2.07	2.49	2.21	6.28	6.31	6.1	3.5	2.1
Number of observations: 1684													

Note: Variables are synchronized for dates but otherwise unmodified.

B. Appendix for diagnostics

Table 20: Ramsey's RESET

2001-2007	JPYvsVIX	GBPvsGRI	NOKvsMRI
Prob > F	0.3816	0.3528	0.7018
2007-2010	**JPYvsVIX**	**NZDvsGRI**	**CHFvsMRI**
Prob > F	0***	0.5919	0.0638*
2007-2016	**JPYvsVIX**	**AUDvsGRI**	**USDvsMRI**
Prob > F	0.012**	0.0135**	0.7754

Note: H0 = Model is correctly spesified. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level.

Table 21: Formal diagnostics

	Simple OLS		HACSE regressions		
2001-2007	**White's test**	**Breusch-Pagan**	**Shapiro Wilk**	**Durbin Watson**	**Observations**
JPY vs VIX	0.7543	0.0277**	0***	2.001144	
USD vs GRI	0.0025***	0***	0***	1.977629	1509
NZD vs MRI	0.0161**	0.0111**	0***	1.917802	
2007-2010					
JPY vs VIX	0***	0.0749*	0***	1.98749	
USD vs GRI	0***	0***	0***	1.931942	757
GBP vs MRI	0.0015***	0.1138	0***	1.998721	
2010-2016					
JPY vs VIX	0***	0***	0***	2.050559	
USD vs GRI	0.0248**	0.0038***	0***	2.037386	1681
NOK vs MRI	0.004***	0.1712	0***	2.006088	

	Simple OLS		HACSE regressions		
2007-2016	**White's test**	**Breusch-Pagan**	**Shapiro Wilk**	**Durbin Watson**	**Observations**
Model (1)					
JPY vs VIX	0***	0***	0***	2.00177	
JPY vs GRI	0***	0***	0***	2.000233	2441
JPY vs MRI	0***	0.0036***	0***	2.002108	
Model (2)					
JPY vs VIX	0***	0***	0***	2.001681	
JPY vs GRI	0***	0***	0***	2.002936	2441
JPY vs MRI	0.0007***	0.0024***	0***	2.007124	

*Note: HACSE adjusted regressions after heteroskedacity tests. White's test, Breusch-Pagan and Shapiro Wilk are reported p-values. *** Statistical significance at 1 % confidence level, ** 5 % confidence level, * 10 % confidence level. Durbin Watson is a value ranging from 0-4.*

C. Appendix for stationarity testing

Table 22: Augmented Dickey-Fuller tests

2001-2007	# lags	T-stat	Observations
JPY	1	-28.32*	1509
CHF	9	-13.16*	1501
NZD	3	-20.36*	1507
AUD	2	-23.85*	1508
USD	0	-38.63*	1510
EUR	1	-28.99*	1509
GBP	2	-23.49*	1508
NOK	3	-19.94*	1507
VIX	6	-16.44*	1504
GRI	8	-13.54*	1502
MRI	3	-19.06*	1507

2007-2010	# lags	T-stat	Observations
JPY	6	-11.27*	752
CHF	0	-27.5*	758
NZD	0	-26.63*	758
AUD	6	-11.31*	752
USD	9	-9.22*	749
EUR	3	-13.28*	755
GBP	3	-14.52*	755
NOK	2	-16.43*	756
VIX	6	-11.79*	752
GRI	6	-11.32*	752
MRI	5	-11.7*	753

2010-2016	# lags	T-stat	Observations
JPY	0	-41.65*	1682
CHF	7	-15.55*	1675
NZD	2	-24.71*	1680
AUD	1	-29.06*	1681
USD	0	-40.16*	1682
EUR	0	-40.48*	1682
GBP	6	-17.77*	1677
NOK	4	-20.34*	1678
VIX	7	-17.58*	1675
GRI	5	-18.71*	1677
MRI	4	-20.63*	1678

2007-2016	# lags	T-stat	Observations
JPY	0	-49.59*	2442
CHF	7	-18.94*	2435
NZD	0	-49.89*	2442
AUD	6	-20.14*	2436
USD	9	-15.78*	2433
EUR	0	-48.3*	2442
GBP	8	-17.21*	2434
NOK	2	-29.78*	2440
VIX	10	-15.34*	2432
GRI	6	-20.54*	2436
MRI	8	-18.92*	2434

*Note: Constant included, but not trend. Lag lengths decided by AIC for highest rejection frequency. Our hardcap is at 10 lags. * Statistical significance at 1 % confidence level. 1% critical value is -3.43.*

D. Appendix for normality tests

Figure 13: NZDvsMRI 2001-2007

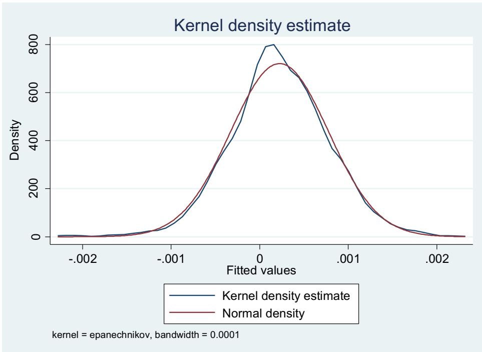


Figure 14: JPYvsVIX 2001-2007

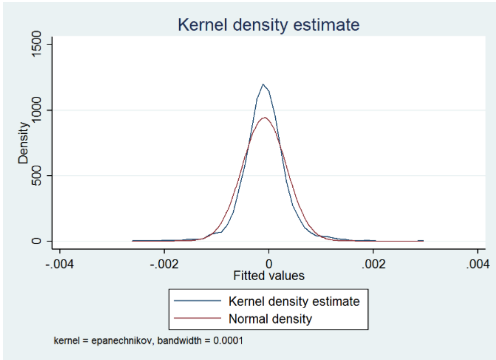


Figure 15: JPYvsVIX 2010-2016

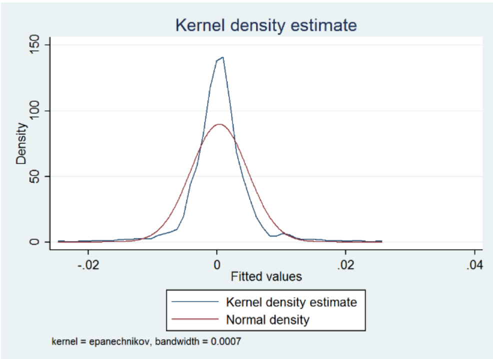


Figure 16: USDvsGRI 2007-2010

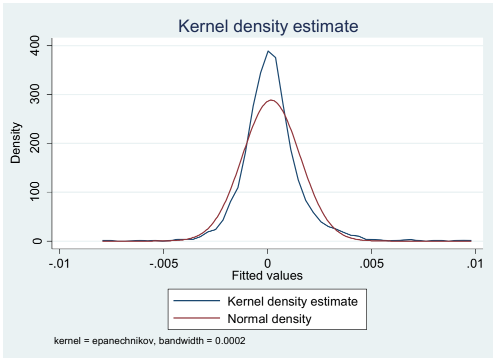


Figure 17: NOKvsMRI 2010-2016

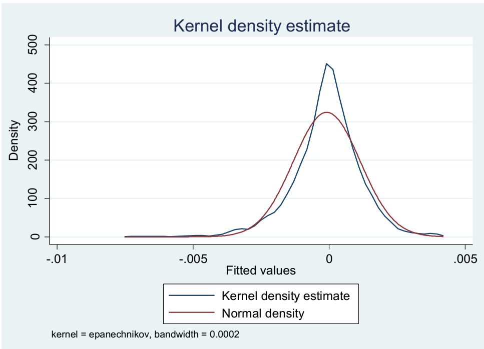
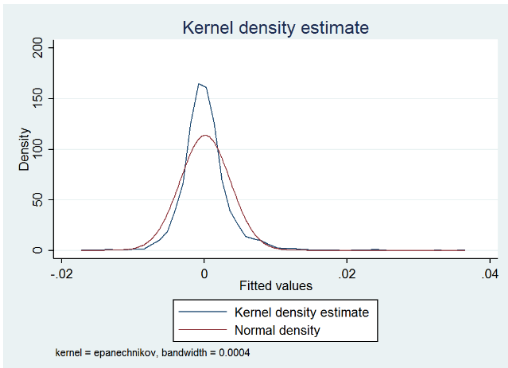


Figure 18: JPYvsVIX Dummy 2007-2016



E. Appendix for mathematical description of diagnostics tests

E1. The coefficient of determination

The coefficient of determination, explanatory power or simply R^2 tells us how much of the observed variance can be explained by our models (Wooldridge, 2015). The primary difference between the R^2 and adjusted R^2 is that the adjusted R^2 imposes a penalty for adding more independent variables to a model. This makes the adjusted explanatory power the more attractive alternative. The consequence is that our reported explanatory powers are marginally lower than a regular R^2. The R^2 and adjusted R^2 is calculated using the following formulas:

$$R^2 = \frac{\text{SSE}}{\text{SST}} = \frac{\text{SST} - \text{SSR}}{\text{SST}} = 1 - \frac{SSR}{SST}$$

,where SST = Total variance , SSE = Explained variance , SSR = Unexplained variance

$$Adjusted\ R^2 = \bar{\bar{R}}^2 = 1 - \frac{(1 - R^2)(n-1)}{n-k-1}$$

,where n = Number of observations, k = Number of estimated parameters

E2. Ramsey's Regression Equation Specification Error Test (RESET)

The idea behind the RESET test is fairly straightforward. It tests if non-linear combinations of the fitted values help explain the independent variable (Wooldridge, 2015). If this proves to be the case, then the model is misspecified. The test uses F statistic for testing the null hypothesis.

For a technical explanation consider the following baseline model:

$$y = \beta_0 + \beta_1 x_1 + \ldots + \beta_t x_t + \delta$$

Then consider the expanded model:

$$y = \beta_0 + \beta_1 x_1 + \ldots + \beta_t x_t + \delta + \mu_1 \hat{y}_1{}^2 + \mu_2 \hat{y}_2{}^2$$

$$, where\ \hat{y} = Baseline\ model's\ fitted\ values,$$

$$H_0: Model\ is\ correctly\ spesified\ \rightarrow H_0: \mu_1 = 0\ ,\ \mu_2 = 0$$

The purpose of this model is to test if the baseline model has missed any nonlinearities. This is a test to detect general functional form misspesification and nothing more.

E3. Statistical information theory

Akaike information criterion (AIC) is meant to estimate the quality between models (STATACorp, 2015). This is based on a tradeoff between a models goodness of fit and excessive use of independent variables. The purpose is to find the model that has the least information loss. AIC formally:

$$AIC = 2k - 2\ln(\hat{L})$$

, where $\hat{L} = the\ maximized\ value\ of\ the\ likelihood\ function\ of\ the\ model$, k = Number of estimated parameters

Bayesian information criterion (BIC) is closely related to the AIC, but also adjusts for the sample size (n). BIC can be shown formally as:

$$BIC = -2\ln\hat{L} + k\ln(n)$$

, where $\hat{L} = the\ maximized\ value\ of\ the\ likelihood\ function\ of\ the\ model$, n = Number of observations, k = Number of estimated parameters

E4. Heteroscedasticity

Testing for heteroscedasticity can be done through informal diagnostics and formal tests. One type of informal diagnostic is plotting OLS residuals against fitted values. Formal diagnostics include White- and Bresuch-Pagan test (STATACorp, 2015).

If problems with heteroscedasticity is detected the regressions can be corrected with Eicker-Huber-White standard errors, also known as heteroskedastic-consistent standard errors or robust regression. The theory behind this is extremely technical but also subtle (Wooldridge, 2015). We will not go into the details behind the theoretical framework. Essentially, this deals with minor concerns about failure to meet homoscedasticity or normality. The robust option produces the same estimated coefficients, but the standard errors are adjusted for problems with heteroscedasticity and normality. This affects the reported tests and can therefore change the conclusions of the simple OLS regressions.

E5. Durbin-Watson

The Durbin-Watson tests for the presence of autocorrelation in the residuals of our models (Wooldridge, 2015). The test can take the value 0-4. Values close to 2 indicate no problems with autocorrelation, values close to 0 indicate strong positive autocorrelation and values close to 4 indicate strong negative autocorrelation. The Durbin-Watson test is formally:

$$DW = \frac{\sum_{t=2}^{n}(\hat{\delta}_t - \hat{\delta}_{t-1})^2}{\sum_{t=1}^{n} \hat{\delta}_t^{\ 2}} \approx 2(1 - \hat{p})$$

E6. Shapiro-Wilk

Our formal test for normally distributed population is the Shapiro-Wilk test (STATACorp, 2015). This test is formally:

$$SW = \frac{(\sum_{t=1}^{n} a_i x_{(i)})^2}{\sum_{t=1}^{n}(x_i - \bar{x})^2}$$

,where H_0: $Population\ is\ normally\ distributed$