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The Hungarian Foreign Exchange Market Reaction to the Recent Central Bank Interest Rate Increases

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Abstract

This study examines the impact of Hungarian National Bank (MNB) base interest rate increases on the Hungarian forint (HUF) exchange rate during 2021 and 2022. An event study methodology is employed, with a carefully chosen portfolio of foreign currencies representing the HUF exchange rate. Abnormal returns are calculated and analysed using various models and statistical tests, including the Student's t-test and the Wilcoxon signed-rank test. The findings suggest that interest rate increases have a statistically significant, but potentially slight, negative effect on the HUF exchange rate. While the constant models and the Market-adjusted model with average return focus are not conclusive, the Market Model with regression estimation reveals a significant difference in abnormal returns before and after interest rate hikes. This implies a measurable impact of MNB's monetary policy on the foreign exchange market. The research contributes to the understanding of the Hungarian foreign exchange market dynamics and the effectiveness of interest rate adjustments. It highlights the importance of considering exchange rate stability when formulating economic strategies and provides valuable insights for international trade, currency investors, and policymakers. The methodological advancements and empirical evidence presented offer valuable resources for both academic research and policymaking in international finance and monetary economics.

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I.Introduction

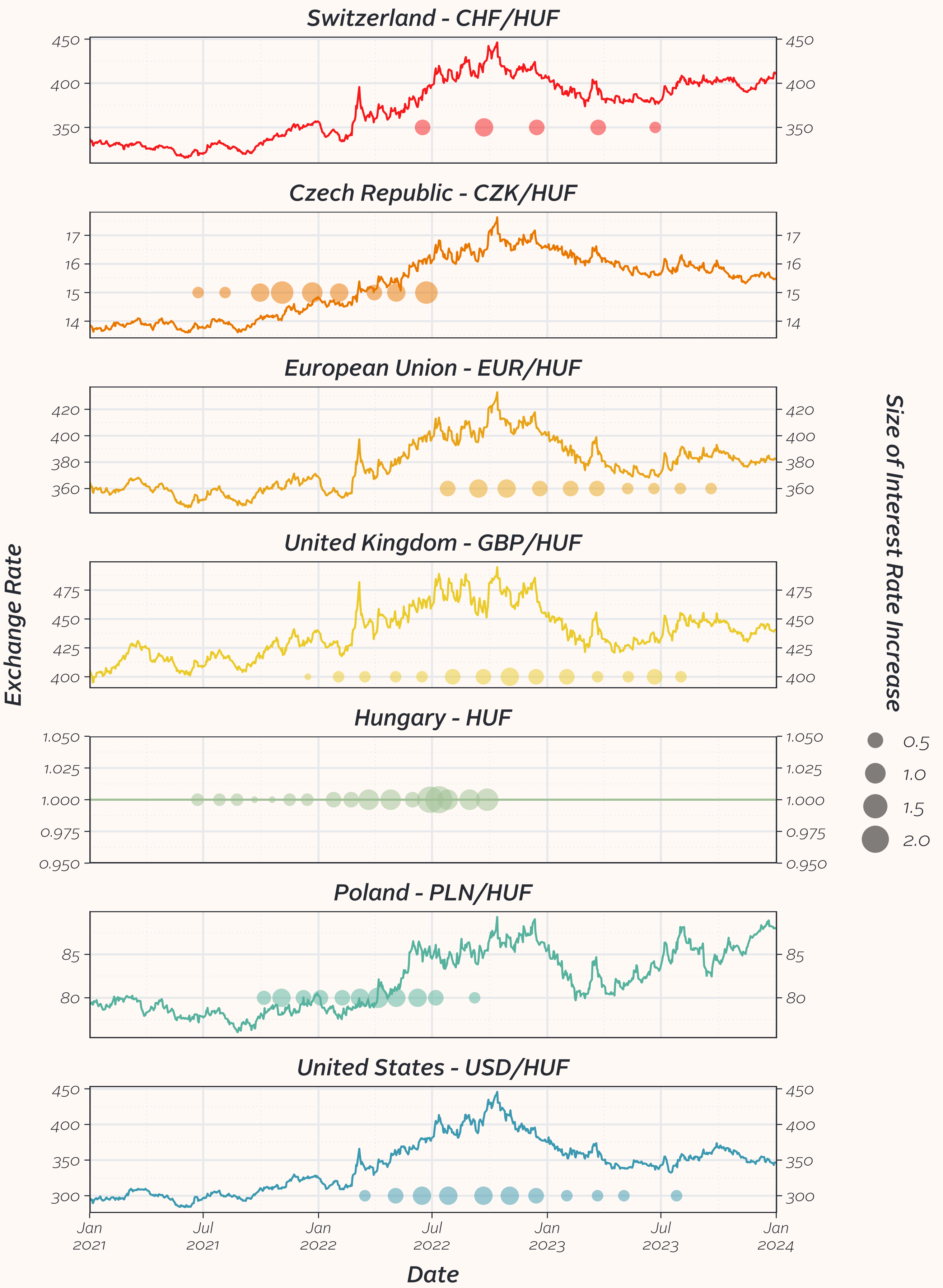
We undoubtedly live in a world full of economic and political crises. After several years of prosperity and consolidation, this decade brought about events that would plunge the economy into recession. Depending on their geographical location, some countries are more concerned than others. Europe, for example, is far more affected, but it is even divided across the continent. Hungary – highlighting as a centre of my research – suffered especially severely. This led to major changes in our political decision-making and overall approach to questions related to national economics. Increasing inflation motivated policymakers to step up against it and take measures. The most obvious decision to make was to increase the interest rates. Despite having a negative impact on productivity, it is thought to be an effective tool against rising prices. However, it affects the value and volatility of foreign exchange rates as well, although it was intentional after a while. Years after the Hungarian forint's continuous but steady depreciation against the stronger currencies, it began to fall drastically, as it can be seen in **Figure I-1**. In such an environment, the effects of different events are exaggerated – easier to catch and measure. Nevertheless, the foreign exchange market is a complex and hardly predictable financial market, but with the appropriate preparation, valuable insights can be gained.

The exchange rates of the forint are continuously fluctuating, sometimes even more drastically. Its rates are influenced by various factors that can be either political announcements and decisions or monetary interventions. In my paper, I examine the effects of the latter, focusing especially on the base interest rate increases implemented in the last couple of years. Increasing interest rates tends to be more efficient when there is demand-side inflation. In recent years, we can rather talk about supply-side inflation due to the disruption of supplies and therefore rising prices in Europe. In this case, increasing interest rates can be an inefficient tool and have a small or only temporary impact on exchange rates. Considering this, my research hypothesis is that *the forint exchange rate exhibits no significant abnormal returns around interest rate increases*. In other words, I expect interest rate increases to have minimal influence on the forint's value relative to the portfolio of currencies. This portfolio contains the most important currencies to the Hungarian national economy, based on its foreign trade. That is, the purpose of this study is to contribute to understanding the impacts of the monetary policy on one of the driving forces of the foreign trade – the foreign exchange rate.

The paper follows an analytical structure, starting with an introduction that provides background information and research objectives. I then delve into the existing literature, covering both international studies and the specific Hungarian context relevant to the impact of interest rate increases on exchange rates. The methodology section details the theoretical framework and the specific methods used during the analysis, including the data sources, sample selection, and the chosen event study methodology. This section explains the abnormal return measures employed. The subsequent section dives into the statistical examination, presenting both descriptive statistics and test statistics. The empirical results section showcases certain prerequisites, the abnormal returns identified and addresses the robustness of my findings. Finally, the paper concludes with key takeaways and potential future research directions. Following the main body of the paper, I have a reference list citing my sources and an appendix containing additional information that might be too detailed for the main text.

"This study was born thanks to the New National Excellence Program (ÚNKP) of the Hungarian Ministry for Culture and Innovation, which has the purpose of supporting the supply of domestic researchers and creative artists, starting, and then maintaining scientific careers, as well as the research work of experienced researchers to also excel at international levels. Besides this, I began writing this paper for various other, personal reasons. Above all, I would like to improve myself as a quantitative researcher. Conducting statistical analysis are complex tasks that require practice and persistence. Examining the financial markets is one of my goals as it can improve my understanding of the area in which I hope to work in the future. Furthermore, I believe in the importance of the connection between science and art, and I attempt to emphasize that by creating spectacular describing figures, and by standardising the layout of the whole study. Furthermore, I visualised the steps of the entire process, making it more understandable – even for those who are not familiar with an event study methodology."

Figure I-1-*Daily Spot Exchange Rates and Interest Rate Changes*



II. Literature review

In this section, I review the existing literature in this field in a logical structure. First, I have an extensive overview of the international papers about event studies and methodologies regarding financial markets. Then I narrow the examination by looking at the event studies focusing on the foreign exchange markets. Finally, I focus on its reaction to the specific events of central bank interest rate changes. As this paper is fundamentally related to Hungary and its currency, the forint, it is crucial to involve domestic literature as well. I conduct a summary of current knowledge, allowing me to identify relevant theories, methods, and gaps in existing research that can be applied to my paper.

An event study is a statistical method for determining the impact of an event. It was created by Ball and Brown (1968). They pioneered the use of event studies in accounting research. Their work involved analysing stock price reactions around the announcement date of a company's earnings report, and they found a significant positive association between unexpected earnings and unexpected stock price increases. MacKinlay (1997) provides one of the most comprehensible descriptions of the general event study methodology. In his work, he uses financial market data to assess the impact of a specific event on a firm's value. He argues that given rationality in the market, the effects of a related event will be reflected immediately in security prices. Thus, a measure of the event's economic impact can be conducted using security prices observed over a relatively short period. Mitchell and Netter (1994) reach similar conclusions, with the addition of uncovering potential securities fraud.

This study focuses on the foreign exchange market. Fortunately, many researchers have previously studied this due to the financial industry being one of the first to make extensive use of event studies. (Miller, 2023) One of the fundamental cornerstones of my work was published by Kwok and Brooks (1990), who issued a significant paper that has helped shape the way researchers approach event studies in the field of foreign exchange. Their insights and methodologies are highly relevant to me, studying the impact of events on exchange rate movements. As I use their methods, I will refer to them frequently throughout this paper. For building a pure foreign exchange asset pricing model, I intend to seek support from Roll and Solnik's (1977) research. Foreign denominated nominally riskless bonds are risky if consumption preferences vary by country. Their model simulates risk-averse, rational consumer-investors who would seek a diversified portfolio of foreign bonds.

The significance of comprehending the efficacy of policy interventions in the management of exchange rate volatility, specifically in emerging market economies such as Hungary, is emphasised by Disyatat and Gabriele (2005). Central banks employ increases in interest rates as a means to manipulate exchange rates and comprehending their efficacy within the framework of wider policy measures, such as foreign exchange interventions, is vital for policymakers. They also reflect to Hungarian studies, such as Barabás et al. (2003). Its conclusion offers valuable insights into the effective management of a speculative attack on the exchange rate of the forint by the Hungarian National Bank. While the study does not specifically examine the impact of increases in interest rates on the foreign exchange market in Hungary, it provides significant insights into the influence of investor behaviour and market responses on the dynamics of the foreign exchange market in response to monetary policy measures. Carvalho et al. (2022) conducted a study closely related to my event study analysis that seeks to assess the influence of significant and minor fluctuations in the Euro Zone and US interest rates on the EUR/USD exchange rate. The results obtained from their analysis demonstrate the presence of abnormal returns that exhibit statistical significance on the days of the event. Furthermore, on the subsequent days, fluctuations in interest rates have a notable influence on the EUR/USD exchange rate. However, it is important to note that the asset's direction following the occurrence of the events remains uncertain.

As for the Hungarian and its foreign exchange markets related studies are hard to find. Such research is usually not published and serves as an internal report about the state of the national economy. A notable Hungarian study is published, however many years ago, as a part of the Hungarian National Bank's Occasional Paper. Rezessy (2005) delves into the relationship between changes in Hungarian central bank policy rates and the immediate responses of various asset classes. The study focuses on three key areas: the exchange rate, government bond yields, and the stock market index. The research confirms a textbook scenario – an increase in the Hungarian policy rate leads to a prompt appreciation of the forint against the euro. This finding aligns with economic theory, where higher interest rates make holding the domestic currency more attractive to investors, leading to a stronger exchange rate. Interestingly, the effect intensifies when considering a two-day window, suggesting that markets might not fully incorporate monetary policy decisions into exchange rates instantaneously. This points to a potential lag or inefficiency in market adjustments.

III. Methodology

I start this section by presenting the data used for my analysis, including its source and the means of selection. The specific currency rates and interest rates are highlighted and defined in detail, as they are the key indicators. Then, an extensive explanation of the utilised event study methodology follows. I define the events and select the proper event windows, present the return measure in the case of interest rate parity, and the calculation of different abnormal returns. The steps are thoroughly visualised for better understanding.

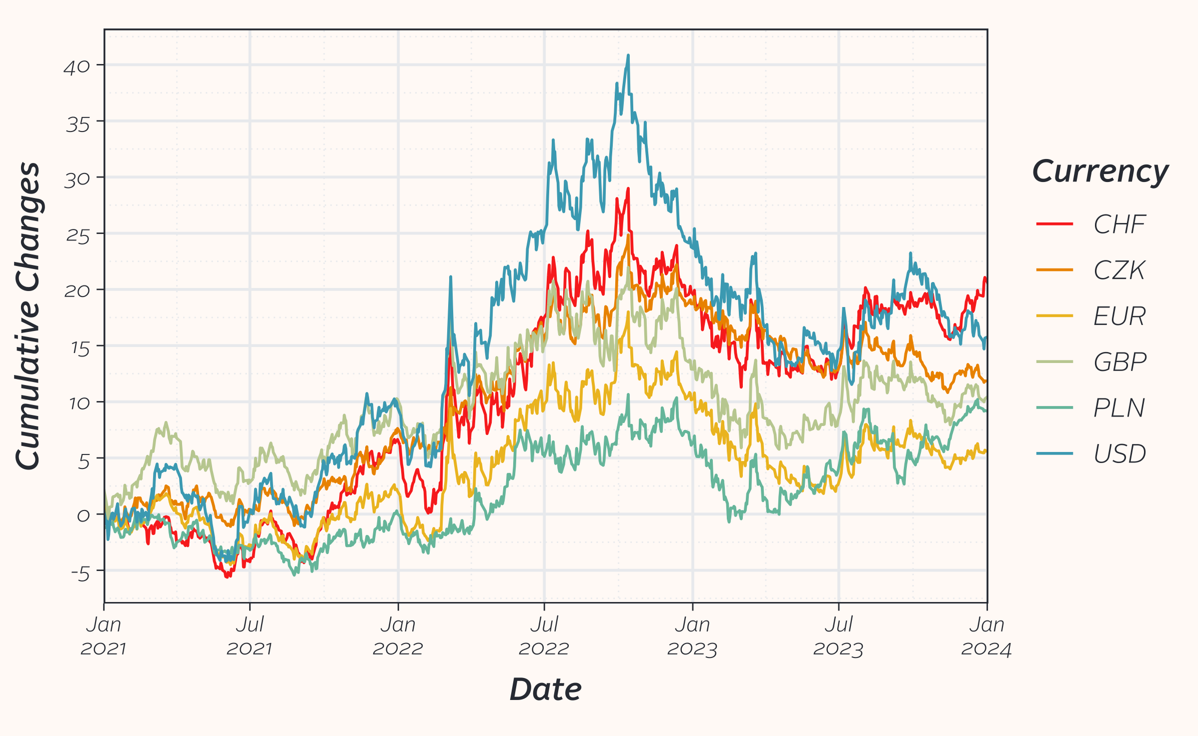
Data

Exchange rates

An exchange rate is the rate at which one currency is exchanged for another, and it represents the value of one country's currency in relation to another. (Frieden et al., 2019) Each country determines its own currency regime, which can be floating, fixed, or hybrid. Governments can impose limits and controls on exchange rates, and countries can have strong or weak currencies. There is no consensus on the optimal national exchange rate policy, rather, national regimes reflect political considerations. (Broz & Frieden, 2001) Floating exchange rates are determined in the foreign exchange market, where currency trading is continuous 24 hours a day, except weekends. This market is unique among the financial markets because of its various characteristics. It has immense trading volume, constituting the largest asset class in the world, resulting in high liquidity and, thus, sometimes high volatility. To this, a large variety of factors contribute. Apart from pure speculation, economic performance, inflation rates, current account deficits, and political (in)stability, interest rate differentials also play an essential role. Countries with higher interest rates tend to attract foreign investments, leading to an increase in demand for their currency and strengthening its value. (Rogoff & Obstfeld, 1996)

For the analysis, I selected six currencies based on their relevance. These are the Euro, US Dollar, Pound Sterling, Swiss Franc, Czech Koruna, and Polish Złoty, all compared to the Hungarian Forint. The explanation for these choices includes membership in the European Union, shared economic and political systems, robust trading partnerships, global currency status, and high levels of exchange. All currencies operate in a floating exchange rate system, making them appropriate for analysis. Furthermore, none of them are subject to any form of direct limitation or control. Generally, USD, CHF, GBP, and EUR are considered stronger currencies, and compared to these, HUF, CZK, and PLN are considered weaker ones. For comparability, I illustrated their cumulative daily exchange rate changes in **Figure III-1**. Based on the values observed on January 1, 2021, the exchange rates appeared to be generally constant for the entirety of 2021. After that, the rates saw a significant surge and exhibited substantial volatility. This may be attributed to political and economic issues, such as the ongoing Russian-Ukrainian War or the escalating inflation crisis.

***Figure III-1**-Cumulative Daily Exchange Rate Changes for examined Currencies*



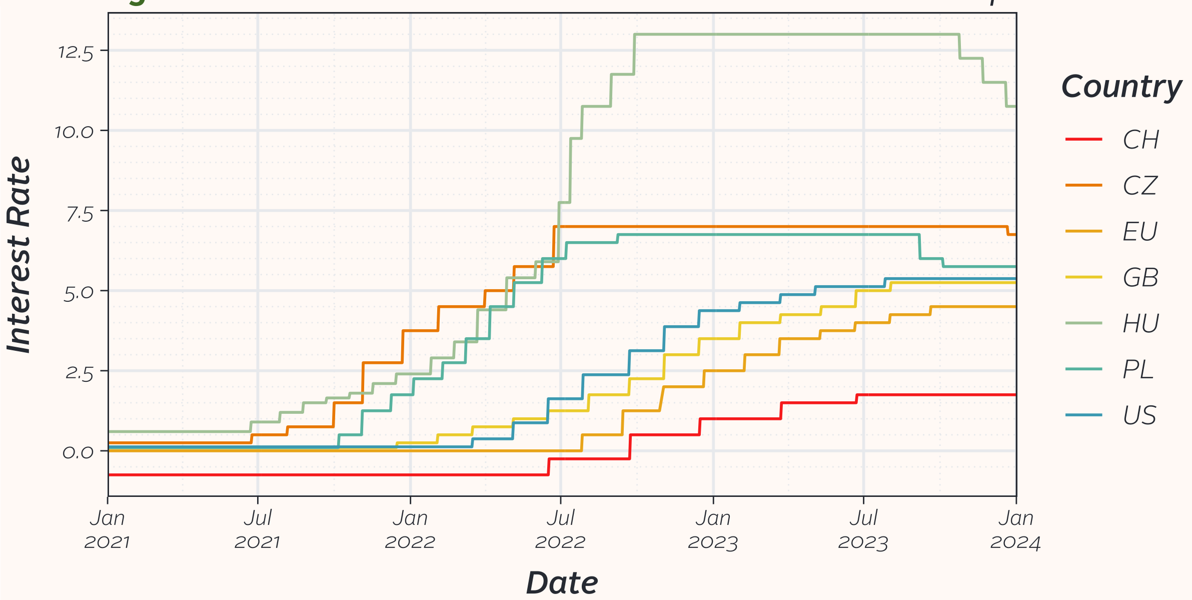
As the sample source, I used official exchange rates publicised by the Hungarian National Bank. They are determined on Mondays, Tuesdays, Wednesdays, Thursdays, and Fridays – unless they are working days. The exchange rates are to be considered valid until the publication of the next exchange rates. The exchange rates are determined at 11:00 a.m. on the indicated days. The daily EUR/HUF official exchange rate is calculated as the unweighted arithmetic mean of the EUR/HUF exchange rate data provided by the eight most active domestic credit institutions, excluding the highest and lowest 1-1 values. The MNB may reject bids and exclude banks whose bids differ significantly from current market conditions from the procedure. The USD/HUF official exchange rate is determined based on the EUR/HUF and EUR/USD cross rates. The exchange rates of other currencies are determined based on the calculated USD/HUF and the cross rates fixed at 11:00 on the international foreign exchange market. (MNB, 2024) The data is collected and processed continuously and can be accessed on their **Exchange rates** page. The database contains the nominal daily central rates.

Interest rates

Interest rate targets play an essential role in monetary policy and are considered when dealing with factors such as investment, inflation, and unemployment. (Mishkin, 2019) Central banks typically lower interest rates to stimulate investment and consumption in a country's economy. Nevertheless, using a low interest rate as a macroeconomic strategy carries inherent risks and has the potential to trigger the emergence of an economic bubble, which involves substantial investments being directed into the real estate and financial markets – such as the foreign exchange market. In developed economies, interest rates are adjusted to maintain inflation within a pre-set range to support economic activities. Alternatively, interest rates may be capped in line with economic growth to protect the momentum of the economy. (Sepehri & Moshiri, 2004)

When selecting the sample of exchange rates, I also considered the interest rates. The examined rates are determined by the Swiss National Bank, Czech National Bank, European Central Bank, Bank of England, Hungarian National Bank, National Bank of Poland, and the Czech National Bank. Not only Hungary, but practically every nation that experienced inflation in this decade raised its interest rates. **Figure III-2** displays the central bank interest rates, specifically highlighting the outstanding levels of Hungary. As for calculating the return in the context of interest rate parity, all the values of all countries are considered, while only the Hungarian rate changes are used as event dates. The interest rates are announced the same time of the day (11:00 a.m.) as of the exchange rates are determined.

***Figure III-2**-The examined Central Bank Interest Rate Developments*



I gathered the sample from the Bank for International Settlements' database. The BIS central bank policy rates data set tracks the changes in policy rates worldwide. This includes extensive time series data for over 40 advanced and emerging market economies, with daily frequency. This dataset is exceptional because the BIS has worked closely with national central banks in selecting the policy rates. The policy rate in different countries may be referred to as the target rate, repo rate, or discounting rate. During periods when monetary policy was not implemented using an interest rate tool, the commonly used reference for the interest rate in the money market or set by the central bank is considered. (BIS, 2017) This and multiple other datasets can be accessed on the BIS' **Central bank policy rates** site.

Event Study

Event definition

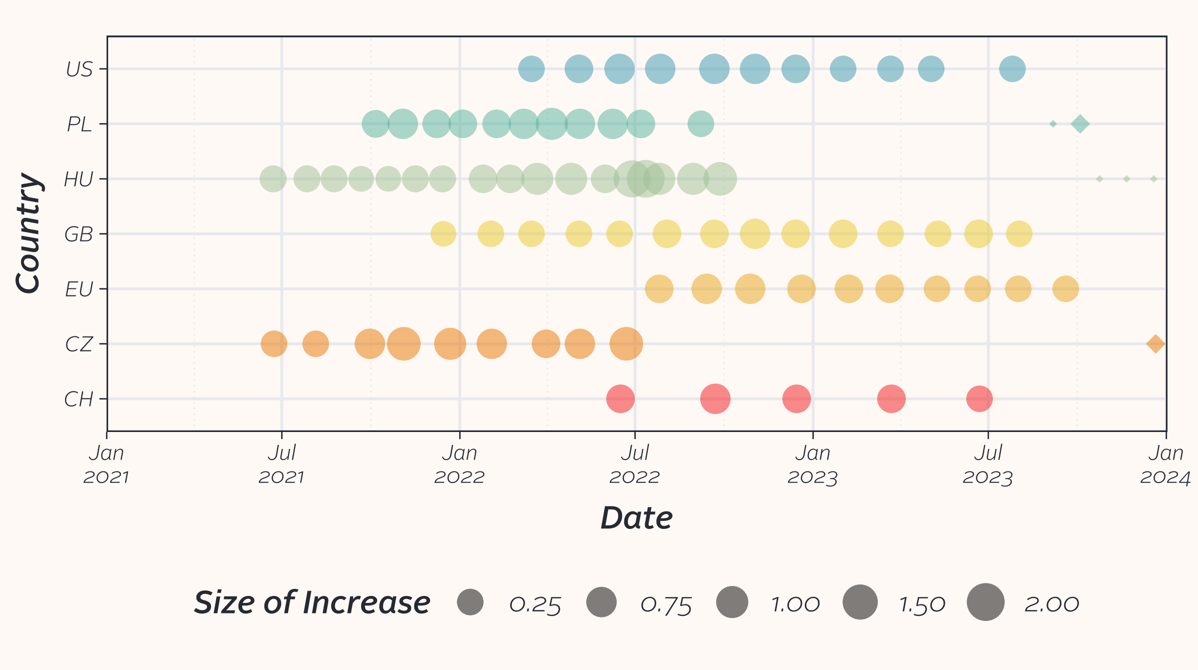
The first step is to define the events in question. It is crucial for them to be precisely defined, as this ensures that the analysis focuses on a specific, isolated event with a clear date and measurable impact. The events of this study are the base interest rate increases decided by the Hungarian National Bank. The announcements are scheduled for Tuesdays at 11:00, and there are 17 such events as listed in **Table III-1**. It is important to acknowledge the exact hour because the definition of the exchange rates is also based on this time of the day. Therefore, its effect can be measured only on the next day at the earliest. Furthermore, as it was a tightening period for most of the countries, several other countries also implemented interest rate increases around the same time as Hungary. These may influence its impact on exchange rates. **Figure III-3** provides visual representations of all these events, including their chronological order and magnitude. Notice the intersection with the Hungarian one.

Table III-1-*Interest Rates and Changes in 2021/2022*

Date	Interest Rate	Change
2021.06.23.	*0.90%*	*0.30pp*
2021.07.28.	*1.20%*	*0.30pp*
2021.08.25.	*1.50%*	*0.30pp*
2021.09.22.	*1.65%*	*0.15pp*
2021.10.20.	*1.80%*	*0.15pp*
2021.11.17.	*2.10%*	*0.30pp*
2021.12.15.	*2.40%*	*0.30pp*
2022.01.26.	*2.90%*	*0.50pp*
2022.02.23.	*3.40%*	*0.50pp*
2022.03.23.	*4.40%*	*1.00pp*
2022.04.27.	*5.40%*	*1.00pp*
2022.06.01.	*5.90%*	*0.50pp*
2022.06.29.	*7.75%*	*1.85pp*
2022.07.13.	*9.75%*	*2.00pp*
2022.07.27.	*10.75%*	*1.00pp*
2022.08.31.	*11.75%*	*1.00pp*
2022.09.28.	*13.00%*	*1.25pp*

Source: *MNB*

Figure III-3*-Interest Rate Changes for the Examined Countries*



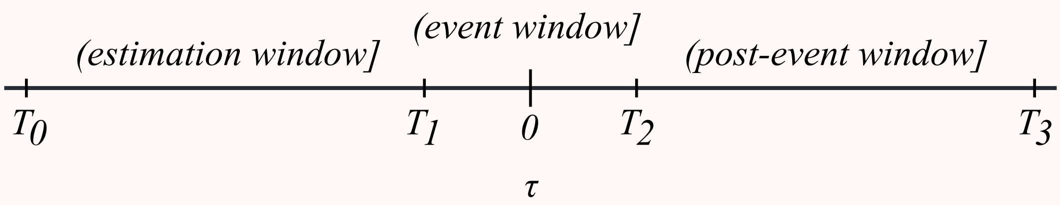
Note: *decreases are also shown for specific countries as diamond shapes, although, these are not subjects of this study*

Window selection

The choice of the length of the event and estimate window is – to a certain extent – arbitrary, which can be determined based on existing literature. The subject I am examining is a short time horizon in event analysis, so a relatively short event window is a good choice for testing my hypothesis. In practice, an interval of a few days is usual, which is symmetrical to the date of the event. (MacKinlay, 1997) In this case, however, there is a certain limitation. The shortest time between two events is 9 trading days. **Table III-1** lists these specific dates: 2022.06.29., 2022.07.13., and 2022.07.27. Due to this fact, the maximal trading days of the event window can be 4 – in case of symmetry. If it were greater, the dates and returns, and thus the abnormal returns, would overlap and cause bias. In addition to the date of the event, at least the following trading day must be included in the event window so that the announcement of the increase will result in a possible abnormal return. Thus, a 4-day window appears to be a good choice. The shorter the event window, the lower the likelihood of bias from other increases affecting exchange rates, but it is still relevant considering **Figure III-5**. We can see that there are certain cases when there is an interest rate increase of the examined country in the event window. This has to be taken into account during the evaluation of the empirical results.

It is important to keep in mind that if the event window is too long compared to the estimation window, it can result in significantly biased test statistics if estimated abnormal returns are correlated. For a 5-day event window and a 100-day estimate window, however, the value of the distorted test statistics is expected to exceed the non-distorted by 1.6 percent each. (Binder, 1998) It is also important to separate the two windows in time because if we also used the return data of the event window for the regression model, we would get the wrong parameter estimation. After all, it would already include the noise resulting from the announcement. (Kothari & Warner, 2004) Due to these factors, I selected a 100-day-long estimation window.

Figure III-4*-Timeline for an Event Study*



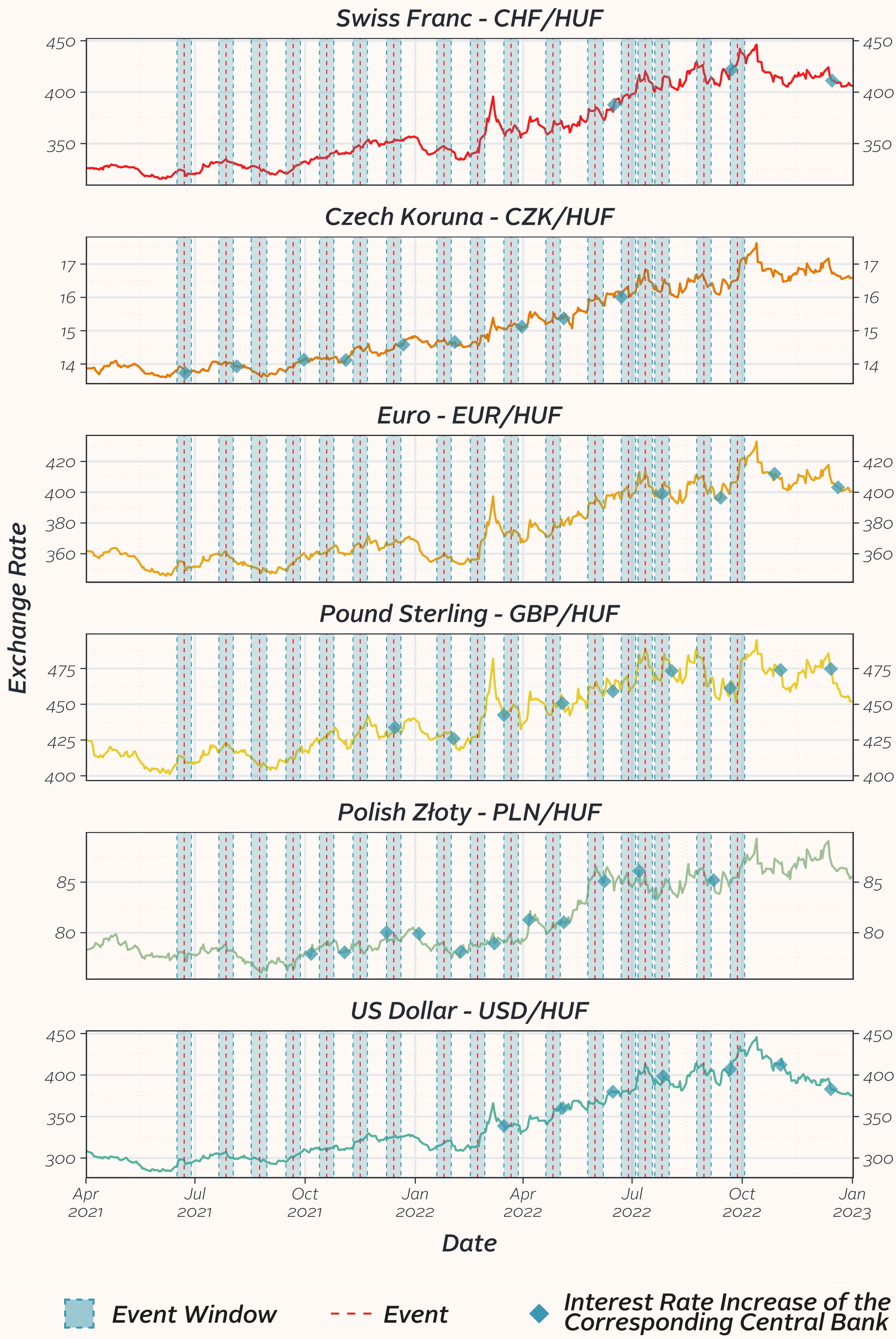
Source: *(MacKinlay, 1997, p. 20)*

Considering the aforementioned, the timeline of the event study can be formally described, as shown in **Figure III-4**. Returns will be indexed in event time using τ. The analysis consists of the following stages: $\tau = 0$ is the date of the event, $T_0 + 1 \leq \tau \leq T_1$ is the estimate window, and $T_1 + 1 \leq \tau \leq T_2$ is the event window. $L_1 = T_1 - T_0$ is the estimate window, $L_2 = T_2 - T_1$ is the length of the event window. The post-event window can be defined by $T_2 + 1 \leq \tau \leq T_3$ and length $L_3 = T_3 - T_2$, but this is not necessary for the purposes of the research questions.

The parameters for this study: $T_0 = -104,\ \ T_{1,2} = \pm 4,\ \ L_1 = 100,\ \ L_2 = 8$

Figure III-5 explicitly illustrates the event windows on the examined exchange rates, enhancing comprehension. It is apparent that, in certain cases, there is another increase in the interest rate during the specified period.

Figure III-5-*The Examined Exchange Rates with the Timeline of an Events Study*



Return measures

In order to measure abnormal returns, it is necessary to establish an exact definition of returns in the foreign exchange market first. The selected measure to calculate returns can be interpreted as the nominal return on investment in either the money market or the foreign exchange market, assuming that interest rate parity prevails. Interest rate parity refers to a state of equilibrium in which investors have equal access to the interest rates offered on bank deposits in two different countries without allowing arbitrage. (Feenstra & Taylor, 2008) When the foreign exchange market is in a state of equilibrium, the condition of interest rate parity implies that the expected return on domestic assets will be equivalent to the expected return on foreign currency assets, adjusted for exchange rates. Investors are unable to earn arbitrage profits by pursuing borrowing activities in a country with a lower interest rate, converting the money into foreign currency, and subsequently investing in a foreign country with a higher interest rate. This is primarily due to the potential gains or losses incurred when converting the funds back into their domestic currency upon maturity. (Mishkin, 2019)

Let $R_{j,t}$ designate the estimate of the arithmetic daily return in the foreign exchange market of foreign currency j for time t where

$$\tilde{R}_{j,t} = \frac{E(\tilde{S}_{j,t} - S_{j,t-1})}{S_{j,t-1}} - (r_{n,t-1} - r_{j,t-1}), \qquad \text{III-1}$$

where $E(.)$ is proxied by using the observed value of $S_{j,t} - S_{j,t-1}$, and $S_{j,t}$ is the spot exchange rate of currency j with respect to the numeraire currency n at time t (in terms of number of units of the numeraire currency n per unit of the foreign currency j). The numeraire is the currency used as a reference point for pricing other currencies in the foreign exchange market. The numeraire currency is the Hungarian forint, given its central focus in this study. The interest rates at time $t-1$ are $r_{n,t-1}$ and $r_{j,t-1}$ for currencies n and j, respectively. The inclusion of interest rates in the equation is necessary to account for the difference in interest rates between the two countries.

The parameters for this study: $n = [HUF]$, $j = [CHF, CZK, EUR, GBP, PLN, USD]$

Using the interest rates of n and the interest rates of j, illustrated in **Figure III-6**, with the spot exchange rate changes of j, the calculated returns can be seen in **Figure III-7**. It is noticeable that the wider the gap between interest rates, the lower the returns in general.

Figure III-6-Interest Rates of the Certain Central Banks

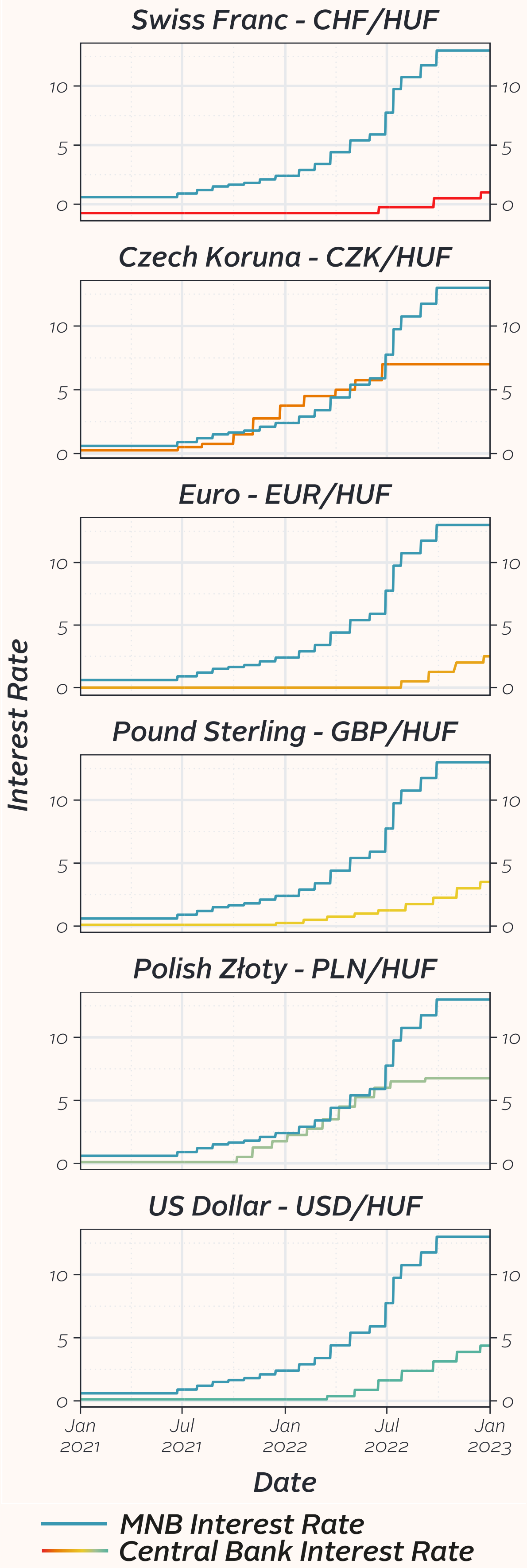
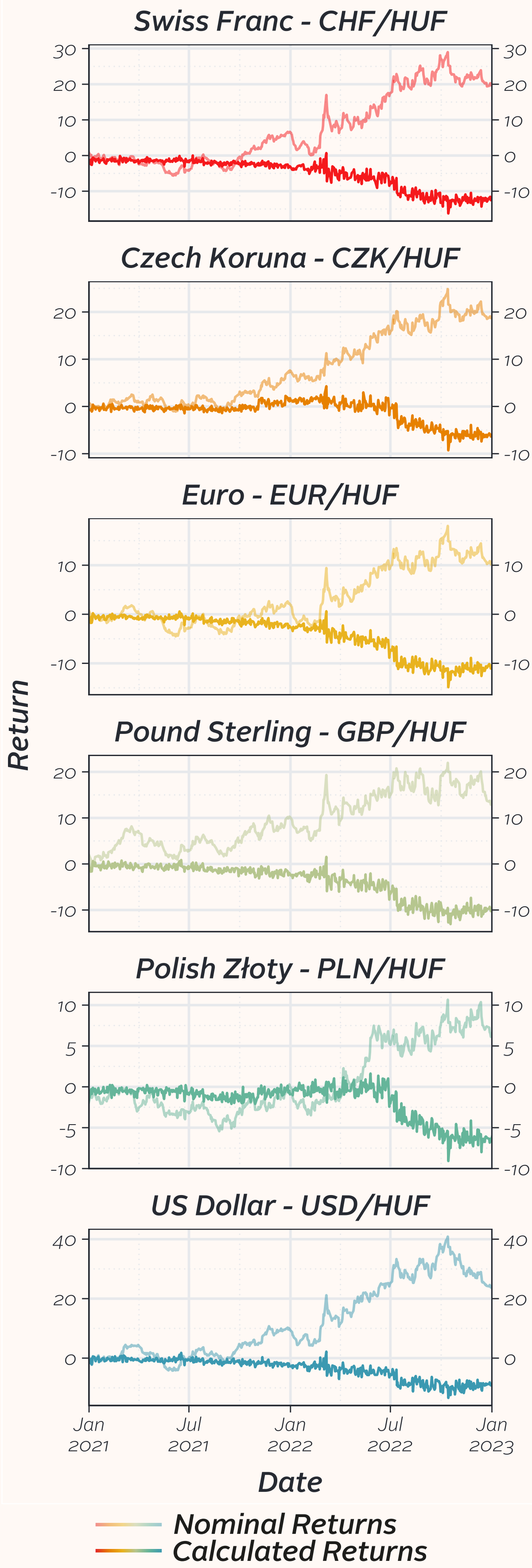


Figure III-7-Calculated Returns for Every Courrency



Abnormal returns

In finance, an abnormal return is the difference between the actual return of a security (in this case, a foreign currency) and the expected return. (Mcwilliams, 1997) Therefore, $A_{j,t}$ is defined as the abnormal return from currency j at day t, as shown in equation **III-2**. The abnormal return for each foreign currency is estimated using four models for the days of interest rate increases, as well as for each day within the event periods (–4, +4) during the examination. In the foreign exchange market, the random walk model is frequently mentioned, whereas the mean-adjusted, market-adjusted, and market models are the ones examined in Brown and Warner (1980; 1985).

$$A_{j,t} = \tilde{R}_{j,t} - E(\tilde{R}_{j,t}) \quad \textit{III-2}$$

1. *Random walk model*

The International Fisher Effect is a theoretical hypothesis within the field of international finance, suggesting that differences in nominal interest rates are reflective of expected changes in the spot exchange rate across countries. (Law & Smullen, 2008) The hypothesis posits that there is an expected inverse relationship between the spot exchange rate and the interest rate differential. Specifically, it suggests that the currency of the country with a higher nominal interest rate will depreciate against the currency of the country with a lower nominal interest rate. This depreciation is assumed because higher nominal interest rates are indicative of an expectation of inflation. In other words, the currency return is a martingale with expected value zero,

$$A_{j,t} = 0 \quad \textit{III-3}$$

The present study examines the performance of the model in relation to other models, as it is frequently referenced in the foreign exchange market.

2. *Mean-adjusted returns*

Mean adjusted returns, also referred to as comparison period mean adjusted returns, is a method used in finance – particularly in event studies – to assess the performance of an investment relative to its own historical performance.

$$A_{j,t} = \tilde{R}_{j,t} - \bar{R}_j \quad \textit{III-4}$$

$$\bar{R}_j = \frac{1}{100} \sum_{t=T_0}^{T_1} \tilde{R}_{j,t} \quad \textit{III-5}$$

$$T_0 = [2021.01.04] \quad T_1 = [2021.05.28]$$

During the period of estimation, the variable $\overline{R}_j$ denotes the mean return of currency j, which is associated to trading days selected from a time-series of returns spanning 100 days. In order to account for missing observations, equation (**III-5**) and subsequent equations are adjusted by excluding days where $R_{j,t}$ is not available. The estimation period necessitates a minimum of thirty observations.

3. *Market-adjusted returns*

Market-adjusted returns serve as a measure for evaluating the investment's performance in relation to the broader market's performance. The process involves isolating the specific performance of the investment by eliminating the impact of wider market fluctuations.

$$A_{j,t} = \tilde{R}_{j,t} - \tilde{R}_{m,t} \qquad \textbf{III-6}$$

where $\tilde{R}_{m,t}$ is the return on the equally weighted portfolio of six foreign currencies. The numeraire and the foreign currency j are excluded from the market return.

4. *Market model*

The Roll and Solnik (1977) foreign exchange asset pricing model is adopted as the market model in this study. This market index captures the common variance among currencies well since it is mainly composed of foreign exchange assets. Thus, the market model is derived from an assumed underlying pure foreign exchange asset pricing mode.

$$A_{j,t} = \tilde{R}_{j,t} - (\hat{\alpha}_j + \hat{\beta}_j \tilde{R}_{m,t}) \qquad \textbf{III-7}$$

where $\hat{\alpha}$ and $\hat{\beta}$ are parameter estimates derived from an OLS regression over estimation period.

$$\tilde{R}_{j,t} = \hat{\alpha}_j + \hat{\beta}_j \sum_{i=1}^{6} w_i \tilde{R}_{i,t} + \xi_{j,t} \qquad \textbf{III-8}$$

where $w_i = 1/6$, resulting in an equal weighting of the six foreign currencies, $i \neq j$.

The graphical representation of the 100-day-long estimation windows, the 17 events and their corresponding event windows, as well as the actual and 4 expected returns for each currency can be found in **Figure VIII-1** in the appendix. The first two models are constant, while the second two are fluctuating, therefore I would except the latter to perform more accurately during the evaluation. Nevertheless, within the estimation window, the actual currencies exhibit a relatively high degree of closeness to the expected ones in every case.

Test Statistics

The statistical significance of the event period excess returns is assessed for each sample, considering the abnormal returns obtained from each method. The null hypothesis under consideration posits that the mean (simple arithmetic average) abnormal return for a specific day is equivalent to zero, thereby addressing the average impact of an event on returns. The test statistic can be defined as the ratio that results from dividing the mean abnormal return of a specific day by its estimated standard deviation. The standard deviation is calculated based on the time series data of abnormal returns within the estimation window. The test statistic for any event day τ is

$$T_\tau = \bar{A}_\tau / \hat{V}_\tau, \qquad \text{III-9}$$

where

$$\bar{A}_\tau = \frac{1}{17}\sum_{i=1}^{17}\frac{1}{6}\sum_{j=1}^{6} A_{i,j,\tau}$$

$$\hat{V}_\tau = \left(\frac{1}{100}\sum_{t=T_0}^{t=T_1}\left(\bar{A}_t - \bar{\bar{A}}\right)^2\right)^{1/2}$$

$$\bar{\bar{A}} = \frac{1}{100}\sum_{t=T_0}^{t=T_1}\bar{A}_t$$

$\bar{A}_\tau$ is the mean daily abnormal return for day τ over the 100 observations in each sample while $\hat{V}_\tau$ is the estimated daily standard deviation. $\bar{\bar{A}}$ is the average abnormal return over the estimation period for the entire sample. The test-statistic follows the notation used by Brown and Warner (1985) and extensively utilised in various event studies related to securities returns. If the $\bar{A}_\tau$ are independent, identically distributed, and normal, the test statistic is distributed Student-*t* under the null hypothesis. In reality, the distributions of the abnormal currency returns may not be normal. In that case, other non-parametric statistical tests, such as the Wilcoxon signed-rank test, need to be used. (Wilcoxon, 1945) Whether the abnormal returns are normally distributed will be discussed later. The Wilcoxon test is a non-parametric rank test that can be used to assess the location of a population based on a sample of data or to compare the locations of two populations using two matched samples. The one-sample version serves a purpose similar to that of the one-sample Student's t-test. It can be a good alternative to the t-test when population means are not of interest (for example, when one wishes to test whether a population's median is nonzero), or when the population is assumed not to follow normal distribution. (Conover, 1999) The one-sample test can be performed for a sample of n paired observations $X_1, X_2, \ldots, X_n$. Then, the differences are calculated between each pair of data,

$$D_i = X_i - \mu_0,$$

where μ_0 is the hypothetical median value under the null hypothesis. The absolute values of the differences $|D_i|$ is then calculated and ranked from smallest to largest, assigning ranks $R_1, R_2, \ldots, R_n$. Signed ranks are assigned to each difference, based on the sign of the differences. If $D_i > 0$, rank of R_i^+ is assigned, and if $D_i < 0$, rank of R_i^- is assigned. The test statistic T_τ for any event day τ is calculated as the sum of the ranks of the positive differences or the sum of the ranks of the negative differences, whichever is smaller. If the sum of the ranks of the positive differences is smaller, then

$$T_\tau = \sum_{i=1}^{k} R_{\tau,i}^+, \qquad \text{III-10}$$

where k is the number of positive differences. The critical value from the Wilcoxon signed-rank distribution **table** is determined for the chosen significance level (α) and sample size (n). Finally, the calculated test statistic T_τ is compared with the critical value. If the calculated test statistic exceeds the critical value, then the null hypothesis is rejected.

IV. Statistical Examination

This section of the study serves as a prerequisite for testing the abnormal returns defined by the four models. It is a base for proving the relevancy of my research question and is a preliminary step, crucial for establishing the validity and significance of my research approach. I first test the data in the estimation window to determine its suitability for estimating expected returns. Then, the descriptive and statistical analysis of the data in the event windows follows.

Estimation Data Testing

I selected the estimation window based on two key factors. First, it should take at least 30 days to be considered a large sample and be applicable for various estimations. Second, it should be a period when no interest rate changes occurred for any of the examined countries, and that would potentially influence the exchange rates. Third, it should be as close to the event windows as possible. As there are several consecutive events to be investigated, this window should be before the first one. That is the reason why the estimation period is in the first five months of 2021. Furthermore, this is a low-interest rate environment, which can be considered the norm in an expanding monetary policy. That is why I expect it to be an appropriate sample to be the basis of my estimations. However, statistical tests should provide the necessary support. I am interested in whether the data in this period has no trend and has constant variance over time, i.e., stationery. Looking at the returns in the estimation windows in **Figure VIII-1** in the **Appendix**, it seems to be stationary, but for testing this hypothesis, I use the augmented Dickey-Fuller (ADF) test. (Fuller, 1996) The test results are in **Table IV-1**.

H_0: The time series data is non-stationary. It has a certain time-dependent structure and does not exhibit constant variance over time causing a biased estimation.
H_1: The time series is stationary and appropriate for estimating.

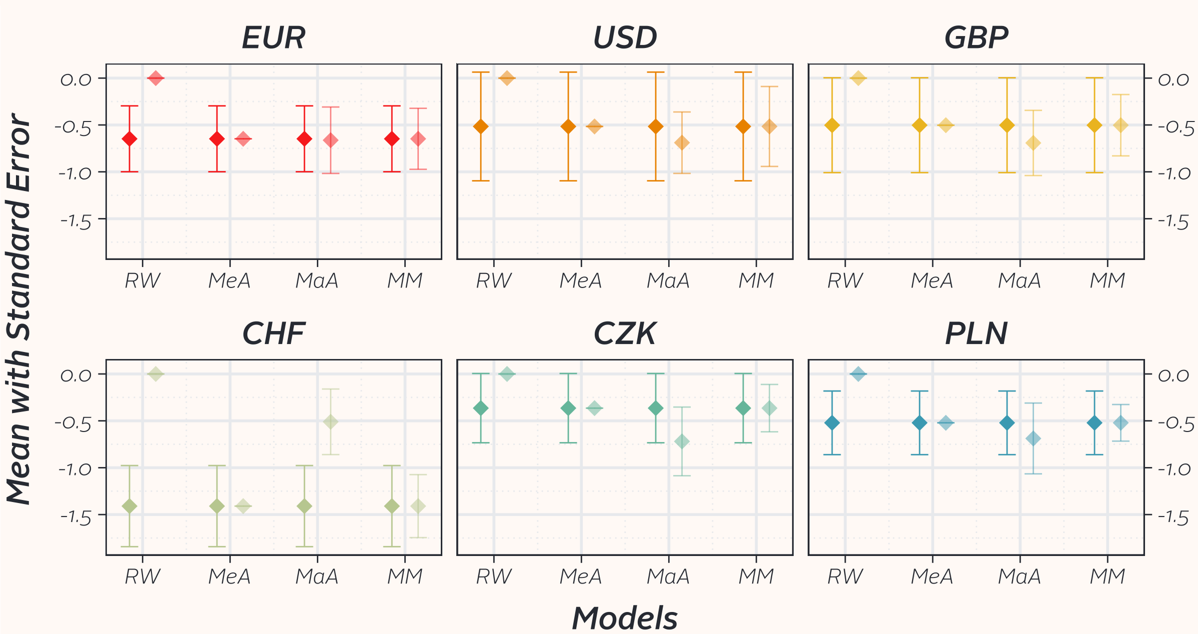
Table IV-1*-Results for the ADF-test of Estimation Data*

Currency	**Return**	**Model**			
		RW	**MeA**	**MaA**	**MM**
EUR	*<0.01*	–	–	*<0.01*	*<0.01*
USD	*<0.01*	–	–	*<0.01*	*<0.01*
GBP	*<0.01*	–	–	*<0.01*	*<0.01*
CHF	*<0.01*	–	–	*<0.01*	*<0.01*
CZK	*<0.01*	–	–	*<0.01*	*<0.01*
PLN	*<0.01*	–	–	*<0.01*	*<0.01*

Table III-1 consists of the p-values of the corresponding ADF-tests. Based on the results in the Return column, we can reject the null hypothesis at all significance levels for each currency. This suggests that the time series exhibits stationarity and can be used for estimation. I also extended the test to the estimated models as well. The *Random Walk* and the *Mean-adjusted Returns* are constant numbers; therefore, the ADF-test is not defined. The *Market-adjusted Returns* and the *Market Models* are, on the other hand, defined and can be interpreted as stationery time series according to the tests.

The actual and expected return of the corresponding currencies in the estimation windows can also be compared for further insights. In **Figure IV-1**, the mean of the returns and estimates with their confidence intervals are illustrated. All exchange rates have similar means (~ -0.5), except for the Swiss Franc (~ -1.5). This affects the *Market-adjusted Returns* by slightly decreasing its value. By definition, the *MaA* is the average of all other exchange rates. In the case of Swiss Franc, it is evident that the *MaA* exhibits a higher value. Regarding the *Random Walk* model, it consistently remains at a value of 0, and in the majority of cases, there is a notable difference between this value and the average returns. The Czech Koruna is the nearest one. The *Mean-adjusted Returns* are equivalent to the sample return by definition, only being a constant, without a confidence interval. Finally, the *Market Model* exhibits an identical mean (due to the OLS estimation), albeit with a varying confidence interval.

***Figure IV-1**-Means of Actual and Expected Returns in the Estimation Window*



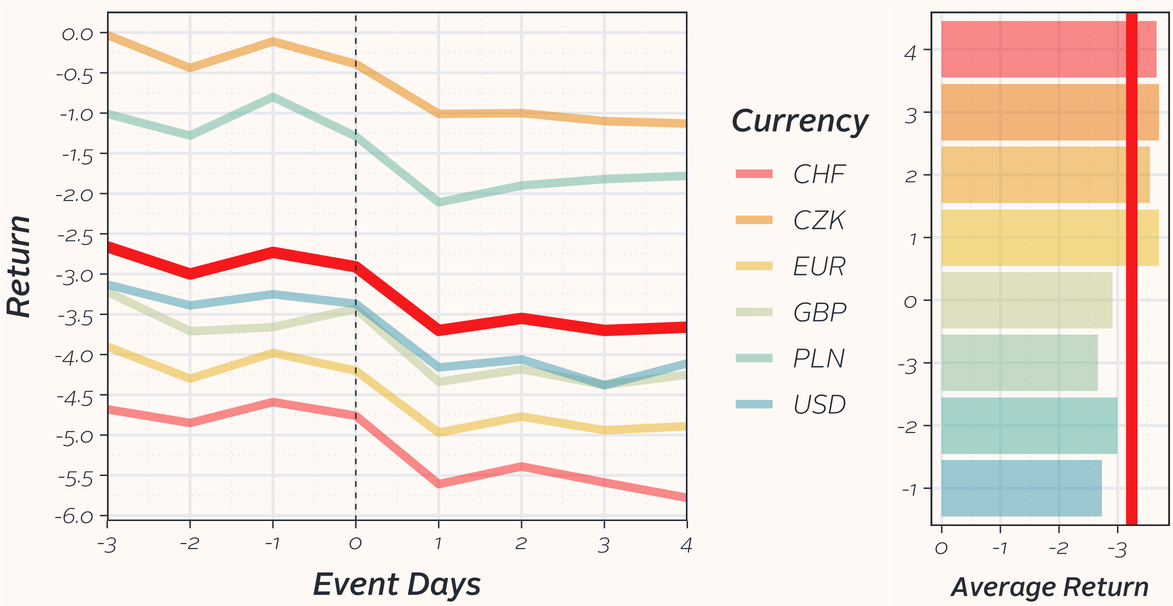
***Note:** for each estimation model, the means of the actual returns (left) are presented next to the corresponding expected returns (right)*

Event Data Testing

In this study, the events were defined as the base interest rate increases implemented by the Hungarian National Bank. There are a total of 17 announcements, indicating an equal number of events associated with event windows. The event windows were defined as a period of 4 days preceding and following the specific event, resulting in a window duration of 9 days. However, my examination focuses on the daily returns of the exchange rates instead of the daily spot exchange rates. It allows for deeper understanding and more insight for an analysis. It also has certain "side-effects". Due to its exact definition, the calculation of its value requires a duration of two days (see equation **III-1**). Consequently, the event window is reduced by one day, resulting in a duration of just 8 days. Furthermore, it is worth noting that the impact of events taking place on day 0 can be observed as early as day 1. Given these considerations, it is essential to examine possible changes in the event windows, without employing any additional methodology. The data within the event windows is categorised into three dimensions: it is specified for the 17 event dates (as indicated in table **Table III-1**), spans a duration of 8 days (ranging from -3 to 4), and is examined for 6 currencies. Converting it to a two-dimensional format gives three different tables for comparison.

In **Table VIII-1** in the Appendix, the event data is aggregated by the event dates. It implies that it has the event days as columns, currencies as rows, and the average returns for all event dates as values. **Figure IV-2** is illustrated based on this table. The left side of the figure shows that the average return drops after day 0, not reaching the same level as before.

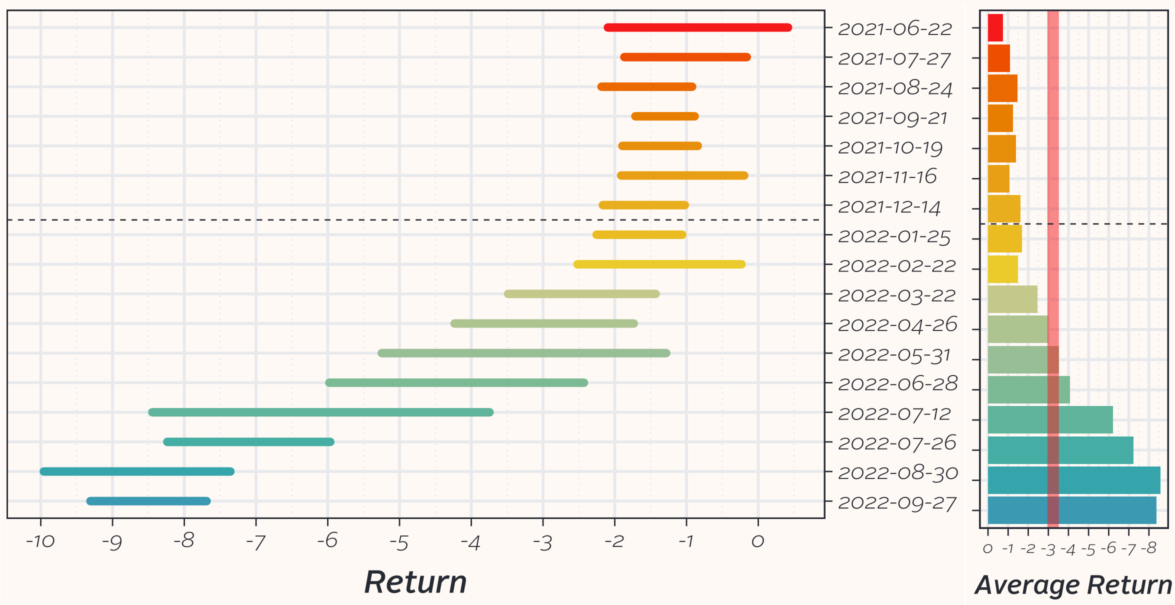
Figure IV-2*-Average Returns on the Event Days*



It is true for all currencies and for their average as well (denoted by the thicker red line). On the right side of the figure, the average returns can be seen for the entire and every event window. From day -4 to day 0, the values show a decrease below the overall average, while from day 1, they demonstrate an increase above it. The overall average – represented by the thicker vertical red line – summarises all changes in the event windows for all currencies. serving as a critical metric. Its value of -3.24 signifies that the average return of the equally weighted portfolio of the six currencies during the event windows is both negative and relatively substantial. All this information could be an argument for conducting further analysis and identifying possible abnormalities in the returns.

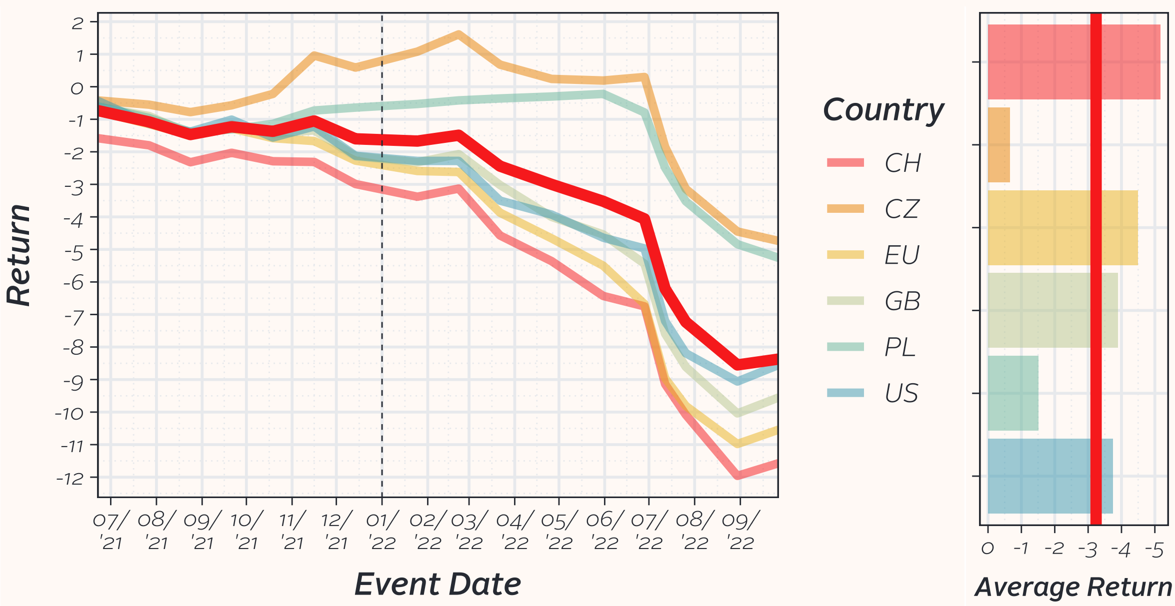
In **Table VIII-2** in the Appendix, the event data is aggregated by the currencies. It implies that it has the event days as columns, the event dates as rows, and the average returns for all currencies as values. **Figure IV-3** is depicted in accordance with this table. The left side shows the range of returns, while the right side illustrates the average return for each event date. Likewise, the vertical red line denotes the overall average return. We can conclude that the ranges of returns in the event windows are varying, but there are greater fluctuations in 2022. The average returns are relatively stable until February 2022; after that, however, they start to escalate drastically. Regarding the focus of this study, examining the event windows, it is also a possible argument that there is a greater chance of abnormal returns occurring in cases of a larger range associated with a greater (negative) average return. Nevertheless, it is evident, that there is a negative trend of average returns over time in the 2021/2022 period.

***Figure IV-3**-Average Returns in the Event Windows*



Finally, in **Table VIII-3** in the Appendix, the event data is aggregated by the event days. It implies that it has the currencies as columns, the event dates as rows, and the average returns for all event days as values. In accordance with this table, **Figure IV-4** is illustrated. It shows the average return in the event windows during the event dates, grouped by the six currencies with their average in the right. It is apparent that the Polish Złoty and the Czech Koruna, which are both weaker currencies, have shown larger and even positive returns throughout this period. However, their average remains negative. Negative returns do not imply abnormal returns as it could be due to a variety of factors, including market condition.

Figure IV-4*-Average Returns of the Examined Currencies*



The presented illustrations and descriptive statistics have convinced me that there is a trend of negative values in the event windows, indicating that the average returns may exhibit abnormal fluctuations. These changes should not be established only by looking at the charts but with statistical tests as well. Once again, I use the augmented Dickey-Fuller (ADF) test for this. After examining the returns within the event windows in **Figure IV-2**, it appears that they exhibit non-stationarity, but testing is required to confirm this hypothesis. The test results (p-values) are in **Table VIII-4** in Appendix, for each currency and every event dates. However, the event windows contain only 8 days of data which is considered a small sample. Conducting an ADF test with small samples demands careful evaluation due to potential concerns regarding low statistical power. Therefore, in addition to the ADF test, it is advisable to use alternative unit root tests that are specifically designed for small samples, such as the Phillips-Perron (PP) test. (Phillips & Perron, 1988) The PP test shares similarities to the ADF test, but with a slightly higher level of complexity. It examines whether the data points are exhibiting predictable patterns of change. A time series is considered stationary if the data points exhibit predictable changes. A time series is considered non-stationary if the data points exhibit unpredictable changes. Its results (p-values) are summarised in **Table IV-2**.

H_0: The time series data is non-stationary. It has a certain time-dependent structure and does not exhibit constant variance over time; therefore, further examinations are required.
H_1: The time series is stationary, thus considering further examination unnecessary.

Table IV-2-*Results for the PP-test of Event Data*

Event Date	Currency						For All Currencies
	EUR	USD	GBP	CHF	CZK	PLN	
2021.06.22	*0.66*	*0.53*	*0.42*	*0.65*	*0.56*	*0.65*	*<0.01*
2021.07.27	*0.74*	*0.75*	*0.73*	*0.69*	*0.63*	*0.68*	*<0.01*
2021.08.24	*0.56*	*0.53*	*0.35*	*0.46*	*0.32*	*0.65*	*<0.01*
2021.09.21	*0.73*	*0.62*	*0.72*	*0.56*	*0.66*	*0.55*	*<0.01*
2021.10.19	*0.26*	*0.26*	*0.18*	*0.20*	*0.34*	*0.41*	*<0.01*
2021.11.16	*0.57*	*0.48*	*0.58*	*0.62*	*0.50*	*0.38*	*<0.01*
2021.12.14	*0.53*	*0.45*	*0.47*	*0.51*	*0.57*	*0.45*	*<0.01*
2022.01.25	*0.75*	*0.59*	*0.70*	*0.83*	*0.75*	*0.46*	*<0.01*
2022.02.22	*0.48*	*0.47*	*0.43*	*0.39*	*0.69*	*0.51*	*<0.01*
2022.03.22	*0.74*	*0.79*	*0.72*	*0.85*	*0.80*	*0.71*	*<0.01*
2022.04.26	*0.80*	*0.89*	*0.77*	*0.89*	*0.80*	*0.80*	*<0.01*
2022.05.31	*0.33*	*0.56*	*0.47*	*0.41*	*0.31*	*0.34*	*<0.01*
2022.06.28	*0.68*	*0.50*	*0.62*	*0.57*	*0.65*	*0.75*	*<0.01*
2022.07.12	*0.60*	*0.57*	*0.60*	*0.67*	*0.65*	*0.60*	*<0.01*
2022.07.26	*0.60*	*0.62*	*0.73*	*0.68*	*0.68*	*0.43*	*<0.01*
2022.08.30	*0.80*	*0.69*	*0.82*	*0.75*	*0.75*	*0.76*	*<0.01*
2022.09.27	*0.52*	*0.56*	*0.52*	*0.47*	*0.46*	*0.25*	*<0.01*
For All Dates	*0.03*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*

Based on the results of the PP-tests, the null hypothesis cannot be rejected at all usual significance levels for all individual currencies and event dates. This suggests that there is a well-grounded need for examining the returns in the event windows, seeking for possible abnormal returns. However, in the aggregated (last) column and row, we can reject the null hypothesis, except for the euro. This supports the statement that the returns have a consistent negative trend over time and across all currencies – with the exception of the Euro.

Upon conducting a statistical analysis on the return data within the specified event windows, it becomes apparent that there exists a fundamental basis and a need for investigating abnormal returns. A comprehensive examination should be done in all individual event windows.

V. Empirical Results

This section serves as a presentation of the empirical findings obtained by examining processed data using the defined methodology. First, I provide an overview of the descriptive statistics pertaining to abnormal returns across different groupings, alongside various types of prerequisite tests and illustrative distribution figures. Then, with two statistical tests with different approach but similar purpose, I attempt to test my main hypothesis. The Student's *t*-test and the Wilcoxon T-test is used based on the attributes of the sample properties. Finally, robustness tests are conducted to validate the resilience and reliability of my models.

Properties

The following tables summarise the abnormal returns by different groupings but has the same structure. The present study focuses on conducting a univariate analysis to describe the distribution of a single variable, namely abnormal returns. This includes the examination of the central tendency (mean and median), dispersion (range), and measures of spread (standard deviation). Skewness and kurtosis are used to describe the shape of the distribution. In order to utilise the Student-*t* test, it is necessary for the sample to have a normal distribution. There are multiple statistical tests that can be employed to determine the normality of a given sample. I selected three from the most frequently used options. The first one is the Jarque-Bera (1980) test which is based on the skewness and kurtosis of my sample and tests whether it has the skewness and kurtosis matching a normal distribution. The second one is the Shapiro-Wilk (1965) test that assesses whether my sample comes from a normally distributed population. And the third one is the Kolmogorov-Smirnov test which is a non-parametric test that compares the cumulative distribution function of my sample with that of a normal distribution. (Feller, 1948) The assumed hypotheses are:

Jarque-Bera test

H_0: Joint hypothesis, the skewness and excess kurtosis are both zero. The expected skewness and expected excess kurtosis of samples from a normal distribution are both equivalent to 0.

H_1: At least one out of the skewness or excess kurtosis is not zero, suggesting that the data deviates from a perfectly symmetrical and normally distributed pattern.

Shapiro-Wilk test

H_0: The population from which the sample is drawn is normally distributed.

H_1: The population from which the sample is drawn is not normally distributed.

Kolmogorov-Smirnov test

H_0: The empirical cumulative distribution function (CDF) of the sample is consistent with the specified (normal) distribution.

H_1: The empirical CDF of the sample significantly differs from the normal distribution.

The distributions of the grouped samples are illustrated by histograms alongside the normal distribution function for comparison. Additionally, the box plots accompanying the histograms provide visual representations of the descriptive statistics.

1. *By models*

The abnormal returns are aggregated by the event days, event windows, and currencies and are categorised by the models. This is the most comprehensive aggregation, and it is crucial to analyse it before further categorising it based on currencies and event days. **Table V-1** contains the descriptive statistics of the models' abnormal returns, where each event day from all event windows for all currencies is taken into account. While this does not directly address the research question, it is still worth analysing as it can provide valuable insights.

Table V-1*-Descriptive Statistics of the Abnormal Returns by Models*

Model	Sample Size	Mean	Standard Deviation	Median	Min. Value	Max. Value	Range	Skewness	Kurtosis
Random Walk	*816*	*-3.24*	*3.35*	*-2.18*	*-13.41*	*2.46*	*15.86*	*-1.03*	*0.28*
Mean-adjusted	*816*	*-2.58*	*3.25*	*-1.48*	*-12.11*	*2.82*	*14.93*	*-1.06*	*0.24*
Market-adjusted	*816*	*0.00*	*2.34*	*-0.35*	*-5.05*	*5.96*	*11.01*	*0.66*	*-0.16*
Market Model	*816*	*-0.34*	*1.67*	*-0.26*	*-5.46*	*4.10*	*9.57*	*0.06*	*-0.03*

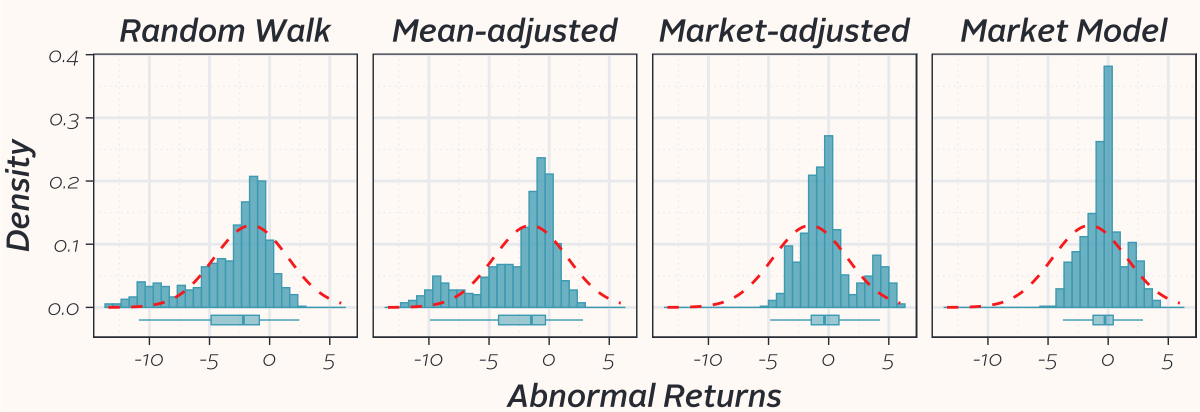
The sample size is sufficiently large for analysis and testing for all models. The *Random Walk* (*RW*) and the *Mean-adjusted Returns* (*MeA*) have means further from zero and a greater standard deviation, while the *Market-adjusted Returns* (*MaA*) and *Market Models* (*MM*) have means closer to zero and a somewhat smaller standard deviation. This is due to the *RW* and *MeA* being constant-based models. A mean closer to zero indicates a smaller divergence between the actual returns and the expected returns. The models are arranged in ascending order of complexity, with the *RW* being the least complex and the *MM* being the most elaborate. The range decreases with model complexity, resulting in a smaller dispersion. Skewness and kurtosis also tend to approach zero as the complexity of the model increases. – closer to a normal distribution. Based on these numbers, the *MaA* and *MM* are expected to perform better than the *RW* and *MeA*. Whether the aggregated sample is normally distributed is tested by statistical tests, and the results are presented in **Table V-2** below.

Table V-2*-Normality Tests Results for the Abnormal Returns by Models*

Model	***p-values***		
	Jarque-Bera test	**Shapiro-Wilk test**	**Kolmogorov-Smirnov test**
Random Walk	*<0.01*	*<0.01*	*<0.01*
Mean-adjusted	*<0.01*	*<0.01*	*<0.01*
Market-adjusted	*<0.01*	*<0.01*	*<0.01*
Market Model	0.79	*<0.01*	*<0.01*

According to the normality test results, only the sample generated by the *Market Model* is normally distributed. It is supported only by the Jarque-Bera test, which is related to skewness and kurtosis. This is not sufficient evidence for normality, even if we look at **Figure V-1**. It shows the distribution of the abnormal returns in the four models with the normal distribution as well. The figures support the numbers in **Table V-1**, but they in fact do not follow a normal distribution. In the next subsection, we group this sample by currencies and days to facilitate further examination. Ultimately, I am interested in the daily abnormal returns as it is important regarding my research question.

Figure V-1*-Distribution of the Abnormal Returns by Models*



2. By currencies

The abnormal returns are aggregated by the event days and event windows and are categorised by the models and currencies. This is an expanded version of the previous description table. The numbers and figures are highly variable across models and currencies. Identifying patterns in the statistics is challenging, but not essential, as we treat the currencies as a portfolio and analyse their combined properties. Intuitively, it is a representative currency portfolio based on its diversity. For these reasons, the description statistics (**Table VIII-5**), with the normality test results (**Table VIII-6**) and histograms (**Figure VIII-2**), are placed in the **Appendix**.

3. *By days*

The most significant table for my research question is **Table V-3**. The abnormal returns are aggregated by the currencies and event windows and are categorised by the models and event days. This way, the descriptive statistics can be examined specific to the day compared to the event. The sample size is 102 for every day for all models and thus considered large sample. The distributions of the means' size are similar to the ones in **Table V-1**, but a pattern can be recognised across the event days. The means tend to be lower in case of day (1, 2, 3, 4) than in day (-3, -2, -1, 0), except for *MaA*. This may suggest a structural break as an effect of the event.

Table V-3*-Descriptive Statistics by Models and Days*

Model	Day	Sample Size	Mean	Standard Deviation	Median	Min. Value	Max. Value	Range	Skewness	Kurtosis
Random Walk	-3	*102*	*-2.66*	*3.20*	*-2.04*	*-12.33*	*2.31*	*14.64*	*-1.07*	*0.85*
	-2	*102*	*-3.00*	*3.25*	*-2.17*	*-10.92*	*1.94*	*12.86*	*-1.01*	*0.10*
	-1	*102*	*-2.73*	*3.27*	*-1.87*	*-12.61*	*2.03*	*14.64*	*-1.11*	*0.60*
	0	*102*	*-2.91*	*3.07*	*-2.08*	*-12.78*	*1.69*	*14.47*	*-1.19*	*0.90*
	1	*102*	*-3.70*	*3.33*	*-2.68*	*-12.84*	*1.18*	*14.01*	*-0.96*	*0.03*
	2	*102*	*-3.55*	*3.43*	*-2.30*	*-13.41*	*1.72*	*15.12*	*-1.04*	*0.10*
	3	*102*	*-3.70*	*3.68*	*-2.19*	*-13.27*	*2.46*	*15.73*	*-0.96*	*-0.13*
	4	*102*	*-3.66*	*3.43*	*-2.46*	*-13.20*	*1.55*	*14.74*	*-0.94*	*-0.16*
Mean-adjusted	-3	*102*	*-2.00*	*3.09*	*-1.26*	*-10.92*	*2.68*	*13.59*	*-1.10*	*0.81*
	-2	*102*	*-2.34*	*3.16*	*-1.22*	*-10.15*	*2.31*	*12.46*	*-1.05*	*0.07*
	-1	*102*	*-2.07*	*3.18*	*-1.08*	*-12.11*	*2.39*	*14.50*	*-1.17*	*0.69*
	0	*102*	*-2.25*	*2.97*	*-1.31*	*-11.37*	*2.05*	*13.43*	*-1.24*	*0.89*
	1	*102*	*-3.04*	*3.24*	*-1.70*	*-11.43*	*1.54*	*12.97*	*-1.00*	*0.00*
	2	*102*	*-2.89*	*3.34*	*-1.64*	*-12.00*	*2.08*	*14.08*	*-1.06*	*0.06*
	3	*102*	*-3.04*	*3.59*	*-1.53*	*-11.86*	*2.82*	*14.68*	*-0.97*	*-0.20*
	4	*102*	*-3.00*	*3.32*	*-1.84*	*-11.79*	*1.91*	*13.70*	*-0.94*	*-0.25*
Market-adjusted	-3	*102*	*0.00*	*2.36*	*-0.46*	*-5.05*	*5.21*	*10.25*	*0.60*	*-0.25*
	-2	*102*	*0.00*	*2.32*	*-0.42*	*-4.03*	*5.33*	*9.36*	*0.67*	*-0.27*
	-1	*102*	*0.00*	*2.48*	*-0.35*	*-4.86*	*5.79*	*10.65*	*0.69*	*-0.18*
	0	*102*	*0.00*	*2.28*	*-0.19*	*-4.69*	*5.34*	*10.03*	*0.64*	*-0.11*
	1	*102*	*0.00*	*2.29*	*-0.31*	*-4.24*	*5.96*	*10.20*	*0.69*	*-0.17*
	2	*102*	*0.00*	*2.28*	*-0.44*	*-4.14*	*5.38*	*9.51*	*0.71*	*-0.02*
	3	*102*	*0.00*	*2.41*	*-0.37*	*-4.76*	*5.58*	*10.34*	*0.69*	*-0.20*
	4	*102*	*0.00*	*2.39*	*-0.25*	*-4.82*	*5.58*	*10.40*	*0.56*	*-0.17*
Market Model	-3	*102*	*-0.27*	*1.76*	*-0.31*	*-4.40*	*4.05*	*8.45*	*0.22*	*-0.13*
	-2	*102*	*-0.31*	*1.69*	*-0.21*	*-4.11*	*4.00*	*8.11*	*0.09*	*-0.07*
	-1	*102*	*-0.28*	*1.87*	*-0.39*	*-5.46*	*4.10*	*9.57*	*0.16*	*-0.05*
	0	*102*	*-0.30*	*1.65*	*-0.28*	*-4.09*	*3.68*	*7.77*	*0.06*	*-0.03*
	1	*102*	*-0.39*	*1.63*	*-0.33*	*-3.96*	*3.12*	*7.09*	*0.13*	*-0.12*
	2	*102*	*-0.37*	*1.53*	*-0.22*	*-3.77*	*3.08*	*6.84*	*-0.20*	*-0.14*
	3	*102*	*-0.39*	*1.65*	*-0.22*	*-4.17*	*3.71*	*7.89*	*-0.02*	*0.02*
	4	*102*	*-0.39*	*1.64*	*-0.21*	*-4.23*	*3.28*	*7.51*	*-0.18*	*-0.18*

The standard deviations, however, tend to be larger after day 0, but only in case of *RW* and *MeA*; in case of *MaA* and *MM* it is less unambiguous. The normality tests results are slightly more promising when categorising for event days. According to the Jarque-Bera test, the *MaA* and *MM* follow normal distribution. The *MM*'s normality is supported by the Shapiro-Wilk test as well, and in some cases also the Kolmogorov-Smirnov test. The descriptive statistics and the normal distributions are illustrated in **Figure V-2**.

Table V-4*-Normality Tests Results by Models and Days*

Model	Day	*p-values*		
		Jarque-Bera test	**Shapiro-Wilk test**	**Kolmogorov-Smirnov test**
Random Walk	-3	*<0.01*	*<0.01*	*<0.01*
	-2	*<0.01*	*<0.01*	*<0.01*
	-1	*<0.01*	*<0.01*	*<0.01*
	0	*<0.01*	*<0.01*	*<0.01*
	1	*<0.01*	*<0.01*	*<0.01*
	2	*<0.01*	*<0.01*	*<0.01*
	3	*<0.01*	*<0.01*	*<0.01*
	4	*<0.01*	*<0.01*	*<0.01*
Mean-adjusted	-3	*<0.01*	*<0.01*	*<0.01*
	-2	*<0.01*	*<0.01*	*<0.01*
	-1	*<0.01*	*<0.01*	*<0.01*
	0	*<0.01*	*<0.01*	*<0.01*
	1	*<0.01*	*<0.01*	*<0.01*
	2	*<0.01*	*<0.01*	*<0.01*
	3	*<0.01*	*<0.01*	*<0.01*
	4	*<0.01*	*<0.01*	*<0.01*
Market-adjusted	-3	*0,04*	*<0.01*	*<0.01*
	-2	*0,02*	*<0.01*	*<0.01*
	-1	*0,02*	*<0.01*	*<0.01*
	0	*0,03*	*<0.01*	*<0.01*
	1	*0,02*	*<0.01*	*<0.01*
	2	*0,01*	*<0.01*	*<0.01*
	3	*0,02*	*<0.01*	*<0.01*
	4	*0,06*	*<0.01*	*<0.01*
Market Model	-3	*0,65*	*0,29*	*<0.01*
	-2	*0,93*	*0,29*	*0,01*
	-1	*0,80*	*0,10*	*<0.01*
	0	*0,97*	*0,08*	*0,01*
	1	*0,84*	*0,06*	*<0.01*
	2	*0,68*	*0,02*	*0,01*
	3	*1.00*	*0,20*	*0,01*
	4	*0,71*	*0,02*	*<0.01*

Figure V-2-*Distribution of the Abnormal Returns by Models and Days*

According to the normality test results, only the Market Model close to a normal distribution on the event days. Using the Student's *t*-test is only acceptable in this particular case. However, the Wilcoxon *T*-test can be conducted for all four models. As it is a non-parametric test, it is often used when the sample is not normally distributed or when the assumption of normality is violated. The main difference between Student's *t*-test and Wilcoxon *T*-test lies in their metrics. The t-test is used to compare the means of two groups and determine if they are statistically different from each other. On the other hand, the Wilcoxon signed-rank test compares the medians or, more precisely, examines if the distribution of differences between paired observations is symmetric around zero.

Abnormal Returns

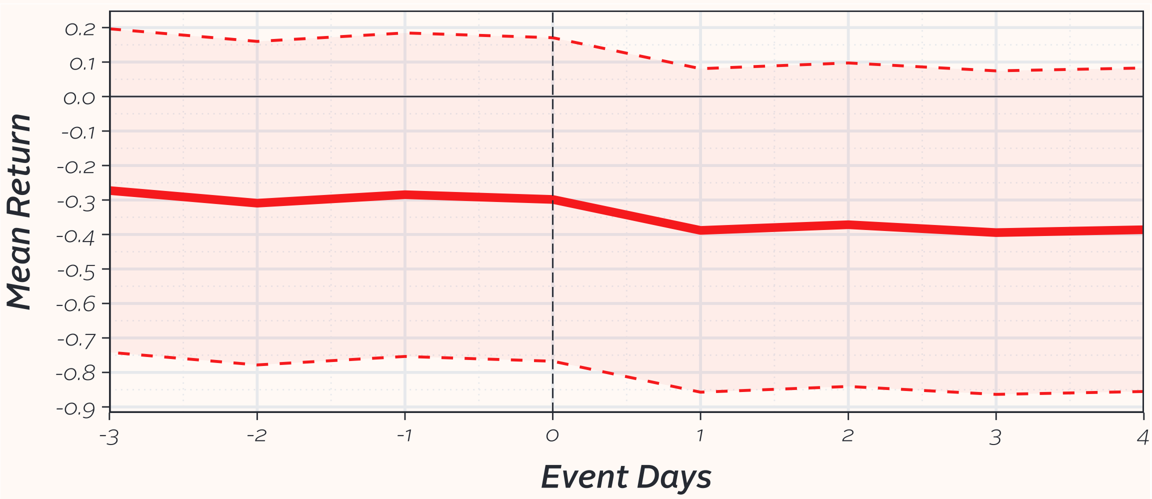
Student's *t*-test

In order to perform various one- and two-sample t-tests, it is necessary to have the mean abnormal returns along with their corresponding estimated standard deviations. The sample means and standard deviations are presented in **Table V-5**. However, considering the previous statistical analyses and the failure to meet the necessary conditions, only the *Market Model* is appropriate for testing. The data is also depicted in **Figure V-3**. There is a small decline observed after the event day, and it is advised to test if this change is statistically significant.

***Table V-5**-Mean Abnormal Returns with Standard Deviations*

Model	Event Days								Average AR
	-3	-2	-1	0	1	2	3	4	
MM	*-0.27* (1.76)	*-0.31* (1.69)	*-0.28* (1.87)	*-0.30* (1.65)	*-0.39* (1.63)	*-0.37* (1.53)	*-0.39* (1.65)	*-0.39* (1.64)	*-0.34* (1.67)

***Figure V-3**-Mean Abnormal Returns in the Event Window*



The results, specifically the *p*-values for the one-sample and two-sample *t*-tests can be found in **Table V-6**. Under the "event days", the individual samples are tested for the null hypothesis. According to the p-values, the null hypothesis cannot be rejected for the days before the event (for day -3, -2, -1, and 0), while the null hypothesis can be rejected for the days after the event (for day 1, 2, 3, and 4) in a 5 percent significance level. This significance level was chosen because of the simplicity of the interpretation. The results can suggest that the abnormal returns before the event are not statistically different from zero, meaning that the actual returns leading up to the event are consistent with what would be expected based on the *Market Model*. In other words, there is no evidence of abnormal price movements or significant deviations from the expected returns prior to the event. However, the abnormal returns are significantly different from zero after the event. It implies that there was a significant impact of the event on currency prices. Under the "average", the pooled event day sample is tested for the null hypothesis, which can be rejected based on the p-value. This indicates that the abnormal returns observed during the entire event window are statistically significant and significantly different from zero, suggesting a clear deviation from the expected returns. Under "pre-event" and "post-event" title, respectively, the pooled samples for event day -3, -2, -1, 0, and for event day 1, 2, 3, 4 are tested for the null hypothesis and can be rejected as well. The "pre-event" sample being statistically different from zero can be caused by the differences between the individual daily means. This is proved by the only two-sample *t*-test under the "paired" subtitle, which compares the pre-event and post-event samples. The null hypothesis can be rejected in this case too; therefore, there is a true difference between the means of abnormal return samples before and after the event occurrence.

***H_0*:** The population mean is equal to zero.
/ The population means of the two groups are equal.

***H_1*:** The population mean is not equal to zero.
/ The population means of the two groups are not equal.

Table V-6-*Significance Tests Results for Student's t-test*

Model	Event Days								Average
	-3	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	
Market Model	*0.120*	*0.067*	*0.127*	*0.070*	*0.018*	*0.016*	*0.018*	*0.019*	*<0.01*
	Pre-Event				**Post-Event**				**Paired**
	<0.01				*<0.01*				*<0.01*

Wilcoxon *T*-test

Only the sample median is required to conduct the non-parametric Wilcoxon T-test. However, I collected the sample median absolute deviation as well in **Table V-7**, alongside the sample median values. Together, they provide more insights into the sample's central tendency and variability, improving the interpretation of the results obtained from the Wilcoxon signed-rank test. According to the previous findings, all four models are appropriate for this test. **Figure V-4** is derived from the table below. It shows similarity between the *Market Model* and the *Market-adjusted Returns*, which is logical since both models are based on measuring the mean of the samples taken during the event window. The *Mean-adjusted Returns* and the *Random Walk* are visibly farther from zero, and the Random Walk has no median absolute deviation as it was constant zero for all currencies.

Table V-7*-Median Abnormal Returns with Median Absolute Deviation*

Model	Event Days								Average AR
	-3	-2	-1	0	1	2	3	4	
RW	*-2.04* *(2.58)*	*-2.17* *(2.56)*	*-1.87* *(2.56)*	*-2.08* *(2.21)*	*-2.68* *(2.34)*	*-2.30* *(2.34)*	*-2.19* *(2.73)*	*-2.46* *(2.45)*	*-2.18* *(2.40)*
MeA	*-1.26* *(2.34)*	*-1.22* *(2.06)*	*-1.08* *(2.29)*	*-1.31* *(1.8)*	*-1.70* *(2.29)*	*-1.64* *(2.07)*	*-1.53* *(2.60)*	*-1.84* *(2.38)*	*-1.48* *(2.18)*
MaA	*-0.46* *(1.56)*	*-0.42* *(1.59)*	*-0.35* *(1.84)*	*-0.19* *(1.53)*	*-0.31* *(1.81)*	*-0.44* *(1.42)*	*-0.37* *(1.78)*	*-0.25* *(1.59)*	*-0.35* *(1.66)*
MM	*-0.31* *(1.54)*	*-0.21* *(1.39)*	*-0.39* *(1.37)*	*-0.28* *(1.08)*	*-0.33* *(1.31)*	*-0.22* *(1.00)*	*-0.22* *(1.36)*	*-0.21* *(1.14)*	*-0.26* *(1.30)*

Figure V-4*-Median Abnormal Returns in the Event Window*

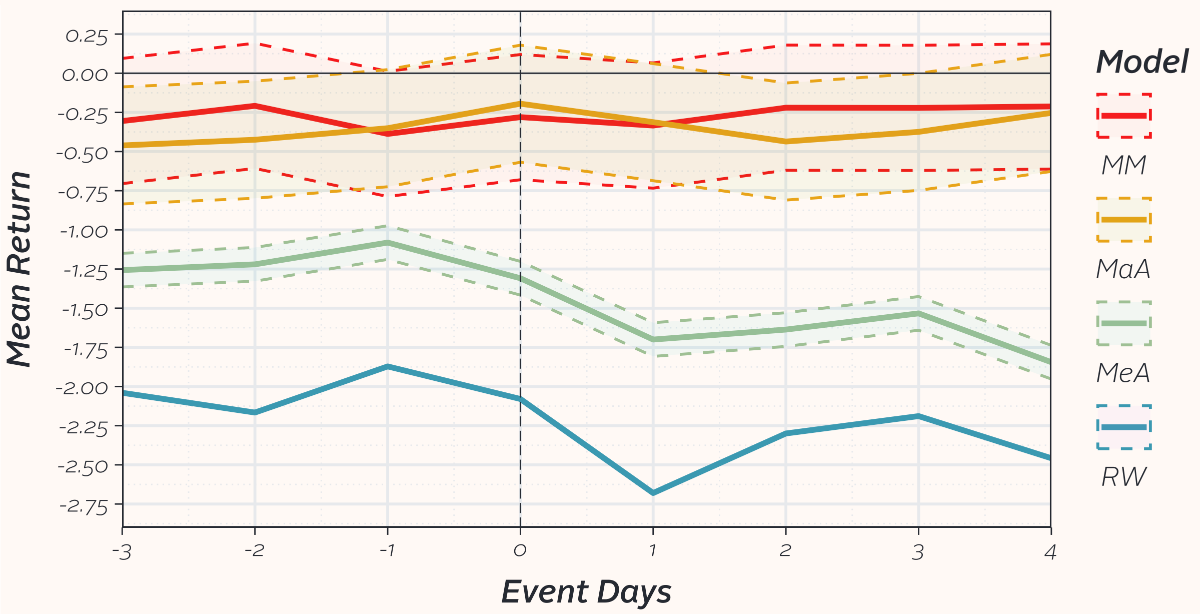


Table V-8 contains all test results, i.e., the p-values for both the one- and two-sample Wilcoxon *T*-tests for all four models. Starting with the *Random Walk* and the *Mean-adjusted Returns*, the null hypothesis can be rejected at any significance level for every single test conducted. Based on the previous findings, this is not unexpected. There was a significantly greater distance between the medians of the individual samples and the overall samples than zero. This would suggest that, according to these two models, there was a continuously prevailing abnormal return over time, and the event had no measurable impact on the currency prices. The lack of consideration for the high interest rate difference renders it unsuitable for final interpretation. However, the *Market-adjusted Returns* and the *Market Model* are capable of doing that. These models are adapting over time and with interest rate changes, providing a more accurate estimation. According to the *MaA*, the overall sample median has a deviation from zero, but not the individual ones. Furthermore, in the samples taken before and after the event, respectively, the null hypothesis can be rejected at 5 percent significance level, suggesting a significant difference in medians from zero. These two samples, however, do not show deviance from each other, according to the paired test. The *Market Model* shows ambiguous p-values as well, but it can be observed that they are generally lower for the post-event event days than those of the pre-event days. Because of this ambiguity, I would consider and compare only the *Market Model* for both statistical tests, as it has the most complexity and adaptability for a changing environment.

H_0: The population median is equal to zero.
/ The population medians of the two groups are equal.

H_1: The population median is not equal to zero.
/ The population medians of the two groups are not equal.

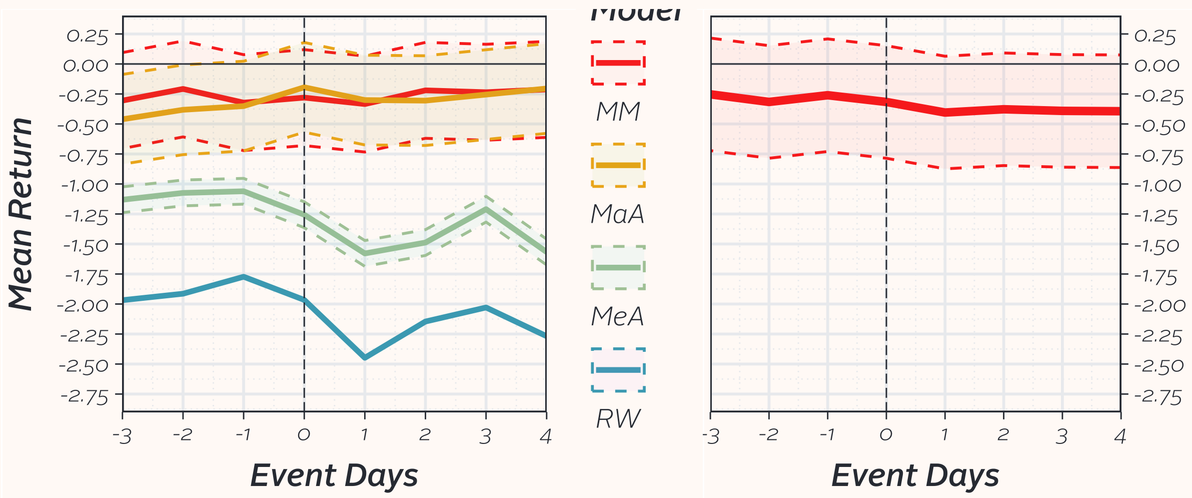
Table V-8*-Significance Tests Results for Wilcoxon T-test*

Model	**Event Days**								**Average**
	-3	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	
RW	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
MeA	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*	*<0.01*
MaA	*0.298*	*0.299*	*0.305*	*0.254*	*0.320*	*0.232*	*0.249*	*0.299*	*<0.01*
MM	*0.063*	*0.039*	*0.050*	*0.032*	*0.008*	*0.018*	*0.012*	*0.011*	*<0.01*
	Pre-Event				**Post-Event**				**Paired**
RW	*<0.01*				*<0.01*				*<0.01*
MeA	*<0.01*				*<0.01*				*<0.01*
MaA	*0.034*				*0.030*				*0.896*
MM	*<0.01*				*<0.01*				*<0.01*

Robustness

Because the Student's *t*-test and Wilcoxon *T*-test results are occasionally ambiguous, it is advised to perform a robustness test. I intend to do that by modifying the sample compositions. There are 17 event windows for 6 currencies, making an overall total of 102 event windows with an 816-sample size. However, in **Figure III-5** shows that in certain event windows, there were interest rate increases implemented by the corresponding central bank. That may influence the effect of the Hungarian interest rate increase in those particular event windows. In practice, the concerned event windows are filtered out, leaving only 90 event windows with a 720-sample size. The robust sample of abnormal return mean and median values can be found in **Table VIII-7** in the **Appendix**, with no obvious difference from the initial sample statistics. Upon examining **Figure V-5**, which shows the median (left side) and mean (right side) abnormal returns in the event windows, barely any difference is apparent compared to the previous figure. In the case of the mean *Market Model*, there is still a slight decrease after the event, while the median *Market Model* shows no obvious direction changes. It is important to observe and note that both the mean and median abnormal returns are negative, suggesting a consistent negative abnormal return.

***Figure V-5**-Median and Mean Abnormal Returns in the Event Window*



As for the test results, **Table V-9** contains every *p*-value gained from the Student's *t*-test and the Wilcoxon *T*-test using the robust sample. The structure of the result presentation table remains unchanged. Each of the following robustness tests yields similar results to the preceding tests. This is attributed to the large sample size, which demonstrates the robustness of the applied models to the impact of potential inference events, such as interest rate increases by other central banks.

Table V-9-Significance Tests Results for Robustness

Test	Student's t-test								
Model	**Event Days**								**Average**
	-3	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	
Market Model	0.155	0.065	0.160	0.065	0.018	0.021	0.022	0.019	<0.01
	Pre-Event				**Post-Event**				**Paired**
Market Model	<0.01				<0.01				<0.01

Test	Wilcoxon T-test								
Model	**Event Days**								**Average**
	-3	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	
RW	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MeA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MaA	0.423	0.342	0.391	0.303	0.320	0.276	0.279	0.407	<0.01
MM	0.080	0.039	0.068	0.033	<0.01	0.017	0.013	<0.01	<0.01
	Pre-Event				**Post-Event**				**Paired**
RW	<0.01				<0.01				<0.01
MeA	<0.01				<0.01				<0.01
MaA	0.068				0.049				0.460
MM	<0.01				<0.01				<0.01

Nevertheless, it is important to proceed with caution when interpreting these results as they can be misleading due to various factors. First, the interest rate set by the Hungarian National Bank consistently and significantly exceeds that of any other central bank. This, by definition, influences the calculated actual and expected returns thus the abnormal returns as well. As a result, all three returns (actual, expected, and the difference between them, known as abnormal returns) were almost always under zero with negative central tendencies. Cumulating these returns would have caused a curve with exponentially decreasing tendency, making it uninterpretable. Furthermore, this could explain the obvious fact that the abnormal returns are significantly different (lower) than zero. Second, the event being the interest rate increase can cause biased estimation for the first and the consecutive event days, as it is also a part of the return definition. An increase in the Hungarian interest rate, without a corresponding increase in the currency's interest rate, can lead to a drop in the actual return and consequently the abnormal return. This problem is partially mitigated by the robustness test, which demonstrates no significant disparity. The average difference between the Hungarian and the other interest rates was calculated and proved to be significantly larger that the drop encountered after the event.

VI. Conclusion

In the focus of my research paper is the Hungarian foreign exchange market and its reaction to the Hungarian National Bank's base interest rate increases during 2021 and 2022. For examining this impact, I utilised the widely used event study methodology. Its advantage is that it is easy to understand and implement, but it requires several modifications to use on the foreign exchange market. The forint exchange rate is defined as a currency against another one, so I had to carefully select a portfolio of foreign currencies for my analysis. This portfolio contains the currencies of notable trading countries and those in similar economic positions as well. This serves as an adequate representation of the forint's exchange rate. The actual returns on the forint are defined as a daily percentage change when interest rate parity prevails. The expected returns are defined by four models with different approaches. The Random Walk assumes an opposing direction between the spot exchange rate and the interest rate differential, therefore having a constant value of zero. The Mean-adjusted model is defined based on the mean estimation of the currency portfolio in a period preceding the event windows, excluding the examined numeraire, therefore being a varying constant value. The Market-adjusted model works in similar ways., but it is not restricted to the estimation period, resulting in a fluctuating expected return over time. Finally, the Market Model uses OLS regression estimation to predict the expected return. The abnormal return is defined as the difference between the actual and expected return. To test whether the abnormal returns are significantly different from zero, I intended to use Student's t-statistics. These statistics, however, require the sample to follow a normal distribution. During the examination, it was discovered that only the abnormal return sample generated by the Market Model is normally distributed. In this case, I needed an alternative test to test my hypothesis. I chose the Wilcoxon signed-rank test, which measures the median difference instead of the mean difference. As a result, I turned out that the constant models, i.e., Random Walk and Mean-adjusted models, are not suitable for testing abnormal returns – at least not in a highly elevated and diverse interest environment. The Market-adjusted model showed no statistical difference in the abnormal returns, as it measured the average return of the six currencies. It is a possible improvement to the study to include several other currencies in the analysis to assemble an even more representative portfolio. Nevertheless, the Market Model provided a promising result in the case of both statistical tests. According to these results, the abnormal returns were not statistically different from zero before the event day (including the event day itself, as the effects can be measured on the next trading day), and they were statistically different from zero following the event day. The use of interest rates in both the calculation of actual returns and event days can lead to endogeneity issues. However, the robustness test showed that this should not cause biased estimation. Furthermore, the statistical tests demonstrated that the abnormal returns before and after the event days were significantly different. The endogeneity of the interest rates does not prove to be distorting, as the event windows followed each other tightly, sometimes only one day between them. The obtained results may suggest that the interest rate increase has a statistically significant negative effect on the forint exchange rate, even if it is rather slight. Therefore, my research hypothesis, that *the forint exchange rate exhibits no significant abnormal returns around interest rate increases*, can only be partially rejected. This implies that monetary policy actions by the Hungarian National Bank have real and measurable consequences on the foreign exchange market. This has implications for international trade businesses, currency trading investors, and policymakers shaping economic strategies. The results suggest that even slight changes in interest rates can influence the foreign exchange market. Policymakers may need to consider the potential impact on exchange rates when making decisions about interest rate adjustments, as exchange rate stability is crucial for economic stability and competitiveness. In summary, my research contributes insights into the dynamics of the Hungarian foreign exchange market and the effects of monetary policy actions on exchange rate movements. It provides methodological advancements with thorough explanation and visualisation and empirical evidence that can inform both academic research and policymaking in the fields of international finance and monetary economics.

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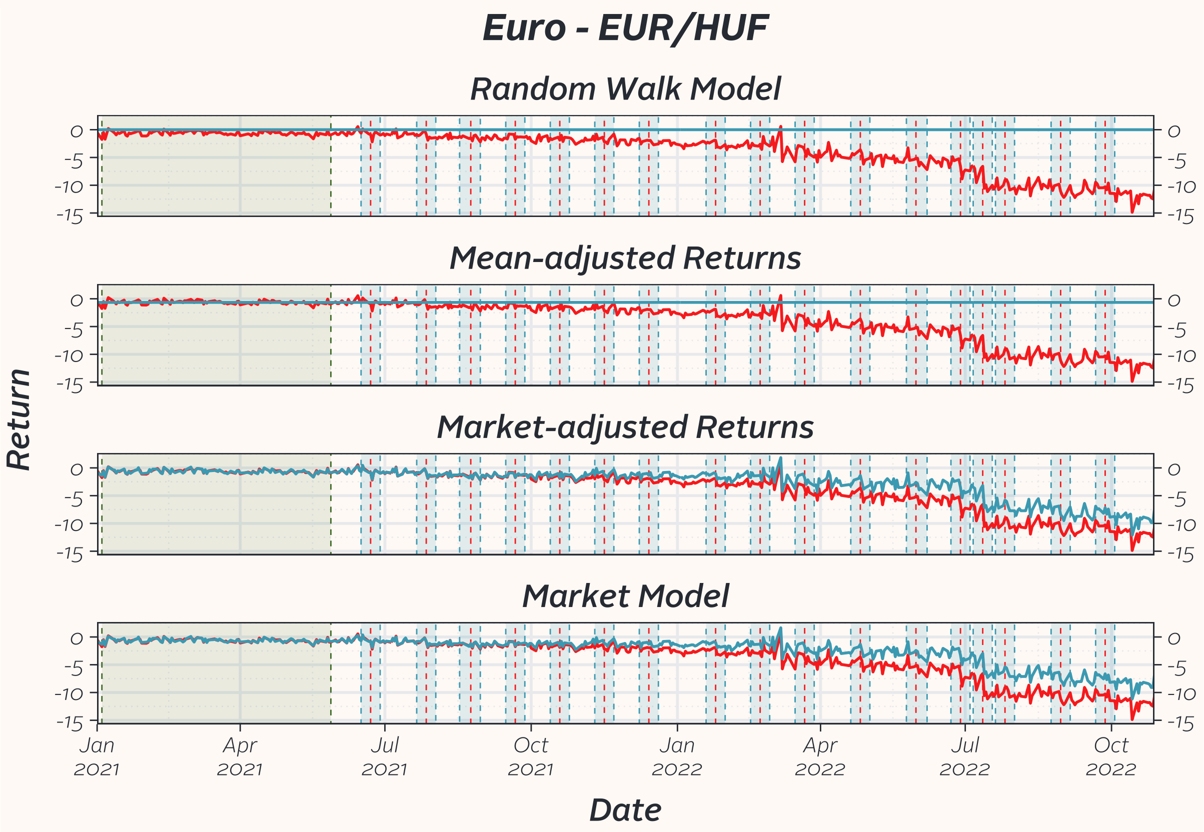
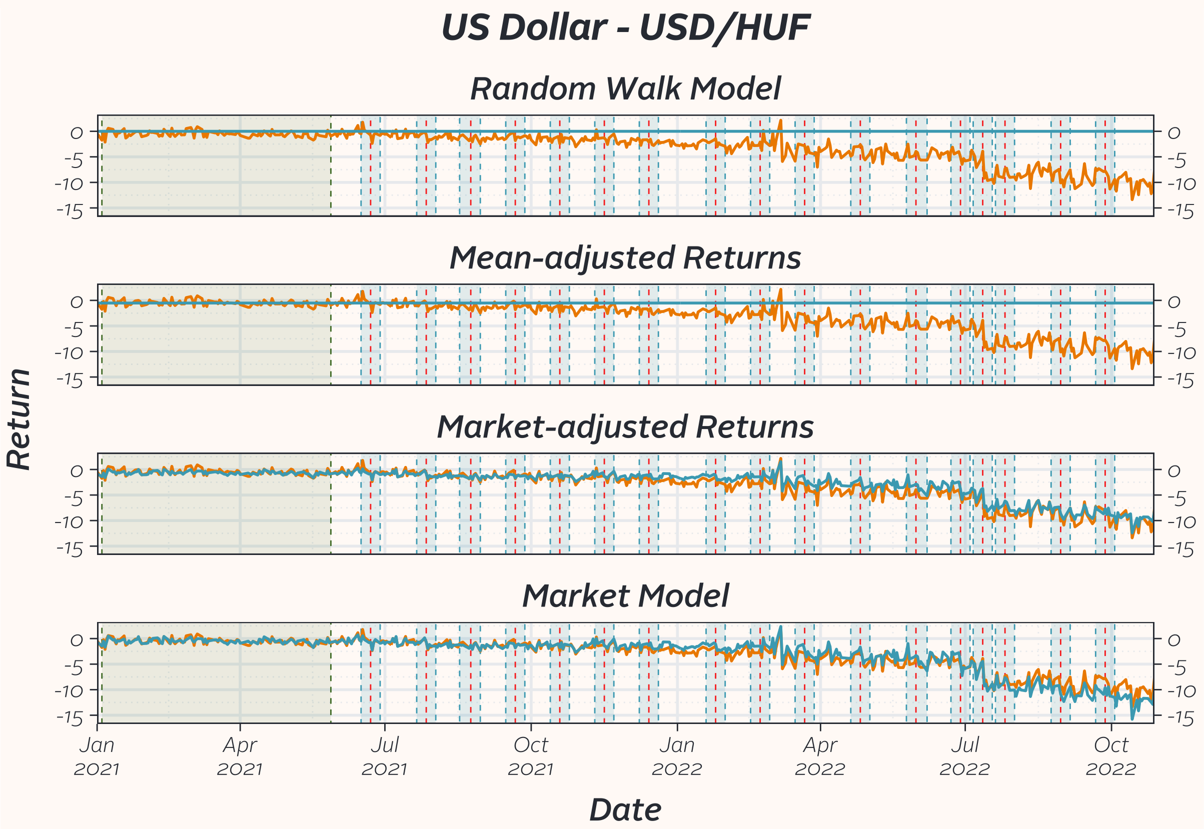
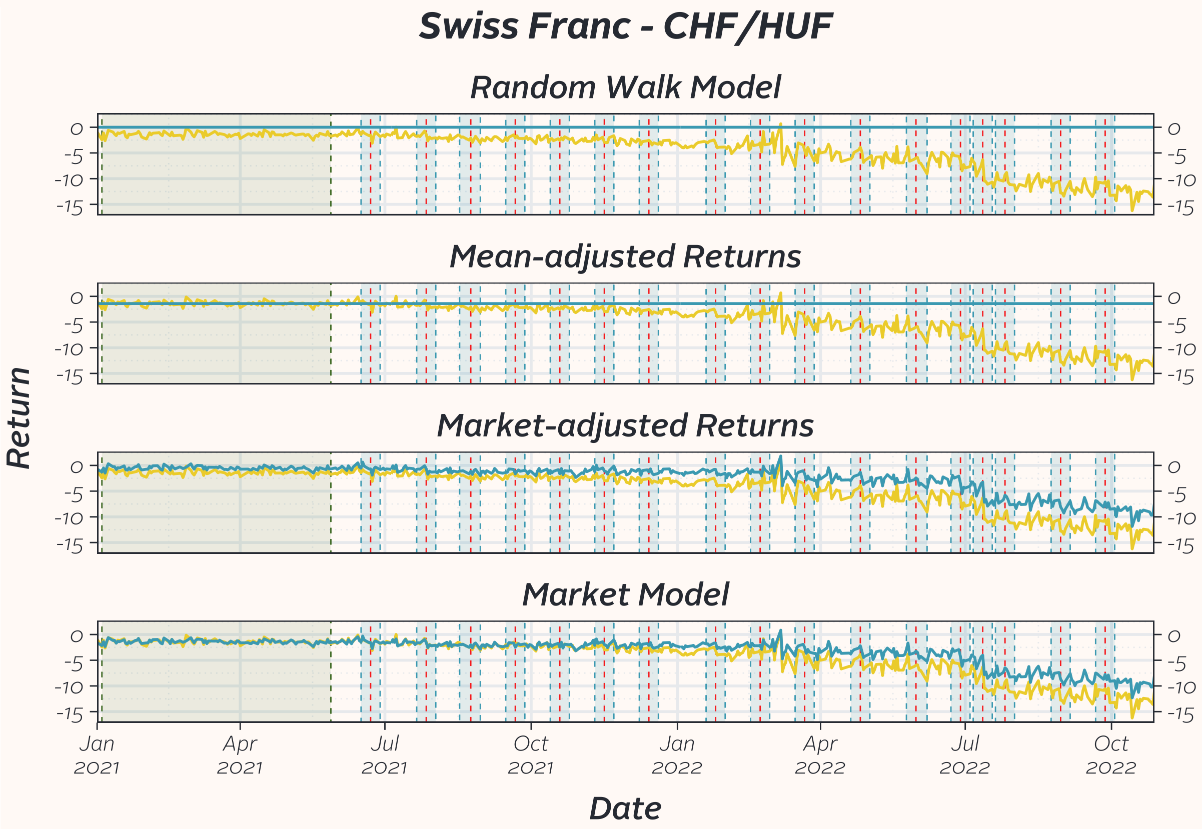
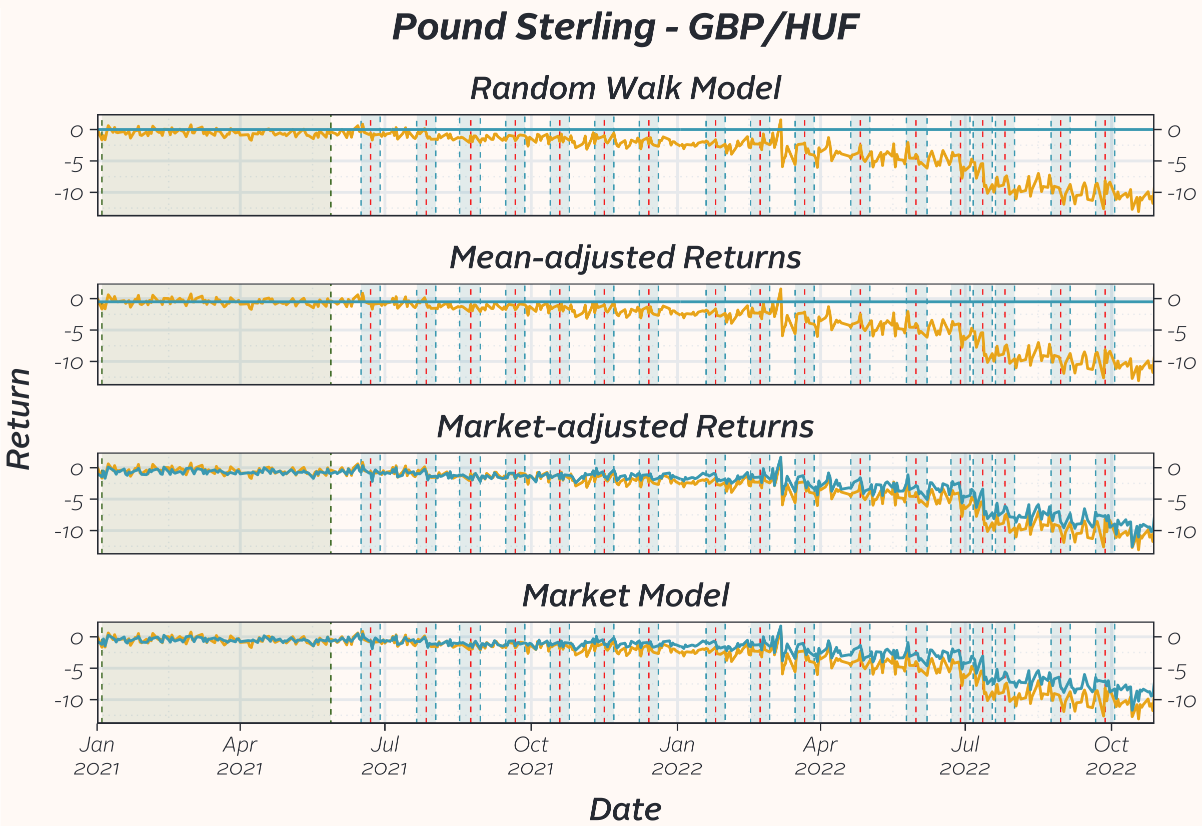
VIII. Appendix

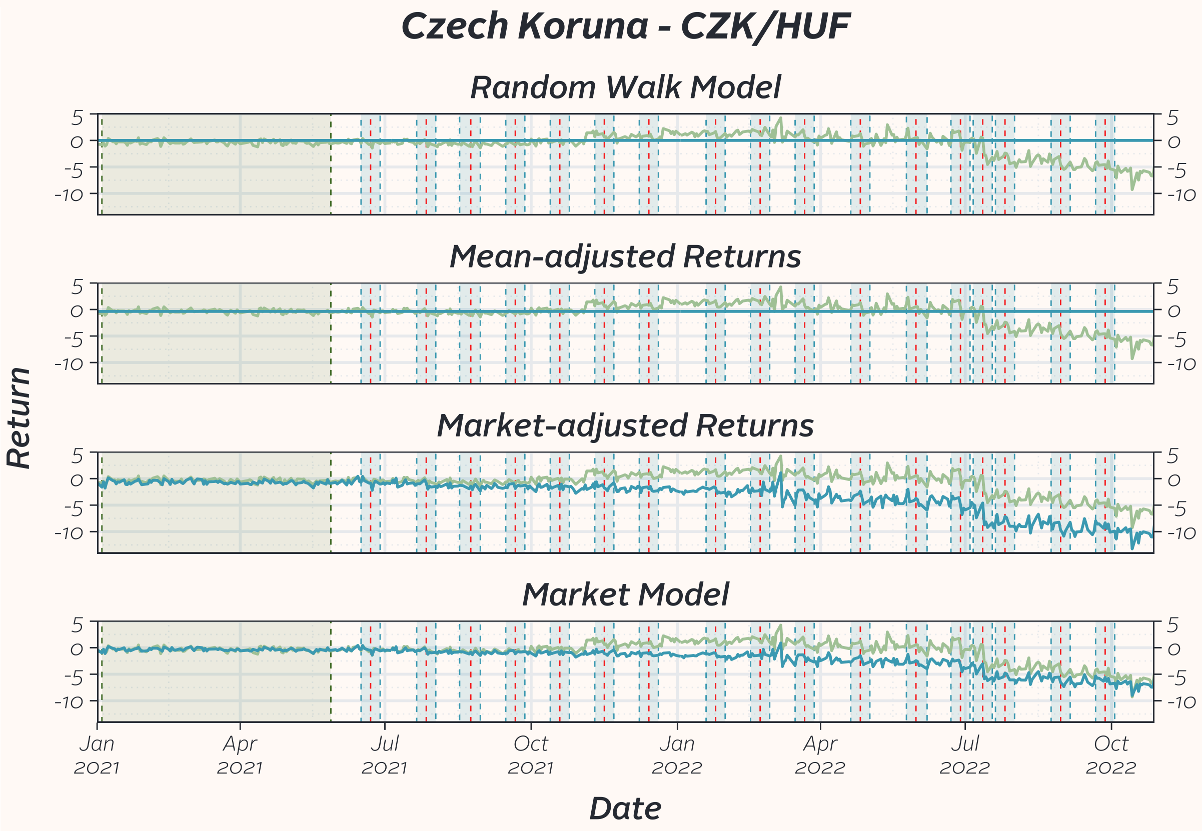
Figure VIII-1-*Timeline for an Event Study with Expected and Actual Returns*






Swiss Franc - CHF/HUF
Random Walk Model
Mean-adjusted Returns
Market-adjusted Returns
Market Model
Return
0
-5
-10
-15
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Date


Pound Sterling - GBP/HUF
Random Walk Model
Mean-adjusted Returns
Market-adjusted Returns
Market Model
Return
0
-5
-10
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Date


Czech Koruna - CZK/HUF
Random Walk Model
Mean-adjusted Returns
Market-adjusted Returns
Market Model
Return
Date
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022

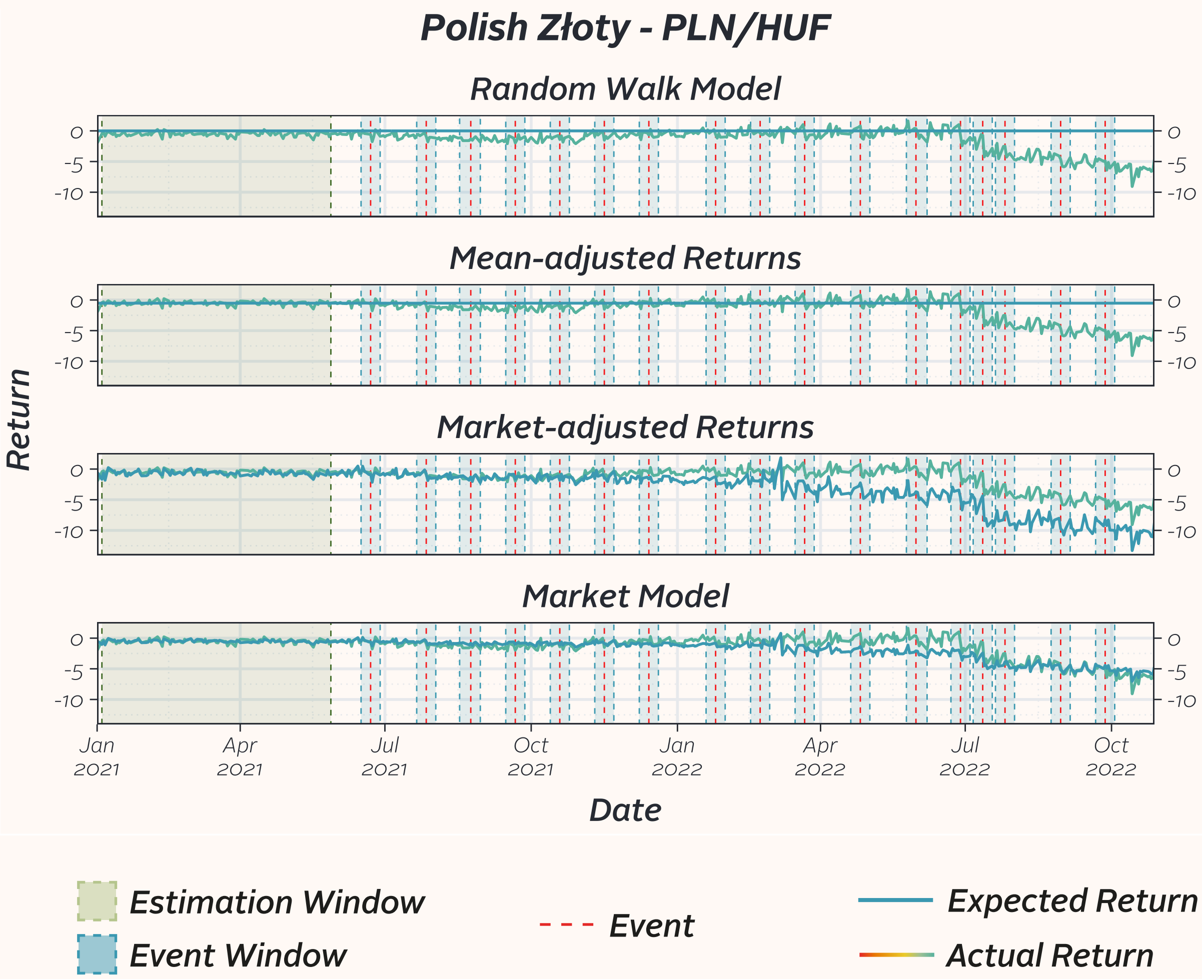

Polish Złoty - PLN/HUF
Random Walk Model
Mean-adjusted Returns
Market-adjusted Returns
Market Model
Return
Date
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Estimation Window
Event Window
Event
Expected Return
Actual Return

Table VIII-1-Returns in the Event Windows Aggregated by Date

Currency	Event Days								Average
	-3	-2	-1	0	1	2	3	4	
EUR	-3.90	-4.30	-3.98	-4.20	-4.97	-4.77	-4.94	-4.89	-4.49
USD	-3.13	-3.39	-3.25	-3.37	-4.16	-4.06	-4.38	-4.11	-3.73
GBP	-3.22	-3.71	-3.66	-3.43	-4.34	-4.18	-4.38	-4.25	-3.90
CHF	-4.68	-4.85	-4.59	-4.76	-5.61	-5.39	-5.59	-5.78	-5.16
CZK	-0.03	-0.44	-0.11	-0.39	-1.01	-1.00	-1.10	-1.13	-0.65
PLN	-1.01	-1.28	-0.80	-1.29	-2.11	-1.90	-1.82	-1.78	-1.50
Average	-2.66	-3.00	-2.73	-2.91	-3.70	-3.55	-3.70	-3.66	-3.24

Table VIII-2-Returns in the Event Windows Aggregated by Currency

Event Date	Event Days								Average
	-3	-2	-1	0	1	2	3	4	
2021.06.22	0.41	-0.32	-0.84	-0.81	-2.10	-0.81	-0.42	-0.98	-0.73
2021.07.27	-0.85	-0.93	-0.16	-0.78	-1.87	-1.24	-1.45	-1.37	-1.08
2021.08.24	-1.24	-1.16	-1.78	-1.29	-1.95	-1.21	-0.92	-2.18	-1.47
2021.09.21	-1.54	-0.89	-0.9	-1.71	-1.25	-1.08	-1.31	-1.15	-1.23
2021.10.19	-1.57	-1.39	-1.05	-1.78	-0.84	-1.89	-1.15	-1.31	-1.37
2021.11.16	-0.20	-1.10	-0.73	-1.39	-1.50	-1.91	-1.21	-0.37	-1.05
2021.12.14	-2.17	-1.29	-1.15	-1.47	-1.02	-1.82	-2.01	-1.83	-1.6
2022.01.25	-1.26	-1.53	-1.06	-1.16	-2.25	-2.01	-2.18	-1.90	-1.67
2022.02.22	-1.13	-1.68	-1.65	-1.52	-2.52	-0.23	-1.27	-1.88	-1.49
2022.03.22	-2.25	-1.62	-1.43	-2.10	-3.30	-2.37	-2.95	-3.49	-2.44
2022.04.26	-3.01	-2.58	-2.23	-1.73	-2.85	-4.23	-3.92	-3.45	-3.00
2022.05.31	-1.28	-3.66	-3.35	-3.01	-3.19	-4.40	-4.05	-5.25	-3.52
2022.06.28	-2.43	-2.97	-2.68	-4.03	-5.98	-4.74	-4.97	-4.65	-4.06
2022.07.12	-4.24	-6.57	-4.18	-3.75	-7.72	-7.28	-8.45	-7.46	-6.21
2022.07.26	-5.97	-7.84	-7.32	-6.36	-6.52	-7.39	-8.24	-8.17	-7.23
2022.08.30	-8.71	-7.56	-7.36	-8.87	-9.31	-9.96	-9.14	-7.54	-8.55
2022.09.27	-7.82	-7.86	-8.56	-7.69	-8.75	-7.77	-9.31	-9.18	-8.37
Average	-2.66	-3.00	-2.73	-2.91	-3.70	-3.55	-3.70	-3.66	-3.24

***Table VIII-3**-Returns in the Event Windows Aggregated by Event Days*

Event Date	Currency						Average
	EUR	USD	GBP	CHF	CZK	PLN	
2021.06.22	-0.75	-0.43	-0.62	-1.58	-0.42	-0.6	-0.73
2021.07.27	-1.15	-1.14	-0.90	-1.80	-0.55	-0.96	-1.08
2021.08.24	-1.48	-1.38	-1.45	-2.32	-0.78	-1.39	-1.47
2021.09.21	-1.28	-1.01	-1.16	-2.03	-0.57	-1.31	-1.23
2021.10.19	-1.58	-1.56	-1.45	-2.29	-0.22	-1.14	-1.37
2021.11.16	-1.67	-1.22	-1.34	-2.31	0.96	-0.73	-1.05
2021.12.14	-2.27	-2.12	-2.14	-2.99	0.59	-0.64	-1.60
2022.01.25	-2.59	-2.28	-2.32	-3.38	1.08	-0.53	-1.67
2022.02.22	-2.62	-2.28	-2.07	-3.13	1.61	-0.42	-1.49
2022.03.22	-3.87	-3.50	-3.02	-4.57	0.68	-0.36	-2.44
2022.04.26	-4.66	-3.93	-4.00	-5.36	0.24	-0.30	-3.00
2022.05.31	-5.50	-4.64	-4.54	-6.43	0.19	-0.22	-3.52
2022.06.28	-6.68	-4.97	-5.44	-6.75	0.3	-0.79	-4.06
2022.07.12	-8.96	-7.20	-7.59	-9.14	-1.85	-2.49	-6.21
2022.07.26	-9.81	-8.19	-8.61	-10.08	-3.14	-3.52	-7.23
2022.08.30	-10.98	-9.06	-10.04	-11.96	-4.45	-4.84	-8.55
2022.09.27	-10.54	-8.55	-9.55	-11.57	-4.74	-5.26	-8.37
Average	-4.49	-3.73	-3.90	-5.16	-0.65	-1.50	-3.24

***Table VIII-4**-Results for the ADF-test of Event Data*

Event Date	Currency						For All Currencies
	EUR	USD	GBP	CHF	CZK	PLN	
2021.06.22	0.93	0.97	0.99	0.95	0.94	0.92	0.51
2021.07.27	0.21	0.02	0.04	0.31	0.23	0.53	0.47
2021.08.24	0.06	0.92	0.74	0.99	0.96	0.74	0.53
2021.09.21	0.51	0.63	0.63	0.03	0.80	0.98	0.30
2021.10.19	0.99	0.01	0.99	0.12	0.92	0.90	0.09
2021.11.16	0.15	0.97	0.64	0.17	0.99	0.97	0.61
2021.12.14	0.90	0.95	0.96	0.65	0.98	0.99	0.43
2022.01.25	0.48	0.80	0.49	0.07	0.41	0.69	0.48
2022.02.22	0.96	0.98	0.95	0.97	0.02	0.18	0.49
2022.03.22	0.55	0.66	0.64	0.66	0.01	0.01	0.40
2022.04.26	0.92	0.91	0.75	0.98	0.01	0.84	0.76
2022.05.31	0.71	0.10	0.89	0.99	0.56	0.92	0.30
2022.06.28	0.58	0.96	0.75	0.81	0.56	0.38	0.70
2022.07.12	0.63	0.81	0.59	0.69	0.55	0.55	0.73
2022.07.26	0.37	0.96	0.03	0.99	0.52	0.01	0.54
2022.08.30	0.99	0.94	0.72	0.98	0.94	0.68	0.98
2022.09.27	0.86	0.99	0.25	0.99	0.96	0.02	0.07
For All Dates	0.99	0.97	0.99	0.99	0.91	0.82	0.12

H_0: The time series data is non-stationary. It has a certain time-dependent structure and does not exhibit constant variance over time causing a biased examination.

H_1: The time series is stationary and appropriate for examining.

Table VIII-5-*Descriptive Statistics by Models and Currencies*

Model	Currency	Sample Size	Mean	Standard Deviation	Median	Min. Value	Max. Value	Range	Skewness	Kurtosis
Random Walk	CHF	*136*	*-5.16*	*3.59*	*-3.52*	*-13.41*	*-0.73*	*12.67*	*-0.83*	*-0.64*
	CZK	*136*	*-0.65*	*1.98*	*-0.20*	*-5.59*	*2.46*	*8.05*	*-0.95*	*0.06*
	EUR	*136*	*-4.49*	*3.59*	*-2.96*	*-12.20*	*0.15*	*12.35*	*-0.76*	*-0.87*
	GBP	*136*	*-3.90*	*3.24*	*-2.44*	*-12.61*	*0.85*	*13.46*	*-0.90*	*-0.44*
	PLN	*136*	*-1.50*	*1.71*	*-1.04*	*-6.41*	*1.63*	*8.04*	*-1.15*	*0.56*
	USD	*136*	*-3.73*	*2.99*	*-2.76*	*-11.30*	*1.78*	*13.08*	*-0.76*	*-0.52*
Mean-adjusted	CHF	*136*	*-3.75*	*3.59*	*-2.11*	*-12.00*	*0.68*	*12.67*	*-0.83*	*-0.64*
	CZK	*136*	*-0.29*	*1.98*	*0.16*	*-5.23*	*2.82*	*8.05*	*-0.95*	*0.06*
	EUR	*136*	*-3.85*	*3.59*	*-2.32*	*-11.55*	*0.80*	*12.35*	*-0.76*	*-0.87*
	GBP	*136*	*-3.39*	*3.24*	*-1.93*	*-12.11*	*1.36*	*13.46*	*-0.90*	*-0.44*
	PLN	*136*	*-0.98*	*1.71*	*-0.52*	*-5.89*	*2.15*	*8.04*	*-1.15*	*0.56*
	USD	*136*	*-3.22*	*2.99*	*-2.24*	*-10.79*	*2.30*	*13.08*	*-0.76*	*-0.52*
Market-adjusted	CHF	*136*	*-2.30*	*1.18*	*-2.15*	*-5.05*	*-0.43*	*4.62*	*-0.26*	*-1.08*
	CZK	*136*	*3.10*	*1.72*	*3.52*	*-0.05*	*5.96*	*6.01*	*-0.31*	*-1.30*
	EUR	*136*	*-1.51*	*1.21*	*-1.35*	*-3.57*	*0.22*	*3.79*	*-0.17*	*-1.42*
	GBP	*136*	*-0.79*	*0.84*	*-0.73*	*-4.86*	*1.12*	*5.98*	*-0.79*	*2.59*
	PLN	*136*	*2.09*	*1.83*	*1.54*	*-0.66*	*5.75*	*6.41*	*0.22*	*-1.42*
	USD	*136*	*-0.59*	*0.75*	*-0.63*	*-2.39*	*1.64*	*4.03*	*0.01*	*-0.28*
Market Model	CHF	*136*	*-1.49*	*1.26*	*-1.26*	*-4.40*	*0.42*	*4.83*	*-0.31*	*-1.07*
	CZK	*136*	*1.80*	*1.18*	*1.96*	*-0.33*	*4.10*	*4.43*	*-0.16*	*-1.03*
	EUR	*136*	*-1.71*	*1.38*	*-1.47*	*-4.11*	*0.21*	*4.32*	*-0.24*	*-1.43*
	GBP	*136*	*-1.12*	*0.95*	*-1.03*	*-5.46*	*0.41*	*5.88*	*-0.81*	*1.75*
	PLN	*136*	*0.52*	*0.95*	*0.26*	*-1.48*	*2.96*	*4.44*	*0.54*	*-0.51*
	USD	*136*	*-0.03*	*0.93*	*-0.11*	*-1.70*	*3.05*	*4.75*	*0.96*	*1.17*

Table VIII-6-*Normality Tests Results by Models and Currencies*

Model	Currency	*p-values*		
		Jarque-Bera test	Shapiro-Wilk test	Kolmogorov-Smirnov test
Random Walk	CHF	*<0.01*	*<0.01*	*<0.01*
	CZK	*<0.01*	*<0.01*	*<0.01*
	EUR	*<0.01*	*<0.01*	*<0.01*
	GBP	*<0.01*	*<0.01*	*<0.01*
	PLN	*<0.01*	*<0.01*	*<0.01*
	USD	*<0.01*	*<0.01*	*<0.01*
Mean-adjusted	CHF	*<0.01*	*<0.01*	*<0.01*
	CZK	*<0.01*	*<0.01*	*<0.01*
	EUR	*<0.01*	*<0.01*	*<0.01*
	GBP	*<0.01*	*<0.01*	*<0.01*
	PLN	*<0.01*	*<0.01*	*<0.01*
	USD	*<0.01*	*<0.01*	*<0.01*
Market-adjusted	CHF	*0,02*	*<0.01*	*<0.01*
	CZK	*<0.01*	*<0.01*	*<0.01*
	EUR	*<0.01*	*<0.01*	*<0.01*
	GBP	*<0.01*	*<0.01*	*<0.01*
	PLN	*<0.01*	*<0.01*	*<0.01*
	USD	*0,79*	*0,75*	*<0.01*
Market Model	CHF	*0,01*	*<0.01*	*<0.01*
	CZK	*0,04*	*<0.01*	*<0.01*
	EUR	*<0.01*	*<0.01*	*<0.01*
	GBP	*<0.01*	*<0.01*	*<0.01*
	PLN	*0,02*	*<0.01*	*<0.01*
	USD	*<0.01*	*<0.01*	*0,04*

***Figure VIII-2**-Distribution of the Abnormal Returns by Models and Currencies*

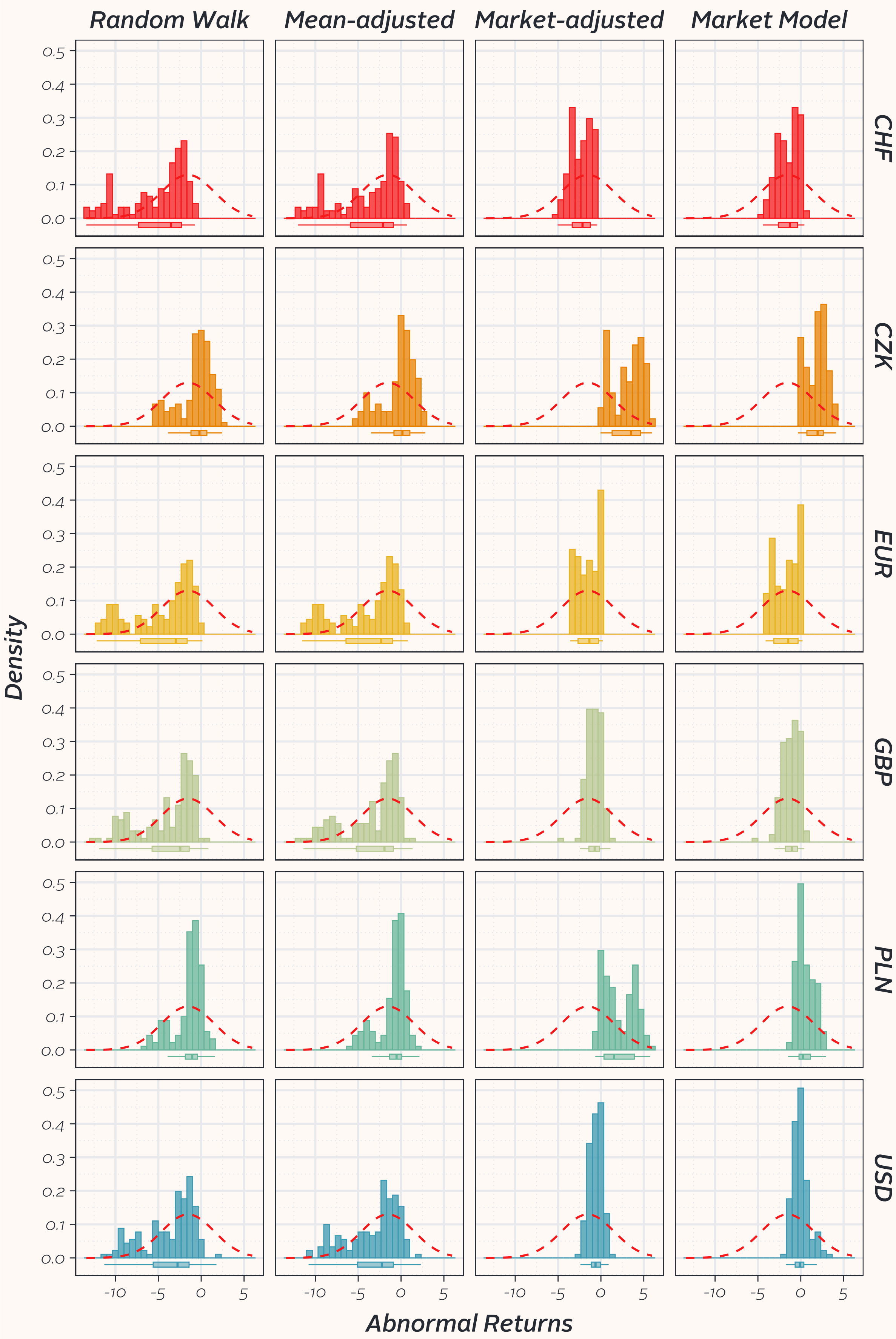


Table VIII-7-*Mean and Median Abnormal Returns for Robustness*

Statistics	*Mean with Standard Deviation*								
Model	**Event Days**								**Average AR**
	-3	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	
RW	*-2.43* (2.98)	*-2.78* (3.02)	*-2.47* (2.91)	*-2.72* (2.91)	*-3.49* (3.22)	*-3.36* (3.34)	*-3.43* (3.48)	*-3.39* (3.19)	*-3.01* (3.15)
MeA	*-1.75* (2.88)	*-2.11* (2.92)	*-1.79* (2.81)	*-2.05* (2.81)	*-2.82* (3.12)	*-2.69* (3.25)	*-2.76* (3.39)	*-2.72* (3.09)	*-2.34* (3.06)
MaA	*0.04* (2.32)	*0.01* (2.28)	*0.05* (2.42)	*0.00* (2.27)	*-0.01* (2.27)	*0.00* (2.26)	*0.01* (2.33)	*0.01* (2.33)	*0.01* (2.30)
MM	*-0.25* (1.67)	*-0.32* (1.61)	*-0.26* (1.74)	*-0.32* (1.61)	*-0.40* (1.59)	*-0.38* (1.52)	*-0.39* (1.59)	*-0.39* (1.56)	*-0.34* (1.61)

Statistics	*Median with Median Absolute Deviation*								
Model	**Event Days**								**Average AR**
	-3	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**	
RW	*-1.97* (2.43)	*-1.91* (2.28)	*-1.77* (2.45)	*-1.97* (2.02)	*-2.45* (2.30)	*-2.15* (2.10)	*-2.03* (2.42)	*-2.27* (2.23)	*-2.06* (2.19)
MeA	*-1.13* (2.16)	*-1.07* (1.81)	*-1.06* (2.29)	*-1.26* (1.74)	*-1.58* (1.98)	*-1.49* (1.89)	*-1.21* (2.16)	*-1.57* (1.96)	*-1.28* (1.87)
MaA	*-0.46* (1.56)	*-0.38* (1.60)	*-0.35* (1.83)	*-0.19* (1.57)	*-0.30* (1.81)	*-0.31* (1.58)	*-0.26* (1.72)	*-0.20* (1.65)	*-0.31* (1.69)
MM	*-0.31* (1.41)	*-0.21* (1.32)	*-0.32* (1.30)	*-0.28* (1.04)	*-0.33* (1.28)	*-0.22* (0.96)	*-0.24* (1.36)	*-0.21* (0.97)	*-0.26* (1.23)