Article

EUR/USD Exchange Rate Characterization: Study of Events

Jorge Carvalho [1,*], Gualter Couto [2] and Pedro Pimentel [2]

1   School of Business and Economics, University of Azores, 9500-321 Ponta Delgada, Portugal
2   School of Business and Economics and CEEAplA, University of Azores, 9500-321 Ponta Delgada, Portugal
*   Correspondence: 20187117@uac.pt

Abstract: This study aims to evaluate the impact of major and minor changes in the Euro Zone and US interest rates on the EUR/USD exchange rate between 1 January 1999 and 31 December 2020. Therefore, twelve events are analyzed in this period, five related to changes in the US interest rate, six related to changes in the European interest rate, and finally, a single event in which both interest rates undergo an equal variation on the same date. The event study methodology was used, which, through the calculation of abnormal returns, makes it possible to evaluate whether there was a repercussion of the events on the value of the EUR/USD exchange rate. This methodology is used in several studies related to capital markets. The obtained results prove that there are abnormal returns with statistical significance on the event days, and, on the days that follow, changes in the interest rates have an impact on the EUR/USD exchange rate; however, there is no clear direction of the asset after the events occur.

Keywords: US dollar; event study; euro; foreign exchange market; interest rates

1. Introduction

Currency exchange plays a fundamental role in everyday life, namely in the export and import of goods, when purchasing a service provider because we may be faced with a situation where the product/service to be purchased is not being sold in our currency.

According to Jansen and Haan (2005), the foreign exchange market is continually flooded with information. Currently, market participants are increasingly interested in understanding the economic effects on exchange rates, according to Sun et al. (2011).

This paper intends to study the impact of changes in the US and the Euro Zone interest rates on the EUR/USD exchange rate on the days of the events and on the days following them, to identify the ones that cause the greatest variation in the exchange rate, to verify whether greater fluctuations are correlated with greater variations in EUR/USD and seek to understand if there are differences in the asset response according to the performance of the European Central Bank or the US Federal Reserve. This study is important to clarify the reaction of the currency pair to changes in interest rates, and to warn investors of the directions that the market may take. Finally, the results are compared with the literature review. For this purpose, twelve events of interest rate changes were selected, occurring between 1 January 1999 and 31 December 2020.

To study the impact of changing interest rates on the EUR/USD exchange rate the event study methodology is applied, introduced in 1969 by Fama et al. (1969). According to Mushidzi and Ward (2004), the event study methodology is regularly used to observe statistically significant differences between normal and abnormal returns.

Many factors affect the exchange rate, this variable being one of the most volatile in the market; hence it is important to study and understand how the exchange market, namely the EUR/USD currency pair, reacts to changes in interest rates issued by central banks. Although monetary authorities seem to see intervention as an effective instrument of exchange rate policy (Neely 2000), there is skepticism among studies about intervention effectiveness to achieve the supposed goals (Nikkinen and Vahamaa 2009).

There is a greater reaction from the markets when central banks update the information on interest rates, and according to Bacchetta and Wincoop (2004), market participants give greater relevance to macroeconomic information; Beckmann et al. (2017) state that the exchange rate is to some extent driven by macroeconomic factors in the long run. Dominguez and Panthaki (2007) studied the impact of government interventions on the GBP/USD, JPY/USD, and EUR/USD currency pairs, concluding that there was a statistical significance that proves the effectiveness of these interventions on the GBP/USD and JPY/USD pairs, but not on the EUR/USD pair.

Many studies confirm that announcements related to the United States of America economy have a greater impact on exchange rates than economic announcements from the Euro Zone, Japan, Great Britain, and Switzerland, as we can analyze in Kuttner (2001), Kearns and Manners (2006), and James and Kasikov (2008). Engel et al. (2007) and Molodtsova and Papell (2009) concluded that macroeconomic news helped to understand the direction of exchange rates. Clostermann and Schnatz (2000) identified GDP, interest rates, fiscal deficits, and oil prices as variables that influence the price of the euro–dollar exchange rate. These results were confirmed by Maeso-Fernandez et al. (2001) and by Alquist and Chinn (2002). According to the study by Apergis et al. (2012) the European Central Bank and the American Federal Reserve, by adjusting their monetary policies and interest rates, can influence the value of the EUR/USD exchange rate.

Changes in interest rates and monetary policies have a major impact on the foreign exchange market, which is why most studies carried out in this area are closely related to central banks' communication. In a study carried out by Conrad and Lamla (2010), they investigated the impact of monetary policy and European Central Bank press conferences on EUR/USD and concluded that, when the interest rate information is made available and the press conference is held, these had significance in the first thirty minutes, appreciating or depreciating the euro against the dollar. These results were also confirmed by Kearns and Manners (2006) and Faust et al. (2007). Studies by Chaboud and Humpage (2005), Kearns and Rigobon (2005), and Nikkinen and Vahamaa (2009) identified that the central bank's actions are more effective in the short term, given that there is a greater correlation between the change in the interest rate and the exchange rate on the first day of intervention and which declines on the following days.

During press conferences, statements regarding inflation are also released, which give rise to variations in EUR/USD. If inflation is high, banks can intervene by applying interest rates higher than those in force to correct the value of inflation, that is, inflation affects the exchange rate of the euro with the dollar. This situation is confirmed by studies by Engel and West (2006) and by Clarida and Waldman (2008), arguing that a country's currency should appreciate in response to an inflation rate that was not foreseen.

Regarding the adopted methodology, the following research questions about the study arise:

1. Is there an impact of interest rate changes on the EUR/USD exchange rate on the days of the event? And in the days following the event?

2. Do interest rate changes cause more significant abnormal returns for a five-day event window or a ten-day event window? What can you conclude?

3. What events led to higher positive and negative abnormal returns?

4. Does the decrease in the interest rate in the US implies that the EUR/USD exchange rate always increases its value for the day of the event?

5. When interest rates in the Euro Zone and the US, on the same day, suffer the same reduction (event 12), what conclusion can you draw?

6. Do greater variations in the Euro Zone interest rate mean greater variation in the EUR/USD exchange rate compared to smaller variations in the same interest rate?

7. From the studied events 1 to 11, in which only one interest rate is changed, is it possible to infer that changes in the US interest rate have a greater impact on EUR/USD than changes in the Euro Zone interest rate or the reverse?

The study is organized as follows: Methodology, where the applied methodology for studying the events is described; as well as the data and description of these events, the calculations, and the statistical tests to be applied. The next chapter, Results, consists of a presentation and discussion of the findings. Finally, in the Conclusion, the outcomes of the study, the applied methodology, and possible suggestions for future investigations are presented.

2. Methodology

Through the event study, which is based on a series of observed returns before the occurrence of a given event, the expected return for the EUR/USD that would have been observed if the event did not exist is calculated. After determining the supposed normal returns, it is compared with the effects observed on the returns of the EUR/USD exchange rate, verifying whether there was evidence that changes in interest rates had an impact on the values presented by the EUR/USD.

For this study, the average adjusted return model is used, according to Chen and Siems (2004).

It is critical to delineate the estimation window and the event window. The time unit will be defined in days. The estimation window corresponds to the period in which the normal performance of the EUR/USD exchange rate pair is quantified, while the event window corresponds to the period in which it is intended to observe the evolution of the EUR/USD exchange rate pair, to identify possible abnormal returns.

The event window ranges from $[-x; t_0; +y]$ where t_0 is the day of the announcement, by the European Central Bank or the Federal Reserve, of the change in the interest rate value.

For this study, two event windows were operated, one with 11 days $[-5; 0; +5]$ and another with 21 days $[-10; 0; +10]$. An event window with five days before and after the event is established because a too-large window can lead to the inclusion of effects from other events in the same period. The ten-day window is used because some events have later effects. The estimation window, composed of the 300 days before the event window, should not overlap the event window so that normal returns are not influenced by abnormal returns surrounding the event, according to Campbell et al. (1997). This fact helps to prevent the parameters from being influenced by the event.

The events focus on different situations giving rise to twelve event dates, five related to changes in the US interest rate, six related to changes in the Euro Zone interest rate, and one event in which the two interest rates are changed on the same day. It should be noted that this event only occurs once in the period studied. Only the moments in which the interest rate suffers the greatest and smallest historical differences are studied.

For better understanding, the Eurozone interest rate is defined by TJE, and the interest rate in the United States of America by TJA. The dates of events related to changes in the US interest rate are as follows:

- Event 1—16 March 2020, the communication date takes place on 15 March 2020; however it corresponds to a Sunday and the market is closed, so the event date changes to Monday. The rate fell by 1.00%, with TJA = 1.25% till the event date and TJA = 0.25% after the event. The Federal Reserve announces the reduction of the interest rate to close to zero values, with an emergency action to protect the economy from the impact of the coronavirus outbreak (source: The Washington Post 2020).
- Event 2—22 January 2008, the TJA suffered a decrease of 0.75%, with TJA = 4.25% until the event date and TJA = 3.50% after the event. The Federal Reserve, concerned about the constant weakening of the economy and turmoil in the financial markets, acted by reducing the interest rate (source: CNN Money 2008b).
- Event 3—18 March 2008, the TJA fell by 0.75%, TJA = 3.00% till the event date and TJA = 2.25% after the event. The FED reduced interest rates to restore confidence in the US economy. Investors supported this decision because it showed that the

US Federal Reserve is constantly worried about the country's recession and inflation (source: CNN Money 2008a).

- Event 4—16 December 2008, the TJA fell by 0.75%, with TJA = 1.00% till the event date and TJA = 0.25% after the event date. Again, to stimulate the US economy, after the great economic recession in 2008, the Federal Reserve reduced the rate to record levels and claimed to keep very low rates for an extended period (source: CNN Money 2008c).

- Event 5—16 May 2000, the TJA increased by 0.50%, with TJA = 6.00% till the event date and TJA = 6.50% after the event. The interest rate rose to slow the pace of the US economy to ensure that the prices of goods and services do not soar, reducing inflation (source: CNN Money 2000).

The events related to changes in the Eurozone interest rate are presented below:

- Event 6—4 December 2008, the TJE suffered a decrease of 0.75%, with TJE = 3.25% till the event date and TJE = 2.50% after the event. The ECB reduced the interest rate to provide liquidity to reduce financial markets tension (source: European Central Bank 2008).

- Event 7—10 March 2016, the TJE fell by 0.05%, with TJE = 0.05% till the event date and TJE = 0.00% after the event. To maintain the liquidity of the financial markets, the interest rate is reduced, on this date (source: European Central Bank 2016).

- Event 8—5 June 2014, the TJE suffered a decrease of 0.10%, with TJE = 0.25% till the event date and TJE = 0.15% after the event. This change is intended to provide a permanent liquidity facility (source: European Central Bank 2014).

- Event 9—4 September 2014, the TJE suffered a decrease of 0.10%, with TJE = 0.15% till the event date and TJE = 0.05% after the event. The European Central Bank unexpectedly cut interest rates to stimulate economic growth and avoid a threat of deflation (source: Bloomberg 2014).

- Event 10—1 December 1999, the TJE increased by 0.50%, with TJE = 2.50% till the event date and TJE = 3.00% after the event. The increase in the interest rate helped to prevent an increase in inflation in Europe (source: European Central Bank 1999).

- Event 11—3 July 2000, the communication date occurs on 1 July 2000, however it corresponds to a Saturday and the market is closed, so the event date is changed to Monday. The rate increased by 0.50%, with TJE = 3.75% till the event date and TJE = 4.25% after the event, to prevent the prices of products and services from increasing (source: European Central Bank 2000).

Finally, the event that occurs when the two rates change on the same day is presented:

- Event 12—8 October 2008, in which the TJE and the TJA reduce their value by 0.50%, and for the TJE until the date of the event was TJE = 4.25% and after the event was TJE = 3.75%, and for the TJA until the event date was TJA = 2.00% and after the event was TJA = 1.50%. Throughout the 2008 crisis, the central banks remained in cooperation and took joint actions, maintaining the liquidity of the financial markets with the reduction of interest rates (sources: CNN Money 2008d and European Central Bank 2008).

In Table 1, the events are summarized (the third column identifies which central bank is acting, whether the FED, related to the US, or the ECB, related to the Euro Zone), TJ_i represents the interest rate before the event occurs, TJ_f the interest rate after the event, and finally, $TJ_f - TJ_i$ the rate change difference.

Table 1. Event description.

Event	Date	ECB/FED	TJi	TJf	TJf-Tji
Event 1	16 March 2020	FED	1.25%	0.25%	−1.00%
Event 2	22 January 2008	FED	4.25%	3.50%	−0.75%
Event 3	18 March 2008	FED	3.00%	2.25%	−0.75%
Event 4	16 December 2008	FED	1.00%	0.25%	−0.75%
Event 5	16 May 2000	FED	6.00%	6.50%	0.50%
Event 6	04 December 2008	ECB	3.25%	2.50%	−0.75%
Event 7	10 March 2016	ECB	0.05%	0.00%	−0.05%
Event 8	05 June 2014	ECB	0.25%	0.15%	−0.10%
Event 9	04 September 2014	ECB	0.15%	0.05%	−0.10%
Event 10	01 December 1999	ECB	2.50%	3%	0.50%
Event 11	03 July 2000	ECB	3.75%	4.25%	0.50%
Event 12	08 October 2008	ECB	4.25%	3.75%	−0.50%
		FED	2.00%	1.50%	

The calculation of daily returns is performed according to Equation (1). The logarithmic calculation Equation (1) is the most suitable since it is intended to use parametric tests and this formula allows a symmetrical distribution, while the discrete formula presents asymmetry in the returns calculated.

$$R_t = \ln(P_t) - \ln(P_{t-1}) \tag{1}$$

where R_t is the real return (or normal return) of the EUR/USD exchange rate, on day t, P_t refers to the EUR/USD exchange rate, on day t, and P_{t-1} is the EUR/USD exchange rate, the day before t.

After calculating the normal daily returns (1), the abnormal returns are calculated (2) for the day of the event and the days of the event windows, according to the average adjusted returns model, since we are assuming that the average return on the exchange price is constant over time.

$$A_t = R_t - \overline{R} \tag{2}$$

where A_t represents the abnormal return of the EUR/USD exchange rate, at time t, R_t is the normal return of the EUR/USD exchange rate, at time t, and $\overline{R}$ is the average adjusted return.

$\overline{R}$ is calculated according to Equation (3). For this calculation, an estimation window of 300 days is considered, from $t = -305$ to $t = -5$, for an event window of 5 days, and $t = -310$ up to $t = -11$, for an event window with 10 days, both regarding the event date $t = 0$. In this way, the expected value for the return of the EUR/USD currency pair results from an arithmetic average of its past returns.

$$\overline{R} = \frac{1}{300} \sum_{t=-x-1}^{-x-300} R_t \tag{3}$$

To analyze the significance of the parameters associated with the explanatory variables, the Student's t-test is used, which assumes that the variable under study has a normal distribution with constant variance, according to the study by Róias (2018).

To test the null hypothesis, confidence intervals of 99%, 95%, and 90% will be used, which correspond to significance levels of 1%, 5%, and 10%, respectively. Then it is necessary to remove the critical t values present in the Student's t distribution table. According to the estimation window, the number of degrees of freedom will be 300 minus 1 unit, that

is, 299 degrees of freedom. According to the distribution table, we obtain the critical *t* values 2.576, 1.960, and 1.645, for the significance levels of 1%, 5%, and 10%, respectively. In this way, whenever the calculated *t* value is higher or lower than its inverse, for each significance level, there is statistical evidence to reject the null hypothesis.

The test for the null hypothesis is calculated between the abnormal return on the day of the event and the standard deviation of the estimation window, that is:

$$t_{AR} = \frac{A_0}{\sigma_{A_t}} \tag{4}$$

To calculate Equation (4), it is necessary to calculate the value of the standard deviation of the estimation window, which is calculated as follows:

$$\sigma(A_t) = \sqrt{\frac{\sum_{t = -x-1}^{-x-300} (A_t - \overline{A})^2}{n-1}} \tag{5}$$

where $n-1$ represents the number of degrees of freedom calculated through the size of the estimation window. In this case, the estimation window has a total of 300 days, so the value of $n-1$ is 299.

According to the objective defined for the event date, the following null hypothesis is tested:

H0: *The abnormal return on the day of the event is equal to zero and, therefore, there was no immediate impact of the event on the EUR/USD currency pair*;

H1: *The abnormal return for the day of the event is non-zero.*

To analyze the event windows $t = +5$ and $t = +10$, the cumulative abnormal return (CAR) is calculated through Equation (6), given by:

$$CAR_t = \sum_{t = 0}^{y} A_t \tag{6}$$

where CAR_t is the cumulative abnormal return at time t, that is, it will be the sum of the abnormal returns from the date of the event to the fifth and tenth days after the event.

The statistical test for the null hypothesis consists of the ratio between the CAR_t value obtained in Equation (6) and the standard deviation value, represented in the following equation:

$$t_{CAR} = \frac{CAR_t}{\sigma_{CAR_t}} \tag{7}$$

To calculate the standard deviation, the following formula is used:

$$\sigma_{CAR_t} = \sqrt{Z \times \sigma_{A_t}^2} \tag{8}$$

In Equation (8), Z corresponds to the total of abnormal returns applied to the sum of the cumulative abnormal returns values. For this case, Z assumes the values of 6 and 11, one day referring to the day of the event and the others referring to the days of the event windows, after the event date.

According to the objective defined for the event window, the following null hypothesis is tested:

H0: *The abnormal return for the days following the event is equal to zero and, therefore, there was no impact of the event on the EUR/USD currency pair*;

H1: *The abnormal return of the days following the event is non-zero.*

3. Results

EUR/USD data were obtained through the Official Investing platform (Fusion Media Limited 2007–2022a), with a data window from 1 January 1999 to 31 December 2020. Announcements for interest rates from the United States of America and the Euro Zone were also obtained from the same platform (Fusion Media Limited 2007–2022b, Fusion Media Limited 2007–2022c). Regarding the exchange quotes, the daily closing quotes for the currency pair under study were selected.

The normal returns related to the day of the event, at the closing date of the daily quotes, implied some variations in the results. Note that, in these twelve events, there were five variations over 1.00% and −1.00% on the event date. Events 2, 4, and 7 reacted positively to EUR/USD, with returns of 1.25%, 2.79%, and 1.61%, respectively. Thus, on these event dates the euro was valued compared to the US dollar. Variations below −1.00% were obtained in two events, for events 5 and 9, with the respective values of −1.25% and −1.58%. In this way, the US dollar was valued compared with the euro. For the moment t_5, that is, for the fifth day after the event date, five events obtained normal positive cumulative returns greater than 1.00% and three negative cumulative normal returns below −1.00%. The positive cumulative normal returns were in events 2, 4, 6, 7, and 10, with results of 2.27%, 1.81%, 4.94%, 2.87%, and 1.79%, respectively. In this way, the euro increased its value when compared to the US dollar in these five days after the event, plus the date of the event. The remaining three events, 1, 9, and 12 obtained negative variations below −1.00% of −3.51%, −1.73%, and −1.17%. Thus, the dollar overvalued itself to the euro. Regarding the t_{10} period, for the positive cumulative returns of more than 1.00% the events occurred as t_5 except event 10 which now has a cumulative value of −0.17%, and event 5 which became more than 1.00%, changing from −0.44% to 1.99%. For the other events, namely events 2, 4, 6, and 7, normal returns are 1.33%, 2.59%, 11.12%, and 1.58%, respectively. Note that 11.12% was the largest variation obtained in all the results with positive variations greater than 1,00%. For the events with negative variation, less than −1,00%, they have values of −1.75%, −1.69%, and −5.78%—events 9, 11, and 12, respectively. Event 12 at moment t_{10} has the highest negative variation of −5.78%.

In Table 2, the twelve events and their respective dates are presented. In columns 3, 4, and 5 are calculated the normal returns for the event day, the normal cumulative returns until the fifth day after the event and the normal cumulative returns until the tenth day after the event, in proper order.

Table 2. Summary of normal returns calculated for t_0, t_{+5} e t_{+10}.

Event	Date	Rt (%)	Rt5 (%)	Rt10 (%)
Event 1	16 March 2020	0.69	−3.51	−0.52
Event 2	22 January 2008	1.25	2.27	1.33
Event 3	18 March 2008	−0.66	0.73	−0.26
Event 4	16 December 2008	2.79	1.81	2.59
Event 5	16 May 2000	−1.25	−0.44	1.99
Event 6	04 December 2008	0.44	4.94	11.12
Event 7	10 March 2016	1.61	2.87	1.58
Event 8	05 June 2014	0.45	−0.34	0.07
Event 9	04 September 2014	−1.58	−1.73	−1.75
Event 10	01 December 1999	−0.11	1.79	−0.17
Event 11	03 July 2000	−0.23	0.28	−1.69
Event 12	08 October 2008	0.08	−1.17	−5.78

However, according to the methodology presented, to assess the impact of changes in interest rates on the EUR/USD exchange rate, it is necessary to analyze abnormal returns. The study will take place in three distinct phases: first, an analysis of the abnormal returns and statistical significance for the days of the events (t_0) is carried out, then the cumulative abnormal returns and their significance for the following five days, after the event date and the event date (t_{+5}), are investigated, and finally, the cumulative abnormal returns and their significance for the following ten days and the event date (t_{+10}) are examined.

Table 3 shows the results obtained for the event days (t_0) about abnormal returns and t values. Its statistical significance is also presented according to the test mentioned in the methodology. It should be noted that events can be significant at different levels of significance, 1%, 5%, and 10%.

Table 3. Abnormal returns, t value, and statistical significance for t_0.

Event	Date	Ai (%)	t	Statistically Significant
Event 1	16 March 2020	0.70	2.253	Yes, to 5%
Event 2	22 January 2008	1.20	3.013	Yes, to 1%
Event 3	18 March 2008	−0.71	−1.643	No
Event 4	16 December 2008	2.83	3.597	Yes, to 1%
Event 5	16 May 2000	−1.19	−1.880	Yes, to 10%
Event 6	04 December 2008	0.47	0.622	No
Event 7	10 March 2016	1.64	2.206	Yes, to 5%
Event 8	05 June 2014	0.43	1.069	No
Event 9	04 September 2014	−1.58	−4.507	Yes, to 1%
Event 10	01 December 1999	−0.05	−0.080	No
Event 11	03 July 2000	−0.20	−0.294	No
Event 12	08 October 2008	0.06	0.100	No

As described in the previous chapter, for an event to have statistical significance, the calculated t value must be greater than the critical t value or inferior to its inverse, for the different levels of significance of 1%, 5%, and 10%. For each of these cases, and in the same order, the critical t assumes the value of 2.576, 1.960, and 1.645.

Although abnormal returns vary between negative and positive values, which indicates that one currency has lost or increased value to the other, it is necessary to verify the statistical significance of the results to study the event's impact on the EUR/USD currency pair.

According to the obtained results, 50% of them were significant, although at different levels of significance. For events 2, 4, and 9, the null hypothesis that the abnormal returns are equal to zero for a significance level of 1% is rejected. Thus, it is stated that these events had a significant impact on the value of the EUR/USD. Thus, changes in US interest rates for events 2 and 4 caused a significant positive change in the value of the exchange rate pair. Thus, it is suggested that the euro has appreciated against the US dollar, but it should be noted that in both the interest rate decreases by 0.75%. Event 4 represents the event for which the positive abnormal return had the maximum value of 2.83%. For event 9, the change in the Euro Zone interest rate caused a decrease in the value of the asset. As a result, the value of the US dollar was overvalued against the euro. In this event, the interest rate in the Euro Zone decreased by 0.10%, this being the event with the highest negative abnormal return of −1.58%. Regarding events 1 and 7, these were significant for a significance level of 5%, thus rejecting the null hypothesis that abnormal returns are equal to zero, so it is concluded that changes in interest rates caused an impact on the value of the EUR/USD exchange rate. In both events, there was a reduction in the interest rate. For event 1, the US

rate was reduced by 1% and for event 7 the Euro Zone rate was reduced by 0.05%. In both situations, the euro increased its value against the US dollar asset's value increased.

Finally, event 10 generated a significant negative abnormal return at 10%, suggesting that there is statistical evidence to reject the null hypothesis. As it generated a negative abnormal return, the US dollar appreciated against the euro. The other results indicate that the event did not change the EUR/USD exchange rate on the day of the event, at least in a statistically significant way for the 1%, 5%, and 10% significance levels.

After studying the significance of the same-day event effect on the EUR/USD currency pair, it is necessary to establish whether the event has a longer effect on the asset under study. Thus, for a sixth-day CAR (the day of the event plus the five days after the event), the cumulative abnormal returns and their statistical significance for the twelve events under analysis are presented in Table 4.

Table 4. Abnormal returns, *t* value, and statistical significance for t_{+5}.

Event	Date	Ai (%)	t	Statistically Significant
Event 1	16 March 2020	−3.44	−4.503	Yes, to 1%
Event 2	22 January 2008	1.98	2.023	Yes, to 5%
Event 3	18 March 2008	0.44	0.422	No
Event 4	16 December 2008	2.04	1.060	No
Event 5	16 May 2000	−0.11	−0.070	No
Event 6	04 December 2008	5.14	2.761	Yes, to 1%
Event 7	10 March 2016	3.06	1.682	Yes, to 10%
Event 8	05 June 2014	−0.45	−0.460	No
Event 9	04 September 2014	−1.72	−2.006	Yes, to 5%
Event 10	01 December 1999	2.16	1.487	No
Event 11	03 July 2000	0.47	0.281	No
Event 12	08 October 2008	−1.30	−0.896	No

Thus, according to the previous table, 41,67% of the results are statistically significant, with two of the results being significant at 1%, two at 5%, and one at 10%. It is worth noting that of the seven events that are not statistically significant, three of them (events 4, 10, and 12) show a variation greater than 1% in the abnormal return calculation for the five days after the event date. This may indicate that before the event occurred, investors already anticipated that these same events could have a large effect on the timing of their occurrence, hence the fact that in the days before these three events there are already large fluctuations in the value of EUR/USD.

For events 1 and 6, the null hypothesis that the abnormal return for the days following the event is equal to zero is rejected. Thus, there is statistical evidence to state that the change in interest rates caused changes in the value of EUR/USD to a significance level of 1%. Thus, for event 1, after a reduction in the US interest rate of 1%, the US dollar appreciated compared to the euro, having obtained the highest negative cumulative abnormal return of −3.44%. On the other hand, for event 6, there was a reduction in the interest rate in the Euro Zone of 0.75%, and thus the euro increased its value when compared to the dollar, with the highest positive abnormal return of 5.14%. Regarding events 2 and 9, these are statistically significant for a significance level of 5%, so the change in the interest rate was responsible for the change in the EUR/USD exchange rate. In event 2, the US interest rate was changed from 4.25% to 3.50%, a reduction of 0.75%, and with this change, the euro increased its value compared to the US dollar, observing an abnormal return of 1.98%. Event 9 is characterized by a reduction in the Euro Zone interest rate from 0.15% to 0.05% and, therefore, with an abnormal return of −1.72%, which shows that the US dollar appreciated compared to the euro regarding this event. Finally, event 7 is statistically significant for a significance level

of 10%, rejecting the null hypothesis that abnormal returns are equal to zero. It is concluded that the EUR/USD exchange rate was affected by the change in the interest rate, in this case, the Euro Zone interest rate was reduced by 0.05%, this is, from 0.05% to 0.00%.

After analyzing the cumulative abnormal returns and significance for the event day and the five days after the event, the same study is also carried out for the event day and the following ten days to capture the effects that occur later. The results of this same analysis are shown in Table 5.

Table 5. Abnormal returns, *t* value, and statistical significance for t_{+10}.

Event	Date	Ai (%)	t	Statistically Significant
Event 1	16 March 2020	−0.39	−0.379	No
Event 2	22 January 2008	0.80	0.608	No
Event 3	18 March 2008	−0.79	−0.558	No
Event 4	16 December 2008	3.01	1.154	No
Event 5	16 May 2000	2.59	1.233	No
Event 6	04 December 2008	11.49	4.558	Yes, to 1%
Event 7	10 March 2016	1.92	0.782	No
Event 8	05 June 2014	−0.13	−0.101	No
Event 9	04 September 2014	−1.74	−1.498	No
Event 10	01 December 1999	0.51	0.259	No
Event 11	03 July 2000	−1.35	−0.600	No
Event 12	08 October 2008	−6.01	−3.058	Yes, to 1%

From the previous table only two of the twelve events, events 6 and 12, are statistically significant, and both at a significance level of 1%. Thus, there is statistical evidence to reject the null hypothesis that the abnormal returns for the following ten days are equal to zero. Therefore, there is an impact on the EUR/USD exchange due to the change in interest rates, for a significance level of 1%. For event 6, the interest rate in the Euro Zone fell by 0.75%, and the highest positive cumulative abnormal return of 11.49% was observed. In this way, the value of the asset has increased, that is, with fewer euros, more US dollars are bought. For event 12, the event in which both interest rates are reduced on the same day by 0.50%, the highest negative cumulative abnormal return of −6.01% was obtained. Thus, the dollar appreciated when compared to the euro.

According to the obtained results, it is stated that there is an impact on the EUR/USD exchange due to changes in interest rates, both in the USA and in the Euro Zone, for the event days, and for the days that make up the event window. These results are also mentioned in the study by Apergis et al. (2012), which ensures that the American Federal Reserve and the European Central Bank can affect the EUR/USD exchange rate by changing interest rates. The same study also adds that the ECB has a disadvantage compared to the US Federal Reserve, as Euro Zone countries do not share the same fiscal policy. Comparing the two event windows of five and ten days, it is proved that the variations in interest rates have more significance in the fluctuations of the EUR/USD for the five-day window, in which 41.67% of the events are statistically significant than for the ten-day event window, in which only 16.67% of the events are statistically significant. Thus, it can be deduced that changes in the EUR/USD exchange rate suffer greater differences in abnormal returns for a shorter period. Thus, it is assumed that changes in interest rates imply greater changes in the exchange rate for a shorter period, these results are in accordance with the studies by Chaboud and Humpage (2005); Kearns and Rigobon (2005); and Nikkinen and Vahamaa (2009).

For the events studied in which only the US interest rate is reduced, events 1 to 4, it is concluded that, for statistically significant abnormal returns, the EUR/USD exchange

rate increases in value whenever the US rate is reduced. These results are in line with the fact that, in general, when an interest rate in a given economy rises, the currency of that economy appreciates to the currencies of other economies.

Regarding event 12, being a unique event in the history of the EUR/USD exchange, it will be hasty to draw any conclusions from the results. However, with the simultaneous drop in interest rates by the same amount, it is observed that the US dollar appreciates when compared to the euro, something that may be related to the greater circulation of US dollars in the world market compared to the euro.

Regardless of whether the Euro Zone interest rate undergoes greater or lesser changes, statistically significant returns are observed in both cases, fluctuating in a diversified way in the EUR/USD exchange rate. Thus, the fact that the interest rate changes, with more or less amplitude, does not correlate with the fact that the EUR/USD varies more or less its value. In this way, it is assumed that each change in interest rates is inserted in different scenarios and different periods.

Regarding the question about which of the rates causes more abnormal returns, statistically significant, in the currency pair, it appears that, in general, both have the same effect, since for the event day, four events related to variations in the US interest rate, while for the Euro Zone there are only two. For the event windows of five and ten days, there are two returns relative to the US interest rate and four to the Euro Zone interest rate. It should be noted that in event 6 there is the highest abnormal return observed, 11.49% for a ten-day event window, which is associated with a change in the Euro Zone interest rate, in which it was reduced by 3.25% to 2.50%. These results are not in agreement with those obtained in studies by Kuttner (2001); Kearns and Manners (2006); and James and Kasikov (2008), where it is observed that advertisements related to the US economy have a greater impact on exchange rates than on economic announcements from the Euro Zone, Japan, Great Britain, and Switzerland.

4. Conclusions

This study allows us to conclude that there is a significant impact of changes in US and Euro Zone interest rates on the EUR/USD exchange rate, although the results are discrepant in terms of the exchange rate fluctuation pattern. Therefore, there is no specific correlation, but in turn, there is a greater probability that a given movement in the EUR/USD exchange will occur, Apergis et al. (2012) claims that both central banks, the European Central Bank and the American Federal Reserve, can influence the EUR/USD exchange rate by adjusting their monetary policies and changing interest rates. The results found are also in agreement with the studies by Clostermann and Schnatz (2000); Maeso-Fernandez et al. (2001); and Alquist and Chinn (2002) who identified that GDP, fiscal deficits, oil prices, and interest rates are macroeconomic indicators that influence the EUR/USD exchange rate. On the other hand, Engel et al. (2007) and Molodtsova and Papell (2009) concluded that macroeconomic news helped to understand the direction of exchange rates, something that was not possible to observe with the results obtained in this study.

According to the results found in this study, it appears that the abnormal returns for t_0, t_{+5}, and t_{+10} are statistically significant in 50%, 41.67%, and 16.67% of the events, in this order. Thus, there is a decrease in the significance of the results, so the impact of interest rate changes by central banks has a more immediate effect over time. This analysis is in line with the result obtained by Nikkinen and Vahamaa (2009), in which they state that central bank interventions temporarily increase the implicit correlations in the EUR/USD, JPY/USD, and GBP/USD exchange rates, since correlations are more significant on the first day of the intervention, and decline on the following days, that is, central banks actions are more effective in the short term. These results are also consistent with the studies by Chaboud and Humpage (2005) and Kearns and Rigobon (2005).

The event study methodology based on the calculation of abnormal returns and their statistical significance through a Student's *t*-test can be applied to several studies in the stock market area. However, for better efficiency of its application, it is necessary to assess

whether the variable we are studying is impacted by the other or other variables, that is if there is the relevance of the event in the asset under study.

According to Róias (2018), the event study methodology depends on the assumption of an efficient market, and this assumption is not valid in several situations. In this way, the abnormal returns of a certain event can be associated with a long period, which can change the values of the abnormal returns. However, a cumulative abnormal returns analysis was made to overcome this situation. In the study by Brown and Warner (1985) it is shown that the models present in the event study methodology have a similar performance, that is, the average adjusted return (applied in this study), market adjusted return, and risk and market adjusted. The identification of the estimation window and the event window in a subjective way gives rise to different results, and in this study, an estimation window with 300 days was applied because it was the window that gave the best results. Since, in this study, the adjusted to mean return method was used, it makes sense to apply a window with a greater number of days, to obtain an average with a significant number of returns in a short period.

Finally, since it is not possible to consider only the interest rate change effect on the EUR/USD exchange rate may harm or strengthen the obtained results, as changes in interest rates do not only occur when the central banks intervene. Other macroeconomic indicators are communicated, as well as other changes in the monetary policy of some economies. However, despite the mentioned limitations, the event study methodology is often used in research, as it can detect abnormal returns through a simple model (Róias 2018).

With the relevant results obtained in this study, it is suggested to analyze whether changes in other economic indicators, such as inflation, GDP, unemployment rate, as well as the price of oil, influence the EUR/USD exchange rate, or other currency pairs. Given that the work produced serves to report and study the evolution of the EUR/USD exchange rate to the interest rate variations that actually occurred, it is proposed that, for future investigations, the marginal effects on the exchange rate returns are studied using linear regression.

Finally, it is proposed to carry out a study of the global impact of the SARS-COV-2 COVID-19 pandemic on the different currency pairs.

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