In USD we trust: Is the strength of the safe-haven effect on US dollars dwindling?

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An abstract of
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Abstract

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I analyze the strength of the safe-haven effect on the US dollar relative to 3 competing currencies over time. My empirical strategy conditions on high and low market volatility to differentiate between periods of economic crisis and relative stability. I answer the question of whether the strength of the safe-haven effect on US dollars is changing over time, and if so, how. Related literature mainly considers the safe-haven effect as a property that is unchanging with time, and uses decades old data to determine current currency behaviors. My results show that the strength of the safe-haven effect on US dollars has been changing over time, weakening in the past decade relative to the Swiss franc and euro, and weakening over the past 20 years relative to the Japanese yen. Furthermore, the safe-haven effect of the US dollar during the Covid-19 recession is found to be much weaker than during the Great Recession. I also briefly explore factors that could be leading to the fall in safe-haveness of the dollar, such as country-specific NFA and debt-to-GDP levels.

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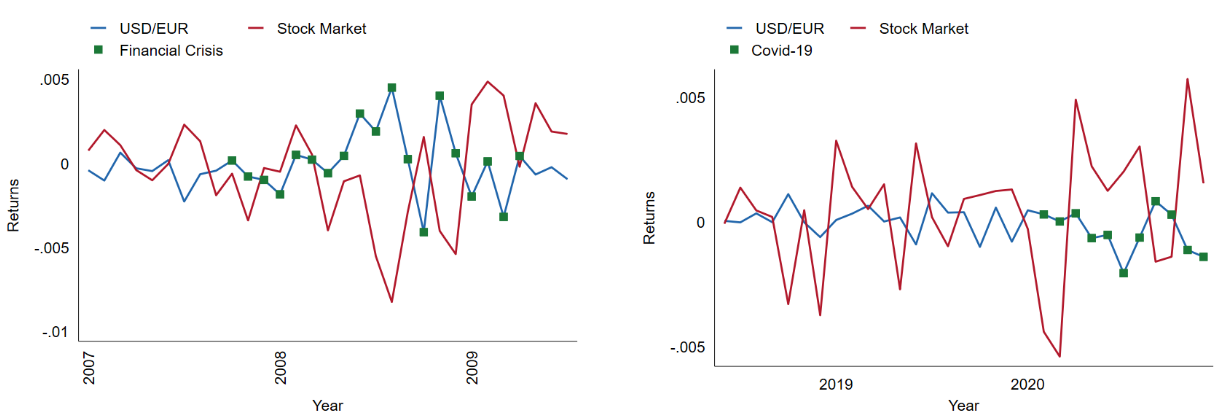
Contents

1 Introduction

The US dollar has long been regarded as a dominant safe-haven asset. However, political uncertainty, trade wars, shaky macroeconomic fundamentals, and increasing competition have led some economists to question the position of the US dollar on the global stage. My research examines whether the US dollar's safe-haven effect has been weakening over time.

There is no single definition of what constitutes a "safe-haven" currency. Ranaldo and Söderlind (2010) define a safe-haven currency as one that "provides a hedge in normal times and an additional shield in times of crisis." Other economists prefer a stricter definition, such as Hossfeld and MacDonald (2015), who consider a safe-haven currency as one that provides a hedge specifically during crises. My research uses the stricter definition of a safe-haven, considering the safe-haven effect as something that only occurs in times with high market volatility.

Most of the existing literature around safe-havens views the safe-haven property as a static feature of the currency, unchanging with time. For example, Maggiori et al. (2013) uses data from 1970 - 2010 to document that investors pay a safety premium for the US dollar. Hossfeld and MacDonald (2015) classify different currencies as safe-havens or hedge currencies based on data spanning all the way back to 1986. However, recent circumstances such as escalated debt and political divisiveness in the US have effected the fundamental characteristics determining the dollar's safe-haveness. This suggests that the dollar's past may no longer be fit to determine its present behavior. For example, Figures 1a and 1b plot the USD/EUR exchange rate returns with stock market returns. In Figure 1a, you can clearly see a strong negative relationship between US dollar returns and stock market returns during the Great Recession. This demonstrates the dollar's



(a) (b)

Figure 1: USD/EUR and Stock Market Returns Over Time
Data source: Bloomberg

safe-haven against the euro. Figure 1b however, does not show such a strong negative relationship between dollar returns and stock market returns. At the start of Covid-19, the stock market crashed and the dollar barely moved. Motivated by these early findings and the US's current state of affairs, my research finds that the safe-haven effect of the dollar has been changing over time.

Concretely, I show that the safe-haven effect of the dollar began to weaken around 2011 relative to both the euro and the franc, and has been weakening since the early 2000's relative to the yen. I also find that that the safe-haven effect of the dollar was significantly weaker during the Covid-19 crisis than during the Great Recession.

Following existing literature from Hossfeld and MacDonald (2015), Lee (2017), and Ranaldo and Söderlind (2010), I assess the US dollar's safe-haven effect by analyzing the relationship between dollar exchange rate returns and stock market returns. For a safe-haven currency, this relationship should be negative because as markets fall, investors rush to "safe" assets, causing their value to appreciate. To see how the safe-haven effect of the dollar has been changing, I allow the relationship between the exchange rate returns and stock market returns to vary over time. An increasingly positive relationship indicates a weakening of the safe-haven effect, while an increasingly negative relationship indicates strengthening.

Hossfeld and MacDonald (2015) classify the Swiss franc and US dollar as safe-haven currencies, but did not find evidence to classify the Japanese yen or euro as safe-havens. I find that the dollar's safe-haven effect relative to the yen has actually been decreasing since 2000, and that during the coronavirus crisis the dollar's safe-haven effect was roughly nonexistent relative to the yen. I also find that, while the dollar behaved as a safe-haven during the housing crisis relative to both the euro and franc, the dollar's safe-haven effect has weakened in the past decade. Ranaldo and Söderlind (2010) find that the euro has a weak safe-haven property. In contrast, my research finds that the euro behaves more like a risk asset relative to the dollar, but that this relationship has been changing since around 2011, suggesting that perspectives around the euro and dollar are changing.

A slacking demand for the US dollar caused by a slipping in its position as a safe asset would have a dramatic impact on the global economy. The high demand for US treasuries from foreign central banks enables the US to borrow cheaply, a benefit which is heightened during recessions thanks to the safe-haven effect. As the share of foreign reserves held in US dollars has been steadily falling over the last several years, it would not be hard to imagine the lowered demand and pricing in of risk leading to higher borrowing costs for the US, particularly in riskier environments. As $7T worth of US treasuries are held by foreign countries, higher borrowing costs could wreak havoc on the US economy if they pass through to American consumers at times when it could hurt them the most.

2 Related Literature

The general factors that go into determining global currencies, as found by Helleiner (2008), are confidence in its stability, liquidity, and the breadth of its transactional networks.

Helleiner (2008) noted that confidence in the stability of a currency's value could be derived from historical stability, as well as the country's macroeconomic fundamentals. Furthermore, Habib and Stracca (2012) researched common fundamentals among countries with safe-haven currencies. They found that the most important predictor of a safe-haven currency was the country's net foreign assets (reflecting riskiness via macroeconomic fundamentals) as well as their historical currency returns during crises (which the authors term a "self-fulfilling prophecy"). While the US dollar has proven over time to be a safe hedge during global downturns, it's macroeconomic fundamentals have been becoming more and more questionable. The US has more external debt that any other country in the world, and in 2011, the S&P downgraded the US government to AA+ from AAA after congress voted to raise the debt ceiling. In 2020, as US debt soared during the coronavirus pandemic, Fitch, the credit rating agency, finally changed their outlook from stable to negative. Figure 2 shows the climb in US debt-to-GDP over the past 20 years. Given that public debt-to-GDP levels were already over 100% going into the Covid-19 recession, investors may view the dollar as riskier now than in prior crises. This worsening of the United States' macroeconomic fundamentals is a potential reason why the safe-haven effect appears to have weakened over the past decade.

In terms of stability, the United States' global image has taken quite a hit over the past few years. The Pew Research Center recorded an 11% drop in favorable views of the US between 2016 and 2019 (64% to 53% favorable) and after the 2016 election, global confidence in our country's leader more than halved (Poushter, 2020). The United States has had the highest number of reported cases and deaths from Covid-19, and has

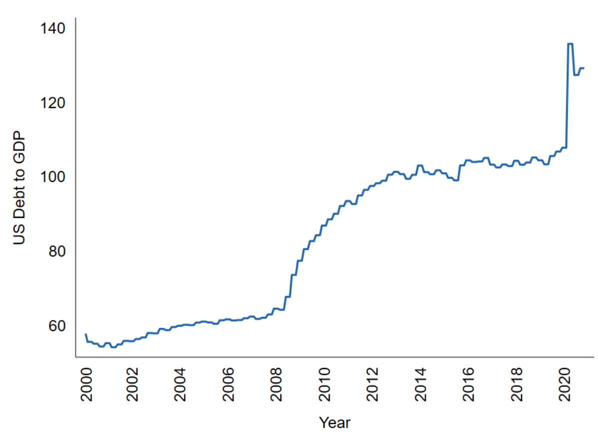


Figure 2: US Federal Debt as % of GDP
Data source: FRED

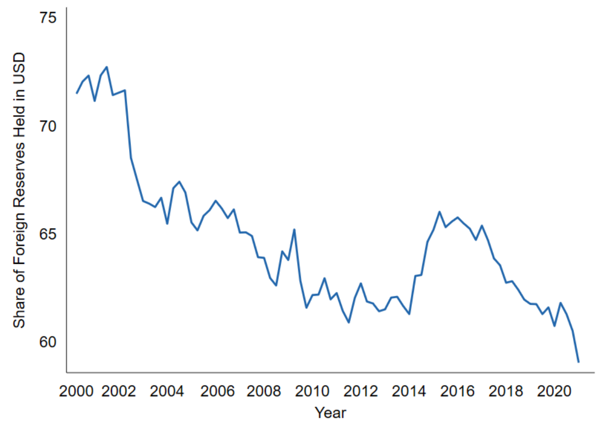


Figure 3: Share of Foreign Reserves Held in USD Over Time
Data source: IMF

seen increasing political instability such as the January 6th storming of the US capitol. Furthermore, A Civil Unrest Index recently placed the US in a 'high-risk' category (Blanco, 2020). As political stability relates to the stability of a country's currency, it can be inferred that confidence in the greenback is falling.

Helleiner (2008) describes liquidity as a factor that can be influenced by politics in the form of developing open and advanced financial markets. This, Helleiner claims, China lacks, limiting their ability to became an international currency despite their growing economic power. During the beginning of the Covid-19 crisis, the US Treasury market experienced an issue with liquidity. The demand for the safe US treasuries outpaced the market's ability to supply them, causing unusually high price volatility and bid/ask spreads to spike, as noted by Cheng et al. (2020). Duffie (2020) also questioned the US dollar's safe-haven status, noting that the Treasury market was "overdue for an upgrade." Liquidity issues in the treasury market may be one reason for a much weaker safe-haven effect of the dollar during the coronavirus as opposed to the Great Recession.

A trade war with China and increasingly protectionist politics could hamper the size of the dollar's transactional network, further reducing demand for the USD. As shown in Figure 3, the amount of foreign reserves held in US dollars has been falling over the past two decades, leaving many wondering whether the greenback's position as the major global currency is fading.

The recent political instability, liquidity issues, trade wars, and debt growth seen by the United States are consistent with my findings that the safe-haven property of the US dollar has been weakening relative to other known safe-haven currencies.

3 Empirical Strategy

In order to measure the changing role of the US dollar as a safe-haven currency, I extend the framework of Hossfeld and MacDonald (2015) to allow a time-varying relationship between exchange rate returns and stock market returns.

$$\Delta e_t = \alpha_t + \beta_t R_t + \delta X_t + u_t \tag{1}$$

Here, Δe_t denotes the dollar exchange rate return relative to a foreign a currency. α_t represents a time-varying intercept and R_t measures stock market returns. X_t is a vector of control variables found to be important in measuring safe-haven effects.

The coefficient of interest here is β_t, which represents the time-varying relationship between dollar exchange rate returns and stock market returns. The dollar can be called a hedge against the stock market if the relationship between stock markets returns and its exchange rate returns is negative, as it would imply that when stock markets fall, the dollar appreciates. A positive relationship would indicate that the dollar is not a hedge and instead behaves similar to risky assets. During crises, investors tend to ditch riskier currencies in exchange for safer currencies that will hold their value throughout the economic downturn. This causes the safe currencies to appreciate in value (relative to less-safe currencies) while markets tank. In result, a safe-haven currency is defined as having a negative relationship between stock market returns and exchange rate returns during crises.

To see how this relationship changes, I specify various functional forms for β_t that allow for time trends. For example, one hypothesis is a linear change in the hedging strength of the dollar, in which $\beta_t = \beta_0 + \beta_1 t$, and $\beta_1 t$ reflects the linear slope by which the hedging property of the dollar is strengthening (if β_1 is negative) or weakening (if β_1 is positive). I allow β_t to be a function of time rather than estimating a new β_t for every month or year because our sample size of 250 observations is not large enough to do so accurately.

In order to separate out the safe-haven effect, which can only be observed in crises, from the overall hedging property of the dollar, we run the above model using a threshold approach to differentiate between times of high and low market volatility. For example, considering a linear trend under this approach would imply that:

$$\beta_t = \begin{cases} \beta_{0,L} + \beta_{1,L} \times t & if\ VXO_t < \gamma \\ \beta_{0,H} + \beta_{1,H} \times t & if\ VXO_t \geq \gamma \end{cases}$$

Here, VXO_t denotes the level of market volatility in each observation, and γ denotes the threshold point that minimizes the sum of squared residuals for each threshold in the model. Different currencies and models may have different γ values due to the nature of its calculation.

In line with our definition of the safe-haven effect, we interpret $\beta_{1,H}$ as the slope of change in the safe-haven effect. Then, $\beta_{1,L}$ can be interpreted as the slope of change in the hedging property of the dollar in "normal" or low volatility times. As previously mentioned, negative slopes indicate a strengthening of the hedging property and positive slopes indicate weakening.

4 Data

If the safe-haven effect of the US dollar has been weakening, it would likely be due to competition from other increasingly safe currencies.

Over the past few decades, several economists have forecasted that the US dollar will likely be overtaken by the euro. For example, Chinn and Frankel (2007) forecasted a strong and fast takeover of the euro if more European countries chose to join the EMU. While only Croatia joined the EU in the past 10 years, I do find evidence that the dollar's safe-haven effect has weakened relative to the euro. Beck and Rahbari (2008) find that the euro acted as a good safe-haven currency during crises that were specific to emerging European countries, while the US dollar was a better hedge for global crises. In contrast, I find that the dollar is actually becoming a weaker hedge during global crises relative to the euro. Lee (2017) finds that in both high and low stress regimes, the euro is expected to yield roughly zero returns, and a small positive correlation with stock returns leads to Lee labeling the euro as a "risky" asset. My research also finds a positive correlation between returns on the euro relative to the dollar and stock returns, however this correlation has been getting weaker over the past ten years.

The Swiss franc is also widely considered to be a safe-haven currency. Hossfeld and MacDonald (2015) and Ranaldo and Söderlind (2010) both classify the Swiss franc as a safe-haven currency using empirical methods. Grisse and Nitschka (2015) find that the franc only exhibits safe-haven properties against certain currencies—particularly carry trade investment currencies such as the Australian dollar—but not the US dollar. Hossfeld and MacDonald (2015), however, find that the franc has safe-haven qualities after controlling for these carry trade investments. Also controlling for carry trade investments, I find that the dollar's safe-haven effect has been weakening relative to the franc in the past decade. In fact, it seems that there was virtually no safe-haven effect from the dollar against the franc during Covid-19.

The Japanese yen was found to be a safe-haven currency by Ranaldo and Söderlind (2010), however Hossfeld and MacDonald (2015) only found the Yen to be a "carry-funding" currency—meaning that after accounting for interest differentials and carry-trades, the yen no longer had safe-haven properties. Lee (2017) had contrasting results, finding that the Japanese yen was a safe-haven by analyzing currency returns and stock returns using a 2-regime model to account for times of crisis. My research shows that when conditioning on crises (through market volatility), the dollar has been steadily becoming a less effective safe-haven relative to the yen over the past 20 years.

I choose to compare the dollar to the euro, franc and yen because the euro, franc and yen seem to be the most viable competitor safe-haven currencies. Other currencies considered but not chosen include the British pound, Australian dollar, Canadian dollar, and the Chinese yuan. Lee (2017) finds strong evidence that the British pound was a risky currency, with strong negative returns in crises and strong positive returns in expansions. Hossfeld and MacDonald (2015) are unable to classify the pound as a speculative, safe-haven, hedge, or carry-funding currency. Hossfeld and MacDonald (2015) determine the Australian dollar and Canadian dollar to both be speculative currencies. Lee (2017) also notes that the Canadian dollar is "the most "equity-like" currency" of those tested, in line with its reputation as a commodity currency. With China's growing importance in the global economy, some may have thought the yuan would be on the road to becoming a safe-haven currency. However, research from Fatum et al. (2017) shows that the yuan depreciated against both the yen and the US dollar in times of growing uncertainty, indicating riskiness.

My model controls for interest rate differentials, inflation differentials, carry trades, and time. The carry trade is a common foreign exchange strategy that involves putting a short position on a currency with low interest rates, and investing in riskier assets with higher interest rates. In a crisis, investors tend to unwind these positions, getting out of their riskier investments. The US dollar is a common short position for the carry trade. So, when a crisis hits, investors unwind their risky positions and turn their original short position into long ones, thereby increasing the demand for the US dollar during global crises. This leads some economists to consider interest rates as a contributor to the safe-haven effect, while others such as Hossfeld and MacDonald (2015) choose to omit the impact of carry trades. My research will be using interest rate differentials and an interaction between the interest rate differentials and volatility index to control for carry trades and their reversals. Inflation is controlled for as higher inflation can generally lead to currency depreciation. A time control is added to models that allow for a time-varying relationship between stock returns and exchange rate returns.

My research uses monthly data from March 2000 to December 2020. I gather daily exchange rate returns for USD/EUR, USD/CHF and USD/JPY currency pairs, daily returns for the Morgan Stanley Capital International (MSCI) World index, and daily Chicago Board of Exchange (CBOE) S&P 100 Volatility Index data from Bloomberg, from which monthly averages are derived

I create the interest differentials based on 1-month money market rates obtained through FRED (federal reserve economic data.) FRED is also utilized to gather monthly CPI (of all items) data for inflation differentials. Both interest and inflation differentials are lagged by one month, following Hossfeld and MacDonald (2015).

5 Results

To understand how the safe-haven property of the dollar has changed, I estimate its time-varying effect across three different currencies. I perform this analysis relative to the euro, franc, and yen, as these may be the dollar's closest competitors in terms of safe-haveness, and consider them each individually.

5.1 Euro

Table 1: USD/EUR OLS Models

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
R_t	-0.272***	-0.245***		0.0686
$R_t \times t$		-0.000247		-0.00795***
$R_t \times 1\{t > 2010\}$			-1.109***	
$R_t \times 1\{t \leq 2010\}$			0.0298	
$R_t \times t \times 1\{t > 2010\}$			0.00424***	
$R_t \times t \times 1\{t \leq 2010\}$			-0.00418***	
$R_t \times t^2$				0.0000305***
Constant	3.88e-08	-0.000157	-0.0000429	-0.000325
Observations	250	250	250	250
R_t^2	0.188	0.193	0.270	0.265
Adjusted R_t^2	0.175	0.173	0.242	0.240
AIC	-2659.2	-2656.9	-2675.8	-2676.0
BIC	-2641.6	-2632.2	-2640.5	-2644.3
df_m	4	6	9	8
df_r	245	243	240	241

Models control for inflation differential, interest differential, interest differential x volatility, and time
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1 contains 4 different model estimations of the dollar's hedging property relative to the euro, unconditional on crises or volatility.

Starting with the simplest model with no trend, we find that the relationship between USD/EUR returns and stock market returns, R_t is negative, and significant at the 0.001 level. This supports the notion that historically, the US dollar serves well as a hedge against stock market downturns relative to the euro.

With a linear trend model, we still see a negative coefficient for R, and while the negative coefficient on $R_t \times t$ would indicate that the hedging property has been strengthening, this coefficient is insignificant and its 95% confidence interval encompasses zero.

Model 3 in Table 1, a piecewise regression which splits the sample in half chronologically, shows that the hedging property's trend is clearly nonlinear. This explains the lack of significance from Model 2. Instead of a linear trend across the whole sample, it appears that from 2000-2010 (the first half of the sample), the dollar is becoming a better hedge, given by a negative $R_t \times t \times 1\{t \leq 2010\}$, the slope of change in the hedging property. From 2010-2020, as shown in Figure 4a, this trend is reversing, as the positive coefficient on $R_t \times t \times 1\{t > 2010\}$ indicates that the hedging property is significantly weakening.

The quadratic model supports what was found in the piecewise model. As seen in Figure 4b, the data again shows a strengthening of the dollar's hedging property to a significantly larger magnitude in the middle of the sample, and a weakening of the hedging property after.

A more flexible model using splines further supports the pattern found in the piecewise and quadratic models, and it can be found in Table 8 in the appendix.

While the adjusted R_t^2, AIC, and BIC statistics are extremely close between the quadratic and piecewise models, the quadratic model is more parsimonious, and is used as the preferred method of estimating the hedging property. The quadratic model also has more significance in its estimators and a lower BIC than the model using splines.

The models in Table 1 provide information pertaining to the hedging property of the dollar. To see the safe-haven effect, one must condition on economic crises. To do so, we use threshold models to differ between times of low and high volatility.

The trends in the safe-haven effect of the dollar determined using threshold analysis are similar to the trends found in the hedging property using OLS models. Both quadratic and piecewise threshold models show that when conditioning on high volatility, the safe-haven effect seems to strengthen into the middle of the sample and weaken after. For example, the high volatility region of the piecewise function shows a

(a) Piecewise Model Estimation

(b) Quadratic Model Estimation

Figure 4: USD/EUR Hedging Property

Table 2: USD/EUR Threshold Models

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
γ	16.40	16.40	16.95	16.40
Region1: $VXO_t \leq \gamma$				
R_t	-0.540***	-0.430		-0.509
$R_t \times t$		-0.000858		0.000797
$R_t \times 1\{t \leq 2010\}$			-1.245*	
$R_t \times t \times 1\{t \leq 2010\}$			0.0127	
$R_t \times 1\{t > 2010\}$			-0.995	
$R_t \times t \times 1\{t > 2010\}$			0.00216	
$R_t \times t^2$				-0.00000666
Constant	0.000313	0.0000252	0.000198	0.000521
Region2: $VXO_t > \gamma$				
R_t	-0.255***	-0.226**		0.0767
$R_t \times t$		-0.000253		-0.00771***
$R_t \times 1\{t \leq 2010\}$			0.0596	
$R_t \times t \times 1\{t \leq 2010\}$			-0.00451***	
$R_t \times 1\{t > 2010\}$			-1.114***	
$R_t \times t \times 1\{t > 2010\}$			0.00436**	
$R_t \times t^2$				0.0000295***
Constant	-0.0000712	-0.000171	-0.0000550	-0.000296
Observations	250	250	250	250

Models control for inflation differential, interest differential, interest differential x volatility, and time

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

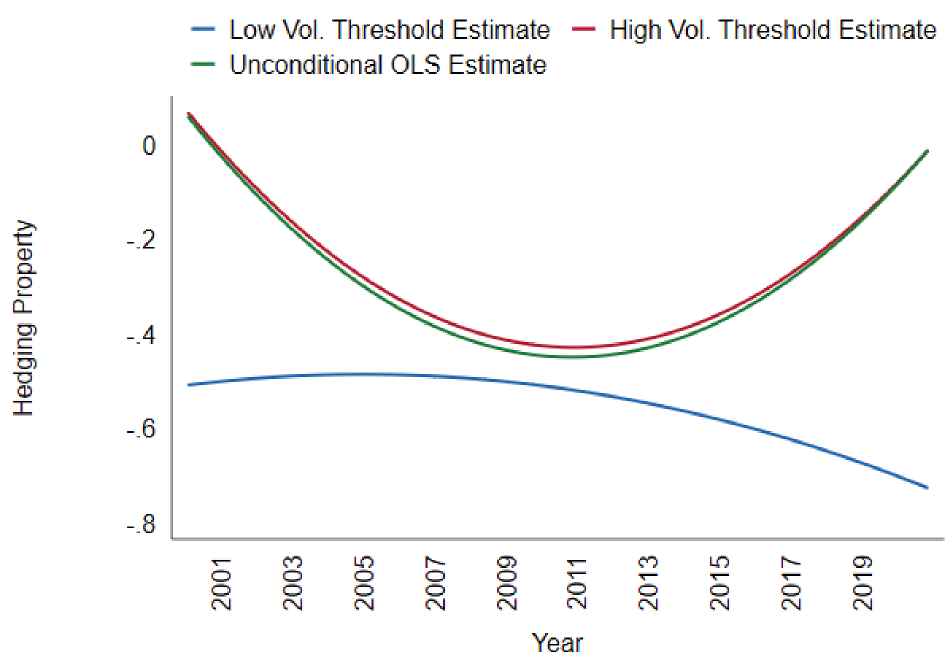
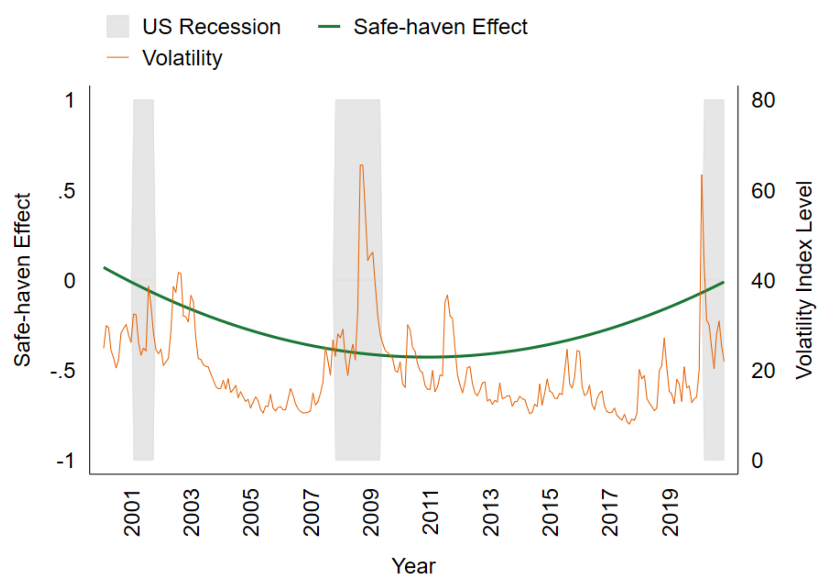


Figure 5: USD/EUR Hedging Property with Threshold Model Estimation

(a) Safe-haven Effect Comparison: Housing Crisis & Covid-19



(b) Estimated Safe-haven Effect Over Time

Figure 6: USD/EUR Safe-haven Effect

significant strengthening of the safe-haven effect by a negative $R_t \times t \times 1\{t \leq 2010\}$ in the first half of the sample, and a significant weakening in the second half, indicated by a positive $R_t \times t \times 1\{t > 2010\}$.

Furthermore, plotting the high volatility quadratic threshold model estimator with the quadratic OLS model estimator, as seen in Figure 5, shows that the 2 estimations nearly overlap each other, meaning that the OLS model is mainly picking up on high volatility trends. Conditioning on low volatility, the dollar actually seems to be becoming a better hedge against stock market returns, indicated by the increasingly negative relationship between stock market returns and dollar returns during low volatility times (however, this relationship lacks statistical significance).

One might assume that the patterns mentioned above can be attributed to the Great Recession, however if this were the case, and there was no change occurring in the safe-haven effect, then we would expect similar levels of the safe-haven effect during the more recent coronavirus pandemic. That is not what we find. Figures 6a and 6b display the safe-haven effect of the dollar estimated using the quadratic high volatility threshold model, highlighting its magnitude during the housing crisis and coronavirus pandemic. Despite similar levels of volatility, the estimated safe-haven effect is much weaker during Covid-19 than during the housing crisis. This is not by fault of the model, either. Both piecewise and spline models produced similar results, and the correlation between USD/EUR exchange rate returns and stock market returns were much more negative (-0.6246) during the housing crisis than during Covid-19 (-0.3935). It could be argued that the housing crisis was worse enough to warrant a stronger safe-haven effect, however, the 20 million jobs lost in the U.S. in April of 2020 due to the coronavirus pandemic seems to dwarf the 8.7 million lost throughout the entire great recession (Bernstein and Jones, 2020).

An alternate theory could be that the safe-haven effect is more of a result from currency-specific crises. For example, while the safe-haven effect was stronger in the housing crisis (using U.S recession dates) than the pandemic, according to the quadratic threshold model, the peak safe-haven strength really occurred shortly after the housing crisis, in alignment with the peak of the European debt crisis in 2011 and 2012. This could explain why the safe-haven effect was not as strong during the pandemic, which has had an impact on all nations. However, this theory does not explain why the safe-haven effect of the dollar was still much stronger in the housing crisis than during the pandemic, both of which had profound impacts on the global economy.

5.2 Franc

The euro and the franc have similar results in their OLS models in terms of direction, however their results vary in terms of magnitude. To be more specific, it seems that the hedging property of the dollar seems to be significantly weaker when taken relative to the franc rather than the euro.

For example, Table 3 presents the estimations of the dollars hedging property in the USD/CHF currency pair, unconditional on volatility. Here, the R_t coefficient using the first model with no trend is -0.189, while in Table 1, the same coefficient was -0.272 using the USD/EUR pairing. The correlation between the USD/CHF exchange rate returns and stock market returns during the financial crisis was -.3781 and -.1967 during the Covid-19 recession, compared to -0.6246 and -0.3935 for the USD/EUR pairing. Since the hedging property is stronger when the relationship between dollar returns and stock returns is more negative, we can infer that the dollar has historically been a better hedge relative to the euro than the franc. This supports past research, which has shown that the franc is a much more definitive safe-haven currency than the euro.

Modeling the hedging property with a linear trend does not seem to give improvement over the trendless model. The linear trend model for the franc lacks significance, and the coefficients for both the R_t and $R_t \times t$ contain zero in their 95% confidence intervals. The linear trend model even has a lower adjusted R_t^2 than the model without trend.

As shown in Figure 7, the quadratic and piecewise models for the USD/CHF pairing both depict a strengthening of the dollar's hedging property up to around 2011 and a weakening of the hedging property afterwords, mirroring the results from the euro. This trend is further supported using a model with splines, which can be found in Table 10 in the appendix.

Table 4 presents results from the threshold method of estimation. Region 2 estimations condition on high-volatility, meaning that they can be interpreted as the dollar's safe-haven effect relative to the franc.

Both the euro and the franc produce a surprising result in their threshold models with no trend. Both currencies had a more negative R_t coefficient in the low volatility region than the high volatility region, implying that the hedging property of the dollar tends to be stronger in low volatility times rather than high volatility times. This is not in line with the definition of a safe-haven currency, in which we would expect the hedging property to become even stronger in times of high-volatility and uncertainty.

The threshold model with a quadratic trend finds that conditional on low volatility, the US dollar is becoming a better hedge against stock market downturns. Conditioning on high volatility, we again find a strengthening of the safe-haven effect until around 2011-2012. This can be seen in Figure 8, which plots the unconditional quadratic estimator from Table 3 with both the high and low volatility quadratic threshold estimators.

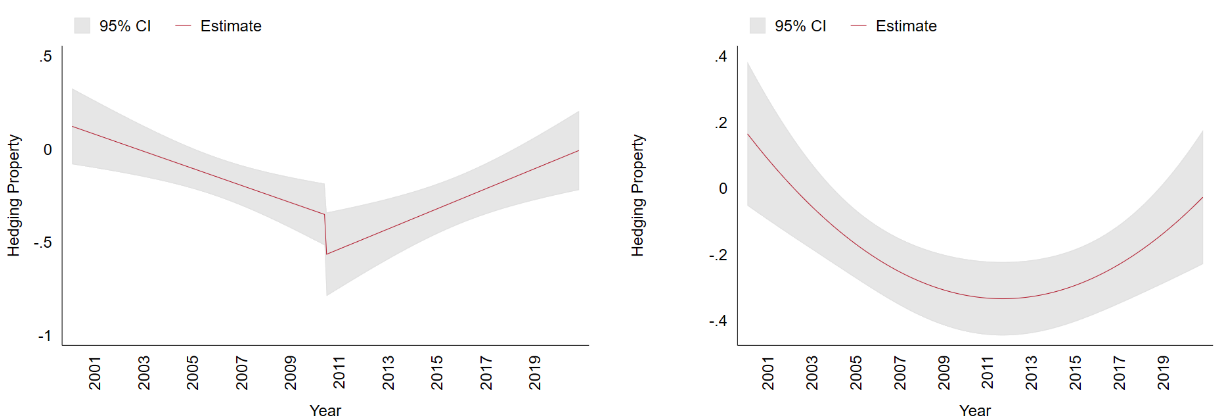
As we saw with the euro, the safe-haven effect of the dollar relative to the franc seemed to have an inflection point around 2011, slightly after the housing crisis in the U.S and amid the European debt crisis. One possible reason for the similar inflection point to the euro could be that the franc was pegged to the euro from about 2011-2015. Due to exchange rate arbitrage, the peg would have forced the relationship

Table 3: USD/CHF OLS Models

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
R_t	-0.189***	-0.126		0.171
$R_t \times t$		-0.000519		-0.00720***
$R_t \times 1\{t > 2010\}$			-1.037***	
$R_t \times 1\{t \leq 2010\}$			0.116	
$R_t \times t \times 1\{t > 2010\}$			0.00408**	
$R_t \times t \times 1\{t \leq 2010\}$			-0.00366**	
$R_t \times t^2$				0.0000256***
Constant	-0.0000877	-0.000210	-0.0000259	-0.000141
Observations	250	250	250	250
R_t^2	0.086	0.092	0.156	0.138
Adjusted R_t^2	0.071	0.069	0.125	0.110
AIC	-2616.1	-2613.7	-2626.2	-2622.8
BIC	-2598.5	-2589.1	-2590.9	-2591.2
df_m	4	6	9	8
df_r	245	243	240	241

Models control for inflation differential, interest differential, interest differential x volatility, and time

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$



(a) Piecewise Model Estimation

(b) Quadratic Model Estimation

Figure 7: USD/CHF Hedging Property

Table 4: USD/CHF Threshold Models

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
γ	16.95	31.83	29.99	29.99
Region1: $VXO_t \leq \gamma$				
R_t	-0.487***	-0.0694		0.0754
$R_t \times t$		-0.000603		-0.00342
$R_t \times 1\{t \leq 2010\}$			0.00991	
$R_t \times t \times 1\{t \leq 2010\}$			-0.000486	
$R_t \times 1\{t > 2010\}$			-0.713*	
$R_t \times t \times 1\{t > 2010\}$			0.00262	
$R_t \times t^2$				0.0000108
Constant	0.000355	-0.000276	-0.0000487	-0.0000824
Region2: $VXO_t > \gamma$				
R_t	-0.145**	-0.147		0.375*
$R_t \times t$		-0.00198		-0.0119***
$R_t \times 1\{t \leq 2010\}$			0.260	
$R_t \times t \times 1\{t \leq 2010\}$			-0.00618***	
$R_t \times 1\{t > 2010\}$			-1.524**	
$R_t \times t \times 1\{t > 2010\}$			0.00631*	
$R_t \times t^2$				0.0000420***
Constant	-0.000221	-0.00134	0.000898	0.000472
Observations	250	250	250	250

Models control for inflation differential, interest differential, interest differential x volatility, and time

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

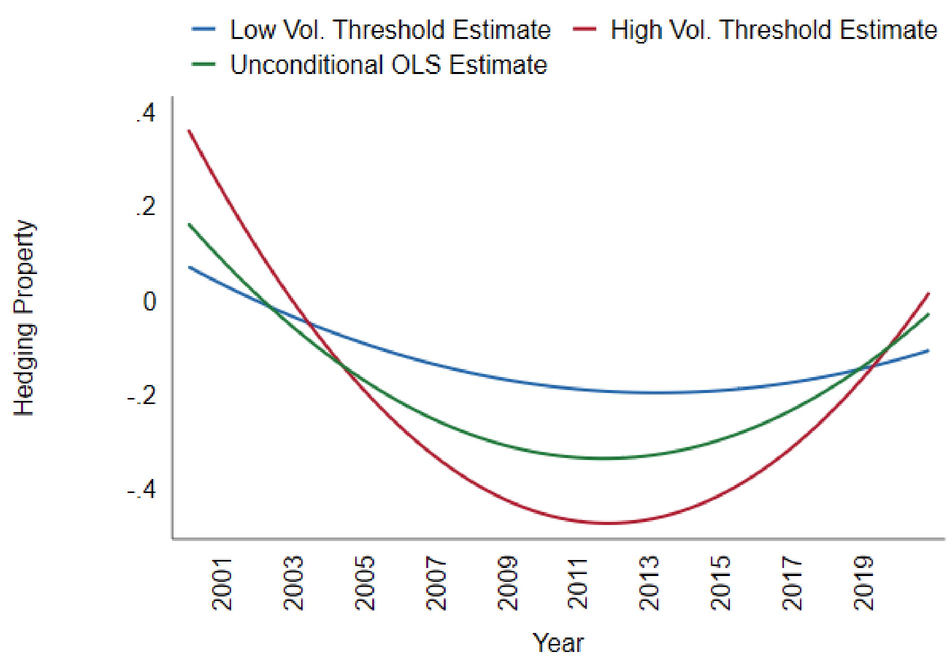
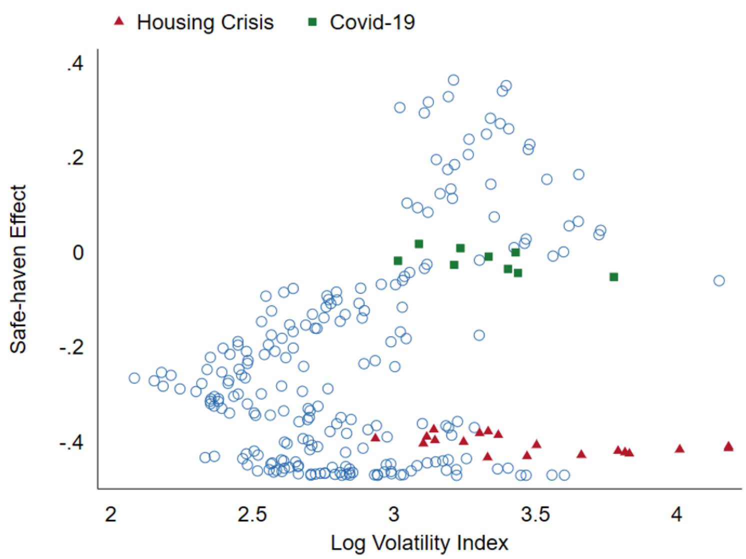
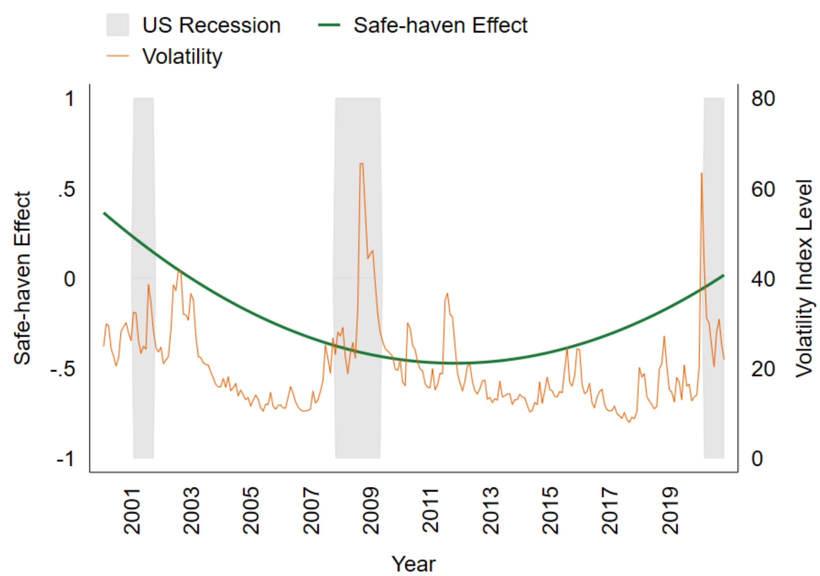


Figure 8: USD/CHF Hedging Property with Threshold Model Estimation



(a) Safe-haven Effect Comparison: Housing Crisis & Covid-19



(b) Estimated Safe-haven Effect Over Time

Figure 9: USD/CHF Safe-haven Effect

between the dollar and the franc to mirror the relationship between the dollar and the euro. This would explain why the European debt crisis could have the same impact on the franc that it did on the euro. During the coronavirus pandemic, the safe-haven effect of the dollar relative to the franc has been relatively non-existent, as shown in Figure 9, leading us to the same conclusion of a weakening safe-haven effect of the dollar.

5.3 Yen

The hedging property and safe-haven effect of the dollar relative to the yen follows a very different pattern than the findings from the euro and franc.

As shown in Table 5, a model without trend finds an insignificant coefficient for R_t, the relationship between USD/JPY exchange rate returns and stock market returns, that hovers around 0, indicating that historically the dollar does not seem to be a hedge against stock market downturns relative to the yen.

The linear trend model finds a positive and significant coefficient for $R_t \times t$, the slope of change in the hedging effect, indicating a weakening hedging property of the dollar over time.

Table 5: USD/JPY OLS Models

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
R_t	0.0162	-0.134		-0.317**
$R_t \times t$		0.00117*		0.00535**
$R_t \times 1\{t > 2010\}$			0.169	
$R_t \times 1\{t \leq 2010\}$			-0.239*	
$R_t \times t \times 1\{t > 2010\}$			-0.000449	
$R_t \times t \times 1\{t \leq 2010\}$			0.00256*	
$R_t \times t^2$				-0.0000162*
Constant	-0.0000253	0.0000322	0.000326	0.000131
Observations	250	250	250	250
R_t^2	0.008	0.028	0.057	0.050
Adjusted R_t^2	-0.009	0.004	0.022	0.018
AIC	-2632.4	-2633.6	-2635.3	-2635.3
BIC	-2614.8	-2608.9	-2600.0	-2603.6
df_m	4	6	9	8
df_r	245	243	240	241

Models control for inflation differential, interest differential, interest differential x volatility, and time

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The piecewise model shows that from 2000-2010 the dollar was becoming a worse hedge (significant at the 0.005 level) and that from 2010-2020 the dollar was becoming a better hedge (however, this trend is insignificant, and it's 95% confidence interval contains zero). This is demonstrated in Figure 10a. Whereas the inflection point for the changing hedging trend for the euro and franc both seemed to be around 2011, the inflection point for the yen seems to be around 2013, shown in Figure 10b. This is likely related to the

Table 6: USD/JPY Threshold Models

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
γ	29.43	29.43	19.86	29.43
Region1: $VXO_t \leq \gamma$				
R_t	0.0435	-0.104		-0.291*
$R_t \times t$		0.00106		0.00559*
$R_t \times 1\{t \leq 2010\}$			-1.388**	
$R_t \times t \times 1\{t \leq 2010\}$			0.0193**	
$R_t \times 1\{t > 2010\}$			0.0788	
$R_t \times t \times 1\{t > 2010\}$			0.000107	
$R_t \times t^2$				-0.0000174
Constant	0.0000447	0.000130	0.000318	0.0000288
Region2: $VXO_t > \gamma$				
R_t	-0.100	-0.282*		-0.383*
$R_t \times t$		0.00160		0.00388
$R_t \times 1\{t \leq 2010\}$			-0.203*	
$R_t \times t \times 1\{t \leq 2010\}$			0.00180	
$R_t \times 1\{t > 2010\}$			0.0436	
$R_t \times t \times 1\{t > 2010\}$			0.0000856	
$R_t \times t^2$				-0.00000874
Constant	-0.000142	-0.000642	0.0000400	-0.000940
Observations	250	250	250	250

Models control for inflation differential, interest differential, interest differential x volatility, and time

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(a) Piecewise Model Estimation

(b) Quadratic Model Estimation

Figure 10: USD/JPY Hedging Property

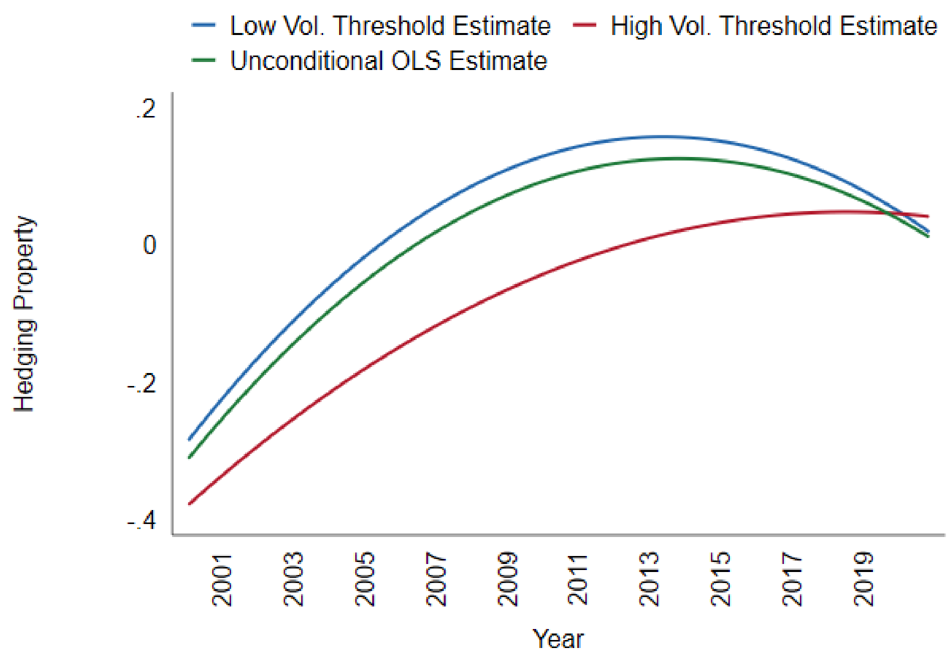


Figure 11: USD/JPY Hedging Property with Threshold Model Estimation

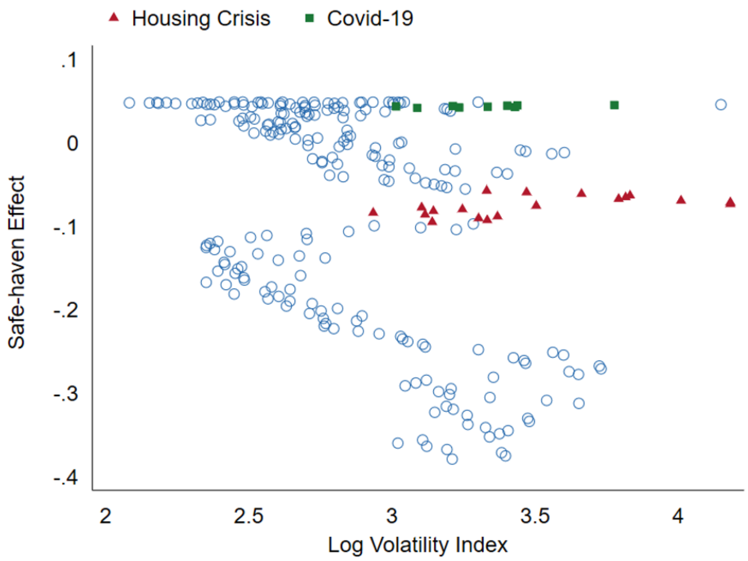
2013 launch of "Abenomics", a massive monetary and fiscal stimulus program that resulted in a depreciation of the yen relative to many other currencies.

Table 6 contains the threshold estimations of the dollars hedging property and safe-haven effect.

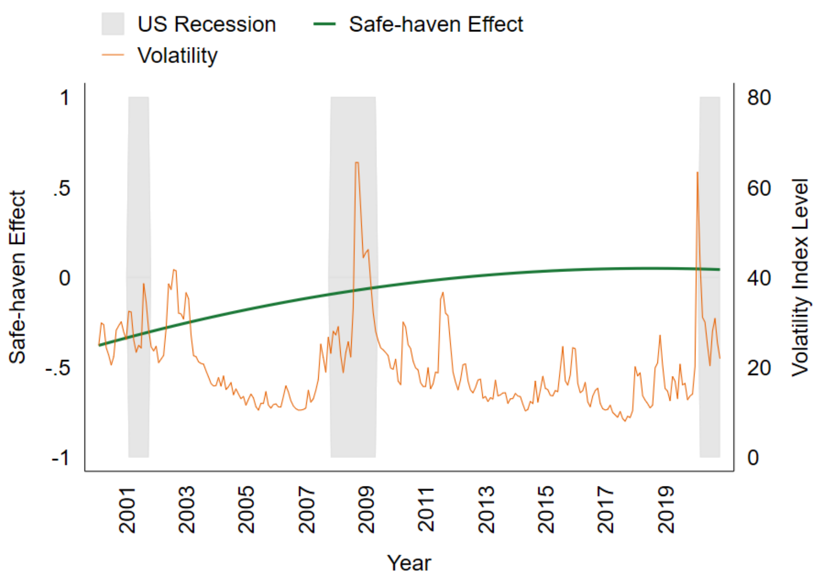
The first threshold model considered, with no trend, provides insignificant results for the R_t coefficient in both high and low volatility periods. Both high and low volatility R_t coefficients contain zero in their 95% confidence interval. The model with a linear trend also provides insignificant results, meaning that the hedging property and safe-haven property of the dollar is likely neither constant nor exhibits a linear change over time.

The threshold model with a piecewise trend shows that both the hedging property and safe-haven effect of the dollar strengthened throughout both halves of the sample. For example, the slope of change in the hedging property, indicated by $R_t \times t$ in the low volatility region, was positive for both $\{t \leq 2010\}$ and $\{t > 2010\}$. Again, a positive slope indicates a weakening of the hedging property. The high volatility region of the piecewise model also finds a positive $R_t \times t$ in both halves of the sample. Because this occurs in the high volatility region, we can interpret the result as a weakening of the safe-haven effect.

Figure 11 plots the estimators from both the quadratic model in Table 5, and the threshold quadratic trend models from Table 6. Contrary to the estimation unconditional on volatility, the high volatility estimation shows a smooth weakening of the dollar's safe-haven effect throughout the entire sample.



(a) Safe-haven Effect Comparison: Housing Crisis & Covid-19



(b) Estimated Safe-haven Effect Over Time

Figure 12: USD/JPY Safe-haven Effect

Using the quadratic threshold model in Figure 12, we can see that the estimated safe-haven effect of the dollar against the yen during the Covid-19 was non-existent. Instead the yen may have been seen as a safer option than the dollar. This could perhaps be a result of the US's perceived mishandling of the pandemic. The figures also show that the dollar seemed to be a safe-haven during the housing crisis, however to a lesser magnitude than we saw with the euro and franc. Furthermore, the correlation between dollar returns against the yen and stock market returns was about 0.1046 during the financial crisis, and 0.1678 during the coronavirus crisis. This means that, without controlling for other variables, it seems that the dollar is becoming more risky and "equity-like" relative to the yen, as it has an increasingly positive correlation with stock returns.

5.4 Discussion

The safe-haven effect of the US dollar relative to the euro, franc and yen has clearly been changing over time. One hypothesis may be that the safe-haven effect of the dollar strengthens in times of crises– as we saw during the housing crisis and European debt crisis relative to the euro and franc. Another theory could be that the safe-haven effect is more of a result of currency specific crises than overall global uncertainty. However, neither hypothesis accounts for the significant decline in safe-haven strength during covid-19 compared to the housing crisis.

Furthermore, there is ample evidence to support the idea that the dollar is no longer a safe-haven currency relative to the yen at all. While the dollar may still serve well as a hedge against stock-market downturns in "normal" low-volatility times against the currencies analysed, it seems to be losing its edge as a safe-haven currency when facing global economic dilemmas. Existing research into the factors that determine global and safe-haven currencies may help explain the dollar's evolving behavior. Helleiner (2008) and Habib and Stracca (2012) both noted the importance of strong macroeconomic fundamentals for confidence in a currency's stable value and safe-haveness. As debt in the US has grown significantly in the past decade, this is a plausible factor as to why the dollar's safe-haven effect has dwindled relative to other strong currencies. The disparity between the dollar's safe-haven effect during the housing crisis and covid-19 may have also been partially caused by the liquidity shortage in the US's treasury market in March of 2020, as liquidity is one of the factors identified by Helleiner (2008) important to the creation of global currencies. Other issues such as political instability and protectionist policies may also be increasing the dollar's perceived riskiness, thereby chipping away at it's status as a safe-haven.

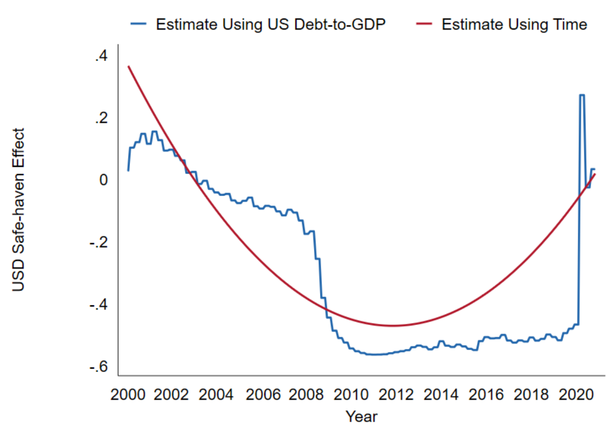
To test factors that may impact the safe-haven effect of the dollar, we can add them into the model interacted with stock returns.

For example one hypothesis considered is that the US's debt-to-GDP ratio helps explain the dollar's safe-haven effect over time. A higher debt-to-GDP ratio in the US may increase the dollar's perceived riskiness. To model this, we can interact debt-to-GDP with stock returns, similar to how we looked for time trends. For example, checking for a quadratic impact of debt-to-GDP would look like this:

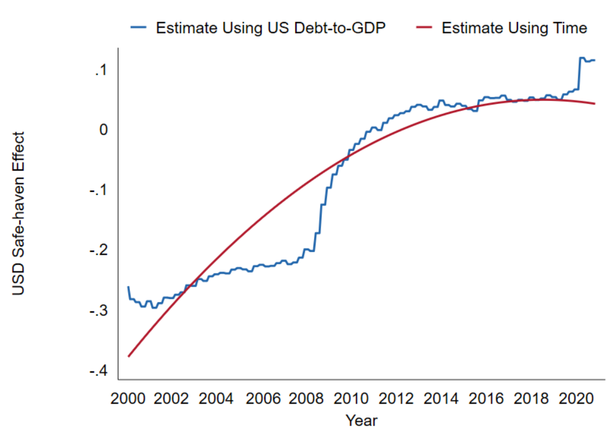
$$\beta_t = \beta_0 + \beta_1 \times DebtToGDP_t + \beta_2 \times DebtToGDP_t^2$$

Through this approach, I find estimates for the safe-haven effect that look very similar to the estimates found using the quadratic time-trend threshold models for each of the currencies, as shown with the franc and yen in Figure 13.

However, there are two issues that arise from using US debt-to-GDP to estimate the safe-haven effect. One, debt-to-GDP is seemingly having a different effect on the dollar relative to the euro and franc rather than the yen, which goes against what we would expect. Secondly, adding in a quadratic time trend removes



(a) USD/CHF



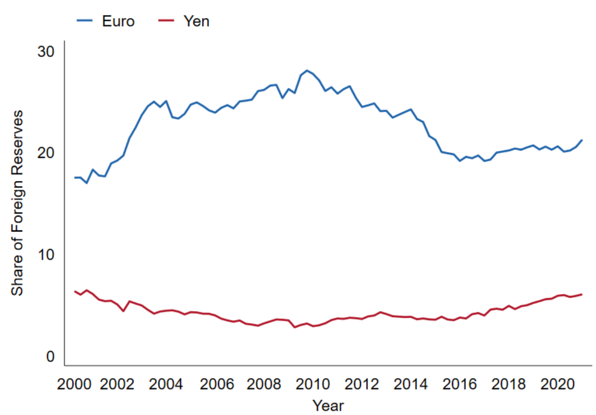
(b) USD/JPY

Figure 13: Safe-Haven Effect Estimates Using US Debt-to-GDP

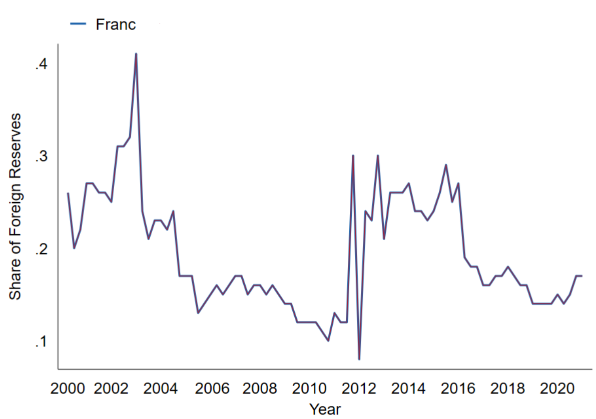
the significance of debt-to-GDP estimates of the safe-haven effect.

I also attempt to model the dollar's safe-haven effect using the share of foreign reserves held in each currency. This proves to be insignificant as well. While the share of foreign reserves held by the dollar fell from above 70% to around 60%, the Swiss franc's share also decreased, as shown in Figure 14b, and the euro and yen both are only slightly higher than they were in 2000. If the franc, yen, and euro aren't taking up a larger share of foreign reserves, this could imply that foreign reserves are increasingly being held in less typical currencies. Figure 14c demonstrates how other major currencies' share of foreign reserves has been changing over time. The only major growth seems to be with the Chinese yuan.

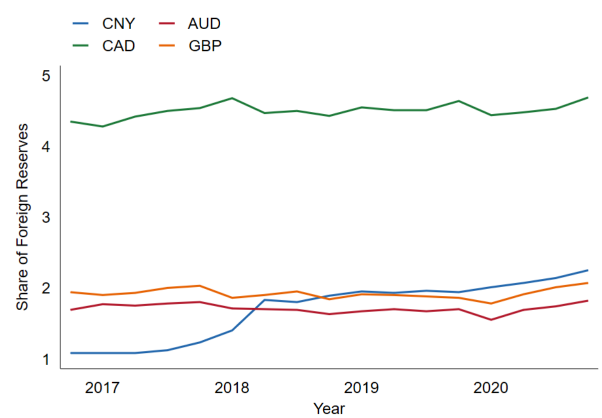
Lastly, I also consider net foreign assets of Switzerland and Japan as factors that could impact the safe-haven effect relative to their countries' currencies. A country with higher net foreign assets may be viewed as safer than a country running a large deficit, such as the US. Both Switzerland and Japan have experienced



(a) EUR and JPY



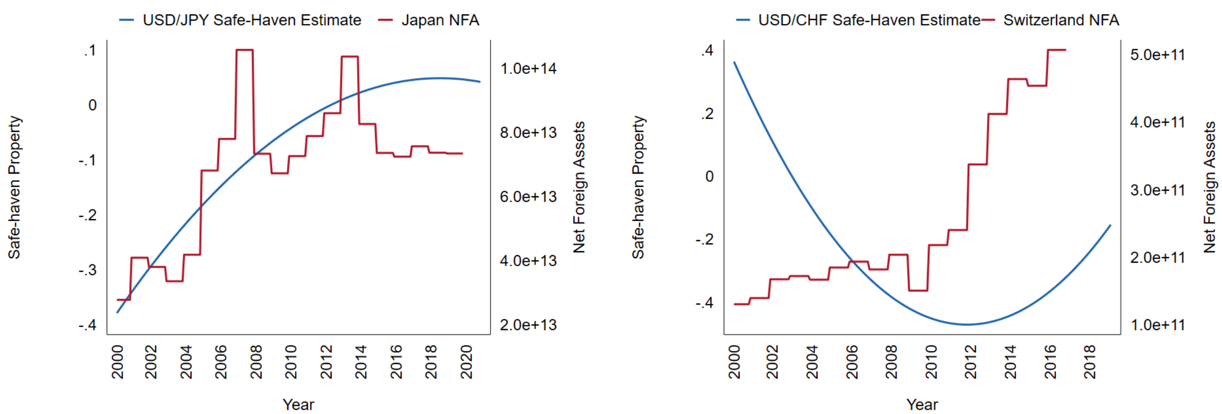
(b) CHF



(c) CNY, AUD, CAD, GBP

Figure 14: Share of Foreign Reserves Over Time
Data source: IMF

increasing NFA balances over the past twenty years, and there are some striking similarities between their NFA growth and the weakening of the dollar's safe-haven effect. For example, Figure 15a shows the estimated safe-haven effect using a quadratic threshold time trend compared to Japan's net foreign assets. Japan's NFA shows strong but volatile growth through 2015, then falls flat. This mirrors the steep weakening of the dollar's safe-haven effect relative to the yen (indicated by a positive slope) until around 2015, where the safe-haven effect starts to bottom out. Figure 15b shows Switzerland's NFA compared to the USD/CHF estimated safe-haven effect, also estimated with a quadratic time trend . The inflection point around 2012, when the safe-haven effect of the dollar begins to decrease, comes right around Switzerland's switch to a postive NFA position.



(a) Japan

(b) Switzerland

Figure 15: Net Foreign Assets and Estimated Safe-haven Effects
Data source: The World Bank

To test whether this pattern is just coincidental, I implement a threshold model conditioning on volatility, with combined data for the USD/JPY and USD/CHF pairing. However, in addition to a time trend, I also analyze the impact of percent change of the NFA balance in Japan and Switzerland on the safe-haven effect of the dollar. Table 7 shows a linear and quadratic trend of percent change in foreign NFA in addition to quadratic time trends. The linear model showed little significance, indicating that percent change in foreign NFA does not have a linear relationship with stock returns and exchange rate returns. However, using a quadratic model showed a significant effect of NFA, particularly when conditioning on high volatility. As change in foreign NFA increases, the safe-haven effect of the dollar seems to decrease, given by $R_t \times \%ChangeNFA$. This lines up well with findings from Habib and Stracca (2012) that show a country's NFA is the most important predictor to whether their currency becomes a safe-haven. However, $R_t \times \%ChangeNFA^2$ has a negative coefficient, showing that relatively larger % changes, positive or negative, in NFA may actually increase the safe-haven effect of the dollar.

Table 7: USD/CHF and USD/JPY Threshold Model using NFA

	(1) Linear	(2) Quadratic
Region1		
R_t	-0.206	-0.219
$R_t \times \%ChangeNFA$	-0.306	-0.662*
$R_t \times t$	0.000689	-0.000544
$R_t \times t^2$	0.00000314	0.00000918
$R_t \times \%ChangeNFA^2$		1.770*
Constant	-0.000111	-0.000101
Region2		
R_t	0.0520	-0.179
$R_t \times \%ChangeNFA$	-0.174	1.000**
$R_t \times t$	-0.000938	0.0139
$R_t \times t^2$	-0.0000114	-0.000103*
$R_t \times \%ChangeNFA^2$		-4.061***
Constant	0.00178*	0.00132*
Observations	432	432

Models control for inflation differential, interest differential, interest differential x volatility, NFA and time

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Next steps in this area of research could include using measures of political stability or market liquidity to model the changing safe-haven effect. Furthermore, comparing the US dollar to riskier, emerging market currencies may prove insightful. For example, since China's share of foreign reserves has been increasing in the past several years, perhaps the yuan is now being viewed as less of a risk, which could dampen the US dollar's relative safe-haven effect. My research was limited in that I only compared the dollar to other strong safe-haven currencies, but I would expect to see the trend of a decreasing safe-haven effect across risky currencies as well.

6 Conclusion

In this paper, I examine the weakening of the US dollar's safe-haven effect relative to the euro, franc and yen. While past research on this topic mostly focuses on the static classification of currencies as safe-havens, my research provides insight into the degree to which the dollar's safe-haven property has changed over time.

To do so, I analyze the time-varying relationship between dollar exchange rate returns and stock market returns, conditional on high volatility. I also consider patterns in the overall hedging property of the dollar, unconditional on crises.

My results suggest that the safe-haven effect of the dollar has been changing over time. Relative to the euro and franc, it seems as though the safe-haven property of the dollar was strengthening between

2000-2011 and began weakening after. Compared to the the yen, the safe-haven effect of the dollar weakens fairly steadily throughout the entirety of the sample (2000-2020). Furthermore, it does not appear that these results are driven by global crises, otherwise we would have likely seen an upturn in the safe-haven effect in response to the coronavirus pandemic. Rather, it seems that the changing strength of the dollar's safe-haven effect may relate to macroeconomic fundamentals such as net foreign assets, in the US and abroad.

Knowing that the dollar's safe-haven property has been weakening against the euro, franc and yen, it may be useful to study the safe-haven effect of the dollar relative to riskier currencies, such as the Canadian dollar, British pound, or Chinese yuan. Based on the results in this paper, I would expect the safe-haven effect of the dollar to be falling against these riskier currencies as well, as investor preferences in crises seems to be sliding away from the dollar and towards currencies such as the yen or franc.

If global investors truly are starting to view the US dollar as a riskier asset than in the past, we may need to prepare for higher interest rates in the future and a slacking demand for the dollar during future economic downturns. On the contrary, if the US is able to lower its debts and inspire more faith in the government's stability, perhaps we will see a strengthening of the dollar's safe-haven effect again in the future.

7 Appendix

Table 8: USD/EUR OLS Models Full

	(1)	(2)	(3)	(4)	(5)
	Constant	Linear	Piecewise	Quadratic	Spline
R	-0.272***	-0.245***		0.0686	-0.114
$i^*_{t-1} - i_{t-1}$	-0.0000303	-0.00000590	0.0000844	0.0000571	-0.0000231
$\pi^*_{t-1} - \pi_{t-1}$	-0.00679	-0.00665	-0.0125	-0.0121	-0.0149
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	-0.00000165	-0.00000138	-0.00000643	-0.00000788	-0.00000467
$R \times t$		-0.000247		-0.00795***	
t		0.00000137		0.00000808	
$R \times 1\{t > 2010\}$			-1.109***		
$R \times 1\{t \leq 2010\}$			0.0298		
$R \times t \times 1\{t > 2010\}$			0.00424***		
$R \times t \times 1\{t \leq 2010\}$			-0.00418***		
$t \times 1\{t > 2010\}$			0.000000715		
$t \times 1\{t \leq 2010\}$			0.000000703		
$R \times t^2$				0.0000305***	
t^2				-3.13e-08	
$R \times Spline1$					0.00270
$R \times Spline2$					-0.0499
$R \times Spline3$					0.175*
$R \times Spline4$					-0.232*
$Spline1$					-0.00000911
$Spline2$					0.0000730
$Spline3$					-0.000204
$Spline4$					0.000169
Constant	3.88e-08	-0.000157	-0.0000429	-0.000325	0.0000898
Observations	250	250	250	250	250
R^2	0.188	0.193	0.270	0.265	0.302
Adjusted R^2	0.175	0.173	0.242	0.240	0.266
AIC	-2659.2	-2656.9	-2675.8	-2676.0	-2680.8
BIC	-2641.6	-2632.2	-2640.5	-2644.3	-2635.1
df_m	4	6	9	8	12
df_r	245	243	240	241	237

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Here, $i^*_{t-1} - i_{t-1}$ denotes the interest differential and $\pi^*_{t-1} - \pi_{t-1}$ the inflation differential. The asterisk reflects a foreign value.

Table 9: USD/EUR Threshold Models Full

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
γ	16.40	16.40	16.95	16.40
Region1: $VXO_t \leq \gamma$				
R	-0.540***	-0.430		-0.509
$i^*_{t-1} - i_{t-1}$	0.000534	0.000531	0.000504	0.000584
$\pi^*_{t-1} - \pi_{t-1}$	-0.0353	-0.0383	-0.0408	-0.0387
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	-0.0000433	-0.0000417	-0.0000344	-0.0000429
$R \times t$		-0.000858		0.000797
t		0.00000215		-0.00000664
$R \times 1\{t \leq 2010\}$			-1.245*	
$R \times t \times 1\{t \leq 2010\}$			0.0127	
$R \times 1\{t > 2010\}$			-0.995	
$R \times t \times 1\{t > 2010\}$			0.00216	
$t \times 1\{t \leq 2010\}$			-0.000000378	
$t \times 1\{t > 2010\}$			0.00000143	
$R \times t^2$				-0.00000666
t^2				3.29e-08
Constant	0.000313	0.0000252	0.000198	0.000521
Region2: $VXO_t > \gamma$				
R	-0.255***	-0.226**		0.0767
$i^*_{t-1} - i_{t-1}$	0.0000156	0.0000416	0.0000541	0.0000501
$\pi^*_{t-1} - \pi_{t-1}$	0.0168	0.0181	0.00557	0.00663
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	-0.00000270	-0.00000280	-0.00000620	-0.00000866
$R \times t$		-0.000253		-0.00771***
t		0.000000939		0.00000867
$R \times 1\{t \leq 2010\}$			0.0596	
$R \times t \times 1\{t \leq 2010\}$			-0.00451***	
$R \times 1\{t > 2010\}$			-1.114***	
$R \times t \times 1\{t > 2010\}$			0.00436**	
$t \times 1\{t \leq 2010\}$			0.000000259	
$t \times 1\{t > 2010\}$			-0.000000241	
$R \times t^2$				0.0000295***
$t2$				-3.92e-08
Constant	-0.0000712	-0.000171	-0.0000550	-0.000296
Observations	250	250	250	250

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: USD/CHF OLS Models Full

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic	(5) Spline
R	-0.189***	-0.126		0.171	-0.0646
$i^*_{t-1} - i_{t-1}$	-0.000195	-0.000176	-0.000151	-0.000167	-0.000206
$\pi^*_{t-1} - \pi_{t-1}$	-0.0199	-0.0204	-0.0263	-0.0288	-0.0311
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	0.0000108	0.00000974	0.00000897	0.00000926	0.00000901
$R \times t$		-0.000519		-0.00720***	
t		0.00000102		0.000000347	
$R \times 1\{t > 2010\}$			-1.037***		
$R \times 1\{t \leq 2010\}$			0.116		
$R \times t \times 1\{t > 2010\}$			0.00408**		
$R \times t \times 1\{t \leq 2010\}$			-0.00366**		
$t \times 1\{t > 2010\}$			0.000000160		
$t \times 1\{t \leq 2010\}$			-0.00000160		
$R \times t^2$				0.0000256***	
t^2				7.46e-10	
$R \times Spline1$					0.00497
$R \times Spline2$					-0.0608*
$R \times Spline3$					0.198*
$R \times Spline4$					-0.238*
$Spline1$					-0.0000119
$Spline2$					0.0000691
$Spline3$					-0.000169
$Spline4$					0.000100
Constant	-0.0000877	-0.000210	-0.0000259	-0.000141	0.0000883
Observations	250	250	250	250	250
R^2	0.086	0.092	0.156	0.138	0.176
Adjusted R^2	0.071	0.069	0.125	0.110	0.134
AIC	-2616.1	-2613.7	-2626.2	-2622.8	-2626.1
BIC	-2598.5	-2589.1	-2590.9	-2591.2	-2580.3
df_m	4	6	9	8	12
df_r	245	243	240	241	237

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: USD/CHF Threshold Models Full

	(1)	(2)	(3)	(4)
	No Trend	Linear	Quadratic	Piecewise
γ	16.95	31.83	29.99	29.99
Region1: $VXO_t \leq \gamma$				
R	-0.487***	-0.0694		0.0754
$i^*_{t-1} - i_{t-1}$	-0.0000285	-0.000220	-0.000166	-0.000163
$\pi^*_{t-1} - \pi_{t-1}$	0.0309	-0.0140	-0.0230	-0.0234
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	0.00000221	0.0000114	0.00000730	0.00000749
$R \times t$		-0.000603		-0.00342
t		0.00000103		-0.00000244
$R \times 1\{t \leq 2010\}$			0.00991	
$R \times t \times 1\{t \leq 2010\}$			-0.000486	
$R \times 1\{t > 2010\}$			-0.713*	
$R \times t \times 1\{t > 2010\}$			0.00262	
$t \times 1\{t \leq 2010\}$			-0.00000316	
$t \times 1\{t > 2010\}$			-0.000000298	
$R \times t^2$				0.0000108
$t2$				1.10e-08
Constant	0.000355	-0.000276	-0.0000487	-0.0000824
Region2: $VXO_t > \gamma$				
R	-0.145**	-0.147		0.375*
$i^*_{t-1} - i_{t-1}$	-0.000141	-0.00546**	0.00102	0.000483
$\pi^*_{t-1} - \pi_{t-1}$	-0.0450	0.00216	-0.0235	-0.0532
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	0.00000663	0.000127**	-0.000000421	0.0000116
$R \times t$		-0.00198		-0.0119***
t		0.0000146**		-0.00000333
$R \times 1\{t \leq 2010\}$			0.260	
$R \times t \times 1\{t \leq 2010\}$			-0.00618***	
$R \times 1\{t > 2010\}$			-1.524**	
$R \times t \times 1\{t > 2010\}$			0.00631*	
tp1			-0.00000810	
tpb			0.00000182	
$R \times t^2$				0.0000420***
t^2				2.89e-08
Constant	-0.000221	-0.00134	0.000898	0.000472
Observations	250	250	250	250

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: USD/JPY OLS Models Full

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic	(5) Spline
R	0.0162	-0.134		-0.317**	-0.421**
$i^*_{t-1} - i_{t-1}$	-0.0000837	-0.000107	-0.000156	-0.000105	-0.000194
$\pi^*_{t-1} - \pi_{t-1}$	-0.0117	-0.0146	-0.0128	-0.0130	-0.0191
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	0.00000378	0.00000551	0.00000814	0.00000607	0.00000964
$R \times t$		0.00117*		0.00535**	
t		-0.000000476		-0.00000260	
$R \times 1\{t > 2010\}$			0.169		
$R \times 1\{t \leq 2010\}$			-0.239*		
$R \times t \times 1\{t > 2010\}$			-0.000449		
$R \times t \times 1\{t \leq 2010\}$			0.00256*		
$t \times 1\{t > 2010\}$			-0.00000164		
$t \times 1\{t \leq 2010\}$			-0.00000612		
$R \times t^2$				-0.0000162*	
t^2				8.86e-09	
$R \times Spline1$					0.0105*
$R \times Spline2$					-0.0506
$R \times Spline3$					0.150
$R \times Spline4$					-0.188
$Spline1$					-0.0000162
$Spline2$					0.0000701
$Spline3$					-0.000151
$Spline4$					0.0000483
Constant	-0.0000253	0.0000322	0.000326	0.000131	0.000504
Observations	250	250	250	250	250
R^2	0.008	0.028	0.057	0.050	0.083
Adjusted R^2	-0.009	0.004	0.022	0.018	0.037
AIC	-2632.4	-2633.6	-2635.3	-2635.3	-2636.3
BIC	-2614.8	-2608.9	-2600.0	-2603.6	-2590.5
df_m	4	6	9	8	12
df_r	245	243	240	241	237

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: USD/JPY Threshold Models Full

	(1) No Trend	(2) Linear	(3) Piecewise	(4) Quadratic
γ	29.43	29.43	19.86	29.43
Region1: $VXO_t \leq \gamma$				
R	0.0435	-0.104		-0.291*
$i^*_{t-1} - i_{t-1}$	-0.000126	-0.000149	0.0000461	-0.000153
$\pi^*_{t-1} - \pi_{t-1}$	0.0270	0.0274	0.0282	0.0254
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	0.00000735	0.00000921	0.00000381	0.00000917
$R \times t$		0.00106		0.00559*
t		-0.000000553		0.000000356
$R \times 1\{t \leq 2010\}$			-1.388**	
$R \times t \times 1\{t \leq 2010\}$			0.0193**	
$R \times 1\{t > 2010\}$			0.0788	
$R \times t \times 1\{t > 2010\}$			0.000107	
$t \times 1\{t \leq 2010\}$			0.00000346	
tpb			-0.000000207	
usdmxwot2				-0.0000174
$t \times 1\{t > 2010\}$				-2.14e-09
Constant	0.0000447	0.000130	0.000318	0.0000288
Region2: $VXO_t > \gamma$				
R	-0.100	-0.282*		-0.383*
$i^*_{t-1} - i_{t-1}$	-0.00139**	-0.00141**	-0.0000647	-0.00144**
$\pi^*_{t-1} - \pi_{t-1}$	-0.118**	-0.144***	-0.0613*	-0.143**
$(i^*_{t-1} - i_{t-1}) \times VXO_t$	0.0000383**	0.0000375**	0.00000310	0.0000368**
$R \times t$		0.00160		0.00388
t		0.00000340		0.00000843
$R \times 1\{t \leq 2010\}$			-0.203*	
$R \times t \times 1\{t \leq 2010\}$			0.00180	
$R \times 1\{t > 2010\}$			0.0436	
$R \times t \times 1\{t > 2010\}$			0.0000856	
$t \times 1\{t \leq 2010\}$			-0.00000689	
$t \times 1\{t > 2010\}$			-0.00000248	
$R \times t$				-0.00000874
t^2				-1.63e-08
Constant	-0.000142	-0.000642	0.0000400	-0.000940
Observations	250	250	250	250

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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