Deree

School of Business and Economics

THE AMERICAN COLLEGE OF GREECE

Pierce

Deree

Alba

1875

Divergent Paths, Convergent Destinations: Analyzing the Economic Integration of Non-Euro Countries with the Euro Area

Rafailia-Argyro Mylona,

Department of Economics, Deree – The American College of Greece

EC4980 Dissertation in Economics

Supervisor: Dr. Nikolaos Stoupos

Spring Semester 2023

Abstract

The European sovereign debt crisis of the past decade has rekindled the researchers' interest in exploring the integration of non-Euro countries with the Euro Area. The Euroscepticism that followed the crisis has led to only 4 new members in the Eurozone since the early 2010s. For this reason, this study examines the integration of 8 non-Euro countries with the Euro Area and the existence of a leverage effect. These countries, in alphabetical order, are Croatia, Czechia[1], Hungary, Poland, Romania, Sweden, Switzerland, and the UK. This approach to this subject results in an ECM-TGARCH model. The data employed are daily, excluding weekends and bank holidays, nominal exchange rates expressed versus the dollar ranging from January 1st, 2002, to December 31st, 2022. The empirical findings of the study indicate that Czechia, Poland, and Switzerland could join the Eurozone, whereas Hungary, Romania, Sweden, and the UK could not. Croatia, the most recent Eurozone member, has only become integrated with the Euro Area after 2018 when it was actively trying to fulfill the convergence criteria. As for the volatility asymmetry, it was only present in the case of Switzerland. With several non-Euro, EU nations remaining to adopt the euro, it is worth examining the reasons why they are skeptical and address potential issues that jeopardize the unity of the Eurozone.

Keywords: Economic integration, ECM, threshold GARCH, Euro Area, EU, exchange rates

JEL Classification: C13, F31, G15

[1] Since May 17th, 2016, the official short name of the Czech Republic at the United Nations in English is Czechia (*UNTERM*, no date).

Table of Contents

Table of Figures

List of Abbreviations

Abbreviation	Definition
ADF	Augmented Dickey-Fuller
ARCH	Autoregressive Conditional Heteroskedastic
CEE	Central and Eastern European
EC	European Community
ECB	European Central Bank
ECM	Error Correction Model
ECT	Error Correction Term
EFTA	European Free Trade Association
EMU	European Monetary Union
ERM	Exchange Rate Mechanism
EU	European Union
GARCH	Generalized Autoregressive Conditional Heteroskedastic
GPPP	Generalized Purchasing Power Parity
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
OCA	Optimum Currency Area
OLS	Ordinary Least Squares
RLS	Robust Least Squares
SSM	Single Supervisory Mechanism
SVECM	Structural Vector Error Correction Model
TGARCH	Threshold Generalized Autoregressive Conditional Heteroskedastic

Acknowledgements

I would like to express my heartfelt gratitude to several individuals who have played a pivotal role in the successful completion of my B.A. Dissertation in Economics. Their guidance, support, and expertise have been invaluable throughout this academic journey.

First, I would like to thank my supervisor, Dr. Nikolaos Stoupos, for introducing me to the field of applied international economics, broadening my econometrics skills, and encouraging me to expand my knowledge on the topic.

I would also like to extend my gratitude to three exceptional economics professors who have made a profound impact on my academic and personal development. Professor Dimitris Doulos, not only as a professor but also as an advisor throughout my studies, has provided me with invaluable guidance, constructive feedback, and opportunities to broaden my understanding of economics and, especially, international economics. Your commitment to fostering a stimulating and engaging academic environment is greatly appreciated. Additionally, I would like to express my heartfelt gratitude to Professor Anna Giannopoulou-Merika. On top of your unwavering faith in your students' capabilities, your continuous support for research initiatives combined with your scholarly prowess have shown me the significance of academic engagement beyond the classroom. Last but not least, I am deeply thankful to Professor Annie Triantafillou who also serves as the Dean of the School of Business and Economics. Your leadership and dedication to the academic community have been a source of inspiration for me. Most importantly, your unwavering support for students' academic and personal endeavors is evident, and I am more than grateful for your insightful feedback and the opportunities you have provided me during my undergraduate years.

Finally, I am indebted to my family and friends for their unwavering encouragement, love, and understanding. Their support has been a constant source of motivation during this challenging yet rewarding endeavor.

This dissertation would not have been possible without the guidance and support of these individuals, and for that, I am truly grateful.

Iliana

1. Introduction

In the wake of increasing globalization and the ever-evolving landscape of international economics, the process of economic integration has emerged as a critical phenomenon shaping the economic fortunes of nations across the globe. Among the many regional integration initiatives, the Eurozone, comprising countries that have adopted the Euro as their common currency, stands as one of the most significant and intriguing developments in recent economic history. Since the adoption of the Euro in 1999, the Euro Area has weathered significant economic challenges, including the global financial crisis of 2008 and some member states' sovereign debt crises that followed the crisis, providing a rich landscape for investigating the dynamics of economic integration.

This study was originally inspired by the recent adoption of the euro by Croatia. Before that, 8 years had passed by since the last time a European country joined the Eurozone and this was Lithuania in 2015 (see Figure 1, p. 10). A deceleration can also be observed in the case of the EU membership as, besides Croatia, 16 years have passed by since the 6th EU enlargement in 2007. Every country that becomes a member of the European Union (EU), unless it negotiates an opt-out agreement, like Denmark, and upon fulfillment of all convergence criteria, replaces its national currency with the euro. Besides the special case of Denmark, there are six other EU members that have not yet joined the Eurozone. Out of these countries, only Bulgaria is not part of this study because, since 1997, its exchange rate regime has been a currency board with a fixed rate against the Deutsche Mark and then the euro. One, therefore, could wonder why it is taking so long for these EU countries to proceed with the adoption of the euro as their national currency. For this reason, with this study, I intend to examine the integration relationship of 8 non-Euro countries with the Euro Area. Specifically, these countries in alphabetical order are Croatia, Czechia, Hungary, Poland, Romania, Sweden, Switzerland, and the United Kingdom (UK). Even though Switzerland and the UK are not EU members and, thus, are not obliged to adopt the euro, I chose to include them in the study as they have very close trade links with the EU.

The novelty of this study lies in the choice of an ECM-TGARCH model to examine the integration of those currencies with the euro and the presence of asymmetry in volatility shocks i.e., the leverage effect. To elaborate, if a currency is found to have a stable long-term equilibrium with the euro i.e., they are cointegrated, I will proceed with an ECM estimation to simultaneously explore their short-term and long-term dynamics. If the ECM indicates a statistically significant and converging behavior, I will employ its residuals along with the returns of each currency to construct the TGARCH's mean equation. The empirical findings of the study indicate that Czechia, Poland, and Switzerland could join the Eurozone, whereas Hungary, Romania, Sweden, and, of course, the UK are not. As for Croatia, it did become integrated with the Euro Area but only after 2018. Pertaining to the leverage effect, it was only present in the case of Switzerland.

The remainder of the paper is organized as follows. Section 2 provides the theoretical background of international monetary economics, while section 3 presents a literature review. Section 4 discusses the methodology of this study and describes the data needed. Then, section 5 provides a data analysis and the empirical results of this study per country. Finally, section 6 provides a summary of the findings and concludes.

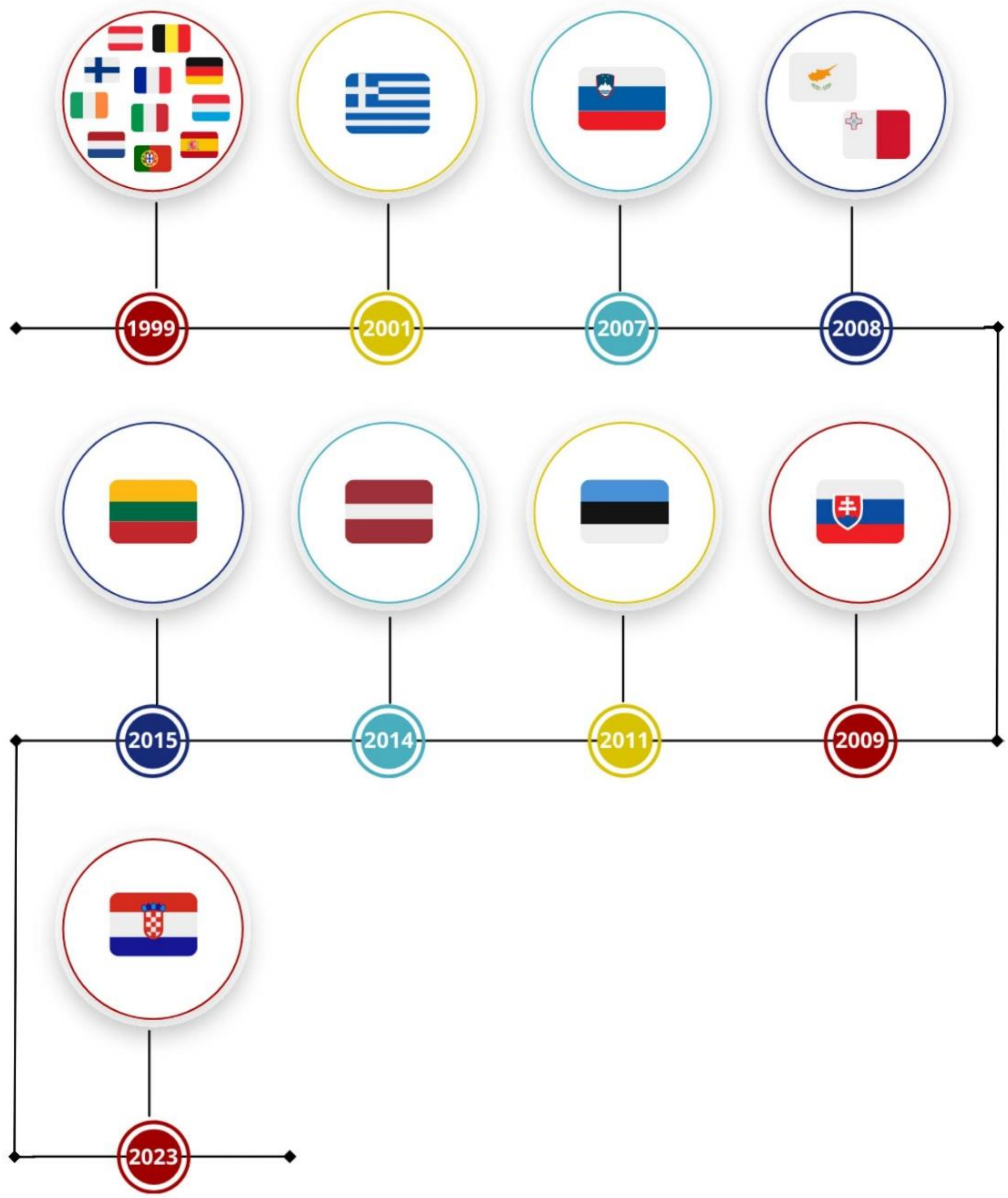

Figure 1: Eurozone Timeline

2. Background Theory on Monetary Economics

2.1. The Theory of Optimum Currency Areas

Mundell (1961) was the first to use the term “optimum currency area” in his seminal in the field of international economics paper. He explored the conditions under which a group of regions should form a common currency area whose borders may not coincide with the national ones. Mundell stressed the importance of factor, and especially labor, mobility for regions to form an Optimum Currency Area (OCA). Indeed, he considered the case of a common currency area where prices and wages are rigid and a shift of goods’ preference occurs from one region to another causing inflationary pressures in the first region and unemployment in the second one. He argued that the only way to resolve the issue would be through labor mobility from the latter region to the former one. He then proceeded to stress that, if there is a high degree of labor mobility in a region, a fixed exchange rate within the region’s borders and a flexible one with the rest of the world is optimal. Furthermore, on a similar note, Mundell highlighted the importance of price and wage flexibility to address adverse demand shocks. Therefore, if labor mobility or price and wage flexibility are present in a region, a flexible exchange rate is not necessary. Mundell’s paper has led to considerable debate and research on the optimal configuration of currency areas, with many economists extending Mundell's framework to consider additional factors.

One of those economists who further developed Mundell’s views was McKinnon (1963). On the one hand, pertaining to Mundell’s labor mobility argument, he proceeded to distinguish factor mobility as a geographical one among regions (i.e., what Mundell had in mind) and an intra-industrial one (McKinnon, 1963). Nonetheless, he agreed with Mundell on the importance of factor mobility in forming a currency union. On the other hand, McKinnon (1963) was the one that emphasized the importance of the degree of openness, which he defined as the ratio of tradable to non-tradable goods, for an internal and external equilibrium in a single currency area. To elaborate, the more economically open a currency union is, the less the degree of money illusion, which means the more flexible prices and wages are.

Another contributor to the OCA theory is Peter Kenen (1969). Kenen's main contribution lies in the introduction of product diversification as a criterion for a currency union's formation, since he believed that perfect labor mobility is rare despite developing Mundell's theory with his perfect occupational mobility view. Kenen argued that if a region produces only one product and the demand for its exports decreases then, if it has a flexible exchange rate, its currency will depreciate, but if the value of its currency is fixed, the region will have to internally devalue or suffer from increased unemployment. However, in a well-diversified economy, an adverse shock to a sector will be cancelled out by a positive one in another sector, resulting in the same number of exports. It is also worth noting that Kenen's diversification argument can lead to McKinnon's one regarding an economy's openness. To elaborate, according to Kenen (1969), large economies are the most diversified and with a smaller exporting sector, thus exchange rate fluctuations affect a smaller part of their economies. On the contrary, smaller, and less diversified economies need to be more open. Kenen (1969) also addressed fiscal integration in a common currency area to mitigate adverse shocks through fiscal transfers from the low-unemployment to the high-unemployment areas.

Apart from the previous three main contributors to the OCA theory, Max Corden (1972) was also highly influential and is worth mentioning. In his paper, Corden (1972) highlighted the loss of direct control of monetary policy and exchange rate that accompanies joining a currency union. Moreover, he argued that a common currency area can be costly if its constituent countries have different inflation rate preferences. Nevertheless, he also believed that the flexibility of prices and wages is the most important criterion for responding faster to asymmetric shocks.

Finally, Tavlas (1994), upon providing an overview of the theoretical framework pertaining to the OCA theory, he pinpointed three problems. First, there is the "problem of inconclusiveness" while examining the OCA criteria, as for a single country different OCA criteria might suggest different exchange rate systems. Second, the "problem of inconsistency" illustrates the fact that small economies tend to be more open and less diversified, thus simultaneously favoring a fixed and a floating exchange rate respectively. Third, there is interdependency between the OCA criteria, further restricting their analysis. Then, Tavlas (1994) examined the research being done on "responses to disturbances" and on "reputational considerations". Regarding the former, he argued that it can be achieved by a time series analysis or stochastic simulations using macroeconomic models. He stressed that the theory can only guide countries by listing the criteria that need to be fulfilled and the costs and benefits of each exchange rate system. As for the "reputational considerations", he highlighted that credibility is not gained only by pegging the country's currency but also through appropriate monetary policy strategies.

2.2.The Impossible Trinity

The "impossible trinity," also known as the "trilemma" in international economics, is a fundamental concept in the field of macroeconomics and international finance (Figure 2). It refers to the idea that it is impossible for a country to simultaneously achieve all three of the following policy goals: fixed exchange rates, free capital mobility, and independent monetary policy (Mankiw, 2022). Specifically, a country can choose up to two of these policy objectives at any given time. If a country decides to maintain a fixed exchange rate (goal 1) and allow free capital mobility (goal 2), it must give up an independent monetary policy (goal 3). In this case, the country's interest rates and money supply are influenced by external factors, such as capital flows and exchange rate stability. Conversely, if a country wishes to pursue an independent monetary policy (goal 3) and allow free capital mobility (goal 2), it must abandon the idea of maintaining a fixed exchange rate (goal 1). In this scenario, exchange rates are determined by market forces and can fluctuate. This concept has been discussed by various economists and is often associated with the work of Robert Mundell. The "impossible trinity" has significant implications for policymakers and central banks as they must carefully consider the trade-offs and challenges associated with each combination of policy goals.

Aizenman (2013) introduces the "policy quadrilemma," which builds upon the trilemma by adding a fourth dimension, financial stability i.e., ensuring the resilience of the domestic financial system, which can be threatened by volatile capital flows and exchange rate movements. Beck and Prinz (2012) explore the, at that time still ongoing, challenges faced by the EMU during the Eurozone crisis. They modify the typical trilemma by having to maintain up to two out of the following three key features: independent monetary policy, national fiscal sovereignty, and a strict no-bailout clause. They conclude that retaining national fiscal sovereignty in a monetary union is the primary issue and suggest the expulsion of overindebted countries and the enactment of strict rules for sovereign default.

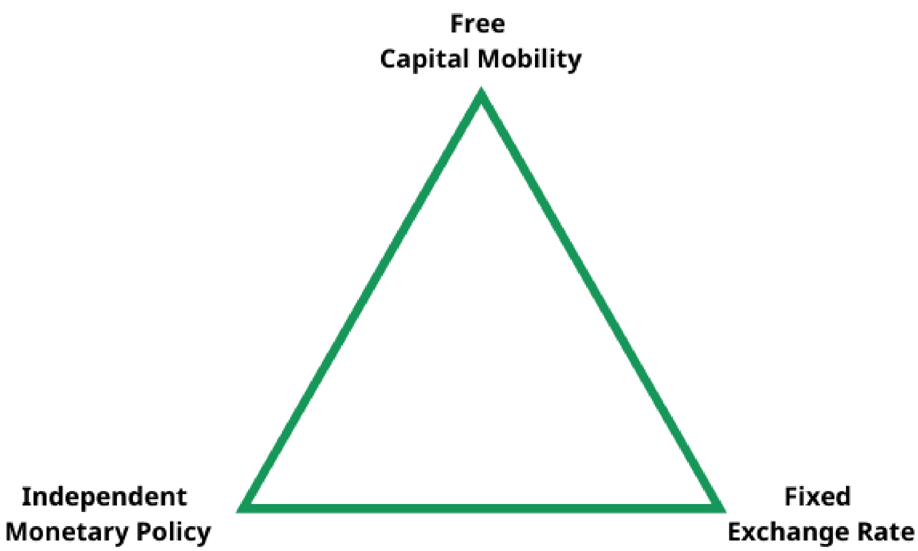

Figure 2: The Impossible Trinity

2.3. The Convergence Criteria

The mechanism of candidate countries' integration into the Eurozone is specified in the Maastricht Treaty and it consists of three phases. During the first phase, a country is preparing to join the EU by adapting its legislative framework to the Community one. Furthermore, it focuses on the Copenhagen criteria, and it begins to harmonize its economic policies with the Maastricht criteria. The second phase is the period when a country is officially an EU member and is, now, preparing for the adoption of the euro. During this phase, the country must fulfill the convergence criteria, also known as the Maastricht Criteria, which are described in Article 140 of the Treaty on the Functioning of the European Union (*Conditions for joining the euro area: convergence criteria*, 2023). The first one is price stability as the country's inflation rate cannot exceed by more than 1.5% the average rate of the three best-performing members. Second are the sound and sustainable public finances which are described by a budget deficit up to 3% of the GDP and a maximum debt-to-GDP ratio of 60%. Third, the country's long-term interest rates must not exceed by more than 2% the average rate of the three best-performing members. The last criterion is the exchange rate stability as the country must participate in the ERM II for at least 2 years with the standard 15% fluctuation band against the euro. However, from 2018, countries that wish to participate in the ERM II must also have close cooperation with the ECB's SSM. Finally, the third phase is the official adoption of the euro.

2.4. European Integration

Eichengreen (1991) examined whether the EC meets Mundell's criteria for being an OCA and, thus, whether it is suitable for the adoption of a single currency. He compared the EC countries with the US and Canada and argued that the EC did not meet all the OCA criteria. Specifically, he stressed the limited factor mobility and the different economic structures. The former can restrain the EC's ability to respond to asymmetric shocks and the latter poses challenges for a single monetary policy. De Grauwe and Vanhaverbeke (1991) reached the same conclusions by analyzing regional data within the EC.

Frankel and Rose (1996) argued that the trade intensity and the business cycle correlation between members of a common currency area are endogenous. To prove that they employed 30 years of panel data from 20 industrialized countries. They showed that countries with closer trade links lead to tightly correlated business cycles. As a result, they suggested that countries that join the EMU might satisfy the OCA criteria upon entering the EMU and not prior to that.

Krugman (2013) discussed the concept of the OCA in the context of the Eurozone's economic challenges. He noted that despite initial skepticism about the Eurozone's viability as a common currency area, the euro has survived the early years of the financial crisis. He also argued that the common currency has been sustained through unprecedented actions by the ECB, which has acted as a lender of last resort. Nonetheless, he acknowledged that the euro has not fully resolved its fundamental structural issues. He pointed out that many of the currency's early critics, including himself, initially believed that the absence of labor mobility, fiscal integration, and a federal budget would pose insurmountable problems for the Eurozone. However, the

Eurozone has managed to muddle through without addressing these issues directly mainly because of the ECB's willingness to step in as a lender of last resort something that has prevented financial collapse and deflation. Yet, he also highlighted the limitations of the Eurozone's current setup, such as high unemployment rates in some member countries and a lack of fiscal transfers to support struggling regions. In conclusion, Krugman stressed that while the Eurozone has survived the crisis, it has not fully addressed its structural challenges.

3. Literature Review

Brada and Kutan (2001) examined the degree of convergence in monetary policy between the EU and candidate countries. They stressed the importance of candidate and new member nations being able to follow the ECB's policies. For that purpose, they employed a VECM model to determine the degree of cointegration between those countries' base money stock and Germany's which they used as a proxy for the ECB. They found out that the monetary policy of the, at the time, recent EU members and some market-economy candidates aligns with Germany's. However, this is not the case for the transition economies whose links are weaker.

Meister (2002) conducted an in-depth examination of Eastern European countries' readiness to meet the Maastricht criteria required for eurozone accession. Meister utilized a cointegration analysis to explore whether a stable, long-term relationship exists between these economic indicators and the Maastricht criteria. The central aim was to determine whether Eastern European nations satisfy these criteria and, consequently, whether they are well-prepared to embrace the euro as their official currency. The study's results were of paramount importance. Meister's analysis revealed that, as of 2002, many Eastern European countries were falling short of meeting the Maastricht criteria, suggesting that their economies may not yet have been sufficiently aligned with the eurozone's stability requirements. In conclusion, Meister (2002) provided valuable insights into the economic convergence and preparedness of Eastern European nations to adopt the euro, shedding light on the potential hurdles they may face in their pursuit of eurozone membership.

Brada et al. (2005) employed a rolling cointegration analysis to determine the monetary and real convergence between recent as well as transition EU members with the EU. They proxied the EU with Germany and France. The cointegration of real variables would indicate whether those countries are subject to similar supply shocks. The cointegration of monetary variables would determine whether a peg of those countries' currencies with the Euro was feasible. Brada et al. found time-varying cointegration for recent EU members. As for the transition ones, they found no cointegration of real variables and comparable cointegration for M2 and CPI but not for monetary policy.

Holtemöller (2005) analyzed deviations of several currencies from the Uncovered Interest Rate Parity (or International Fisher Effect). Moreover, he chose an ECM approach to observe the long-run relationship between interest rates and a rolling regression one to determine the size and volatility of the country-specific risk premia. According to their degree of monetary integration, the examined countries were divided into three groups: low, medium, or high. The Czech Republic, Hungary, Latvia, Poland, and Slovenia were in the first group. The second group consisted of Greece and Slovakia, while Estonia and Lithuania were the highest integrated ones (group three).

Economidou and Kool (2009) examined the output and consumption asymmetries in the Eurozone and the enlarged EU between 1992 and 2007 and determined how non-euro countries and candidate countries differ from the Eurozone. The output asymmetry was found unaltered and consumption smoothing was enhanced. However, they noted that the EMU's enlargement ought to be gradual and upon careful consideration of each country's specific characteristics. Overall, the authors argue that the UK, Denmark, and Sweden could join the EMU with no significant macroeconomic implications.

Rhodes (2010), after highlighting the continuous expansion of the Euro Area, investigated the readiness of Eastern European accession countries to adopt the euro as their common currency. Specifically, he focused on the post-communist countries that have expressed interest in adopting the euro and have taken steps towards meeting the Maastricht Convergence Criteria. The author chose a GPPP model to evaluate the real economic convergence of these accession countries with the euro as this methodology goes beyond nominal evaluations and measures real economic convergence. Rhodes also used an ECM to analyze how accession country exchange rates react to changes in the euro exchange rate. The results of the analysis indicated that the accession countries' exchange rates were not fully integrated with the euro, as their real exchange rates did not exhibit a strong long-run relationship with the euro exchange rate. This suggests that they may not meet McKinnon’s OCA criteria who argued that smaller, more open economies benefit from fixed exchange rates. Overall, the paper suggests that based on the GPPP methodology and the observed limited impact of the euro exchange rate on accession country exchange rates, these countries may not be fully ready for euro adoption. Further integration and economic adjustments may be needed before they can successfully join the euro area.

Keppel and Prettner (2015) examined the interrelations of the 12 initial EU members with the Czech Republic, Hungary, Poland, Slovakia, and Slovenia using a SVECM. Additionally, through an impulse response analysis, they observed the effects of shocks on several variables in both groups of countries, like the exchange rate, interest rates, output, and relative prices. Their final results were in line with economic intuition and supported the choice of a smaller model for the study.

Stoupos and Kiohos (2017) used an ECM-APARCH model to examine whether Croatia, Czech Republic, Hungary, Poland, and Romania were ready to adopt the euro. In the short run, all countries were positively affected by the euro. However, in the long-run, only Poland and Romania had a positive relationship with the Euro Area. Negative shocks of the euro had a greater or neutral effect on the volatility of these currencies. Overall, the authors observe that, out of the examined countries, only Poland and Romania were already aligned with the Euro Area.

Stoupos (2019) extended the above research to include EU and EEA countries. The model consisted of an ECM followed by a model from the GARCH family. His results were aligned with the ones of Stoupos and Kiohos (2017). Specifically, in the countries that could benefit from a euro adoption Denmark, Norway, and Sweden were added. In the negatively related ones Bulgaria, Iceland, and the UK were added, while Switzerland exhibited an independent relationship pertaining to the euro’s adoption.

Stoupos (2020) addresses the slowdown in the Eurozone enlargement by assessing the suitability of Estonia and Lithuania 9 and 5 years after their adoption of the euro, respectively. He also examines the potential participation of Bulgaria in the Eurozone. For that purpose, he employed an ECM-TGARCH model which revealed that Bulgaria is far from ready to adopt the euro, while it confirmed the suitability of Estonia and Lithuania.

4. Methodology and Data Description

4.1. Unit Root Analysis – ADF Test

One of the most important steps in time series analysis is to examine whether the variables are stationary or not. A stationary time series maintains its statistical properties over time. To elaborate, it has “a constant mean, constant variance and constant autocovariances for each given lag” (Brooks, 2019). Nonstationary series, on the other hand, can lead to spurious regressions, not accurate t-tests and F-tests, as well as the persistence of shocks to the system (Brooks, 2019).

Dickey and Fuller (1979) developed a test that detects the presence of a unit root in a time series and thus establishes it as nonstationary. They considered 3 versions of the autoregressive model distinguishing the presence or not of a drift and/or a trend:

$$y_t = \rho y_{t-1} + e_t \ where \ y_0 = 0 \ and \ t = 1, 2, \ldots. \tag{1}$$

$$y_t = \mu + \rho y_{t-1} + e_t \ where \ y_0 = 0 \ and \ t = 1, 2, \ldots. \tag{2}$$

$$y_t = \mu + \beta t + \rho y_{t-1} + e_t \ where \ y_0 = 0 \ and \ t = 1, 2, \ldots. \tag{3}$$

In any case, Dickey and Fuller (1979) distinct the following cases:

$$if \ |\rho| < 1, y_t \ converges \ to \ a \ stationary \ time \ series$$

$$if \ |\rho| = 1, y_t \ is \ not \ stationary$$

$$if \ |\rho| > 1, y_t \ is \ not \ stationary \ and \ it \ is \ explosive$$

The null hypothesis in the Dickey-Fuller unit root test (DF) is the presence of a unit root in the time series and, subsequently, nonstationarity. In that scenario, the time series can be transformed to be stationary by differencing it (Dickey and Fuller, 1979). When a nonstationary series y_t must be differenced d times in order to become stationary, it is said to be integrated of order d (Brooks, 2019). Specifically, when $y_t \sim I(d) \Leftrightarrow \Delta^d y_t \sim I(0)$.

The Augmented Dickey-Fuller (ADF) test, which is the one employed in this study, is an extension of the Dickey-Fuller test developed by Said and Dickey (1984) and was designed to handle a wider range of time series data by accounting for potential serial correlation and lags. I chose to determine the lag length of the test with the Schwarz information criterion. When the ADF test statistic was computed by EViews, I compared it with the relevant critical values of the ADF test. If it was more negative than the critical value at the significance level of my interest, I proceeded to reject the null hypothesis of a unit root.

4.2.Cointegration

In some econometric models, the combination of variables that are nonstationary individually may lead to a stable equilibrium in the long run. This means that, even though the individual variables may exhibit random fluctuations, a linear combination of them exists and is stationary, suggesting a meaningful and stable relationship in the long run. Those variables are said to be cointegrated with one another. More specifically, the linear combination of variables that are nonstationary and $I(1)$ (i.e., integrated of order 1), may be stationary (i.e., $I(0)$). To further elaborate, when some variables are cointegrated, at any point in time, deviations from their equilibrium may occur but those will only be temporary as those variables will ultimately revert to their long-run equilibrium. This concept of cointegration was introduced by Granger (1981). However, Granger highlighted that the nonstationary variables need to be integrated of the same order for them to potentially be cointegrated (Granger, 1981). There are various ways to test for cointegration between variables. The two that I will employ in this study are the simple unit root test suggested by Engle and Granger (1987) and the Engle-Granger test provided by EViews. Both are further explained in the last part of subsection 4.3.1.

4.3. Engle and Granger Two-Step Procedure

Building upon Granger's (1981) findings regarding cointegration, Engle and Granger (1987) developed the Error Correction Model (ECM). With an ECM we can examine whether short-run and long-run dynamics exist between two time series that both are cointegrated and $I(1)$. Prior to the estimation of the ECM, Engle and Granger (1987) proposed to run a regression, save its residuals, examine their stationarity, and, if they are found to be stationary, proceed in including them in the ECM specification. The derivation of the residuals and the ECM estimation are the constituents of the Engle and Granger two-step procedure. The two steps of this procedure are analyzed separately in subsections 4.3.1. and 4.3.2. that follow.

4.3.1. Robust Least Squares (RLS)

The first step of the Engle and Granger two-step procedure begins with a regression analysis to obtain the residuals that will be part of the ECM specification. However, Ordinary Least Squares estimators are liable to outliers and for this reason, I decided to use a different method of estimation namely the RLS (Brooks, 2019). The RLS method of estimation is a statistical technique that is comprised of several regression methods aiming to minimize the impact of outliers and influential data points on parameter estimation. RLS combines the principles of robust estimation with the least squares approach to provide parameter estimates that are less sensitive to the influence of extreme observations. EViews offers several methods for RLS, one of them being the M-estimation ("M" standing for maximum likelihood type) proposed by Huber (1964). M-estimation is a general framework for estimating model parameters by minimizing an objective function. With regards to RLS, the objective function is often defined as the weighted sum of squared residuals, similar to Ordinary Least Squares (OLS). However, unlike OLS, in robust regression different weights are assigned to each residual to downweigh the influence of outliers. The Welsch function is a robust weight function used in M-estimation. It assigns weights to data points based on their residuals. The Welsch weight function is less sensitive to outliers compared to the squared loss function used in traditional least squares as it gives less weight to large residuals (outliers) compared to smaller ones, making it robust to the presence of outliers in the data. It is also worth noting that the Welsch function is designed to work well with data that may follow a heavy-tailed distribution like the nominal exchange rates do (Liang, 2016). After obtaining parameter estimates using the M-estimation with the Welsch weighting function, one can compute robust standard errors and covariance estimates of those parameters while also accounting for the potential heteroscedasticity (i.e., varying spread of residuals) and the presence of outliers in the data. The Huber I standard errors are robust alternatives to the standard errors obtained in traditional least squares and are calculated by adapting the Huber sandwich estimator to the weighted residuals. Those standard errors provide a robust estimate of the uncertainty in the parameter estimates that is less sensitive to outliers and heteroscedasticity compared to traditional OLS standard errors. Combining everything, this approach is particularly useful when dealing with datasets that may contain outliers and/or exhibit heteroscedasticity as it provides more reliable parameter estimates.

Upon the creation of the residuals, we need to test their stationarity. Engle and Granger (1987) proposed a simple unit root test. However, we can only take advantage of the t-statistic of the unit root test as the ADF's critical values are not relevant in the case of residuals. Thus, we should compare the ADF's t-statistic with a different set of critical values provided by MacKinnon (2010) for this exact purpose. Another option is to employ the Engle-Granger test for cointegration that is built-in EViews. This is a residuals-based cointegration test that applies a unit root test to the residuals that are obtained from a static OLS regression. This test's null hypothesis is no cointegration. Both methods will be employed in this study. It is also worth noting that the Engle-Granger test was chosen over other tests, and more specifically the Johansen test, as it is optimal for determining a cointegrating relationship in a bivariate analysis like this study is.

4.3.2. Error Correction Model (ECM)

Engle and Granger (1987) in their seminal work introduced the concept of an Error Correction Term (ECT) in the ECM that captures short-term deviations from the long-run equilibrium. The ECT is calculated as the difference between the actual and predicted values of the dependent variable, and for this reason it is usually represented by the residuals obtained from the regression of one nonstationary variable on another. This error correction term is critical in the ECM as it models how quickly the system adjusts back to its long-run equilibrium after experiencing a shock or deviation in the short run. If the ECT is significantly different from zero, it suggests that the system is adjusting back to equilibrium. The coefficient of the ECT represents the speed at which the system corrects deviations from the long-run equilibrium. Therefore, if the coefficient is statistically significant and negative the system converges towards its long run equilibrium and diverges from it in the case that it is positive.

According to Engle and Granger (1987), the ECM for two variables relates "the change in one variable to past equilibrium errors, as well as to past changes in both variables". Considering this and using the notation of Stoupos (2019), the ECM specification is:

$$\Delta Y_t = \omega + \varphi EC_{t-1} + \sum_{i=1}^{p} \psi_i \Delta Y_{t-i} + \sum_{j=0}^{q} \theta_j \Delta X_{t-j} + \varepsilon_t \qquad (4)$$

In equation (4), φ is the coefficient of the ECT and it represents the speed of adjustment back to equilibrium, ψ indicates the short-run dynamics, and θ the long-run ones (Stoupos, 2019).

4.4.TGARCH Model

The second part of this study's methodology is occupied with the estimation of a TGARCH(1,1) model, as it allows the isolation of the long-run volatility. In econometrics, financial assets' returns and their volatility can be modeled with the use of one of the autoregressive conditional heteroskedastic (ARCH) family of models. One of the reasons why there was a need to develop a model to measure the conditional variance instead of the unconditional one is volatility clustering (Asteriou and Hall, 2021). Volatility clustering is a phenomenon observed in financial data where periods of high volatility tend to be followed by periods of high volatility, and periods of low volatility tend to be followed by periods of low volatility. In other words, volatility tends to cluster together in time rather than being randomly distributed. In subsections 4.4.1., 4.4.2., and 4.4.3. that follow, the evolution of the ARCH family models is provided to further justify the choice of the TGARCH model for this study's aims.

4.4.1. The ARCH Model

The ARCH model was developed by Engle (1982). The key idea behind an ARCH model is that the volatility of a time series is not constant over time but instead exhibits some degree of autocorrelation and time-varying behavior. In other words, the conditional variance of the time series' residuals is not constant, but it depends on past periods' squared errors (Engle, 1982). Following the notation used by Asteriou and Hall (2021), the equations for the mean and conditional variance for an ARCH(q) model, where q represents the number of lagged squared errors the conditional variance depends upon, are:

$$Y_t = \alpha + \beta X_t + u_t \tag{5}$$

$$h_t \equiv \sigma_\tau^2 = \gamma_0 + \sum_{j=1}^{q} \gamma_j u_{t-j}^2 \tag{6}$$

It is also worth noting that the estimated parameters need to be non-negative for positive variance (Engle, 1982).

4.4.2. The Generalized ARCH (GARCH) Model

The GARCH model was developed by Bollerslev (1986) while he was employed as Engle's research assistant. The GARCH model is an extension of the ARCH one as it allows for a more general specification of the conditional variance by additionally including lagged values of the conditional variance in its equation. This leads to a more parsimonious specification while assuring the variance coefficients' non-negativity suggested by Engle (1982) (Bollerslev, 1986). The mean equation is the same as in the case of an ARCH model, but the conditional variance equation using Bollerlev (1986)'s notation is:

$$h_t = a_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} \tag{7}$$

Moreover, like in an ARCH model, all the estimated parameters need to be non-negative (Bollerslev, 1986).

4.4.3. The Threshold GARCH (TGARCH) Model

A major drawback of both the ARCH and GARCH models is that they are both symmetric in the sense that, because the residual term is squared, negative and positive shocks will have the same effect on the variance. However, in financial markets, asset prices are known to have an inverse relationship with volatility (Christie, 1982). To capture this asymmetric behavior, Zakoian (1994) introduced the TGARCH model as an extension of the GARCH one. Negative shocks tend to influence volatility more than the positive ones do and this is captured by the TGARCH model from the inclusion of a dummy variable that detects the statistical significance of negative shocks (Asteriou and Hall, 2021).

Again, the mean equation is the same as in the ARCH model case and the conditional variance equation for a TGARCH(1,1) following the notation of Asteriou and Hall (2021) is the following:

$$h_t = \gamma_0 + \gamma u_{t-1}^2 + \theta u_{t-1}^2 d_{t-1} + \delta h_{t-1} \tag{8}$$

- $d_t = 1$ for $u_t < 0$ (bad news) and 0 otherwise, so the good news' impact equals to γ whereas the bad news' one is $\gamma + \theta$
- θ is the asymmetry or leverage term and, if it is greater than 0 and significant, bad news will have a greater impact than the good ones

4.5. Data Description

The data employed in this study are daily, excluding weekends and bank holidays, spot nominal exchange rates of the currencies of Croatia, Czechia, Hungary, Poland, Romania, Sweden, Switzerland, UK, and Euro Area, ranging from January 1st, 2002, to December 31st, 2022. The specific currencies were chosen over some others because they were floating and not pegged to the Euro at any point during my data period. The only exception, which is acknowledged in the results, is Croatia after it joined the ERM II in 2020. Furthermore, I chose to employ nominal, instead of real, exchange rates since they are more sensitive to short-term market fluctuations and, thus, any short-term deviations from a long-run equilibrium, which is the ECM's purpose, will be better defined. All the exchange rates were retrieved from the ECB's Data Portal (*ECB Data Portal*, no date). However, the exchange rates in the ECB's database are expressed versus the euro, so I derived the relevant cross rates to express the currencies versus a neutral currency i.e., the dollar, which is the most traded currency globally.

For the second part of the study, I derived each currency's natural logarithmic returns by using the basic formula $r_t = ln\left({}^{P_t}/_{P_{t-1}}\right)$. For the first (i.e., oldest) observation of each time series I calculated its return as the average of all the other observations' natural logarithmic returns.

Table 1. Description of Variables

Variable (per $)	**Acronym**	**Measure**
Croatian Kuna	HRK	Kn/$
Czech Koruna	CZK	Kč/$
Hungarian Forint	HUF	Ft/$
Polish Zloty	PLN	Zl/$
Romanian Leu	RON	L/$
Swedish Krona	SEK	kr/$
Swiss Franc	CHF	SFr/$
British Pound	GBP	£/$
Euro	EUR	€/$

Table 2. Currencies' Returns	
Variable (per $)	**Acronym**
Croatian Kuna	RHRK
Czech Koruna	RCZK
Hungarian Forint	RHUF
Polish Zloty	RPLN
Romanian Leu	RRON
Swedish Krona	RSEK
Swiss Franc	RCHF
British Pound	RGBP
Euro	REUR

5. Empirical Chapter

5.1. Data Analysis

5.1.1. Descriptive Statistics

After importing my data into EViews, I observed scale differences between many of the currencies and the Euro. Thus, I decided to reduce these scale differences by transforming those specific currencies' exchange rates through the natural logarithms. The transformed exchange rates are *HRK*, *CZK*, *HUF*, *PLN*, *RON*, and *SEK*.

Table 3a. Descriptive statistics of currencies that needed a natural logarithmic transformation

	LEUR	LHRK	LCZK	LHUF	LPLN	LRON	LSEK
Mean	- 0.197136	1.812010	3.098817	5.476627	1.233876	1.235623	2.059539
Median	- 0.195978	1.812530	3.100341	5.431492	1.263782	1.208978	2.061656
Maximum	0.153384	2.181533	3.612945	6.092812	1.613986	1.643559	2.435016
Minimum	- 0.469378	1.508183	2.671131	4.969099	0.706930	0.803236	1.765755
Std. Dev.	0.113822	0.120175	0.158237	0.202335	0.157015	0.180246	0.145717
Skewness	0.238112	0.063617	0.374028	0.269088	- 0.608411	- 0.237614	0.149195
Kurtosis	3.032257	2.909684	3.556615	2.676067	3.335006	2.390819	2.078747
Jarque-Bera	51.06255***	5.456446*	194.8560***	88.43221***	357.0053***	133.7899***	210.1718***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table 3b. Descriptive statistics of currencies that did not need a natural logarithmic transformation

	EUR	CHF	GBP
Mean	0.826462	1.068352	0.656171
Median	0.822030	0.993235	0.641557
Maximum	1.165773	1.717883	0.943732
Minimum	0.625391	0.727431	0.474737
Std. Dev.	0.095670	0.175944	0.094321
Skewness	0.593612	1.268607	0.177928
Kurtosis	3.633117	4.235278	2.184417
Jarque-Bera	405.7423***	1784.791***	177.4642***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table 3a presents the descriptive statistics for the currencies that need a logarithm transformation and Table 3b presents the descriptive statistics of the currencies that do not. Regarding the kurtosis of each variable, *LEUR*, *LCZK*, *LPLN*, *EUR*, and *CHF* exhibit excess kurtosis (i.e., value above 3) versus *LHRK*, *LHUF*, *LRON*, *LSEK*, and *GBP* whose kurtosis is less than 3. Furthermore, all variables are positively skewed except *LPLN* and *LRON* which are negatively skewed. As for the value of the Jarque-Bera statistic, it is employed to detect the normality of a series. Pertaining to my variables, the Jarque-Bera statistic reveals the statistically significant at the 1% level non-normality (i.e., a value larger than zero) of all currencies except *LHRK* whose non-normality is significant at the 10% level and smaller than the rest of the currencies. This is anticipated considering the quite large sample size.

It is worth mentioning that, as a first stage, I ran a simple OLS regression to then examine whether there is heteroskedasticity or serial correlation in the respective model. All currencies' regressions suffered from both heteroskedasticity and autocorrelation. I detected heteroskedasticity with the heteroskedasticity test under the White specification. As for autocorrelation, it was evident through both the value of the Durbin-Watson statistic, which was close to 0, and the dot plot of the regression's residuals. I corrected autocorrelation by including a lag of the dependent variable in my regression and heteroskedasticity by using the RLS method of estimation. The results of these RLS estimations for all 8 countries can be found in Appendix A, Tables A1 – A8.

5.1.2. Unit Root Results

Table 4a. Augmented Dickey-Fuller Test (ADF) Results

Variable	t-statistic (levels)	t-statistic (1st difference)
EUR	- 3.240503*	- 73.45529***
LEUR	- 3.056414	- 73.45986***
LHRK	- 2.934137	- 72.87658***
LCZK	- 2.666406	- 71.56739***
LHUF	- 3.068803	- 72.59081***
LPLN	- 2.339716	- 71.28698***
LRON	- 2.360498	- 71.15742***
LSEK	- 2.795755	- 73.37031***
CHF	- 3.327714*	- 73.63737***
GBP	- 3.353687*	- 70.12845***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table 4a presents the results of the ADF test for all the variables. All of them have a unit root and, thus, are $I(1)$ (i.e., integrated of the same order). In the case of *EUR*, *CHF*, and *GBP* that are $I(1)$ at levels but at the 10% level, I additionally ran the KPSS test that confirmed their nonstationarity at levels by rejecting the test's null hypothesis of stationarity (Table 4b).

Table 4b. Kwiatkowski-Phillips-Schmidt-Shin Test (KPSS) Results

Variable	t-statistic (levels)	t-statistic (1st difference)
EUR	1.306959***	0.421237*
CHF	1.674150***	0.239328
GBP	0.714750***	0.185086

Note: *** and * denote significance at the 1% and 10% level, respectively.

5.2. Empirical Results Per Country

5.2.1. Croatia

Table 5 presents the results of the Engle-Granger cointegration test for *LHRK* and *LEUR*. In the case of *LHRK* being the dependent variable, which is the one I am interested in, *LHRK* and *LEUR* were found to be cointegrated. This is because the tau-statistic of the test rejects the null hypothesis of no cointegration.

Table 5. Engle-Granger Cointegration Test Results

Dependent Variable	tau-statistic
LHRK	- 3.860008***

Note: *** denotes significance at the 1% level (MacKinnon (1996) p-values).

Since *LHRK* and *LEUR* are cointegrated and the RLS's residuals exhibit no autocorrelation (see Appendix C, Figure C1), I can proceed with the estimation of the ECM. The ECM specification in this case becomes:

$$\Delta(LHRK)_t = \omega_1 + \varphi_1 EC_{t-1} + \psi_1 \Delta(LHRK)_{t-1} + \theta_1 \Delta(LEUR)_{t-1} + \varepsilon_t \qquad (9)$$

Table 6. Error Correction Model (ECM) Estimation Results – **LHRK vs. LEUR**

Variable	**Coefficient (st. error)**
Constant	- 6.26E-05 (8.34E-06)***
ECT$_{t-1}$	0.033812 (0.004760)***
Δ(LHRK)$_{t-1}$	0.060510 (0.007525)***
Δ(LEUR)$_{t-1}$	- 0.086455 (0.006193)***

Note: *** denotes significance at the 1% level.

The results of the ECM, seen in Table 6, suggest that the EUR influences the HRK slightly negatively in the long-run and slightly positively in the short-run. Moreover, since the coefficient of the ECT is positive and statistically significant, the system diverges from its long-run equilibrium. Notably, in each period, the distance $LHRK/LEUR$ will be expanded by 3.38%.

Nonetheless, since Croatia is the most recent member of the Eurozone, I decided to additionally examine several subperiods in case the results differ. Indeed, despite the coefficient of the ECT being positive and significant from 2002-2015, it then becomes negative but not significant until 2018-2022 when it finally becomes negative and statistically significant (see Appendix B, Figures B1-B3). To elaborate, only after 2018 the system converges towards its long-run equilibrium. This is valid if we consider Croatia's journey towards its Euro adoption on January 1st, 2023. Specifically, Croatia joined the ERM II mechanism on July 10th, 2020, and the central rate was determined at 1 *EUR* / 7.53450 *HRK* with the usual 15% fluctuation band (European Central Bank, 2020). As such, the Croatian authorities were obliged to pursue policies that would lead to "a high degree of sustainable economic convergence" (European Central Bank, 2020).

Also, the discrepancy between the overall and subperiods' results makes sense as the final value of the ECT's coefficient is the average of the examined period. Since Croatia joined the EU just on July 1st, 2013, and only started converging towards the Euro Area shortly after, this means that for a bit over half of this study's examined period, Croatia was actually diverging from the Eurozone.

These results, suggesting the divergence of the Croatian Kuna from the Euro, are in line with the literature (Stoupos, 2019; Stoupos & Kiohos, 2017). One therefore should wonder about Croatia's euro adoption. Darvas (2022) highly criticized the ECB's decision to allow Croatia to adopt the euro as he supports that it only managed to do so due to the ECB's "discretionary adjustment" in one of the convergence criteria already mentioned in section 2.3. Specifically, one of the convergence criteria is price stability suggesting that a euro-candidate country's inflation rate must not exceed by more than 1.5% the average rate of the 3 best performing Eurozone member countries. Darvas (2022) highlights that the inflation rates of April 2022, according to which the final decision of Croatia's euro adoption was made, Malta, Portugal, and France were the 3 best performing members in terms of price stability with inflation rates of 2.1%, 2.6%, and 3.2%, respectively. The average of those is 2.6% and by adding 1.5% the resulting maximum inflation rate of candidate countries is 4.1%. Under those circumstances, Croatia with an inflation rate of 4.7% would not have been able to join the Eurozone. However, the ECB replaced Malta and Portugal with Finland and Greece with inflation rates of 3.3% and 3.6%, respectively, as it considered the former as outliers because their inflation rates were a lot lower than other Eurozone members due to "exceptional factors" (European Central Bank, 2022). Thus, the final maximum inflation rate was 4.9% allowing Croatia to join the Eurozone. On the contrary, Bulgaria which joined the ERM II the same day as Croatia was denied the euro's adoption as its inflation rate was 5.9% (Darvas, 2022). Adding up the results of this study of no overall cointegration between LHRK and LEUR except only after Croatia was actively trying to meet the convergence criteria, one can only wait to see how Croatia's future as a Eurozone member unfolds.

As far as monetary policy is concerned, it is interesting that, as depicted in Figure 3, Croatia had been following the ECB's policies way before becoming an EU member.

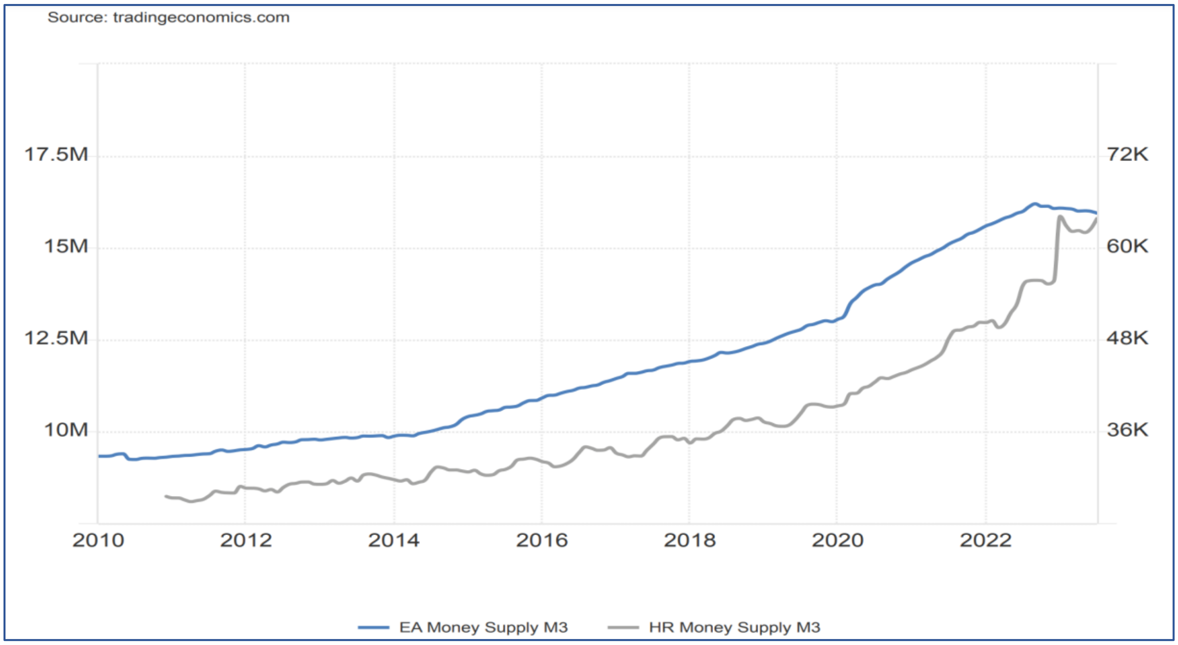

Figure 3: Euro Area vs. Croatia M3 Money Supply (TRADING ECONOMICS, no date c)

5.2.2. Czechia

Table 7 presents the results of the Engle-Granger cointegration test for *LCZK* and *LEUR*. With *LCZK* as the dependent variable, the tau-statistic is not significant and, consequently, cannot reject the null hypothesis of no cointegration.

Table 7. Engle-Granger Cointegration Test Results

Dependent Variable	tau-statistic
LCZK	- 1.470266

Note: MacKinnon (1996) p-values.

Despite the outcome of the Engle-Granger test, and since the RLS's residuals were not serially correlated (see Appendix C, Figure C2), I decided to run the ECM and determine whether its results were in line with the cointegration test. Its specification is:

$$\Delta(LCZK)_t = \omega_2 + \varphi_2 EC_{t-1} + \psi_2 \Delta(LCZK)_{t-1} + \theta_2 \Delta(LEUR)_{t-1} + \varepsilon_t \qquad (10)$$

Table 8. Error Correction Model (ECM) Estimation Results – **LCZK vs. LEUR**

Variable	**Coefficient (st. error)**
Constant	- 0.000133 (1.00E-05)***
ECT_{t-1}	- 0.155278 (0.015760)***
$\Delta(LCZK)_{t-1}$	0.209245 (0.015935)***
$\Delta(LEUR)_{t-1}$	- 0.043233 (0.003370)***

Note: *** denotes significance at the 1% level.

The results presented in Table 8 disagree with the Engle-Granger test as the coefficient of the ECT is not only negative but also significant at the 1% level. This means that *LCZK* and *LEUR* are cointegrated. More specifically, in each period 15.53% of the distance *LCZK/LEUR* will be covered. This relationship is meaningful by also looking at Figure 4 which depicts the similarities in the Euro Area's and Czechia's monetary policies. These similarities can also explain the positive influence of the euro on the koruna indicated by the positive short-run dynamics between the currencies. As for the long-run dynamics, they are found to be negative, suggesting that the *CZK* does not follow the long-term economic behavior of the *EUR*. This could be attributed to the November 7th, 2013, decision of the Czech National Bank (CNB) to use foreign exchange interventions as an additional monetary policy tool (Czech National Bank, no date). Specifically, the CNB decided on a 27 *CZK/EUR* cap to stimulate their economy against deflation which they supported by selling korunas and buying euros. This resulted in lower prices for their exports but higher ones for their imports, so the public was not content. However, they ended up removing the cap and returning in conventional monetary policy of inflation targeting on April 6th, 2017, after fears of increased inflation (Czech National Bank, no date). The overall results are only aligned with the literature's as far as the dynamics are concerned (Stoupos & Kiohos, 2017; Stoupos, 2019). This discrepancy in my results regarding the cointegration of the CZK and the EUR can be explained by the gradual warming up of the traditionally against the euro's adoption

Czechs which is evident in the past few Eurobarometer reports (European Commission 2022; European Commission 2023).

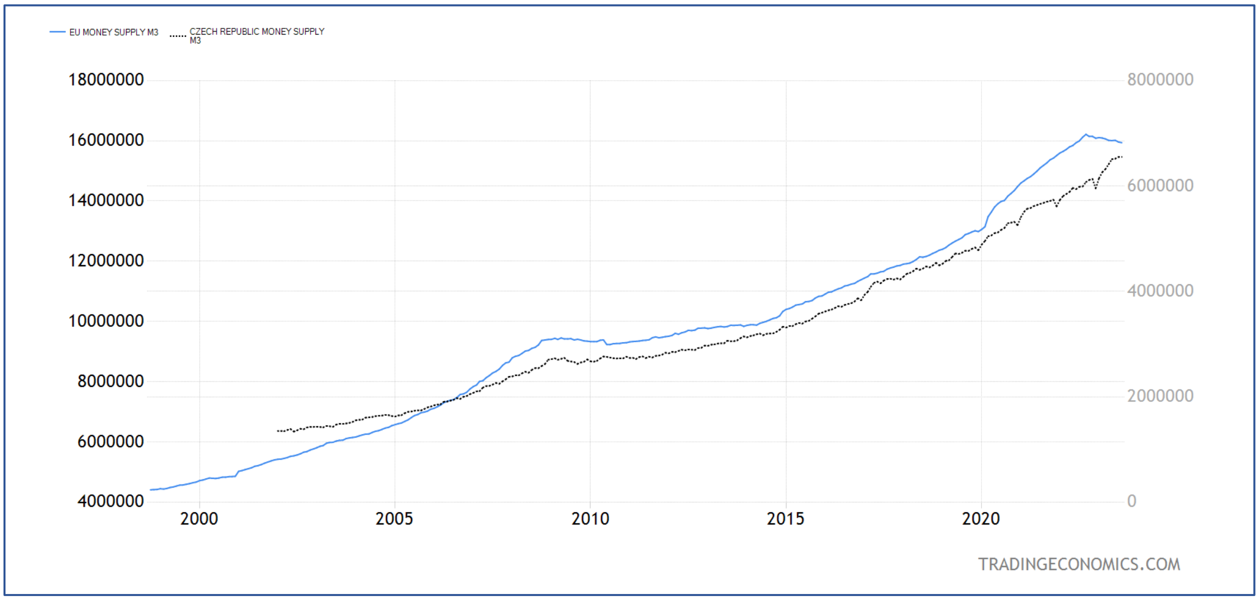

Figure 4: Euro Area vs. Czechia M3 Money Supply (TRADING ECONOMICS, no date c)

Given the negative ECT and the not serially correlated residuals of the ECM (see Appendix C, Figure C3), I can proceed with a TGARCH(1,1) estimation to examine the long-run volatility of these currencies. In the mean equation, the dependent variable was *RCZK* i.e., the returns of *CZK* and the residuals of the ECM were the independent variable.

Table 9. ECM-TGARCH Estimation Results – **LCZK vs. LEUR**

Dependent variable: **RCZK**

Variable	**Coefficient (st. error)**
Constant	3.04E-10 (4.07E-11)***
RESID(-1)^2	0.077781 (0.004647)***
RESID(-1)^2*(RESID(-1)<0	- 0.003052 (0.003668)
GARCH(-1)	0.923683 (0.004712)***

Note: *** denotes significance at the 1% level.

Table 9 presents the results of the TGARCH model. The leverage effect is negative but not significant, so conclusions cannot be made regarding the different effects of positive and negative shocks. However, the sum of the ARCH and GARCH coefficients is close to 1, meaning that the volatility shocks are persistent. Combining this with the large coefficient of the GARCH term, I can conclude that large changes in the volatility will affect the future volatilities for a long period of time since a shock's decay is slower. This persistence of volatility shocks can also justify the negative long-run relationship estimated by the ECM between the Czech koruna and the euro. As shocks tend to have a very persistent effect on the *CZK*, there will be a capital outflow among traders towards more stable currencies like the *EUR*. Thus, the *CZK* will begin to depreciate versus the *EUR* which will start to appreciate because of the capital inflow.

5.2.3. Hungary

Table 10 presents the results of the Engle-Granger cointegration test with *LHUF* as the dependent variable. From the value of the tau-statistic, I cannot reject the null hypothesis of no cointegration between the two currencies.

Table 10. Engle-Granger Cointegration Test Results

Dependent Variable	**tau-statistic**
LHUF	- 1.699507

Note: MacKinnon (1996) p-values.

It is worth noting that the potential nonexistence of a cointegrating relationship between *LHUF* and *LEUR* was also confirmed by the nonstationarity of the RLS residuals as dictated by the critical values of MacKinnon (2010). This relationship was additionally confirmed by the ECM whose results are in Table 11 and indicate a positive and significant ECT. The RLS's residuals employed in the ECM exhibited no autocorrelation and this is evident by their dot plot (see Appendix C, Figure C4). The specification of the ECM is the following:

$$\Delta(LHUF)_t = \omega_3 + \varphi_3 EC_{t-1} + \psi_3 \Delta(LHUF)_{t-1} + \theta_3 \Delta(LEUR)_{t-1} + \varepsilon_t \qquad (11)$$

Table 11. Error Correction Model (ECM) Estimation Results – **LHUF vs. LEUR**

Variable	**Coefficient (st. error)**
Constant	- 0.000144 (1.27E-05)***
ECT_{t-1}	0.967197 (0.050566)***
$\Delta(LHUF)_{t-1}$	- 0.934449 (0.050580)***
$\Delta(LEUR)_{t-1}$	- 0.045549 (0.003426)***

Note: *** denotes significance at the 1% level.

These results, suggesting that Hungary is not ready to join the Eurozone, are aligned with the literature (Stoupos & Kiohos, 2017; Stoupos, 2019). The relationship between *LHUF* and *LEUR* is negative both in the short-run and the long-run. This is a clear statement of Hungarian authorities' views regarding the adoption of the euro i.e., the Euroskeptic Fidesz which has been governing since 2010 with Viktor Orbán as its Prime Minister. To elaborate, despite having joined the EU since 2004, Hungary has not been interested in adopting the euro but has not negotiated an opt-out agreement either. Its Central Bank governor stated last June that if from 2030 onwards Hungary manages to reach "90% of the EU's average in terms of development", then they might consider adopting the euro (Reuters, 2023). For now, it is enjoying the flexibility of not being a part of a monetary union while fighting the highest inflation rate not only among EU members but among all European countries (TRADING ECONOMICS, no date d). It is, however, worth mentioning that after its EU membership, and despite its refusal of a Eurozone membership, Hungary seems to follow the ECB's policies as depicted in Figure 5.

On another note, since there is not a long-run equilibrium between the Hungarian forint and the euro, I cannot proceed with a TGARCH model.

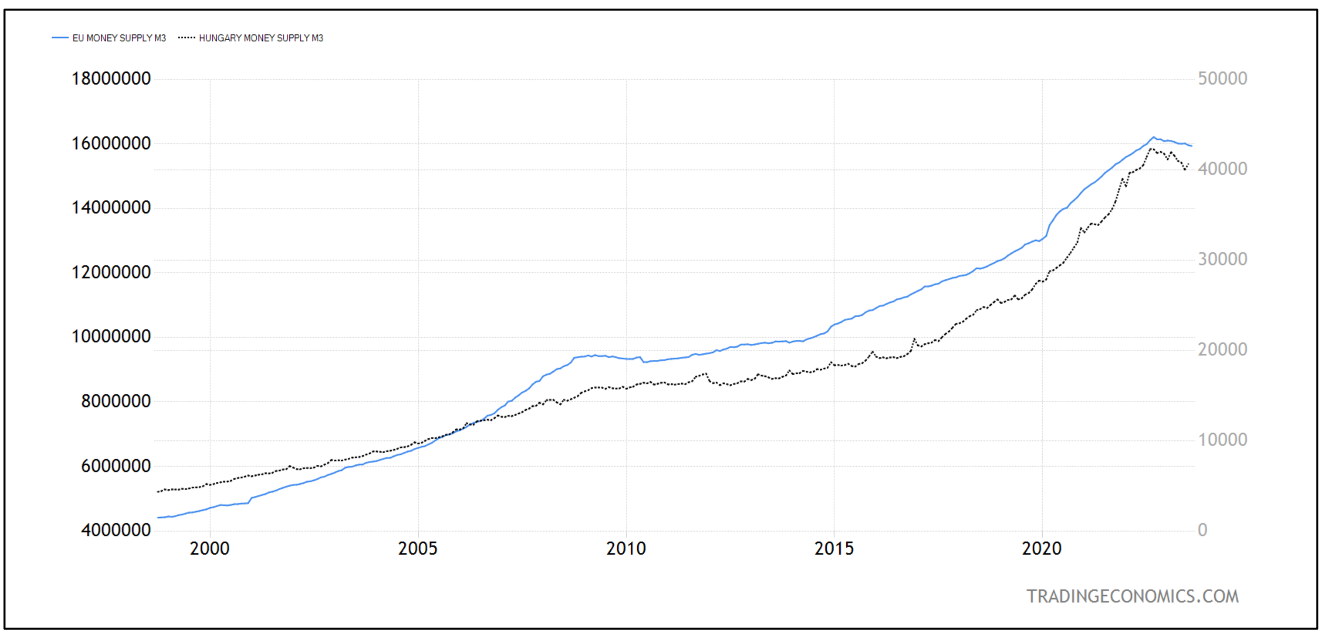

Figure 5: Euro Area vs. Hungary M3 Money Supply (TRADING ECONOMICS, no date c)

5.2.4. Poland

The results of the Engle-Granger cointegration test with *LPLN* as the dependent variable are presented in Table 12. The value of the test's tau-statistic leads to the rejection of the null hypothesis of no cointegration between *LPLN* and *LEUR*. Thus, there is a long-term relationship between the two currencies. This was also confirmed by the stationarity of the RLS residuals which was concluded upon comparison with the MacKinnon (2010) critical values.

Table 12. Engle-Granger Cointegration Test Results

Dependent Variable	**tau-statistic**
LPLN	- 3.710332***

Note: *** denotes significance at the 1% level (MacKinnon (1996) p-values).

Since the two variables were cointegrated and there was no autocorrelation in the RLS residuals (see Appendix C, Figure C5), I proceeded with the estimation of the ECM under the following specification:

$$\Delta(LPLN)_t = \omega_4 + \varphi_4 EC_{t-1} + \psi_4 \Delta(LPLN)_{t-1} + \theta_4 \Delta(LEUR)_{t-1} + \varepsilon_t \qquad (12)$$

The results of the ECM are depicted in Table 13. Indeed, the speed of adjustment is negative and significant at the 10% level. This means that every period 3.06% of the distance *LPLN/LEUR* is covered. In addition, there are positive and significant long-term and short-term dynamics between the euro and the Polish zloty. This only strengthens the view that Poland can adopt the euro as the *PLN* follows the long-term economic behavior of the *EUR* (Stoupos, 2019; Stoupos & Kiohos, 2017).

Table 13. Error Correction Model (ECM) Estimation Results – **LPLN vs. LEUR**

Variable	**Coefficient (st. error)**
Constant	- 0.000103 (1.13E-05)***
ECT_{t-1}	- 0.030585 (0.016555)*
$\Delta(LPLN)_{t-1}$	0.045474 (0.016582)***
$\Delta(LEUR)_{t-1}$	0.013931 (0.003109)***

Note: *** and * denote significance at the 1% and 10% level, respectively.

Nevertheless, the reason that Poland, an EU member since 2004, has not yet become a Eurozone member is mainly due to political issues. The, since 2015, Polish government along with the Polish central bank governor have been actively rooting against the adoption of the euro as they fear that it will limit Poland's growth potential (Staff, 2019). This behavior is more than evident in my empirical results. Specifically, I decided to examine two subperiods of my sample i.e., from 2002-2015 (as the current government was elected in late 2015) and from 2016-2022 (see Appendix B, Figures B4-B5). The results highlighted the influence of both the government's and the central bank's views pertaining to the euro's adoption. Notably, from 2002-2015 the ECT was negative and significant indicating a cointegrating relationship between the PLN and the *EUR*. On the other hand, from 2016-2022 there is de-cointegration between the variables as the ECT becomes positive albeit not significant. It becomes highly significant and increases a lot in absolute value from 2017-2022 i.e., after the government's first year (see Appendix B, Figure B6).

Even more astonishing about those authorities' influence is that until 2016 Poland was only missing the 2-year ERM II participation out of the convergence criteria before adopting the euro (European Central Bank, 2016). Since then, this has drastically changed. Nonetheless, despite its opposition to the euro adoption, it seems like Poland still follows the ECB's policies as depicted in Figure 6.

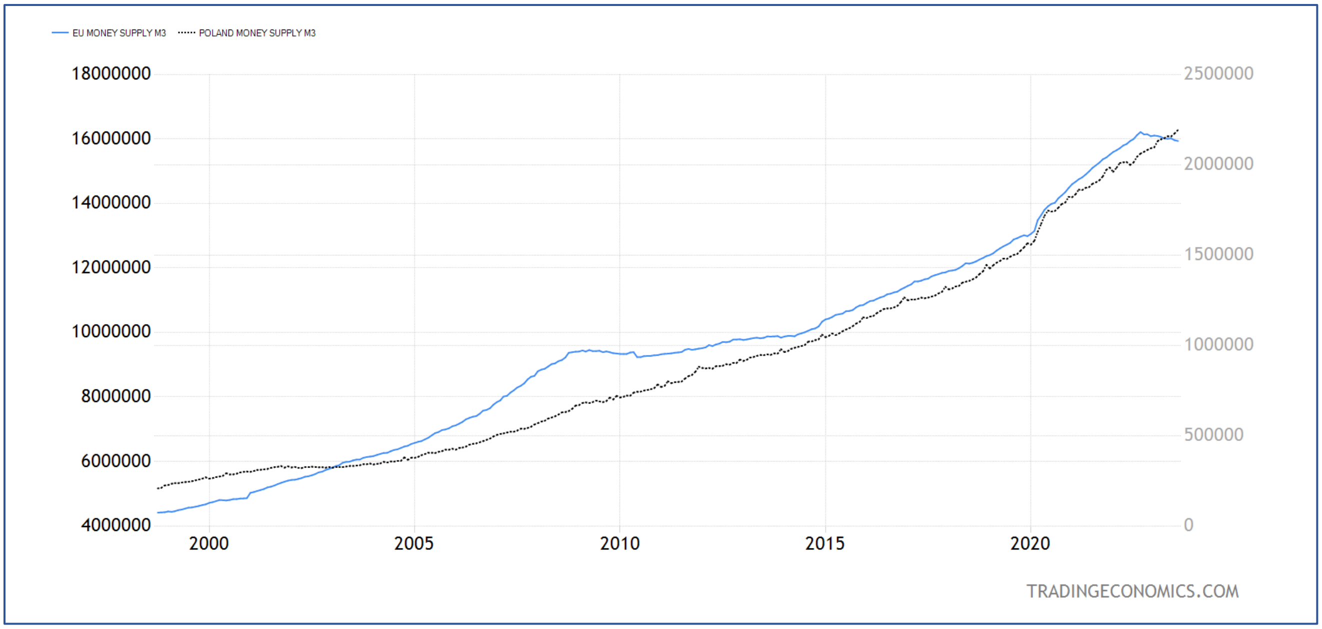

Figure 6: Euro Area vs. Poland M3 Money Supply (TRADING ECONOMICS, no date c)

On another note, as there is a negative and significant ECT and no autocorrelation was observed between the residuals of the ECM (see Appendix C, Figure C6), I was able to proceed with the estimation of the TGARCH(1,1) model to isolate the long-run volatility. In the mean equation, *RPLN* (i.e., the returns of *PLN*) was the dependent variable and the no autocorrelated residuals of the ECM comprised the independent variable.

Table 14 contains the results of the TGARCH model. The leverage term is negative and statistically significant. This means that negative shocks (i.e., bad news) have a lower impact on the volatility of the zloty's returns compared to positive shocks. Furthermore, the sum of the ARCH and GARCH terms is close to 1 suggesting that the shocks are quite persistent. This can affect the traders' behavior towards the zloty.

Table 14. ECM-TGARCH Estimation Results – **LPLN vs. LEUR**

Dependent variable: **RPLN**	
Variable	**Coefficient (st. error)**
Constant	1.45E-10 (3.56E-11)***
RESID(-1)^2	0.042249 (0.003717)***
RESID(-1)^2*(RESID(-1)<0	- 0.012346 (0.004120)***
GARCH(-1)	0.960320 (0.003280)***

Note: *** denotes significance at the 1% level.

5.2.5. Romania

Table 15 presents the results of the Engle-Granger cointegration test between the *LRON* and *LEUR* with *LRON* as the dependent variable. The value of the test's tau-statistic rejects the null hypothesis of no cointegration at the 10% level, so the variables are cointegrated. As an additional step, I also checked the stationarity of the RLS's residuals according to the MacKinnon (2010) critical values. They were found to be stationary.

Table 15. Engle-Granger Cointegration Test Results

Dependent Variable	**tau-statistic**
LRON	- 3.161055***

Note: *** denotes significance at the 10% level (MacKinnon (1996) p-values).

Upon the cointegration test's results and the no serial correlation between the RLS's residuals (see Appendix C, Figure C7), I estimated the ECM under the following specification:

$$\Delta(LRON)_t = \omega_5 + \varphi_5 EC_{t-1} + \psi_5 \Delta(LRON)_{t-1} + \theta_5 \Delta(LEUR)_{t-1} + \varepsilon_t \qquad (13)$$

Table 16. Error Correction Model (ECM) Estimation Results – **LRON vs. LEUR**

Variable	**Coefficient (st. error)**
Constant	- 4.58E-05 (8.99E-06)***
ECT_{t-1}	- 0.032286 (0.028576)
$\Delta(LRON)_{t-1}$	0.084287 (0.028595)***
$\Delta(LEUR)_{t-1}$	- 0.055335 (0.002765)***

Note: *** denotes significance at the 1% level.

The results of the ECM are presented in Table 16. Despite the ECT having a negative coefficient, it is not statistically significant, so I cannot make any inferences regarding the converging or diverging attitude of the variables towards their stable long-run equilibrium. This comes in opposition to the literature's findings as their ECT was significant (Stoupos, 2019; Stoupos & Kiohos, 2017). At the same time, the results pertaining to the short-run and long-run dynamics between the two currencies also do not agree with the literature's ones (Stoupos, 2019; Stoupos & Kiohos, 2017). Notably, my results suggest the existence of positive short-run and negative long-run dynamics.

These results can be justified considering that Romania, an EU member since 2007, despite just having to fulfill the 2-year ERM II participation according to the ECB's 2016 Convergence Report, managed to distance itself from the satisfaction of the convergence criteria for the euro's adoption. To elaborate, according to the most recent 2022 Convergence Report of the ECB, out of all convergence criteria, Romania has only managed to, on average, maintain a low degree of volatility in its exchange rate and a debt-to-GDP ratio below the maximum reference value of 60%, although the latter has been increasing since 2019 (European Central Bank, 2022). Therefore, Romania is falling short in fulfilling the vast majority of the convergence criteria. Furthermore, the ECB highlights that a sustainable convergence will be achieved if Romania applies “stability-oriented economic policies and wide-ranging structural reforms” (European Central Bank, 2022). Additionally, what is more alarming is that the ECB stresses that the quite low productivity levels are pushing the brake in Romania’s growth potential. Perhaps, if Romania manages to overcome these obstacles, they will become Eurozone members as in other aspects they are following the ECB’s policies. This is evident in Figure 7 depicting the Euro Area’s M3 money supply with the one of Romania.

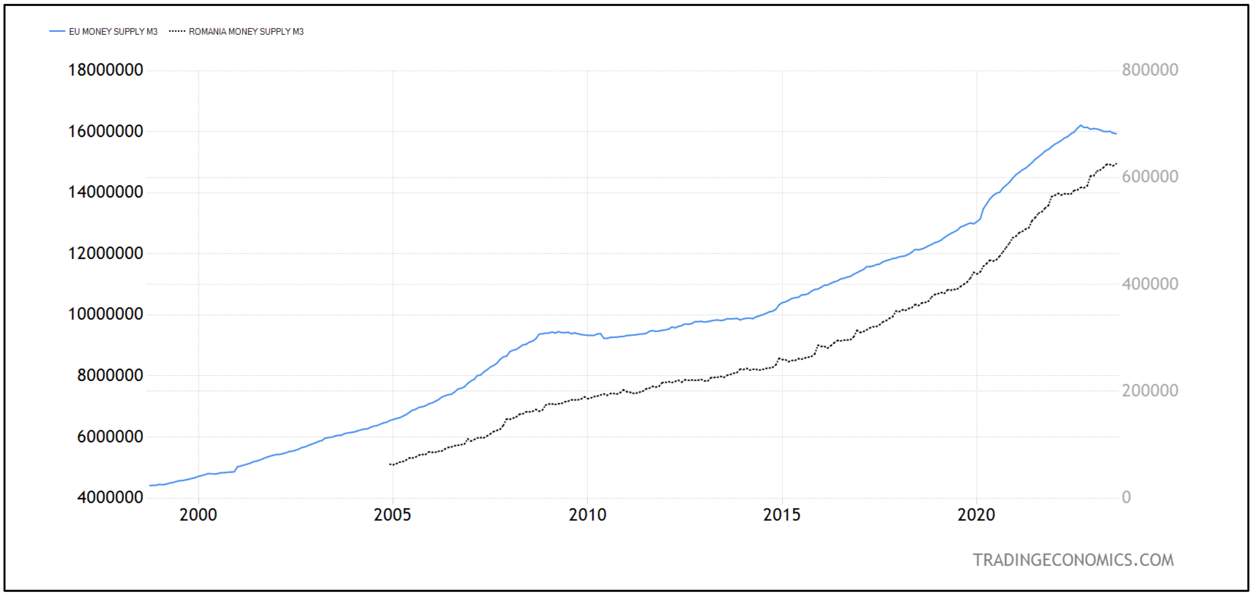

Figure 7: Euro Area vs. Romania M3 Money Supply (TRADING ECONOMICS, no date c)

On another note, as the ECT was not significant I could not estimate a TGARCH model with the ECM’s residuals.

5.2.6. Sweden

The Engle-Granger cointegration test between the *LSEK* and *LEUR* with *LSEK* as the dependent variable found no cointegration relationship between the two currencies. This result, depicted in Table 17, was in line with the indication of nonstationarity of the RLS's residuals according to the MacKinnon (2010) critical values.

Table 17. Engle-Granger Cointegration Test Results

Dependent Variable	**tau-statistic**
LSEK	- 2.021439

Note: MacKinnon (1996) p-values.

Just like with the other currencies, despite the evidence of no cointegration from the Engle-Granger test, and since the RLS's residuals were not autocorrelated (see Appendix C, Figure C8), I also ran the ECM under the following specification to examine whether the results coincide:

$$\Delta(LSEK)_t = \omega_6 + \varphi_6 EC_{t-1} + \psi_6 \Delta(LSEK)_{t-1} + \theta_6 \Delta(LEUR)_{t-1} + \varepsilon_t \qquad (14)$$

Table 18. Error Correction Model (ECM) Estimation Results – **LSEK vs. LEUR**

Variable	**Coefficient (st. error)**
Constant	- 6.78E-05 (1.03E-05)***
ECT_{t-1}	0.328005 (0.021488)***
$\Delta(LSEK)_{t-1}$	- 0.343323 (0.021577)***
$\Delta(LEUR)_{t-1}$	0.028113 (0.003126)***

Note: *** denotes significance at the 1% level.

The empirical results, which are presented in Table 18, indicate a positive and significant ECT. This is different compared to Stoupos (2019)'s findings, but it can be justified as he used the effective exchange rate versus the nominal exchange rate that I am using. The same results appeared in every subperiod that I examined. As for the long-run and short-run dynamics, the former were negative and the latter positive. Positive long-run dynamics suggest that the *SEK* follows the long-term economic behavior of the *EUR* and so Sweden, which has been an EU member since 1995 and has not yet negotiated an opt-out agreement, could potentially benefit from a Eurozone participation (Figure 9). Since the ECT is significantly positive, I did not proceed with a TGARCH.

Nonetheless, and most importantly, my findings are in line with the general attitude of Sweden towards the euro's adoption over the years. Exactly 20 years ago the Swedish authorities, who were open to the euro-adopting scenario, held a referendum where the public rejected the Eurozone membership. However, due to recent developments pertaining to the 17.5% depreciation of the *SEK* against the *EUR* over the past 18 months, the euro adoption option has resurfaced (Johnson, 2023). The highly developed Swedish economy is reliant on both its imports and exports. With this depreciation, the Swedish exporting activities have increased at the cost of more expensive imports. The latter may mean that the Swedish central bank will have to keep fighting inflation with high interest rates for a longer period (Johnson, 2023). Specifically, to control the depreciating trend of the *SEK*, the Swedish authorities are trying to keep up with the ECB's interest rate hikes to minimize the capital outflow towards the *EUR* (Figure 8). This policy is also evident if we take a closer look at the M3 money supply of Sweden which has rapidly declining versus the Euro Area's for over a year now (Figure 10). As a final note, when the depreciating trend of the *SEK* began, the public started revising their attitude towards the euro. This attitude is quite evident in the past couple Eurobarometer surveys as in 2023 54% of the interviewees were in favor of the euro compared to the previous year's 45% (European Commission, 2022; European Commission, 2023). In case Sweden decides to adopt the euro, it will most probably be relatively quick as the only convergence criterion it still has to fulfill is the 2-year ERM II participation (European Central Bank, 2022).

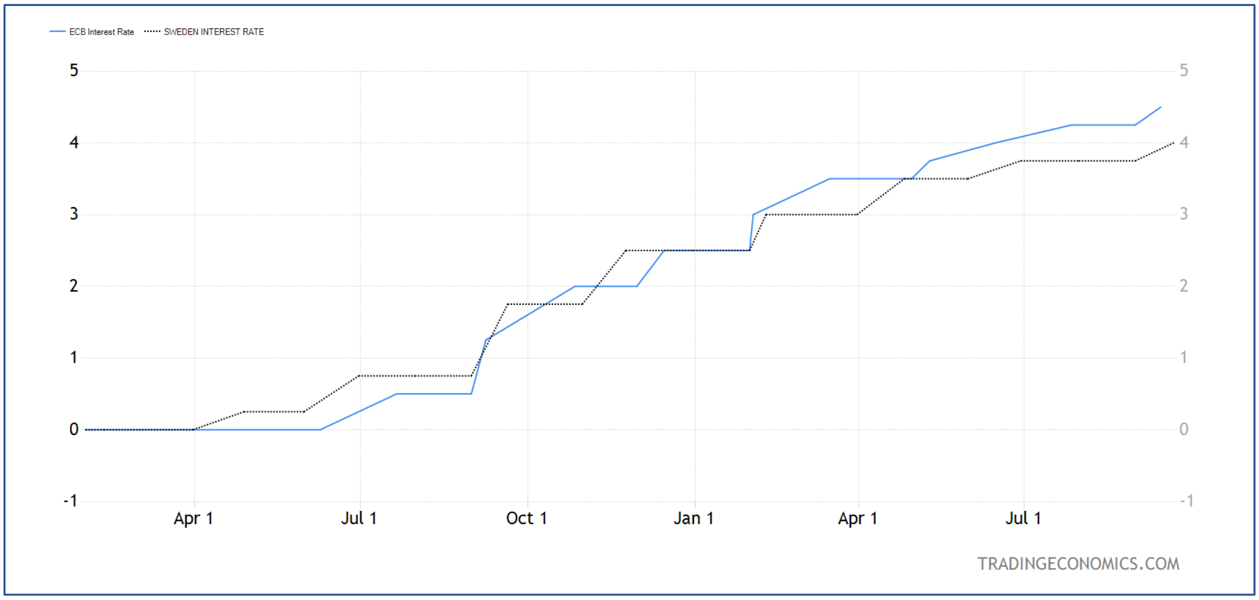

Figure 8: Euro Area vs. Sweden Interest Rate (TRADING ECONOMICS, no date b)

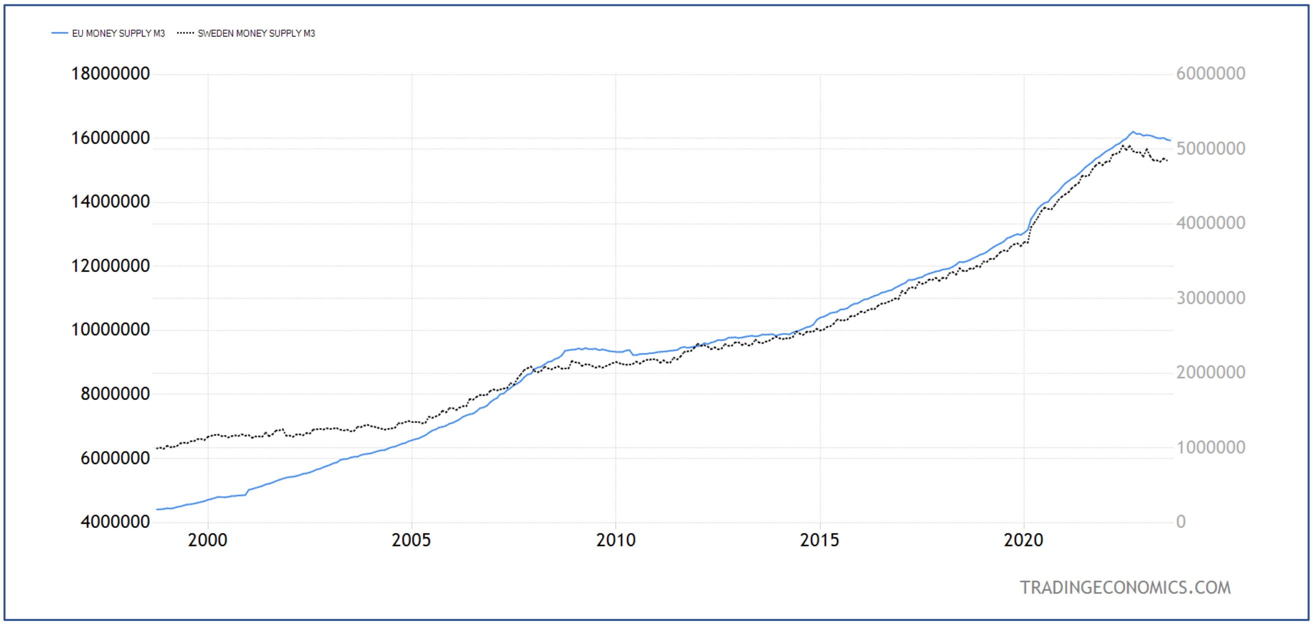

Figure 9: Euro Area vs. Sweden M3 Money Supply (TRADING ECONOMICS, no date c)

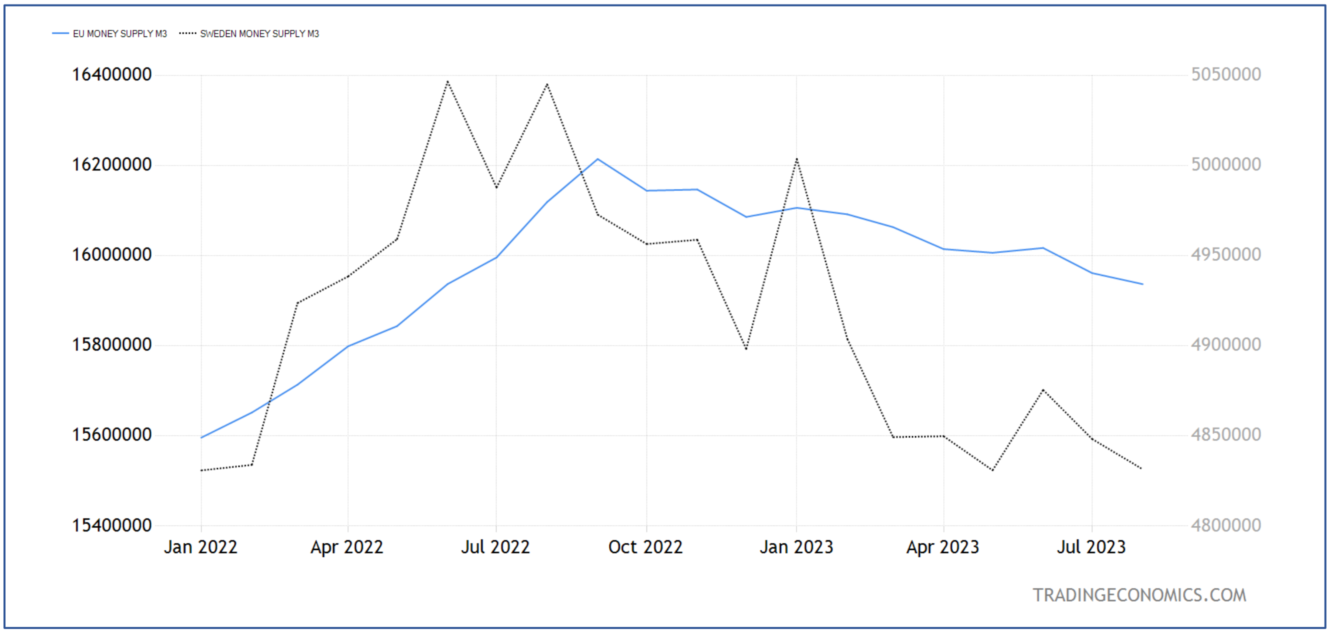

Figure 10: Euro Area vs. Sweden M3 Money Supply 2022-2023 (TRADING ECONOMICS, no date c)

5.2.7. Switzerland

The Engle-Granger cointegration test between the *CHF* and *EUR* with *CHF* as the dependent variable, whose tau-statistic is found in Table 19, cannot reject the null hypothesis of no cointegration.

Table 19. Engle-Granger Cointegration Test Results

Dependent Variable	**tau-statistic**
CHF	-2.002968

Note: MacKinnon (1996) p-values.

As in previous cases, despite the results of the Engle-Granger test, and since no autocorrelation was observed in the RLS's residuals (see Appendix C, Figure C9), I proceeded with the ECM estimation to solidify the results. The equation employed was the following:

$$\Delta(CHF)_t = \omega_7 + \varphi_7 EC_{t-1} + \psi_7 \Delta(CHF)_{t-1} + \theta_7 \Delta(EUR)_{t-1} + \varepsilon_t \qquad (15)$$

The results of the ECM are presented in Table 20. The coefficient of the ECT is negative and significant at the 1% level, indicating that there is a stable long-run equilibrium between the *CHF* and the *EUR*. Specifically, in each period 44.7% of the distance *CHF/EUR* is covered. My results differ from Stoupos (2019)'s as they suggest a stronger cointegrating relationship between the two currencies. As for the short-run and long-run dynamics, they are both positive. To elaborate, Switzerland follows the long-term economic behavior of the Euro Area. This comes as no surprise considering the close ties between the two economies with Switzerland being an EFTA member.

I additionally decided to examine 2 subperiods. From 2002-2011 the ECT was positive and significant at the 10% level but from 2012 onwards it is negative and significant at the 1% level (see Appendix B, Figures B7-B8). To elaborate, the two currencies have a different relationship before and after 2012. This is an anticipated outcome as from September 9th, 2011, until January 15th, 2015, the *CHF* had a minimum peg versus the *EUR* of 1.20 *CHF*/*EUR*.

Table 20. Error Correction Model (ECM) Estimation Results – **CHF vs. EUR**

Variable	**Coefficient (st. error)**
Constant	- 3.05E-05 (9.40E-06)***
ECT_{t-1}	- 0.447030 (0.030722)***
$\Delta(CHF)_{t-1}$	0.428438 (0.030769)***
$\Delta(EUR)_{t-1}$	0.022193 (0.003051)***

Note: *** denotes significance at the 1% level.

Since the ECM suggested a significant long-term relationship between the CHF and the EUR and the ECM's residuals exhibited no autocorrelation (see Appendix C, Figure C10), I can estimate a TGARCH(1,1) model to isolate the long-run volatility. The results can be seen in Table 21. The leverage effect is positive and significant at the 1% level so there is an asymmetry in the effect of good and bad news as the former have a smaller effect on the volatility of the *CHF*'s returns compared to the latter. Notably, according to theory, the effect of good news is 0.062307 whereas the effect of bad news is 0.062307 + 0.125135 = 0.187442. Furthermore, the sum of the ARCH and GARCH terms is close to 1 which means that the volatility shocks are persistent. The existence of this asymmetric reaction to shocks, compared to the other currencies where the asymmetry was in favor of the good news, may be justified by the Swiss National Bank's sudden abandonment of the floor peg of 1.20 francs/euro in 2015 which created a turmoil in the financial markets (Figure 11).

Table 21. ECM-TGARCH Estimation Results – **CHF vs. EUR**

Dependent variable: **RCHF**

Variable	**Coefficient (st. error)**
Constant	3.94E-10 (3.99E-11)***
RESID(-1)^2	0.062307 (0.005709)***
RESID(-1)^2*(RESID(-1)<0	0.125135 (0.009490)***
GARCH(-1)	0.881304 (0.005238)***

Note: *** denotes significance at the 1% level.

Figure 11: EURCHF 01/2002 to 09/2023 (TRADING ECONOMICS, no date a)

5.2.8. United Kingdom (UK)

By examining the value of the Engle-Granger cointegration test between the *GBP* and *EUR* with *GBP* as the dependent variable, I observe that the null hypothesis of no cointegration cannot be rejected (Table 22). That was confirmed by the nonstationarity of the RLS's residuals when compared with the MacKinnon (2010) critical values.

Table 22. Engle-Granger Cointegration Test Results

Dependent Variable	**tau-statistic**
GBP	- 1.812566

Note: MacKinnon (1996) p-values.

Besides the outcome of the Engle-Granger test, and since the RLS's residuals exhibited no autocorrelation (see Appendix C, Figure C11), I proceeded with the estimation of the ECM to observe any discrepancies. The ECM specification had the following form as no natural logarithmic transformation was needed:

$$\Delta(GBP)_t = \omega_8 + \varphi_8 EC_{t-1} + \psi_8 \Delta(GBP)_{t-1} + \theta_8 \Delta(EUR)_{t-1} + \varepsilon_t \qquad (16)$$

The results of the ECM are presented in Table 23. The coefficient of the ECT is both positive and statistically significant suggesting a no cointegrating and diverging relationship between the British pound and the euro. This relationship is expected considering the UK's troubled relationship with the EU over the past decade resulting in the well-known referendum of June 23rd, 2016, that led to Brexit as of February 1st, 2020 (*The EU-UK withdrawal Agreement*, no date). Also, the pound is negatively affected by the euro in the short run and slightly positively affected in the long run. The results pertaining to the non-existence of a speed of adjustment back to equilibrium are aligned with the literature (Stoupos, 2019). On the contrary, both the long-run and the short-run dynamics are opposing the ones of Stoupos (2019), but this only highlights the effect that Brexit has had in the relationship between the two currencies.

Table 23. Error Correction Model (ECM) Estimation Results – **GBP vs. EUR**

Variable	**Coefficient (st. error)**
Constant	-5.91E-06 (5.37E-06)
ECT_{t-1}	0.272373 (0.054150)***
$\Delta(GBP)_{t-1}$	- 0.270994 (0.054136)***
$\Delta(EUR)_{t-1}$	0.007814 (0.001453)***

Note: *** denotes significance at the 1% level.

Nonetheless, it is quite interesting that despite distancing itself from the EU, the Bank of England has been following the ECB's behavior from 2020 onwards as illustrated in Figure 12. This should not come as a surprise since the UK maintains its strong trade relations with the EU which are also highlighted by the signing of the EU-UK Trade and Cooperation Agreement which has been in effect since May 1st, 2021. Specifically, the EU is the UK's biggest trading partner accounting for 40% of the UK's foreign trade in goods in 2022 and, from the EU's perspective, the UK is its third biggest trading partner (9.8% of trade in 2022) (*EU trade relations with the United Kingdom*, 2022).

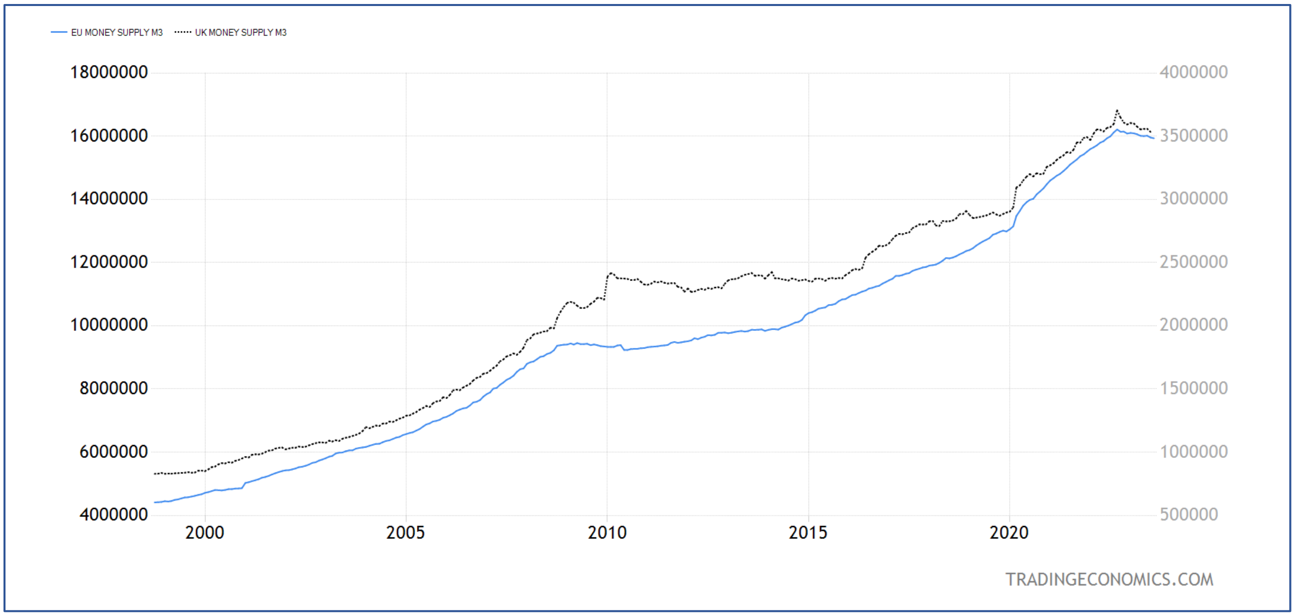

Figure 12: Euro Area vs. UK M3 Money Supply (TRADING ECONOMICS, no date c)

6. Conclusion

Given the inherent challenges that arise from the Eurozone's ongoing enlargement, a careful examination of the potential future Eurozone members is necessary. The purpose of this study was to examine the relationship that non-Euro countries have with the Eurozone and pinpoint the reasons behind their no participation in the Eurozone as well as investigate the existence of leverage effects that would directly affect traders among other economic agents. Any discrepancies between this study's findings and the literature are justified by recent developments in the respective countries as the data of Stoupos and Kiohos (2017) and Stoupos (2019) were up until the mid-2010s.

The empirical findings suggest that out of the countries under consideration only Czechia, Poland, and Switzerland are already aligned with the Euro Area and could consider adopting the euro. In the case of Czechia and Poland, there are mainly political reasons for delaying the euro adoption as they both closely follow the ECB's policies. As for Switzerland, it has always been choosing to maintain its sovereignty. Nonetheless, it is highly integrated with the Eurozone due to their tight trade ties. As for the leverage effect, it was only present in the case of Switzerland whose currency is heavily traded and has been considered by traders as a "safe haven". This could be attributed to the turmoil created in the financial markets after the Swiss National Bank's sudden drop of the floor peg in 2015.

As for the rest of the countries, i.e., Hungary, Romania, Sweden, and the UK are far from replacing their respective national currency with the euro. In the case of Hungary and Romania, the delay in adopting the euro stems from their respective authorities' opposition to such a scenario. However, both do follow the ECB's policies as EU members with unavoidable trade relationships with the Euro Area. Sweden on the other hand respects its citizens' wish of no euro adoption since the referendum of 2003. Nonetheless, it still follows very closely the ECB's policies which along with the recent shift in public opinion might raise the barriers of its Eurozone membership. As for the UK, the results were anticipated after the infamous Brexit of 2016 which was made official in 2020. Nevertheless, the close trade ties between the UK and the Eurozone remain as the Bank of England follows the ECB's behavior. Lastly, Croatia which just joined the

Eurozone this past January, does not appear to be integrated with the Eurozone in the overall examined period but only after 2018 when it was already actively fulfilling the convergence criteria. It will then be worth observing its new path as a Eurozone member.

As for some future recommendations, I believe that this study can benefit from the use of intraday instead of daily data as the foreign exchange market is being heavily traded. Most importantly, the Eurozone's enlargement should continuously be evaluated to safeguard its unity.

References

Aizenman, J. (2013) 'THE IMPOSSIBLE TRINITY — FROM THE POLICY TRILEMMA TO THE POLICY QUADRILEMMA', *Global Journal of Economics*, 02(01), p. 1350001. https://doi.org/10.1142/s2251361213500018.

Asteriou, D. and Hall, S.G. (2021) *Applied Econometrics*. Bloomsbury Publishing.

Beck, H. and Prinz, A. (2012) 'The trilemma of a monetary union: Another impossible trinity', *Intereconomics*, 47(1), pp. 39–43. https://doi.org/10.1007/s10272-012-0404-0.

Bollerslev, T. (1986) 'Generalized Autoregressive Conditional Heteroskedasticity', *Journal of Econometrics*, 31(3), pp. 307–327. https://doi.org/10.1016/0304-4076(86)90063-1.

Brada, J.C. and Kutan, A.M. (2001) 'The convergence of monetary policy between candidate countries and the European Union', *Economic Systems*, 25(3), pp. 215–231. https://doi.org/10.1016/s0939-3625(01)00027-9.

Brada, J.C., Kutan, A.M. and Zhou, S. (2005) 'Real and monetary convergence between the European Union's core and recent member countries: A rolling cointegration approach', *Journal of Banking and Finance*, 29(1), pp. 249–270. https://doi.org/10.1016/j.jbankfin.2004.06.024.

Brooks, C. (2019) *Introductory Econometrics for Finance*. Available at: https://doi.org/10.1017/9781108524872.

Christie, A.A. (1982) 'The Stochastic Behavior of Common Stock Variances Value, Leverage and Interest Rate Effects', *Journal of Financial Economics*, 10(4), pp. 407–432. https://doi.org/10.1016/0304-405x(82)90018-6.

Conditions for joining the euro area: convergence criteria (2023). Available at: https://www.consilium.europa.eu/en/policies/joining-the-euro-area/convergence-criteria/.

Corden, W.M. (1972) *Monetary Integration*. Princeton: Princeton University. Essays in International Finance, No. 93.

Czech National Bank (no date). *What was the exchange rate commitment?* https://www.cnb.cz/en/faq/What-was-the-exchange-rate-commitment/.

Darvas, Z. (2022) 'Discretion lets Croatia in but leaves Bulgaria out of the euro area in 2023', *Bruegel Blog*, 22 June. Available at: https://www.bruegel.org/blog-post/discretion-lets-croatia-leaves-bulgaria-out-euro-area-2023.

De Grauwe, P. and Vanhaverbeke, W. (1991) 'Is Europe an Optimum Currency Area? Evidence from Regional Data', CEPR Discussion Papers, No. 555.

Dickey, D.A. and Fuller, W.A. (1979) 'Distribution of the Estimators for Autoregressive Time Series with a Unit Root', *Journal of the American Statistical Association*, 74(366a), pp. 427–431. Available at: https://doi.org/10.1080/01621459.1979.10482531.

ECB Data Portal (no date). Available at: https://data.ecb.europa.eu/.

Economidou, C. and Kool, C. (2009) 'European economic integration and (a)symmetry of macroeconomic fluctuations', *Economic Modelling*, 26(4), pp. 778–787. https://doi.org/10.1016/j.econmod.2008.07.009.

Eichengreen, B. (1991) *Is Europe an optimum currency area?* https://doi.org/10.3386/w3579.

Engle, R.F. (1982) 'Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation', *Econometrica*, 50(4), p. 987. https://doi.org/10.2307/1912773.

Engle, R.F. and Granger, C.W.J. (1987) 'Co-Integration and Error Correction: Representation, Estimation, and Testing', *Econometrica*, 55(2), p. 251. Available at: https://doi.org/10.2307/1913236.

EU trade relations with the United Kingdom (2022). https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/united-kingdom_en.

European Central Bank (2016) *Convergence Report, June 2016*. Available at: https://www.ecb.europa.eu/pub/pdf/conrep/cr201606.en.pdf.

European Central Bank (2020) *Communiqué on Croatia*. https://www.ecb.europa.eu/press/pr/date/2020/html/ecb.pr200710_1~88c0f764e7.en.html?utm_source=ecb_twitter&utm_medium=social&utm_campaign=20200710_PR_ECBCroatia.

European Central Bank (2022) *Convergence Report, June 2022*. Available at: https://www.ecb.europa.eu/pub/convergence/html/ecb.cr202206~e0fe4e1874.en.html.

European Commission (2022) *Introduction of the euro in the Member States that have not yet adopted the common currency - Spring 2022 - June 2022 - Eurobarometer survey*. Available at: https://europa.eu/eurobarometer/surveys/detail/2662.

European Commission (2023) *Introduction of the euro in the Member States not yet having adopted the common currency - Spring 2023 - June 2023 - Eurobarometer survey*. Available at: https://europa.eu/eurobarometer/surveys/detail/2982.

Frankel, J.A. and Rose, A.K. (1996) *The endogeneity of the optimum currency area criteria*. https://doi.org/10.3386/w5700.

Granger, C.W.J. (1981) 'Some Properties of Time Series Data and Their Use in Econometric Model Specification', *Journal of Econometrics*, 16(1), pp. 121–130. Available at: https://doi.org/10.1016/0304-4076(81)90079-8.

Holtemöller, O. (2005) ‘Uncovered interest rate parity and analysis of monetary convergence of potential EMU accession countries’, *International Economics and Economic Policy*, 2(1), pp. 33–63. https://doi.org/10.1007/s10368-005-0026-0.

Huber, P.J. (1964) ‘Robust estimation of a location parameter’, *Annals of Mathematical Statistics*, 35(1), pp. 73–101. https://doi.org/10.1214/aoms/1177703732.

Johnson, S. (2023) ‘Twenty years after euro “No” vote, Swedes fret over weak crown’, *Reuters*, 14 September. Available at: https://www.reuters.com/markets/currencies/twenty-years-after-euro-no-vote-swedes-fret-over-weak-crown-2023-09-14/.

Kenen, P. (1969) ‘The Theory of Optimum Currency Areas: An Eclectic View’, in Mundell, R.A. and Swoboda, A. (eds.) *Monetary Problems of the International Economy*. Chicago: The University of Chicago Press, pp. 41-60.

Keppel, C. and Prettner, K. (2015) ‘How interdependent are Eastern European economies and the Euro area?’, *The Quarterly Review of Economics and Finance*, 58, pp. 18–31. https://doi.org/10.1016/j.qref.2015.02.012.

Krugman, P. (2013) ‘Revenge of the optimum currency area’, *NBER Macroeconomics Annual*, 27(1), pp. 439–448. https://doi.org/10.1086/669188.

Liang, H. (2016) *Real exchange rate volatility: Does the nominal exchange rate regime matter?* https://www.imf.org/en/Publications/WP/Issues/2016/12/30/Real-Exchange-Rate-Volatility-Does-the-Nominal-Exchange-Rate-Regime-Matter-2763.

MacKinnon, J.G. (2010) *Critical values for cointegration tests*. Available at: http://hdl.handle.net/10419/67744.

Mankiw, N.G. (2022) *Macroeconomics*. Macmillan Higher Education.

McKinnon, R.I. (1963) ‘Optimum Currency Areas’, *The American Economic Review*, *53*(4), pp. 717-725.

Meister, I.S. (2002) 'Is Eastern Europe ready for the Euro? A Cointegration Analysis for the Maastricht Criteria', WO Research Memoranda, 699, Netherlands Central Bank, Research Department. Available at: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=ae8b82ba22f0928fcfdbac11feca37c604c51855.

Mundell, R.A. (1961) 'A Theory of Optimum Currency Areas', *The American Economic Review*, *51*(4), pp. 657-665.

Reuters (2023) 'Hungary central-bank chief sees chance for euro adoption only after 2030', *Reuters*, 2 June. Available at: https://www.reuters.com/markets/europe/hungary-cbank-chief-sees-chance-euro-adoption-only-after-2030-2023-06-02/.

Rhodes, J. (2010) 'The Suitability of Accession Countries in the Euro Area', *Issues in Political Economy*, 19, pp. 51–68.

Said, S.E. and Dickey, D.A. (1984) 'Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order', *Biometrika*, 71(3), pp. 599–607. Available at: https://doi.org/10.1093/biomet/71.3.599.

Staff, R. (2019) 'UPDATE 1-Poland's central bank head says won't allow euro adoption', *Reuters*, 22 May. Available at: https://www.reuters.com/article/poland-eurozone-glapinski-idUSL5N22Y2V6.

Stoupos, N. (2019) 'Expanding Eurozone or not?', PhD thesis, University of Macedonia, Thessaloniki. Available at: https://dspace.lib.uom.gr/bitstream/2159/22765/1/StouposNikolaosPhd2018.pdf.

Stoupos, N. (2020) 'BULGARIA, ESTONIA, LITHUANIA AND THE EUROPEAN COMMON CURRENCY', *Archives of Economic History*, 32(1), pp. 35–53. Available at: https://archivesofeconomichistory.com/webdata/magaz/Volume_XXXII_No1_2020.pdf#page=35.

Stoupos, N. and Kiohos, A. (2017) 'Post-communist countries of the EU and the euro: Dynamic linkages between exchange rates', *Acta Oeconomica*, 67(4), pp. 511–538. https://doi.org/10.1556/032.2017.67.4.2.

Tavlas, G.S. (1994) 'The theory of monetary integration', *Open Economies Review*, 5(2), pp. 211–230. https://doi.org/10.1007/bf01000489.

The EU-UK withdrawal agreement (2023). Available at: https://www.consilium.europa.eu/en/policies/eu-relations-with-the-united-kingdom/the-eu-uk-withdrawal-agreement/.

TRADING ECONOMICS (no date a) *EURCHF Euro Swiss Franc - Currency exchange rate live price chart*. Available at: https://tradingeconomics.com/eurchf:cur.

TRADING ECONOMICS (no date b) *Euro area interest rate - 2023 data - 1998-2022 historical - 2024 forecast - calendar*. Available at: https://tradingeconomics.com/euro-area/interest-rate.

TRADING ECONOMICS (no date c) *Euro Area Money Supply M3 - August 2023 Data - 1980-2022 historical*. Available at: https://tradingeconomics.com/euro-area/money-supply-m3.

TRADING ECONOMICS (no date d) *Hungary inflation rate - August 2023 data - 1992-2022 historical - September forecast*. Available at: https://tradingeconomics.com/hungary/inflation-cpi.

UNTERM (no date). https://unterm.un.org/unterm2/en/view/4275087d-4018-4082-899d-95f37efeda65.

Zakoian, J.-M. (1994b) 'Threshold Heteroskedastic Models', *Journal of Economic Dynamics and Control*, 18(5), pp. 931–955. https://doi.org/10.1016/0165-1889(94)90039-6.

Appendix A

Appendix A comprises of the RLS estimation results for each one of the eight countries that this study examines, in alphabetical order.

Table A1. Robust Least Squares (RLS) Estimation Results

Dependent variable: **LHRK**	
Variable	**Coefficient (st. error)**
Constant	0.229102 (0.000974)***
LEUR	0.119336 (0.000510)***
LHRK(-1)	0.886540 (0.000483)***

Note: *** denotes significance at the 1% level.

Table A2. Robust Least Squares (RLS) Estimation Results

Dependent variable: **LCZK**	
Variable	**Coefficient (st. error)**
Constant	0.025853 (0.000416)***
LEUR	0.010759 (0.000173)***
LCZK(-1)	0.992288 (0.000124)***

Note: *** denotes significance at the 1% level.

Table A3. Robust Least Squares (RLS) Estimation Results

Dependent variable: **LHUF**

Variable	**Coefficient (st. error)**
Constant	0.008085 (0.000546)***
LEUR	0.003326 (0.000169)***
LHUF(-1)	0.998629 (9.48E-05)***

Note: *** denotes significance at the 1% level.

Table A4. Robust Least Squares (RLS) Estimation Results

Dependent variable: **LPLN**

Variable	**Coefficient (st. error)**
Constant	0.013926 (0.000240)***
LEUR	0.013481 (0.000223)***
LPLN(-1)	0.990765 (0.000161)***

Note: *** denotes significance at the 1% level.

Table A5. Robust Least Squares (RLS) Estimation Results

Dependent variable: **LRON**

Variable	**Coefficient (st. error)**
Constant	0.001691 (9.99E-05)***
LEUR	0.003478 (0.000107)***
LRON(-1)	0.999138 (6.77E-05)***

Note: *** denotes significance at the 1% level.

Table A6. Robust Least Squares (RLS) Estimation Results

Dependent variable: **LSEK**

Variable	**Coefficient (st. error)**
Constant	0.016546 (0.000359)***
LEUR	0.009078 (0.000201)***
LSEK(-1)	0.992798 (0.000157)***

Note: *** denotes significance at the 1% level.

Table A7. Robust Least Squares (RLS) Estimation Results

Dependent variable: **CHF**	
Variable	**Coefficient (st. error)**
Constant	- 3.07E-05 (8.46E-05)
EUR	0.002134 (0.000101)***
CHF(-1)	0.998307 (5.51E-05)***

Note: *** denotes significance at the 1% level.

Table A8. Robust Least Squares (RLS) Estimation Results

Dependent variable: **GBP**	
Variable	**Coefficient (st. error)**
Constant	- 0.000297 (4.78E-05)***
EUR	0.001234 (7.08E-05)***
GBP(-1)	0.998883 (7.18E-05)***

Note: *** denotes significance at the 1% level.

Appendix B

Appendix B comprises of tables depicting the ECM estimation results of the currencies for which specific subperiods were also acknowledged in this study (i.e., Croatia, Poland, and Switzerland).

Table B1. Error Correction Model (ECM) Estimation Results – **LHRK vs. LEUR** (2002 – 2015)

Variable	**Coefficient (st. error)**
Constant	- 0.000109 (1.12E-05)***
ECT_{t-1}	0.038957 (0.005525)***
$\Delta(LHRK)_{t-1}$	0.044523 (0.008849)***
$\Delta(LEUR)_{t-1}$	- 0.077230 (0.007349)***

Note: *** denotes significance at the 1% level.

Table B2. Error Correction Model (ECM) Estimation Results – **LHRK vs. LEUR** (2016 – 2017)

Variable	**Coefficient (st. error)**
Constant	- 0.000183 (2.35E-05)***
ECT_{t-1}	0.183165 (0.023791)***
$\Delta(LHRK)_{t-1}$	- 0.340486 (0.030960)***
$\Delta(LEUR)_{t-1}$	0.194435 (0.022369)***

Note: *** denotes significance at the 1% level.

Table B3. Error Correction Model (ECM) Estimation Results – **LHRK vs. LEUR** (2018 – 2022)

Variable	**Coefficient (st. error)**
Constant	0.000132 (1.36E-05)***
ECT_{t-1}	- 0.070502 (0.013826)***
$\Delta(LHRK)_{t-1}$	0.370670 (0.021192)***
$\Delta(LEUR)_{t-1}$	- 0.293998 (0.016942)***

Note: *** denotes significance at the 1% level.

Table B4. Error Correction Model (ECM) Estimation Results – **LPLN vs. LEUR** (2002 – 2015)

Variable	**Coefficient (st. error)**
Constant	- 0.000152 (1.50E-05)***
ECT_{t-1}	- 0.091971 (0.019275)***
$\Delta(LPLN)_{t-1}$	0.078829 (0.019305)***
$\Delta(LEUR)_{t-1}$	0.029343 (0.003762)***

Note: *** denotes significance at the 1% level.

Table B5. Error Correction Model (ECM) Estimation Results – **LPLN vs. LEUR** (2016 – 2022)

Variable	**Coefficient (st. error)**
Constant	- 1.80E-05 (2.09E-05)
ECT_{t-1}	0.039630 (0.048106)
$\Delta(LPLN)_{t-1}$	0.086493 (0.048130)*
$\Delta(LEUR)_{t-1}$	- 0.077842 (0.006229)***

Note: *** and * denote significance at the 1% and 10% level, respectively.

Table B6. Error Correction Model (ECM) Estimation Results – **LPLN vs. LEUR** (2017 – 2022)

Variable	**Coefficient (st. error)**
Constant	- 8.11E-05 (2.30E-05)***
ECT_{t-1}	0.169002 (0.049434)***
$\Delta(LPLN)_{t-1}$	- 0.067485 (0.049524)
$\Delta(LEUR)_{t-1}$	- 0.060706 (0.007019)***

Note: *** denotes significance at the 1% level.

Table B7. Error Correction Model (ECM) Estimation Results – **CHF vs. EUR** (2002 – 2011)

Variable	**Coefficient (st. error)**
Constant	- 0.000342 (4.41E-05)***
ECT_{t-1}	0.211387 (0.114987)*
$\Delta(CHF)_{t-1}$	- 0.250832 (0.115047)**
$\Delta(EUR)_{t-1}$	0.043811 (0.006106)***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% level.

Table B8. Error Correction Model (ECM) Estimation Results – **CHF vs. EUR** (2012 – 2022)

Variable	**Coefficient (st. error)**
Constant	4.32E-05 (4.41E-05)***
ECT_{t-1}	- 0.346379 (0.080003)***
$\Delta(CHF)_{t-1}$	0.360522 (0.079986)***
$\Delta(EUR)_{t-1}$	0.003262 (0.002986)

Note: *** denotes significance at the 1% level.

Appendix C

Appendix C contains the dot plots of the residuals of RLS and, for the currencies that a TGARCH model was also estimated (i.e., *CZK*, *PLN*, and *CHF*), of ECM. This is to show that no autocorrelation was found in the respective residuals.

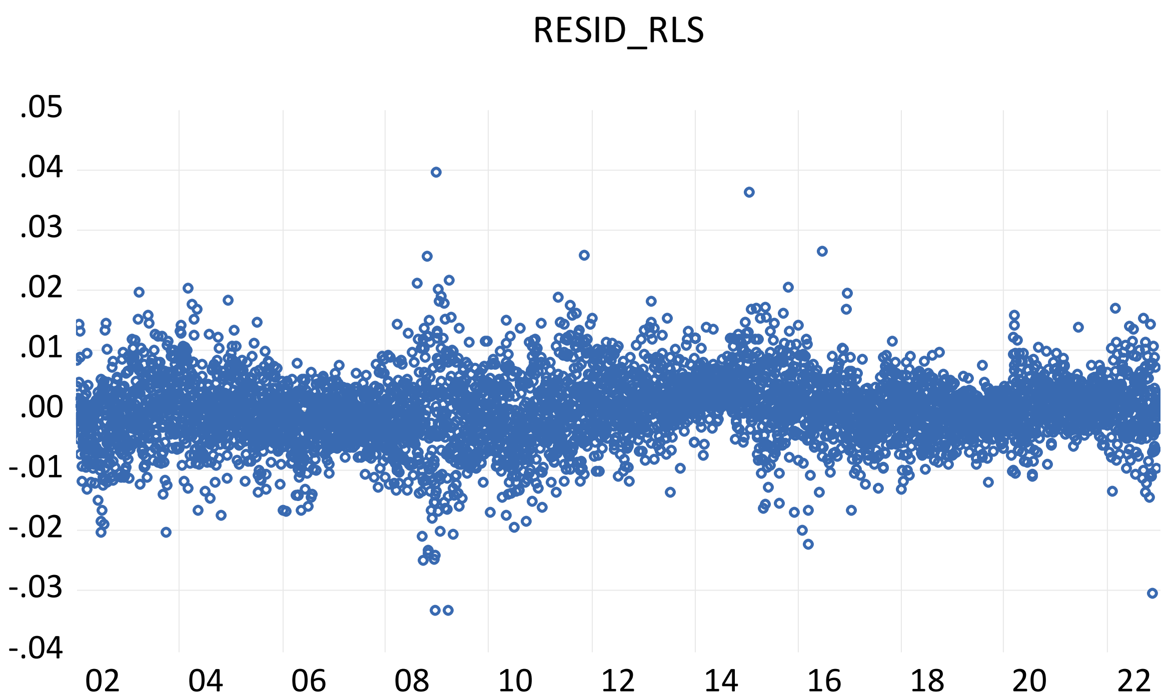

Figure C1: Dot plot of RLS estimation's (LHRK, LEUR) residuals

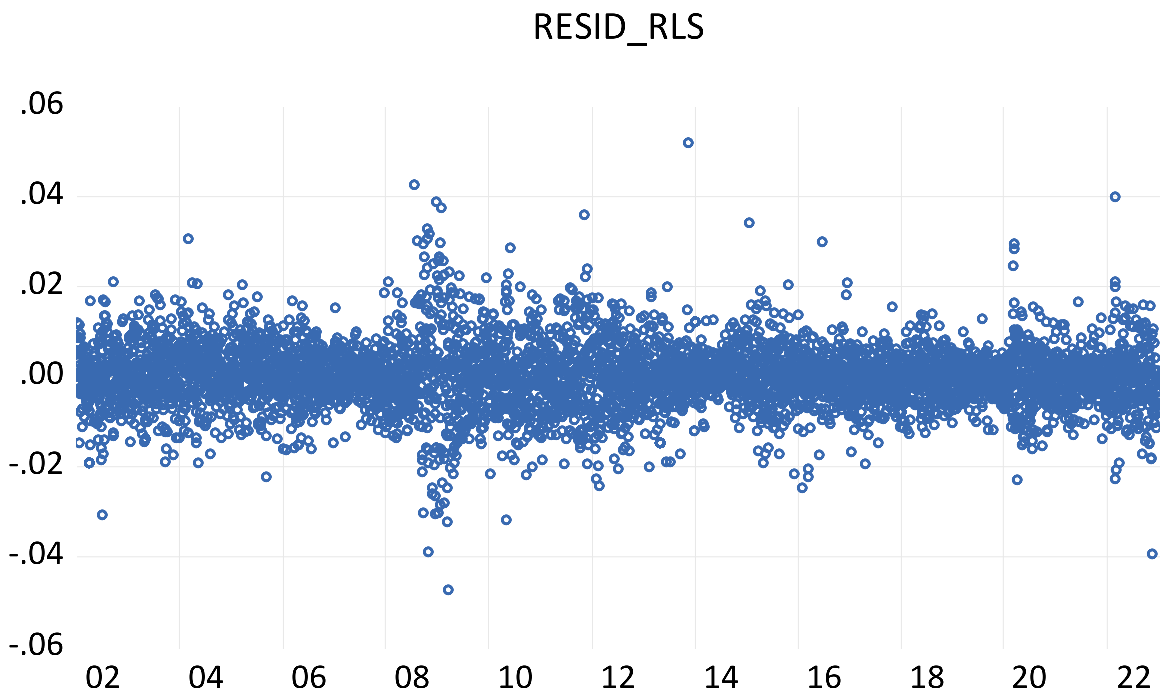

Figure C2: Dot plot of RLS estimation's (LCZK, LEUR) residuals

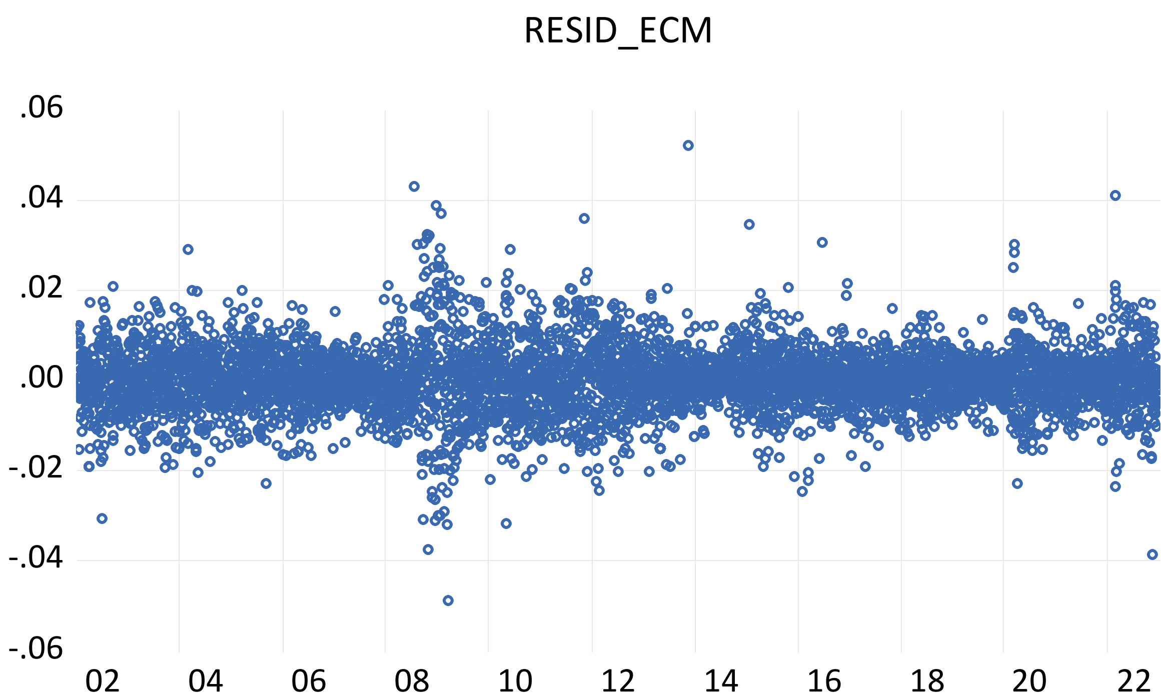

Figure C3: Dot plot of ECM estimation's (LCZK, LEUR) residuals

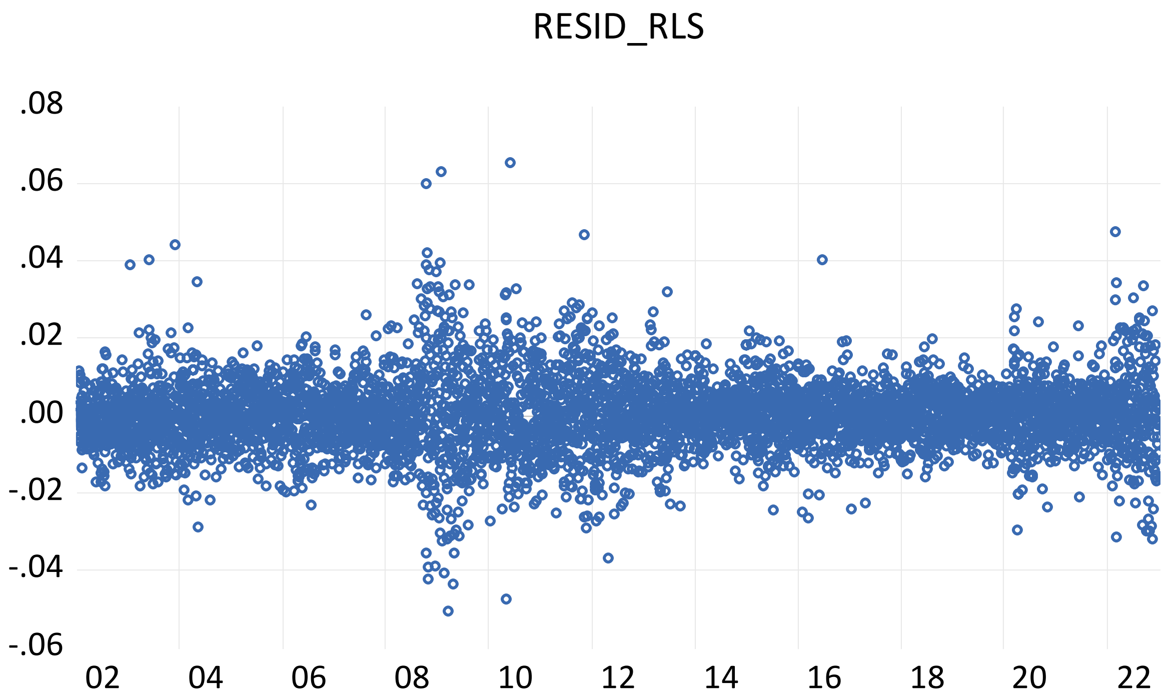

Figure C4: Dot plot of RLS estimation's (LHUF, LEUR) residuals

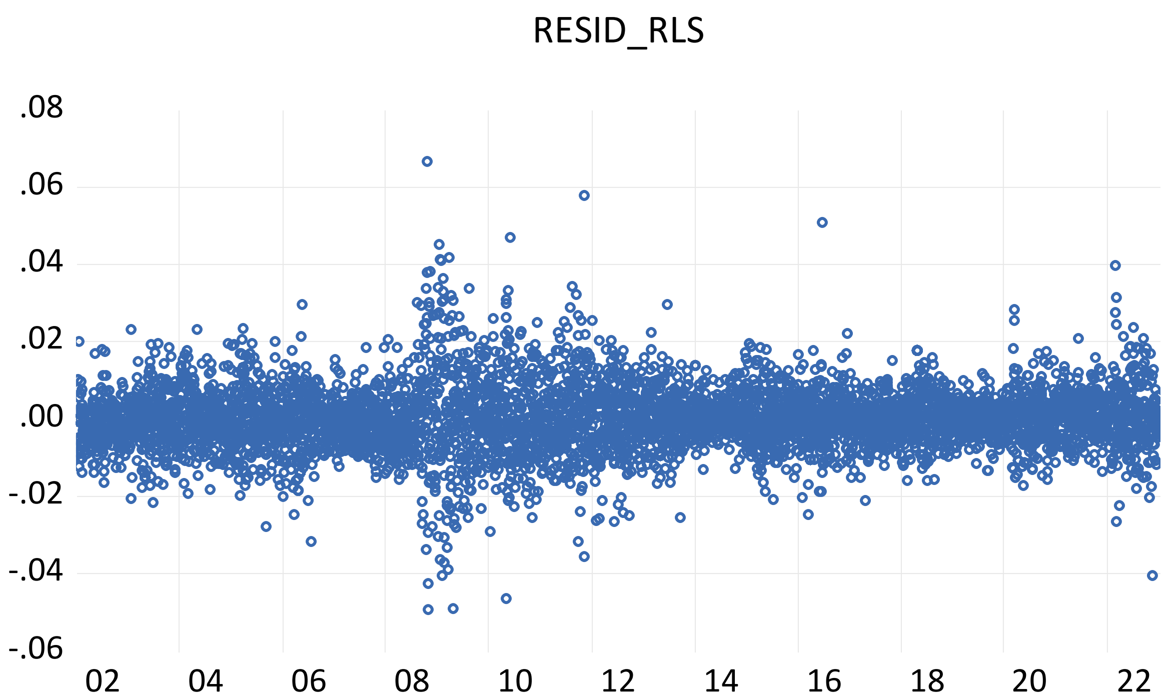

Figure C5: Dot plot of RLS estimation's (LPLN, LEUR) residuals

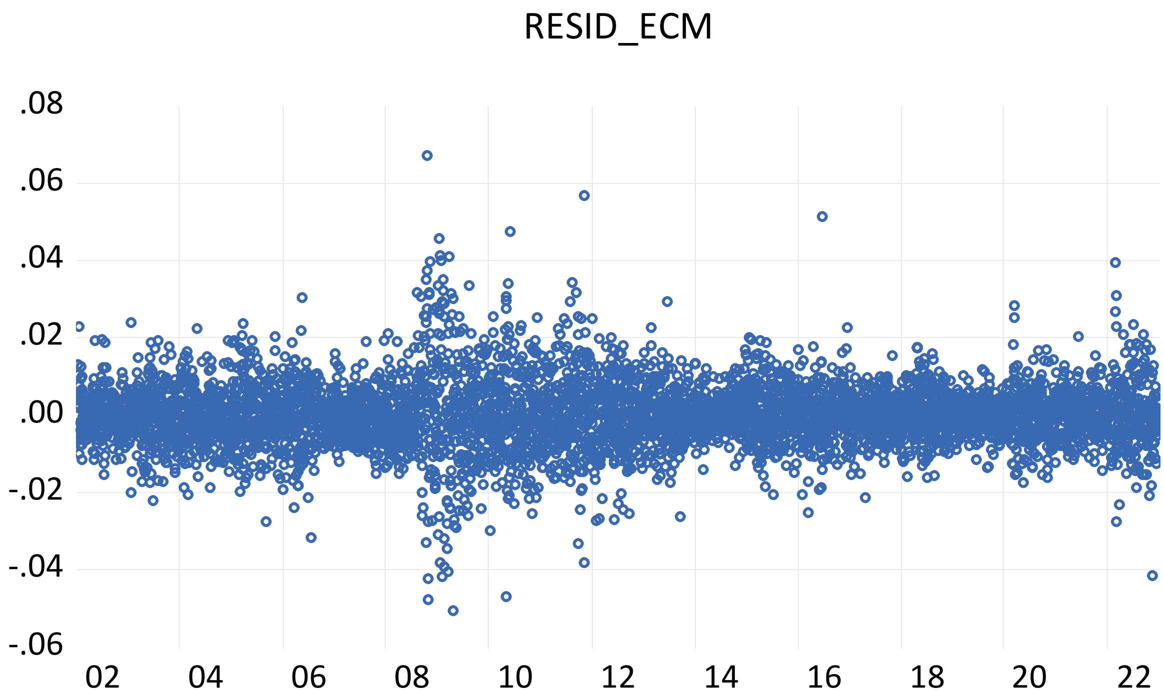

Figure C6: Dot plot of ECM estimation's (LPLN, LEUR) residuals

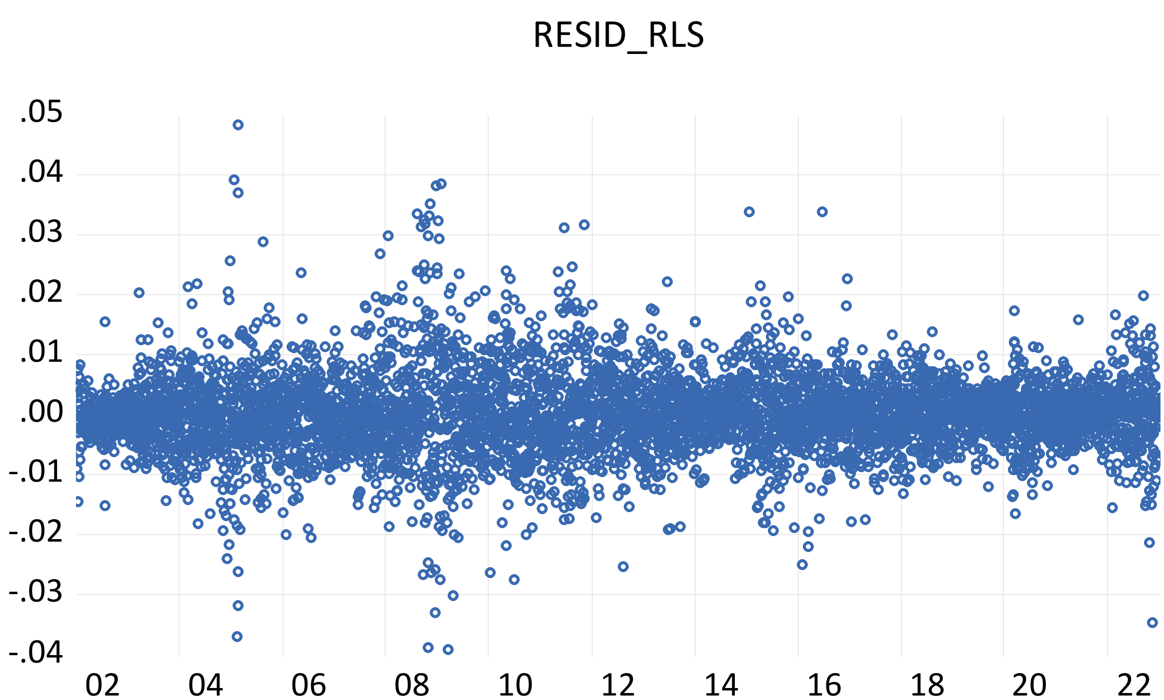

Figure C7: Dot plot of RLS estimation's (LRON, LEUR) residuals

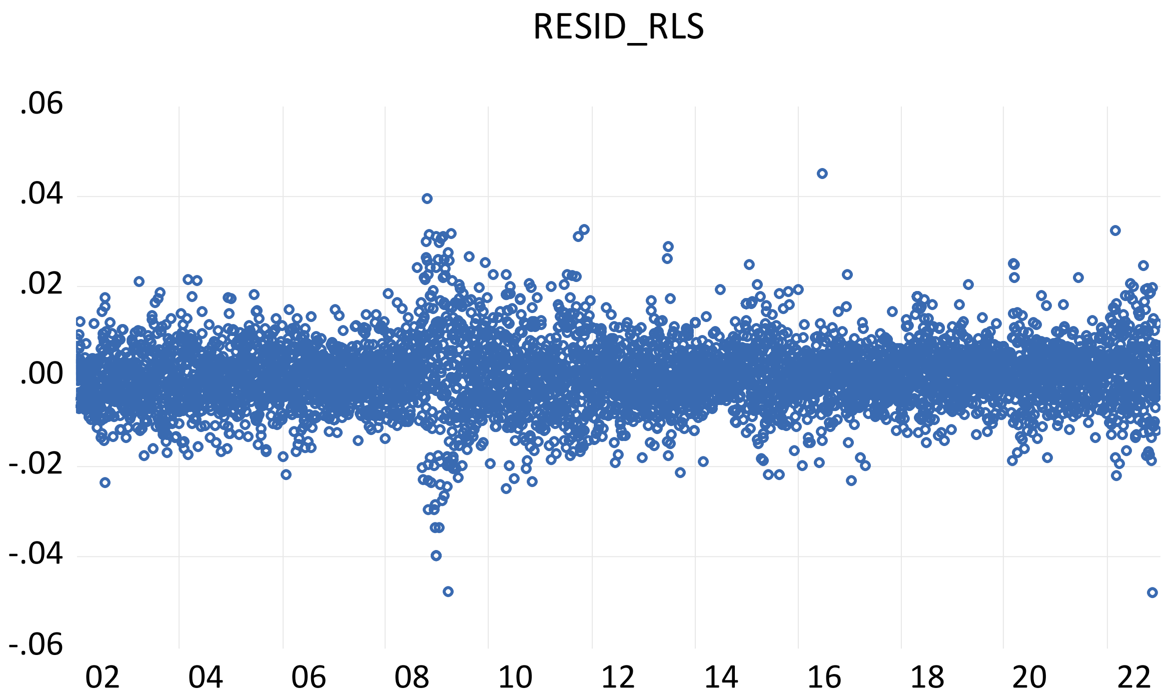

Figure C8: Dot plot of RLS estimation's (LSEK, LEUR) residuals

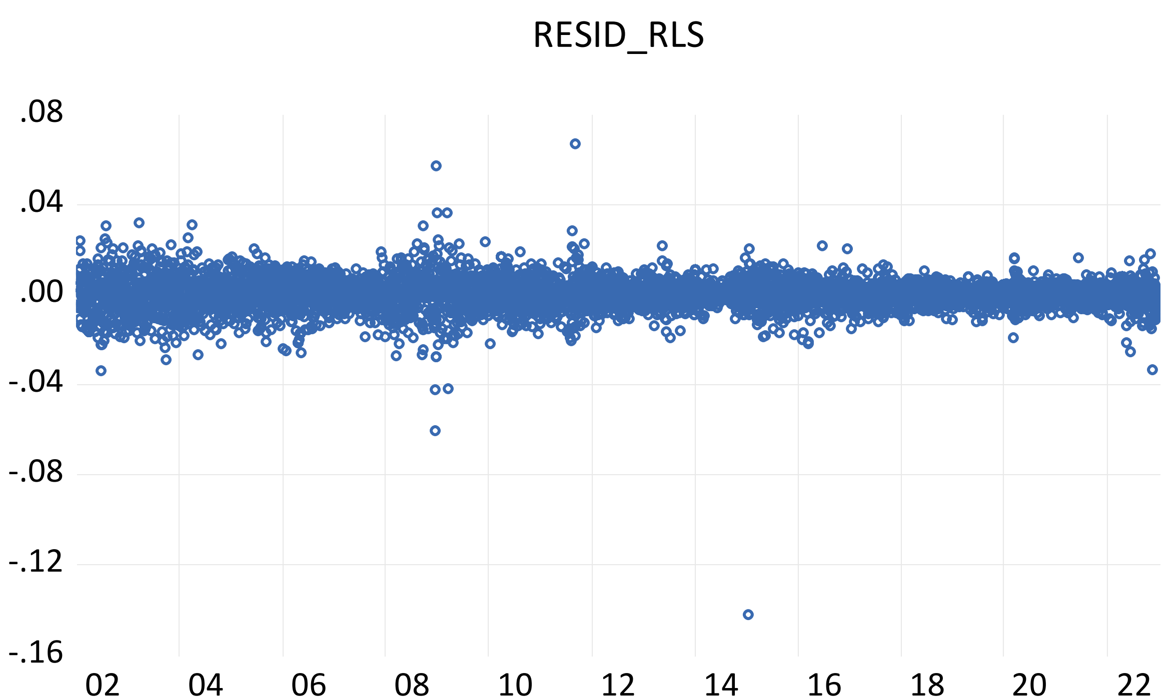

Figure C9: Dot plot of RLS estimation's (CHF, EUR) residuals

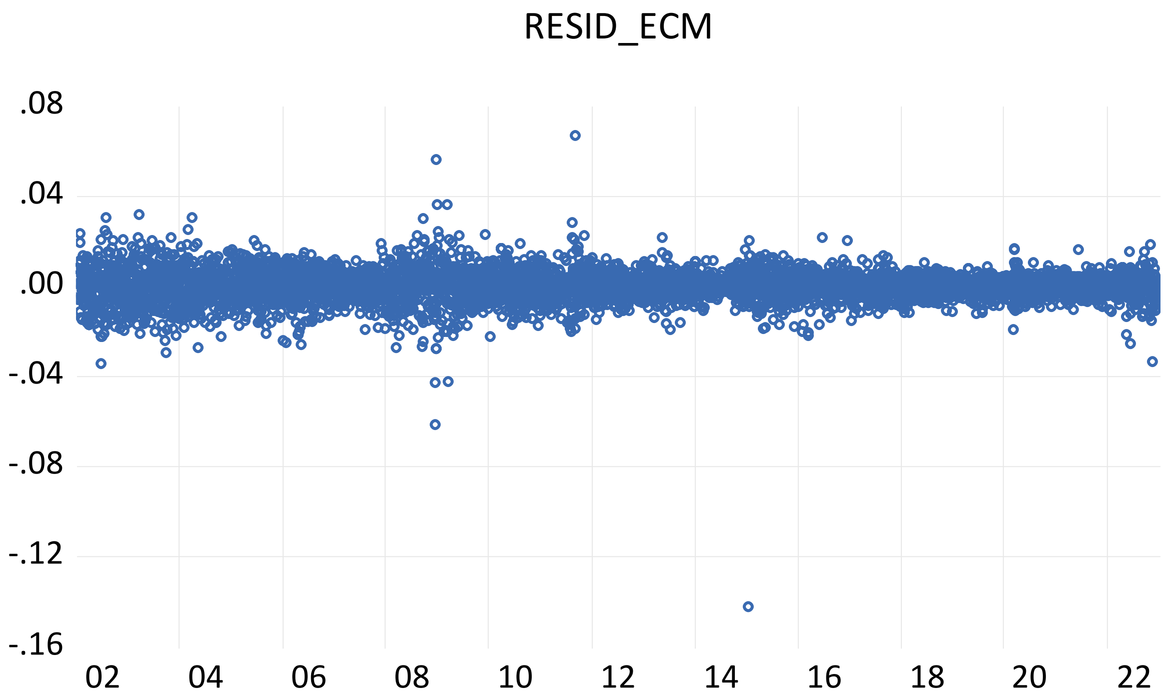

Figure C10: Dot plot of ECM estimation's (CHF, EUR) residuals

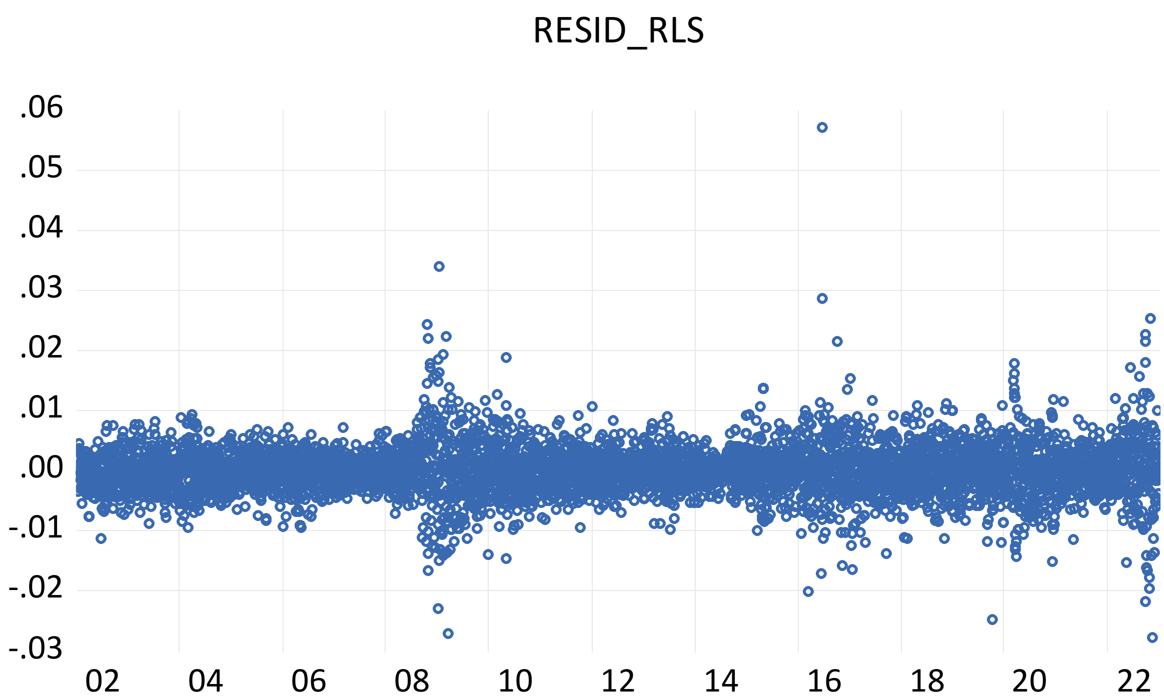

Figure C11: Dot plot of RLS estimation's (GBP, EUR) residuals