Brexit: Changes in cross-market correlation throughout Europe

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A R T I C L E I N F O

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A B S T R A C T

The aim of this study is to investigate the effects of Brexit on financial markets of Western Europe in the short and long term. To measure the strength of economic linkages between the UK and each of the 16 countries under consideration, cross-market correlation of returns and volatility was analysed before and after the Referendum. I found that in the short-term most stock markets experience negative returns and contagion effects following the Brexit announcement. However, these effects seem to disappear after two weeks and in the long run markets follow a detachment process. Considering potential country-specific variables affecting the scale and direction of those changes, it has been discovered that factors such as pre-Brexit interdependence, geography, trade and size significantly influence market reactions. Mediterranean countries experience consistently stronger market reactions. My results highlight the high degree of interdependence between the UK and most European countries and how Brexit has been changing pre-existing equilibria.

I N F O R M A Ç Ã O
DO A R T I G O

Palavras chave:
Brexit
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Curto e Longo Prazo
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A B S T R A C T O

O objetivo deste estudo é compreender os efeitos do Brexit nos mercados financeiros dos países da Europa ocidental, a curto e longo prazo. Para medir a força das ligações económicas entre o Reino Unido e os restantes 16 países em consideração, a correlação entre mercados em termos de retornos e volatilidade foi analisada antes e após o referendo. A maioria da amostra refletiu uma queda nos retornos, com um efeito de contágio a curto prazo. No entanto, estes efeitos tendem a desaparecer em duas semanas e, a longo prazo, os mercados seguem um processo de desapego. Considerando variáveis específicas de cada país, com potencial de afetação das escala e direção das variações observadas, relevou-se que em diferentes períodos, distintos fatores como interdependência pré-Brexit, geografia, comércio e tamanho do país, tiveram diferentes influências nas reações de mercado. Os países do Mediterrânio sentiram constantemente maior impacto. Concluindo, este estudo demonstra uma grande interdependência entre Inglaterra e maior parte dos países Europeus e como o Brexit está mudando os equilíbrios pré-existentes.

Table of Contents

1 Introduction

On the 23rd of June 2016, the UK voted to leave the European Union. This decision deeply shocked European markets and created a general state of uncertainty that is still persisting. The issue is widely debated, and serious areas of concern are the modality of the UK exit and the scale of future economic losses on both sides due to trade barriers, the exclusion from the Single Market, restrictions of immigration and reductions of investment. The exit vote not only shacked financial markets in the few days after the event, but it may also have changed the mechanism of interaction and the structure of economic relationships between the UK and the rest of Europe in the long term.

This study aims at retracing step by step the development of market movements from the Referendum date until the beginning of 2019. I quantified the economic linkages between 16 European countries and the UK, measuring the cross-market correlation of returns and volatility of each country and the UK before and after the event. Using differences in differences models on price data from the main indexes, I measured the immediate decline in returns and changes in market co-movement with the UK for each country in the sample. Being financial markets the mirror of investors' sentiment about future developments of Brexit, changes in correlation could vary in scale and direction depending on the period under analysis and according to their expectations. Prior studies argue that during a crisis, correlation between markets increases due to a contagion effect, therefore I tested whether Brexit could be categorized as a crisis, and I measured the intensity and duration of the contagion effect. To analyse the evolution of investors' reactions and Brexit effects in both the short and long term, I subdivided the timespan in six periods of different length.

The second research question addressed by this study is whether market reactions consistently and significantly differ between the 16 countries considered and whether these differences depend on country-specific characteristics. Implementing a multivariate regression model, I used seven explanatory variables to test the potential influence of specific features on changes in returns and volatility and changes in cross-market correlation of returns and volatility. The factors analysed for each of the six periods are the level of pre-Brexit correlation, geography, participation to the EFTA agreement, distance, bilateral trade and size.

Being Brexit an extremely recent and uncertain event, prior research on the issue is clearly incomplete and contradictory. Therefore, main contribution of the present study is to provide for the first time a comprehensive view of the problem, analysing it across a longer timeframe and including in the discussion all Western Europe. I analysed in detail the development of market reactions and I provided a key of interpretation of those movements. The message of this research is of utmost importance because only understanding the mechanism that has driven the markets in the last two years and a half, it may be possible for investors to be prepared for future Brexit developments. The rest of the paper is organized as follows. Section 2 provides an overview of recent academic findings by other authors, Section 3 describes the methodology adopted in the study and the analysis performed, Section 4 presents the results of the paper. Section 5 regards discussion of results, extension and limitations and Section 6 reports a brief conclusion.

2 Literature review

2.1 Immediate stock market reaction

The referendum on the 23rd of June 2016, represents one of the most disruptive events in the history of European Union. The UK voted to exit the EU after more than 40 years of membership. The relationship between the United Kingdom and the other member states has always been jeopardized by the special position of the country inside the EU, an exceptional treatment symbolized by the use of a different currency, the establishment of "British rebate", and the adoption of "opt-in" and "opt-out" clauses (Clavel, 2016). Notwithstanding the incomplete commitment of the UK to the Union and its partial integration, the Brexit vote heavily shocked financial markets and has created a situation of uncertainty that is still persisting. There is uncertainty regarding the type of exit deal and the potential benefits and costs in the short and long term. The net effect of the decision to leave Europe is still debatable and uncertain. However, potential costs include tariffs on exportations, exclusion from the Single Market, huge loss for the City of London (financial headquarter of the British economy) and reductions of investments. On the other side, the benefits would be related to the savings on EU budget, exemption from regulations, freedom to engage in new overseas trade agreements and restrictions on immigration. (Ramiah, Pham, & Moosa, 2017).

Multiple studies try to delineate and forecast how Brexit will affect the British economy in different sectors and for different types of firms by quantifying the abnormal returns experienced by different entities on the 24th of June. According to Breinlich, Leromain, Novy, Sampson, and Usman (2018), future economic consequences of Brexit can be studied looking at movements in stock prices. Prices embed all present information available to investors and future expectations of market participants. They find that market reactions on the first day after the vote are influenced by the dependence on the British economy and on the business cycle, level of exports and currency used in accounting reports. These results indicate investors' fear of an economic downturn and a further depreciation of the pound. Indeed, the first day after the Referendum the pound heavily depreciated, losing 8.1% against USD and 5.8% against the euro. FTSE100 as a whole lost more than 3%, the decline continued during the 27th of June, yet slowing down and the 29th of June prices were back to normal levels. On the other hand, firm size and performance are ambiguously correlated with Brexit given the higher solidity of large profitable companies to cope with future losses, but their higher dependence on foreign exchanges and investments. Finally, no significant effect is driven by forecasted change in immigration or trade barriers in this early stage of analysis.

Performing an event study, Oehler, Horn, and Wendt (2017) investigate whether the extent of the economic damage caused by the Brexit announcement could be related to the level of internationalization of British companies. Companies with higher levels of sales abroad experience lower declines in returns in the first trading day, however the effect becomes irrelevant in the following days, indicating a quick market adjustment. Ramiah *et al.* (2016) study whether the shock in prices is connected with industry-specific characteristics, calculating abnormal returns for the 24th of June and cumulative abnormal returns for the first two, five and ten days after the vote. Finally, they prove that most of the sectors negatively react to Brexit announcement, with banking, travel and leisure industries suffering the most.

Overall, all these studies focus on the characteristics that could influence the immediate decline in returns experienced by the UK, however no research has been conducted in order to quantify the immediate stock price reactions that occurred in the rest of Europe. This study provides a measure of the effect that Western European markets experienced in the ten trading days following the Brexit announcement. Moreover, I conducted a similar investigation on the characteristics that could potentially influence the magnitude of the shock. In this case, the variables were not used in order to explain price movements in the UK but to investigate different market reactions across Europe.

2.2 Contagion or interdependence

Once investigated the market reactions across Europe at the time of the Brexit announcement, I considered of great interest to study whether a contagion between British and European markets occurred. Previous studies show market correlation movements during crises and argue about the correct definition and measurement of contagion and interdependence. Forbes and Rigobon (2002) define contagion “as a significant increase in cross-market linkages after a shock to one country” (p.2223), while interdependence refers to the situation in which correlation between markets presents no significant changes in the period under examination. Interconnection between markets is usually measured by cross-market correlation coefficients, yet the coefficients are conditional on market volatility. During a crisis, the potential increase in correlation coefficients can thus be related to the increase in volatility due to uncertainty. In order to obtain an unbiased measure of correlation, the authors create an unconditional correlation coefficient adjusted for the increase in volatility. In this way, they find no evidence of contagion during the US market crash of 1987, Mexican devaluation of 1994 and the Asian crisis of 1997.

The correction for heteroscedasticity implemented by Forbes and Rigobon (2002) is applied by Bordo and Murshid (2000) to the period preceding the First World War and to the interwar and they find no evidence of contagion. It is also implemented by W.-S. Kao, T.-C. Kao, Changchien, Wang, and Yeh (2018), who find evidence of contagion during the US subprime mortgages crisis of 2007 in emerging economies and East Asia. However, this effect disappears in most countries when considering a longer time span. This finding suggests that it is extremely important to perform an appropriate choice of the timeframe of analysis, choice that can distort empirical results.

Notwithstanding several applications of the procedure designed by Forbes and Rigobon (2002), Corsetti, Pericoli, and Sbracia (2005) do not agree with their methodology and argue about the arbitrary of their adjustment of volatility. The increase in variance can be related to common factors or country-specific noise, and restrictions on the second type of volatility can lead to the incorrect conclusion of "no contagion". Applying a different methodology, they find evidences of contagion for the 1997 Asian crisis for at least five countries. King and Wadhwani (1989) acknowledge that the correlation coefficient increases as a function of volatility but do not apply any type of correction and conclude that in October 1987 contagion spread across New York, London and Tokyo, persisting for eight months after the market crash. Finally, Rigobon (2003) himself admits that "the adjustments in the correlations are biased if the data suffers from simultaneous equations or omitted variable problems—both of which are likely to be present" (p.264), creating further uncertainties about the treatment of correlation coefficients.

Bodart and Candelon (2009) adopt the same definition of contagion implemented by Forbes and Rigobon (2002), or "shift-contagion", emphasizing the difference from "pure" contagion. "Pure" contagion does not account for changes in market linkages, but it aims at the identification of channels of shock transmission as trade, financial ties, similarities between countries and policies, and geographical proximity. However, their study focuses on "shift-contagion" using an innovative measurement approach and investigates the difference between temporary and permanent shifts in market co-movement, the first denominated as contagion and the second as interdependence. Therefore, they conclude that contagion occurs both during the "Tequila" and Asian crisis.

The differentiation between short-term and long-term effects studied by these authors was applied in the present study by subdividing the sample period in shorter periods of analysis. In order to understand whether the definition of contagion can be applied in this specific case, I studied the entity and persistence of Brexit effects. Since cross-market changes in correlation usually occur during crises, it was considered of great interest to study whether any change occurred after the Referendum, the event that originated the worst crisis of the European Union. Given the controversial arguments on the type of measurement of contagion and on the bias created by volatility, I measured both the initial increase in volatility and the changes in correlation of returns and volatility using differences in differences models. Since no agreement has been found in the literature regarding the adjustments to perform, no correction was applied to the model. A simple essential model may present some pitfalls but was considered here more advantageous than a complex procedure, which needs strong assumptions to be implemented and may anyway deliver a biased outcome.

2.3 Brexit spillovers in financial markets

Brexit effects on financial markets have been widely studied in the recent literature. Research mainly focuses on volatility spillovers to other countries as evidence of financial shock transmission, however none of the previous studies presents a comprehensive view on the consequences of the UK vote in the whole Western Europe in the short and long term. Analysing 16 countries, this study underlies similarities and differences in market reactions, leaving room for comparison and drawing conclusions on the general average effect of the event.

Bouoiyour and Selmi (2018) investigate the transmission process between financial markets and they consider CDS prices as a good proxy of credit risk. Credit default swap prices represent the cost that investors are willing to pay to hedge against the risk of default of government bonds, also known as country risk. After Brexit, CDS prices boost in France, Italy, Germany and Spain, indicating that uncertainty and risk spread across Europe, undermining the creditworthiness of its member states. Studying the direction of volatility spillovers, they determine that the UK, Italy and Spain work as transmitters of volatility, whilst Germany and France as receivers. Differences in market reactions depending on individual country-specific characteristics are taken into consideration in the present study, and this concept is further developed in the following paragraphs.

In another study, Bohdalová and Greguš (2017) try to define the impact of Brexit on selected European markets, focusing on the analysis of changes in the dependence structures. They find that cross-market correlation increases after Brexit, however the influence of the event is asymmetric, affecting bear markets more strongly than bull markets. More precisely, under normal markets conditions, dependence structures deeply change in the first three days after the Referendum in France, Turkey and Germany; whilst no change is recorded in Poland and Spain. Not only correlation shifts are recorded throughout Europe, but interdependence also increases in emerging economies. Bhunia and Chandra (2017) study the dynamics of stock co-movement between British and Indian markets, showing how "increasing financial integration has increased Emerging markets' vulnerability to external global shocks" (p.2). Regarding the specific case, the authors find that during Brexit, in the short term, interconnection between UK and India increase, confirming the theory of international contagion. Finally, they claim that the understanding of international cross-market correlations and contagion is of utmost importance for investors in order to diversify their portfolios during crises.

Other authors argue that on the first days after the event, stock prices movements were not determined by rational expectations of investors regarding future changes in economic equilibria due to Brexit, and they think that the sharp decline of EU markets was caused by the general panic. Raddant (2016) considers it necessary to examine market reactions using a longer timeframe, applying a philosophy similar to the one followed in this study. The author analyses stock market movements in France, Germany, Italy, Spain and UK before and after Brexit. He shows that cross-market correlation in the year before the vote is high and stable, with Germany and France presenting stronger ties than Italy and Spain. After the vote, volatility increases but the effect mitigates in three weeks. Only Italy, which was in a particular situation of uncertainty and instability even before the event, shows a persistently higher level of risk. One month after Brexit, integration of European stock markets is still high, however British stocks present a slight detachment from the rest of Europe. Financial linkages between the UK and the EU have always been weaker than between other European countries, however differences in behaviour have increased since the vote.

These findings seem to be confirmed and reinforced by the study of Bashir *et al.* (2019), who analyse changes in correlation using observations of price indexes until March 2017. They reach the extreme conclusion that after Brexit, in the long term, most of European economies start showing a negative correlation with the UK. These studies, performed after less than one year since the event, were regarded interesting but limited in time. Therefore, I further developed the research on long-term Brexit effects, implementing market data of 2017, 2018 and 2019 now available. Thanks to the longer timeframe of analysis, it is possible here to have a more complete perspective of Brexit impacts and to draw conclusions with greater confidence.

2.4 Effects on different countries

As previously described, the present study investigates the scale and timing of Brexit impact on the 16 countries of Western Europe. After having obtained a measure of change in interdependence with the UK, I considered of great interest to investigate whether different market reactions were determined by country-specific characteristics as geographical position, size and bilateral trade. The literature mainly focuses on predicting how Brexit will hit British economy, with limited research studying European exposure to Brexit by state.

Regarding the first issue, according to Breinlich *et al*. (2018) in the long run the UK will experience a reduction of living standards, however it is still too early to have a reliable evaluation of this effect. In the short term, it is possible to claim that Brexit has caused a decrease in GDP growth and an increase in inflation. Kierzenkowski, Pain, Rusticelli, and Zwart (2016) evaluate that in the short term the undermined confidence of investors and the uncertain financial conditions are hurting British economy, but the situation will worsen when the formal exit will occur. The first losses will be caused by higher trade barriers and labour mobility restrictions, whilst "in the longer term, structural impacts would take hold through the channels of capital, immigration and lower technical progress" (p.5). Consequently, the amount of foreign direct investment and the pool of labour skills will reduce. A study conducted by Berg, Saunders, Schäfer, and Steffen (2019) documents the considerable decline in loan issuance in the British syndicated loan market in the five quarters after Brexit. The 23% reduction is due to the contraction of lending to British firms and banks, whilst international entities are not significantly affected. To conclude, the UK remains an attractive market for international companies, but the domestic drop of loans is a comprehensive effect, spread across British economy regardless of industry and firm-specific characteristics.

Brexit effects on the UK are of utmost importance to understand the deriving consequences for the rest of Europe, a topic that I addressed in this paper taking a country perspective. Recent studies prefer to evaluate Brexit effects on various industries and determine the most affected European regions depending on the nature of their industrial operations. The Commission for Economic Policy (2018) analyses regional impacts by the six major sectors for EU economy. For the "Transport vehicles" industry the most affected regions will be in Denmark, France and Romania, for the "Machinery" Italy and Denmark, for the "Electronics" mainly Eastern Europe. In the "Textile and Furniture" sector, Brexit restrictions will hit Italian, Portugal and Bulgarian regions, in the "Vegetables, Foodstuff and Wood" industry Greece and France, in the "Chemical and Plastics" sector, the most affected regions are located in France, Denmark, Belgium and Greece. Republic of Ireland and Netherlands are the most exposed small countries in most of the sectors under examination.

Chen *et al.* (2018) claim that the material on long-term impacts of Brexit on both the UK and the EU is limited due to the high uncertainty surrounding the present situation and previous incorrect predictions. Before the Referendum, multiple forecasts predicted a heavy recession in the UK, which has not materialized yet. Moreover, the UK is still part of the European Union, and the terms of the future separation are unclear. Notwithstanding these constrains, they measure Brexit effects on both the UK and the EU, analysing the scope and scale of trade relationships. They develop an index to measure exposure to Brexit based on the analysis of geographies where different stages of the production process are completed. They demonstrate that British regions are the biggest losers, presenting a degree of vulnerability substantially higher than European countries. Ireland will incur economic losses close to the levels of less-affected British regions, whilst Southern Germany presents a level of exposure that is half the risk incurred by Ireland. In general, north-western Europe is more exposed to economic losses than Mediterranean and Eastern regions, outcome that is in accordance with the logic suggested by geographic proximity and the well-known gravity theory. In particular, a specific study into Germany, states that the automotive sector will be the most damaged by the reduced exportation to the UK, followed by wood, paper, leather, pharmaceuticals and chemical industries, comprehensively lowering forecasted economic growth by half a percentage point (Fichtner, Steffen, Hachula, & Schlaak, 2016).

As it is possible to deduce by these academic studies, Brexit economic consequences can hardly be predicted, and the variables used to measure exposure of different regions are widely diversified. In this study, the magnitude of changes in correlation measures how the linkages and consequently the exposure of different countries changes over time. The present research is focusing on the reasons beyond bigger or smaller changes in correlation of returns and volatility, changes that have already occurred in the past years. Those changes could be interpreted as expectations of investors regarding the future impact of Brexit; however, it is important to remember that the following analysis are performed on past data.

3 Methodology

3.1 Data

The study is developed around market reactions in Western Europe, which is defined according to the description of the United Nations Regional Groups of Member States provided by the Department for General Assembly and Conference Management. The countries taken into consideration are Italy, Germany, France, Spain, Portugal, Ireland, Belgium, Austria, Denmark, Finland, Iceland, Netherlands, Sweden, Norway, Switzerland, Greece and UK. Due to their limited dimensions, Liechtenstein, Luxembourg, Malta, Monaco and San Marino were not included. For the selected countries, I retrieved data about the benchmark stock market indexes by Datastream. I downloaded daily Price Indexes from 27/02/2015 to 27/02/2019 for FTSE 100, FTSE MIB INDEX, DAX 30 PERFORMANCE, FRANCE CAC 40, IBEX 35, PORTUGAL PSI-20, ISEQ ALL SHARE INDEX, BEL 20, ATX - AUSTRIAN TRADED INDEX, OMX COPENHAGEN (OMXC20), OMX HELSINKI (OMXH), OMX ICELAND ALL SHARE, AEX INDEX (AEX), OMX STOCKHOLM 30 (OMXS30), OSLO SE OBX, SWISS MARKET (SMI) and ATHEX COMPOSITE.

In order to analyse the differences in financial market reactions, I collected data regarding specific characteristics of the countries. I gathered information about the distance between the UK and European countries, the level of bilateral trade and the amount of nominal GDP. Firstly, I calculated the kilometres of distance using a distance calculator ("Distance Between Cities on Map", 2019). Secondly, I determined the level of bilateral trade summing imports and exports between the UK and each European country in 2016 (Office for National Statistics, 2017). Data were then transformed from billions of pounds into billions of dollars, which is the benchmark currency of this study, using the yearly average currency exchange rate for 2016 of 0.77 GBP/USD (U.S. Department of the Treasury, 2019). Finally, I collected GDP per country for 2016 in billions of USD (International Monetary Fund, 2019). Data were transformed and analysed using Excel.

3.2 Analysis of the correlation of returns before and after the Referendum

I used the correlation between stock returns before and after the 23rd of June 2016 as a measure of the level of connection between British and European markets. The purpose of the following analysis is to quantify the dependence of each European country from the UK and investigate the potential effects of Brexit, measured as changes in correlation occurred in the last two and a half years. Firstly, I calculated daily returns from the price index of each country using the following formula:

$$R_t = \frac{P_t}{P_{t-1}} - 1 \tag{1}$$

I computed the returns from 02/03/2015 to 27/02/2019 because the first observation was lost in calculations. Afterward, I created a dummy variable $After$ and an interaction term $After \times R_{UK,t}$. $After$ is taking value 0 on every day of the sample preceding and including the Referendum date and 1 from the 24 of June 2016 onward. The differences in differences model implemented was:

$$R_{EU,t} = \alpha + \beta_0 R_{UK,t} + \beta_1 After + \gamma_1 After \times R_{UK,t} + u_t \tag{2}$$

I applied the model equation 16 times, changing the dependent variable according to the specific returns of each country in the sample. The independent variables remain fixed. β_0 represents the correlation between the returns of the country under consideration and British market before Brexit, β_1 measures the net average change in returns in the period $After$, while γ_1 accounts for the average change in correlation between the two countries after the event. Since the whole period from the 24 June 2016 to the end of February 2019 was taken into consideration, the average change in returns experienced by each country is not considered related to Brexit due to the extended length of the timeframe. The focus of the analysis is on γ_1, or the resulting change in the level of connection, which represents the long-term effect of Brexit. It is worth noticing that given the length of the timespan, potentially contrasting reactions occurred in shorter periods are incorporated in a final average result.

3.3 Analysis of the different periods post-Referendum

The first model delivers an insight on the general effect of Brexit on European markets. The results will include both the market reactions of the first tumultuous weeks and the stabilization and adjustments of market expectations to the new setting that occurred with the passing of time. Therefore, I conducted a further analysis on the short and long-term effects of the Referendum on financial markets. I subdivided the $After$ period in six timespans of different length and every period is subsequent and not inclusive of the previous one. A dummy variable was created for each interval. $After_1$ takes value 1 only during the first two trading weeks after Brexit, $After_2$ represents the trading month going from the 08/07/2016 to the 05/08/2016, $After_3$ accounts for the subsequent three months, $After_4$ from 03/11/2016 to 27/04/2017, $After_5$ includes the subsequent trading year until the 27 of April 2018 and $After_6$ is defined approximatively as the last year of observations of the sample. For each period, I calculated an interaction factor multiplying the dummy variable by returns of the UK. In order to enhance the comparability between $After_5$ and $After_6$ I reduced the time frame of the period before Brexit to one trading year, taking into consideration observations from the 08/07/2015 to the Referendum date.

It is worth mentioning that the length of periods was chosen as previously described in order to maximize the probability to catch different effects. $After_1$ is made of just 10 days in order to have a measure of the immediate stock market reactions, which would get lost or smoothed considering a longer period. On the other hand, it would be inappropriate to consider less than 10 days because less than 10 data points would deliver a biased and partial measure of correlation. As time passes, periods get longer because initial strong market reactions are replaced by smoother market adjustments and slower movements. For this reason, $After_5$ and $After_6$ consider a timespan of one year. Those variables measure the long-term effect and the stabilization around a new equilibrium of correlation. The model implemented is:

$$R_{EU,t} = \alpha + \beta_0 R_{UK,t} + \sum_{j=1}^{6} \beta_j After_j + \sum_{j=1}^{6} \gamma_j After_j \times R_{UK,t} + u_t \quad (3)$$

As for the previous analysis, I applied the model for every country in the sample. Regarding the interpretation of the coefficients, the betas of the dummy variables represent the average increase or decrease of returns for the country under consideration in the specific period analysed. It is worth mentioning that β_1 now accounts for the change in returns in the first two weeks after Brexit, or the immediate stock market reaction caused by the announcement of the result of the Referendum. The coefficients of the other dummies are irrelevant to the purpose of this study because they represent average changes in returns occurred after more than two weeks since the announcement. Thus, those changes cannot be considered in any way related to Brexit.

The coefficients of the interaction terms account for the average changes in correlation between stock returns of each European country and the UK. A negative gamma represents a decrease in connection and a positive coefficient an increase in correlation compared to the level of interdependence before Brexit. An absolute measure of the level of correlation during a specific period can be obtained summing β_0 and the γ_j of the interaction term for the period of interest. Separating the different periods, it is possible to investigate how time affects market reactions and whether short and long-term effects differ. This model allows you to study whether contagion occurred in the short term and which is its level of persistence. Moreover, each phase of the process of market adjustment can be studied in detail, and it will be possible to individuate the trend of correlation over time.

3.4 Investigation on potential causes of different reactions across countries

Applying model (3) to every country, it will be possible to compare not only different market reactions by timespan but also different market reactions by country. It is then of great interest to study whether the scale and nature of changes in returns and correlation could be related to some country-specific characteristics. Since markets incorporate expectations about future potential effects of Brexit, forecasts about the economic damages that will occur once the UK will exit the European Union could be already visible in the calculated coefficients. It is presumable that European countries are trying to reduce economic linkages with the UK in order to minimize future losses, but for every country the detachment may have started and developed at a different time, at a different speed and with a different smoothness. Some countries may have not detached at all, some others may present inconsistent and extreme reactions.

I made some hypotheses on the characteristics that could have affected market reactions to Brexit. Firstly, the degree of correlation before Brexit (β_0) could have affected post-Brexit changes in returns and correlation. Considering short-term reactions, I assumed that countries strictly dependent from the UK, experienced a sharper price shock at Brexit announcement. However, the direction of β_0 effect in the long term could be two-ways: on the one hand countries highly connected with the British economy could find higher difficulties in breaking economic ties, on the other hand they may be the countries that detached the most given the urgency to reduce a previously high correlation. In order to investigate the potential effects of different levels of pre-Brexit correlation, I created a numerical variable *Previous Beta* with all the b_0 obtained from model (3).

The second step was to classify countries into three categories: Mediterranean, Northern and all the rest of the sample, called for simplicity Central countries. This classification is useful to individuate different reactions given by the considerable divergences between geographies in welfare, solidity and credibility of institutions, culture, indebtedness, GDP growth, financial stability, degree of political uncertainty and level of country risk. According to multiple indexes published by The World Bank (2018), Transparency International (2018) and Property Rights Alliance (2018) measuring the ease of doing business, the level of corruption and protection of property rights, the distinction between Northern and Southern Europe is immediately evident, with Northern countries always positioning well above Southern neighbours. Therefore, it is reasonable to expect a sharper decline in returns and a higher risk of contagion in the short term for the more fragile Mediterranean countries than for the safer Northern economies. Indeed, the intrinsic uncertainty of the Southern region may have boosted negative market reactions and the uncertainty derived from Brexit summed to pre-existing risk may have created an unsustainable situation. Regarding the long term, I supposed that market reactions will converge toward a general detachment from the UK, with Northern countries following a faster and more coherent path than Southern volatile markets (Tassinari, 2014). The countries defined as Mediterranean are Italy, France, Spain, Portugal and Greece, while the Northern states are

Ireland, Denmark, Finland, Iceland, Sweden and Norway. I created two dummy variables, *Mediterranean* and *Northern,* taking value 1 for the respective countries and zero otherwise. Both variables are equal zero for all the other countries that do not fall into one of the two categories.

The third characteristic taken into consideration was whether the country is part of the European Union, or it is part of the EFTA agreement. The countries in our sample that take value 1 according to the *EFTA* dummy variable are Norway, Switzerland and Iceland. These countries are not part of the Customs Union, hence their relationship with the EU is regulated by the EEA convention in the case of Norway and Iceland and by the Swiss-EU bilateral agreement for Switzerland. Even though EFTA states have access to the EU's single market, their economic ties with the EU are substantially weaker than within the Union. The hypothesis that the UK would apply to become part of EFTA or enter the EEA agreement is not credited and EFTA countries are already preparing for Brexit through meetings and negotiations (EFTA, n.d.). Therefore, the reactions of EFTA countries will presumably present the same direction but lower intensity than reactions of markets in the EU. Given the limited economic loss foreseen for Norway, Iceland and Switzerland, the decline in returns and changes in correlations will probably be bounded.

The fourth factor taken into consideration is the distance from the UK. Geographical distance could be used sometimes as a proxy for economic, cultural, administrative or political distance. Indeed, I supposed that across Europe more distant countries present greater differences in culture, history, political associations, institutional structures and level of wealth of consumers. According to the CAGE framework, these variables influence in multiples ways the relationship between the UK and European countries. Overall, it has been estimated "that the amount of trade that takes place between countries 5,000 miles apart is only 20% of the amount that would be predicted to take place if the same countries were 1,000 miles apart" (Ghemawat, 2001, p.3).

Firstly, geography affects transportation costs and consequently the level of bilateral trade. It clearly becomes less convenient to exchange goods as distance increases. Secondly, culture and wealth of consumers influence consumer choices and hence the attractiveness of a foreign market. Institutional structures and political distance are fundamental when a business entity plans to invest or establish a subsidiary in a foreign country. The amount of FDI increases with a high level of legal protection and well-functioning markets (Blonigen, 2005). For these reasons, I assumed that countries that are closer to the UK share more similarities than further countries and therefore, their economic ties are stronger. Presumably, closer countries experienced sharper shocks in prices at the announcement of Brexit and higher contagion in the short term. The variable *Distance* is a comprehensive factor that accounts for the effects described above. Distance is measured as the natural logarithm of kilometres between London and the other European capitals.

In order to account for the level of bilateral trade right before Brexit, I created a specific variable related to 2016. Whilst distance is related to bilateral trade in a more generic way, the amount of imports and exports between the UK and the other countries of the sample represents a precise and direct measure of economic interdependence. On the one hand, distance is fixed throughout time and represents a stable benchmark of comparison; on the other hand, the level of imports and exports is an updated and reactive measure of bilateral trade. The amount of exchanges between the UK and member states is a clear indicator of their interconnection in the year of the event. Even though the event occurred in the middle of the year, the data for 2016 are calculated at year end. I considered the measure representative of pre-Brexit level of trade given that potential changes would need more than 5 months to occur and to significantly influence the yearly average. I calculated the variable *(Exp+Imp)/GDP* as the sum of exports and imports between the UK and each European state on billions of dollars of GDP. The amount of trade is scaled by GDP in order to account for the different size of the countries and obtain comparable measures of bilateral trade. The resulting percentages represent the weight of bilateral trade with the UK for the economy under consideration. Presumably, in the short term the stronger the trading linkages, the higher the risk of contagion and the decline in returns. In the long term, the detachment from the UK might result slower and harder for its main trading partners, hence, decrease in correlation may be delayed in time and limited in scale.

The last factor taken into consideration is the size of European economies. Since Brexit undermines the strength and solidity of the European Union, small countries are presumably the economies suffering the highest costs. In the case of the dissolution of the EU, size would become a fundamental factor affecting bargaining power in commercial negotiations. Therefore, small isolated countries would be crushed by the power of giant economies like the

US or China. The risk of a future breakdown of the European Union may have affected market reactions and changes in correlation differently depending on country size. Considering a different perspective, bigger countries might, on average and in absolute values, have invested in the UK more than small countries. Thus, the effects could have been more dramatic as size increases. I conducted the empirical analysis of the size effect using the variable *GDP*, which is calculated as the natural logarithm of billions of dollars of GDP in 2016 and it represents a good proxy for size.

With these four numerical variables and three dummies, I developed a regression model to study the significance of potential causal relationships between the country-specific characteristics mentioned above and Brexit market reactions. The independent variables are *Previous Beta, Mediterranean, Northern, EFTA, Distance, (Exp+Imp)/GDP* and *GDP* and they are the same for every application of the model. I applied the model seven times trying to explain the changes in seven dependent variables. Firstly, I implemented the regression to investigate the immediate stock market reaction resulting from model (3) as a list of 16 figures of b_1 and here denominated as *2-week change in returns*. The regression model is:

$$
\begin{aligned}
2 - week\ change\ in\ returns \\
&= \alpha + \delta_1\ Previous\ Beta + \delta_2\ Mediterranean + \delta_3\ Northern \\
&+ \delta_4\ EFTA + \delta_5\ Distance + \delta_6\ (Exp + Imp)/GDP + \delta_7\ GDP \\
&+ u
\end{aligned}
\tag{4}
$$

The delta coefficients of the numerical variables measure the average change in daily returns in the two weeks after Brexit corresponding to a unit increase in each independent variable. For instance, δ_1 has to be interpreted as the average change in returns given a unit change in *Previous Beta*, *ceteris paribus*. Regarding the dummy variables, the delta coefficients represent the average difference in changes of returns for different types of countries. For instance, δ_2 represents the average difference in changes in returns between Mediterranean and Central countries. The absolute value of δ_2 - δ_3 represents the difference between Mediterranean and Northern regions.

Afterwards, I applied the model to the changes in correlation obtained from equation (3). g_1, g_2, g_3, g_4, g_5, g_6 of model (3) became here the dependent variables to be analysed. For the purpose of clarity, I called them *Change in correlation of returns 1, 2, 3, 4, 5* and *6.* The model equation remains the same, but the dependent variable changes each time assuming the values of *Change in correlation of returns 1, 2, 3, 4, 5* and *6.* In the following equation j represents the different periods and takes values from 1 to 6.

$$\begin{aligned} Change\ in\ correlation\ of\ returns_j \\ &= \alpha + \delta_1\ Previous\ Beta + \delta_2\ Mediterranean + \delta_3\ Northern \\ &+ \delta_4\ EFTA + \delta_5\ Distance + \delta_6\ (Exp + Imp)/GDP + \delta_7\ GDP \\ &+ u \end{aligned} \tag{5}$$

In this way, I determined whether the contagion or the detachment between the UK and European markets is dependent on their specific characteristics. The resulting coefficients are to be interpreted as the average change in correlation of returns due to a unit increase in the independent variable corresponding to the specific coefficient. For instance, δ_1, in the model where the list of g_1 is the dependent variable, represents the average change in correlation in the two weeks after Brexit that is related to an increase of one unit in *Previous Beta*, *ceteris paribus*. This interpretation is valid for every coefficient and for all the applications of the model.

3.5 Analysis of volatility

Volatility is defined as the change in the stock price of a financial instrument over time. Volatility is considered the main measure of risk, risk that increases during periods of crisis or uncertainty. Often a specific event that affects a particular market or a particular asset class triggers an increase in volatility not only in the objects directly hit but also in entities indirectly connected with it. This is called a spillover effect, and it occurs when the consequences of an event spread across multiple economies due to their economic ties (Polyzoidou, 2014). This study investigates whether, after the Referendum announcement, the European Union experienced an increase in market volatility and whether the correlation of volatility between the UK and European countries has changed in the short and long term. The correlation of volatility represents the degree of connection in the movement of market risk, and it is a measure of the interdependence between two economies. The type of analysis conducted on volatility is similar to the study on returns described above. Therefore, it will be interesting to compare the results obtained by the analysis of these two types of correlation to see whether there is a co-movement of market risk and returns and in turn which of the two variables is most affected by Brexit. I calculated daily volatility for each country in the sample for the same time span of returns using the following formula:

$$\sigma_t = \sqrt[2]{{R_t}^2} \tag{6}$$

I analysed this measure of the realized volatility of daily returns using a similar model to the one applied to stock market returns. The differences in differences model implemented to understand post-Brexit changes in volatility and correlation of risk is:

$$\sigma_{EU,t} = \alpha + \beta_0 \sigma_{UK,t} + \sum_{j=1}^{6} \beta_j After_j + \sum_{j=1}^{6} \gamma_j After_j \times \sigma_{UK,t} + u_t \tag{7}$$

As for the returns case, I applied the model 16 times, one for each European country. β_0 represents pre-Brexit correlation of risk between the country under examination and the UK, β_1 the net change in volatility of each state in the two trading weeks after Brexit and $\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6$ represent the changes in correlation between the UK and every European market for the same time periods that were implemented in the analysis of returns. In this way, short and long-term effects and trends of changes in correlation will be visible.

In order to investigate the country-specific characteristics that may have affected country-specific market reactions in a particular period, I used models (4) and (5) to study changes in volatility and in correlation of volatility.

The first equation is:

$$
\begin{aligned}
&2 - week\ change\ in\ volatility \\
&\quad = \alpha + \delta_1\ Previous\ Beta + \delta_2\ Mediterranean + \delta_3\ Northern \\
&\quad + \delta_4\ EFTA + \delta_5\ Distance + \delta_6\ (Exp + Imp)/GDP + \delta_7\ GDP \\
&\quad + u
\end{aligned} \tag{8}
$$

The dependent variable is composed by the 16 values of b_1 obtained from model (7), whilst the independent variables are the same that were used in the returns model. Similarly, the coefficients that in model (7) represent the changes in correlation of risk in different timespans become here the dependent variables of the model and are denominated as *Change in correlation of volatility 1, 2, 3, 4, 5* and *6.* I applied the regression six times and the following equation is an example of its application:

$$
\begin{aligned}
&Change\ in\ correlation\ of\ volatility_{\ j} \\
&\quad = \alpha + \delta_1\ Previous\ Beta + \delta_2\ Mediterranean + \delta_3\ Northern \\
&\quad + \delta_4\ EFTA + \delta_5\ Distance + \delta_6\ (Exp + Imp)/GDP + \delta_7\ GDP \\
&\quad + u
\end{aligned} \tag{9}
$$

The coefficient δ_1 is to be interpreted as the average change in correlation of risk due to a unit change in *Previous Beta*, *ceteris paribus.* The other coefficients have to be interpreted similarly.

4 Results

4.1 The change in correlation of returns after Brexit

Implementing model (2), it is possible to get a measure of the correlation of daily stock returns of each country with returns of the UK. More precisely, I used model (2) to investigate the amount of variation of returns of the country under consideration that can be explained by the variation of returns in the FTSE100. All the 16 values of b_1 obtained in every application of the model are significant for any significance level, showing an unconfutable correlation between the EU and the UK markets. Figure 1 shows the levels of correlation measured as b_0 before the event for each country in the sample. A b_0 of 1 represents a perfect linear correlation between the two markets: when the returns of British market increase by 1%, the European market under consideration experiences a 1% increase too. Markets where movements are more extreme show a coefficient higher than 1, like Italy or France. It is then possible to infer that those markets are more volatile than the UK and market reactions are more intense. On the other hand, coefficients lower than 1 indicate that the market under analysis experiences lower than 1-to-1 variations in returns in response to British market movements. This fact can be due to a lower responsiveness of that market, lower volatility or lower correlation with the UK. The average b_0 for this period is 0.93. It is worth noticing that the countries presenting the lower correlation are Iceland and Greece. In those two cases, it is possible to claim that a lower beta corresponds to a lower correlation, a statement that is further confirmed by a R Square respectively around 2 and 14%. The explanatory power of the model is thus limited, meaning that changes in the UK cannot properly explain variations in the Icelandic and Greek markets.

As previously mentioned, $\beta_1$is not taken under consideration because it is probably not related to Brexit. The focus of the study is γ_1, which represents the change in correlation between the UK and each European country occurred from Brexit to February 2019. Figure 2 shows changes in correlation by country. Here it is possible to notice that every country experienced a decrease in correlation in the last two and a half years. This symbolizes a general detachment of European markets from the UK, effect that is in line with the expectation of higher trade barriers, restrictions on labour mobility and other structural changes that will impoverish the British economy at the exit from the EU (Kierzenkowski *et al.*, 2016). It is worth mentioning that the countries experiencing the lowest decrease in correlation are Ireland and Iceland and that g_1 is not significant for them. This means that it is not possible to state that the change in correlation is different from zero. Greece also presents a non-significant coefficient, whilst for Austria it is significant just at 10% significance level. Switzerland is significant at 5%, whilst all the other countries present significant gamma at 1% or lower.

Apart from Iceland and Greece, the R Square of the other countries ranges approximately from 40 to 75%. In those cases, the regression model explains a considerable part of the variation of the dependent variables. The goodness-of-fit is relatively high, meaning that the data are well represented by a linear relationship. Additionally, the residual plots do not present any particular pattern and the residuals seem to be randomly distributed. A visual example of the linear relationship between returns of Netherlands and the UK is shown in Figure 3. In Figure 4, a representation of the residual plot for the same two countries is presented. The same type of analysis has been conducted on every country to verify the appropriateness of the model. In conclusion, the analysis performed show consistent long-term reactions among countries, reactions that will be analysed in more detail in the following paragraph.

4.2 Effects on returns and correlation in different periods post-Referendum

In order to have a more detailed analysis of the evolution of Brexit effects, I applied model (3) to every country in the sample. The values of b_0 obtained from this model are approximately equal to the b_0 collected from model (2), and small differences are due only to the reduction of the timespan executed on model (3) for the pre-Brexit period. The average value is one hundredth higher, equal to 0.94. The focus of the study is the examination in model (3) of β_1, *id est* the immediate shock in prices and γ_1, γ_2, γ_3, γ_4, γ_5, γ_6, *id est* the changes in correlation. Given the extensive literature on the meaning of contagion and given that contagion usually occurs during crises, this study aims at investigating whether Brexit can be considered as the triggering event prompting a crisis and whether contagion occurs, where did it spread, which forms did it take and how long did it last. As it is possible to conclude from the analysis of results of model (2), the general effect in the long term was a detachment experienced more or less significantly by all of Europe. The decrease in correlation accounted by the estimated g_1 in model (2) is, however, the net result of potentially positive and negative intermediate changes in correlation, where in the end the decrease offset a presumable initial increase in correlation.

From the analysis of the resulting b_1 of model (3), it appears clear that the two-week decline in returns is a phenomenon spread across all of Europe. Every country experienced a negative shock in the main price index. Figure 5 reports the amounts of reduction in returns by state. Switzerland, Norway and Denmark present the lowest decreases in returns and for the last two the results are not significant. Switzerland's beta is significant at 10%, Iceland's -0.5% is significant at a 5% significance level, whilst all the other countries show significant results at 1% or less and a decline that ranges from 0.5% to almost 2% in the case of Italy and Ireland. Considering an average return of Italian and Irish markets for the entire timespan of approximatively 0.0076% and 0.0055%, the sharp drop in prices caused losses that are around 255 and 360 times bigger than a normal daily return in those markets. The average loss is around 1%.

The 16 values of g_1, or *Change in correlation 1*, are the estimated coefficients of model (3) that accounts for the change in correlation that occurred in the 10 days after Brexit. In the case of contagion, it would be possible to observe an increase in correlation between the UK and the European market under consideration and thus a positive sign gamma. On the other hand, g_1 would not present significant results for those countries that were not affected by contagion. Germany, Denmark, Sweden, Norway and Switzerland show negative but insignificant coefficients, it is thus not possible to claim that any change in correlation occurred. Portugal, Finland and Netherlands present positive changes in correlation of negligible amounts and the figures are not significant. The increase of 0.17 for France and the Austrian 0.27 are significant at a 5% level, whilst all the other countries experienced increases between 0.30 and 0.92 significant at 1% or less. Ireland is the country subject to the strongest effect in absolute terms and to an increase of 110% in relative terms. This result is due to its special linkage with the United Kingdom, and it is in line with precedent studies reported in the literature.

The series of g_2, or *Change in correlation 2*, presents both positive and negative values, however it is not significant for the entire sample. This means that in the month of July 2016 there was no change in correlation compared to the levels recorded before the event. After the initial increase experienced by most countries, correlation in this period goes back to normal levels. It is possible to claim that market contagion was limited to the first two weeks after the Referendum. The estimated g_3, or *Change in correlation 3,* are mixed in sign, but most of them are insignificant. The significant coefficients display negative sign, meaning that some countries start to detach from the UK after less than two months from the event. Germany and France show significant decreases in correlation at a 10% significance level; Italy, Spain, Ireland, Belgium, Netherlands and Sweden at a 5% and Denmark is the country experiencing the strongest change at a significance level of less than 1%. The decline ranges from -0.19 to -0.58.

The figures of g_4, or *Change in correlation 4*, represent the change in correlation calculated on the six months after the first four and a half months from the Referendum. It is possible to notice the beginning of an alignment of market reactions: all the coefficients show negative sign and almost all results are significant. Ireland and Greece experience the lowest and not significant change, gamma for Austria is significant at 10%, for Italy and Iceland at 5%, and for all the other countries at 1% or less. The average change is equal to -0.3, which represents a relative decrease of 31% compared to the average correlation pre-Brexit. Comparing these results with the figures obtained in the previous period, it could be claimed that the volatile and heterogenous market reactions experienced in the previous months are here taking a more defined and homogeneous shape.

This intuition is confirmed by the figures obtained for g_5 and g_6, or *Change in correlation 5* and *Change in correlation 6*. Both these coefficients present negative sign and similar ranges and averages, strengthening the belief that after the initial market reactions, the long-term effect of Brexit is a general detachment from the UK. Given the subdivision of the post-Brexit period in multiple timeframes, I could identify with higher precision the moment when the detachment process began. Indeed, markets started to detach less than 5 months after Brexit.

Change in correlation 5 shows insignificant results for Austria, Iceland and Switzerland; the decrease in Greece is significant at a 10% significance level, and in Ireland, Finland and Sweden it is significant considering α equal to 5%. For the rest of the sample the coefficient is significant at 1% or less. The average reaction is now of -0.22, thus less dramatic than the previous one. The markets seem to approach in this year the stabilization that will last until February 2019, the end of timeframe of the sample. The average figure for *Change in correlation 6* is -0.23, very close to g_5. During the last year, correlation declines all over Europe, however the range of variation has considerably reduced taking a minimum value of -0.08 and a maximum of -0.38. The reduction of the range symbolizes an alignment of market reactions across countries, with less countries experiencing extreme decreases in correlation. Interestingly, Switzerland is the state subject to the lowest and insignificant decrease in both periods. On the other hand, Mediterranean countries and Denmark suffer the strongest decreases. g_6 is insignificant for Norway and Switzerland, significant at 10% for Ireland and at 5% for Austria and Greece. The other countries present significant results at less than 1% significance level. A visual representation of changes in correlation by period and by country is shown in Figure 6.

Overall, the long-term average effect in the last two years has steadily reduced the average correlation between the UK and the EU approximatively from 0.9 to 0.7. I calculated the figures of correlation of returns in the last year as the sum of *Previous Beta*, the yearly correlation before Brexit, and *Change in correlation of returns 6.*, or in model (3) as b_0+ g_6. The range of values has approximatively the same width of correlation before Brexit, just lower amounts. Interestingly, Iceland presents a slightly negative correlation of -0.05, close to zero. However, Iceland is a particular case even before the event, showing a very weak positive linear correlation of 0.19. No country presents values equal or higher than 1. Figure 7 shows the new figures of correlation by country.

To conclude, with few exceptions, the coefficients of interest are significant, and the explanatory power of the model is high. Apart from an R Square of 5% in the case of Iceland and of 19% in the case of Greece, for the rest of the sample the R Square range of values goes from the 42% of Denmark to the 78% of Netherlands, showing a good fit of the data with the model.

4.3 Explanation of different reactions across countries

I implemented the variables *Previous Beta, Mediterranean, Northern, EFTA, Distance, (Exp+Imp)/GDP* and *GDP* as independent variables in models (4) and (5) to investigate the country-specific characteristics that may have influenced different market reactions. Running model (4), the following equation was estimated:

$$\begin{aligned} 2 - week\ change\ in\ returns \\ &= 0.0456 + 0.0114\ Previous\ Beta - 0.0044\ Mediterranean \\ &+ 0.0025\ Northern + 0.0078\ EFTA - 0.0057\ Distance - 0.1006\ (Exp \\ &+ Imp)/GDP - 0.0035\ GDP \end{aligned}$$

The coefficient of *Previous Beta* and *Northern* are not significant, *Mediterranean* and *GDP* are significant at 10%, *EFTA* and *Distance* at 5% and finally *(Exp+Imp)/GDP* is significant at less than 1% significance level. The extent of the decline in returns is thus significantly affected by some of the country-specific factors. For Mediterranean countries, *ceteris paribus*, the decline is more severe than Central countries, with a decrease in returns, on average, 0.44 p.p. stronger. This result was not unexpected given the higher volatility and financial fragility of Southern Europe. On the other hand, EFTA countries are not part of the European Union and economic ties with the UK are weaker. For this reason, Norway, Iceland and Switzerland experienced a less dramatic decline, on average 0.78 percentage points lower. Against any expectation, *Distance* presents a negative coefficient. A 1% increase in kilometres of distance, *ceteris paribus*, corresponds to an average decrease in returns of 0.000057. The further the country taken into consideration, the stronger the effect on returns. This evidence is counterintuitive; however, it can be interpreted as a sign that geographical distances inside Western Europe are not representative of economic, political and cultural distances and that distances do not influence the strength of economic linkages between markets.

On the other hand, the level of bilateral trade shows a strong effect on changes in returns. As *(Exp+Imp)/GDP* increases by 1 percentage point, *ceteris paribus*, the decrease becomes 0.1006 p.p. stronger. The result is in line with the assumption that countries with higher levels of bilateral trade will suffer higher losses once the UK will leave the European Union. This expectation translates here in a sharper shock of stock prices. Finally, keeping all other variables fixed, an increase of 1% in GDP leads to a change in daily returns of -0.000035. Since larger countries experienced more dramatic declines, economic ties between the big European economies and the UK might be on average stronger than those between the UK and smaller states. Overall, the model has a good explanatory power and the independent variables chosen are able to explain 82% of the variation of the two-week change in returns. To measure the explanatory power of only significant variables Adjusted R Square is considered. For model (4), Adjusted R Square is equal to 67%, still a considerably high value.

Model (5) applied to *Change in correlation of returns 1* investigates on the factors affecting higher or lower levels of contagion in the two weeks after Brexit, when eight countries experienced significant increases in correlation and the others were subject to insignificant variations. The application of the model produced the following estimated regression equation:

$$\begin{aligned} Change\ in\ correlation\ of\ returns\ 1 \\ = -1.9544 - 0.8769\ Previous\ Beta + 0.3232\ Mediterranean \\ - 0.0011\ Northern - 0.3241\ EFTA + 0.2497\ Distance + 5.6163\ (Exp \\ + Imp)/GDP + 0.1403\ GDP \end{aligned}$$

The significant variables are *Mediterranean*, *EFTA* and *(Exp+Imp)/GDP*. The first two are significant at a 10% significance level and the last one at a 5%. As expected, Mediterranean countries are subject to a stronger contagion effect given the higher level of uncertainty and instability of their financial markets. *Ceteris paribus*, Southern Europe experiences an average increase in correlation 0.3232 higher than Central countries. On the other hand, EFTA states are subject to the opposite effect. Not being part of the European Union, contagion is limited and the increase in correlation is, on average and *ceteris paribus*, 0.3241 lower than for the rest of the sample. Since the average increase in correlation is equal to 0.2264, both effects are relatively strong, and they create a substantial difference between these categories of countries.

Bilateral trade is also a relevant factor in the explanation of contagion and the empirical result is in line with theoretical assumptions. Higher connections lead to higher contagion, and the shock spread strongly across economies that share a strict interdependence. Keeping all else unchanged, an increase of 1 p.p. in *(Exp+Imp)/GDP* causes an increase of 0.056163 in *Change in correlation 1*. Even though in this application of the model only three variables are significant, the overall amount of variation explained is equal to 73%, and the explanatory power of significant variables is around 49%.

I run model (5) on the dependent variable *Change in correlation 2*, even though it is composed by figures representing insignificant variations of correlation. The resulting equation is reported below:

$$\begin{aligned} &Change\ in\ correlation\ of\ returns\ 2 \\ &\quad = -2.3706 - 0.1400\ Previous\ Beta + 0.1123\ Mediterranean \\ &\quad - 0.1838\ Northern - 0.0625\ EFTA + 0.2707\ Distance + 3.5720\ (Exp \\ &\quad + Imp)/GDP + 0.0736\ GDP \end{aligned}$$

Distance and *(Exp+Imp)/GDP* are significant at a 10% significance level; however, the result is debatable given the insignificance of the dependent variable itself. Keeping the other variables fixed, a 1% increase in kilometres of distance determines an increase in correlation of 0.002707 and an increase of 1 p.p. in bilateral trade is related to an increase of 0.035720 in correlation. It is thus possible to conclude that even though in this period variations in interdependence between the EU and the UK are small and insignificant, distance and bilateral trade have an impact similar to the one of previous period. Additionally, the explanatory power of significant variables is substantially reduced in this implementation of the model, and Adjusted R Square is equal to 21%.

Similarly, the third application of model (5) brought poor results. The equation estimated was:

$$
\begin{aligned}
&Change\ in\ correlation\ of\ returns\ 3 \\
&\quad = 0.0556 - 0.0934\ Previous\ Beta - 0.0248\ Mediterranean \\
&\quad - 0.0649\ Northern + 0.2018\ EFTA - 0.011\ Distance - 0.1256\ (Exp \\
&\quad + Imp)/GDP - 0.0181\ GDP
\end{aligned}
$$

None of the independent variables is significant and the Adjusted R Square falls to 2%. Market reactions in periods 2 and 3 are mixed and variations are close to zero, it is thus not surprising that the models cannot explained the figures obtained for these periods of transition.

In period 4, the process of detachment began to engage all Europe. Model (5) applied to *Change in correlation 4* delivers the following equation:

$$
\begin{aligned}
&Change\ in\ correlation\ of\ returns\ 4 \\
&\quad = -0.2891 - 0.2969\ Previous\ Beta + 0.0299\ Mediterranean \\
&\quad - 0.0990\ Northern - 0.0784\ EFTA + 0.0204\ Distance + 0.9775\ (Exp \\
&\quad + Imp)/GDP + 0.0176\ GDP
\end{aligned}
$$

The only variable significant at a 10% significance level is *Northern*. Keeping all other variables fixed, countries considered part of Northern Europe experienced a decrease in correlation on average 0.0990 higher than Central EU. It means that market reactions in those economies are around 34% stronger than the average. The model in this period has a higher explanatory power. Overall, the model explains 64% of the differences in changes of correlation, and Adjusted R Square is equal to 33%.

Longer-term effects are described in the period April 2017 – April 2018 by the following equation:

$$\begin{aligned} &Change\ in\ correlation\ of\ returns\ 5 \\ &\quad = 0.3013 - 0.3583\ Previous\ Beta - 0.1493\ Mediterranean \\ &\quad - 0.0436\ Northern + 0.0249\ EFTA - 0.0373\ Distance - 0.5975\ (Exp \\ &\quad + Imp)/GDP + 0.0273\ GDP \end{aligned}$$

Here *Previous Beta* is significant at 10% and *Mediterranean* at 1% significance level. Countries showing a strong correlation before Brexit detached the most: *ceteris paribus*, an increase in previous correlation of 0.1 corresponds to a decrease of 0.03583 in the dependent variable. It seems then that previous levels of financial markets correlation did not significantly influence stock market reactions until period 5, when it is possible to assist a more drastic decrease associated with high values of *Previous Beta*. Additionally, Mediterranean countries experienced an average decrease in correlation 0.1493 stronger than Central countries and a relative effect 67% higher than the total average. The model shows a high R Square of 80% and an Adjusted one of 63%. The two significant variables explain thus a substantial part of the variations in changes of correlation.

In the last year of observations, the regression equation obtained was:

$$\begin{aligned} &Change\ in\ correlation\ of\ returns\ 6 \\ &\quad = -0.3727 - 0.0296\ Previous\ Beta - 0.1079\ Mediterranean \\ &\quad - 0.0472\ Northern + 0.0968\ EFTA + 0.0025\ Distance + 0.5142\ (Exp \\ &\quad + Imp)/GDP + 0.0240\ GDP \end{aligned}$$

The only significant variable is again *Mediterranean*. Keeping the rest unchanged, Southern Europe shows an average decrease 0.1097 stronger than Central countries. This result is similar to the 0.1493 obtained in period 5, showing a persistence of the differences between the Mediterranean region and the rest of Europe. It is thus possible to conclude that in the long term, the only country-specific characteristic significantly and consistently affecting financial markets co-movement of returns is *Mediterranean*. This last application of the model presents a R Square of 62% and Adjusted R Square of 29%, both values showing that the capacity of the model to explain variations in this period is lower than in the previous year. Figure 8 present all the estimated coefficients for the country-specific numerical variables. Overall, it is worth mentioning that long-term reactions are harder to analyse given the longer temporal distance from the event and the greater presence of multiple factors and events not included in the study. For these reasons, the interpretation of empirical evidences is more complex and uncertain.

4.4 Effects on volatility

I studied the effects on volatility using models that are similar to the ones implemented in the analysis of returns. Applying model (7), I measured the co-movement of risk between the UK and European markets before and after the event. b_0, or the pre-Brexit correlation of volatility between the country under examination and the UK is significant for all countries at less than 1% significance level. Figure 9 is a visual representation of the results obtained. Figures of correlation are similar to those collected in the analysis of returns. Italy, France, Netherlands and Germany present top values, Iceland shows an extremely low correlation, followed by Greece, and all other countries are in a middle position.

The main difference with correlation of returns is a general reduction of the values of the coefficient, and thus an average beta of 0.81. It is possible to conclude that co-movement of risk is generally weaker than co-movement of returns. Not only correlation shows lower levels but also the explanatory power of the model is reduced. The range of R Square here goes from the 31% of Denmark, compared to the 42% obtained in the analysis of returns, to the 67% of Netherlands, which substitutes the preceding 78%. Iceland and Greece still represent the less efficient applications of the model, with an R Square of 5 and 14%. Figure 10 shows the linear fit of data in the case of Netherlands, where it appears that linearity is less clear than in Figure 3.

The values of b_1 of model (7) accounts for the two-week changes in volatility for each country. Evidences here are mixed, with some coefficients presenting positive values and some others negative. Few results are significant. Sweden's 0.0097 is significant at 1%; Norway, Finland and Spain at 5%, whilst Greece and Italy at 10% significance level. Figure 11 shows the change in volatility for each country. It is possible to conclude that this measure is not representative of any Brexit effect. Most of the countries experienced insignificant changes and the heterogeneity of results symbolizes the absence of a cause-effect relation.

The estimated g_1 represent the change in correlation of volatility in the first two weeks after Brexit. At 1% significance level Italy, Spain, Ireland and Greece show an increase in co-movement of risk with the UK, whilst Sweden a decrease. Belgium and Iceland experienced an increase significant at 5%, whilst Norway's coefficient shows negative sign. Finally, Finland's decline is significant at 10% and the rest of the sample presents non-significant results. Overall, the average value for g_1 is 0.20, slightly lower than the average increase in correlation of returns. The main difference with *Change in correlation of returns 1* is that decreases in correlation experienced mainly by Northern countries are significant, and market reactions show stronger divergences across the sample.

g_2, or *Change in correlation of volatility 2*, produced non-significant changes, similarly to results for g_2 in the analysis of returns. However, all coefficients show negative sign. g_3 is also negative across the entire sample and presents an average value of -0.34. In these transition periods, results for volatility across countries are more homogeneous and more extreme than for returns. *Change in correlation of volatility 3* is significant for α equal or less than 1% for Italy, Denmark and Spain, which are the countries showing the most negative reactions. Germany, Austria, Netherlands and Sweden are significant at 5% and Ireland at 10%.

The 16 figures of g_4 follow the trend outlined in period 3, however the decline in correlation becomes more uniform and more countries show significant results. The average gamma is around -0.31 but the range of values is smaller. Here Italy, Portugal, Iceland and Greece show insignificant results. The coefficient for Austria is significant at 10%, for Ireland and Spain at 5%, whilst for the rest of the sample results are significant at 1% or less.

g_5 values show a homogeneous decline in correlation similar to the one analysed in period 4. During this period, only Iceland, Switzerland and Greece show insignificant coefficients, confirming the assumption that more and more countries significantly detach from the UK with the passing of time. Austria's coefficient is significant at 10%, Sweden at 5% and all the other countries at 1% or less. The average decrease is equal to -0.28, close to the mean of the previous period.

Estimated coefficients of g_6 are significant across all the sample, even for Switzerland and Norway that in the analysis of changes in correlation of returns experienced non-significant variations. Here Iceland's coefficient is significant for α equal to 10%, Ireland, Austria, Norway and Switzerland at 5% and the rest of Europe at less than 1%. The average decline is approximatively -0.31 and the range of values, similarly to period 5, goes from -0.13 to -0.49. Figure 12 shows changes in correlation of risk by country and by period.

The long-term average variations in correlation 4, 5 and 6 is substantially and persistently higher than long-term changes in correlation of returns. Pre-Brexit co-movement of risk was weaker than co-movement of returns, but still classified as a strong linear relationship. After Brexit, the average correlation decreased to 0.5, representing a moderate linear relationship. Overall, comparing effects on volatility with effects on returns, it seems that the detachment from the UK in the case of interdependence of market risk is stronger, given the higher values of the long-term coefficients, quicker, given the uniform negative sign of changes in correlation in the transition period, and more homogenous, given the consistency of results across countries. Therefore, it is possible to claim that in the short-term results are not indicative of Brexit market reactions, whilst in the long-term volatility presents evidences similar or even stronger than those collected in the analysis of returns. The new figures of correlation for last year are calculated from model (7) as b_0+g_6, or the sum of the initial level of connection and the change recorded in period 6. Figure 13 presents the results. The range goes from 0.06 to 0.69, showing a compression of 0.2 and thus a higher similarity of levels of correlations.

To analyse the causes of cross-country differences, I applied models (8) and (9). Regarding model (8), the following equation was estimated:

$$
\begin{aligned}
2 - & week\ change\ in\ volatility \\
&= 0.0125 + 0.0283\ Previous\ Beta - 0.0054\ Mediterranean \\
&+ 0.0084\ Northern + 0.0023\ EFTA - 0.0026\ Distance - 0.0453\ (Exp \\
&+ Imp)/GDP - 0.0027\ GDP
\end{aligned}
$$

Mediterranean is significant at 10%, *Previous Beta* is significant at 5%, and *Northern* at 1%. This means that, keeping the other variables constant, Mediterranean countries experience an average change in risk that is 0.0054 inferior to the variation shown by Central countries; on the other hand, Northern Europe is subject to a variation in volatility on average 0.0084 higher. These results seem counterintuitive and need to be interpreted carefully. As already mentioned, the heterogenous variations in volatility experienced across the sample in the two weeks after Brexit are mostly insignificant and may not be a direct consequence of the event. Hence, in this case, the model has a partial validity and low reliability. Additionally, *ceteris paribus*, a 0.1 increase in pre-Brexit correlation of risk is associated with an increase in volatility of 0.283 p.p. A higher correlation with market risk of the UK before June 2016 positively influences the net change in volatility, symbolizing a diffusion of risk in more interconnected countries. Even though R Square is equal to 87% and Adjusted R Square to 76%, for the reasons discussed above solid inferences cannot be made.

Model (9) applied on *Change in correlation of volatility 1* delivered the following equation:

$$\begin{aligned} Change\ in\ correlation\ of\ volatility\ 1 \\ &= -2.0417 - 1.7131\ Previous\ Beta + 0.4744\ Mediterranean \\ &- 0.3110\ Northern - 0.3396\ EFTA + 0.2783\ Distance + 6.9826\ (Exp \\ &+ Imp)/GDP + 0.2075\ GDP \end{aligned}$$

Mediterranean and *(Exp+Imp)/GDP* are significant at 5%. *Ceteris paribus*, Southern Europe experience a contagion 0.4744 stronger than Central countries: an increase that is 2.3 times the average effect on the entire sample. An increase of 1 percentage point in bilateral trade determines an increase of 0.069826 in the dependent variable. These results are in the line with the evidences derived from the analysis of correlation of returns. It is then a confirmation that countries in the South of Europe and countries with high levels of bilateral trade experienced higher contagion from the UK. Finally, R Square is equal to 79% and Adjusted R Square to 61%, showing a good explanatory power of both the model and significant variables.

Implementing the model in period 2, 3 and 4, none of the country-specific characteristics under examination significantly influences the variations occurred in this timespan. The complete uselessness of the model is confirmed by the negative Adjusted R Square obtained in each period. The application of the model in period 5 delivered better results. The estimated equation was:

$$\begin{aligned} Change\ in\ correlation\ of\ volatility\ 5 \\ &= 0.2129 - 0.0979\ Previous\ Beta - 0.1353\ Mediterranean \\ &- 0.0722\ Northern + 0.0463\ EFTA - 0.0198\ Distance - 0.6659\ (Exp \\ &+ Imp)/GDP - 0.0279\ GDP \end{aligned}$$

Here *Mediterranean* is significant at 1%, whilst all the other variables are insignificant. *Ceteris paribus*, the average difference in change of correlation of risk between Southern and Central Europe is equal to -0.1353, a decrease 48% stronger than average. In the long term, Mediterranean countries experience thus a more drastic detachment from the UK both in terms of co-movement of risk and returns. The explanatory power of the model is high, with a R Square of 76% and Adjusted R Square of 56%.

In the last year, changes in correlation of volatility are explained by the following equation:

$$\begin{aligned} Change\ in\ correlation\ of\ volatility\ 6 \\ &= -0.1512 - 0.0795\ Previous\ Beta - 0.1028\ Mediterranean \\ &- 0.0902\ Northern + 0.1484\ EFTA - 0.0218\ Distance + 0.7715\ (Exp \\ &+ Imp)/GDP + 0.0076\ GDP \end{aligned}$$

The only significant variable is $EFTA$, at 10% significance level. In period 6, the detachment process is weaker for the countries participating in the EFTA agreement. *Ceteris paribus*, those countries experience a decrease on average 0.1484 lower than the rest of the sample. This result is plausible with their weaker economic ties with the UK and thus lower future losses expected after the British exit. Moreover, the model presents an R Square of 74% and an Adjusted R Square of 52%. Figure 14 presents the estimated coefficients of country-specific numerical variables for every application of the model.

5 Discussion

5.1 Comment on results

The results of the present study regarding the changes in returns and correlation of returns are significant and homogeneous across Western Europe. In the two weeks after the event, most countries present a decline in returns due to the shock caused by the "exit" vote and half of the sample experience an increase in correlation that resembles a contagion effect. As discussed in the literature, controversies about contagion can easily arise because increases in the variance of returns during tumultuous periods could cause an artificial increase of correlation. However, "variance-oriented" adjustments could produce other types of biases; therefore, I did not perform any correction to correlation measures. In order to reassure the reader about the validity of the results of the study, I proved that in the 10 trading days after the Referendum, *id est* in the period when contagion occurred, volatility did not significantly increase. More precisely, a low but significant increase in volatility occurred only in Finland, Sweden and Norway: three of the countries that did not experience contagion in the two weeks after Brexit. All the countries subject to increases in correlation of returns do not show increases in volatility, proving that there is no heteroskedasticity bias to account for.

Even though contagion spread across half of the sample, the duration of the effect is relatively short. After the first two weeks, levels of correlation move back to pre-Brexit levels, remain stable for one month, and at the end of 2016 some countries start the detachment. It is possible to claim with fair confidence that European markets are detaching from the UK due to the consistency of results of models (2) and (3) and the uniformity of significant results. In figure 6, the phenomena described is clearly evident in the last two years, where the average decline in correlation is almost constant and the movement across countries becomes highly synchronized. The trend is smooth and persistent similarly to the one of changes in correlation of volatility. In the long-term the pronounced changes of cross-market correlation of volatility confirm the tendency observed for the returns case, strengthening the detachment theory. Overall, results of the volatility analysis mirror results obtained from returns, giving further support to the conclusions of the study.

Evidences on the country-specific factors influencing market reactions are mixed and uncertain. Different variables affect changes in returns and correlation over time, and in the same period different variables affect the changes in returns and in volatility. However, the variable *Mediterranean* presents high consistency both across time and type of analysis. Therefore, it is possible to claim that Mediterranean countries experienced persistently different changes compared to Central countries. They present extreme market changes both during contagion and detachment. In the short term, they are subject to a sharper decline in returns and a violent contagion probably due to their fragile financial systems. In the longer term, Southern Europe is the region that detached the most from the UK and that may thus be hit only partially by future economic losses, prediction that seems confirmed by the recent literature.

5.2 Extension of the study

I considered of great interest to evaluate whether an extension of the study would be feasible. In order to have a complete view of the effects of Brexit on the other 27 member states of the European Union, I introduced in the analysis Eastern European countries and small EU states previously excluded due to their size. Prices of the main stock indexes of Bulgaria, Croatia, Estonia, Poland, Czech Republic, Romania, Slovakia, Slovenia, Hungary, Luxembourg, Cyprus and Malta were retrieved from Datastream. It was not possible to find PI data for Latvia and Lithuania. I downloaded data for the period going from the 8th of July 2015 to the 27th of February 2019 for BULGARIA SE SOFIX - PRICE INDEX, CROATIA CROBEX - PRICE INDEX, OMX TALLINN (OMXT) - PRICE INDEX, WARSAW STOCK EXCHANGE - PRICE INDEX, PRAGUE SE PX - PRICE INDEX, ROMANIA BET (L) - PRICE INDEX, SLOVAKIA SAX 16 - PRICE INDEX, SLOVENIAN BLUE CHIP (SBI TOP) - PRICE INDEX, BUDAPEST (BUX) - PRICE INDEX, LUXEMBOURG SE LUXX - PRICE INDEX, CYPRUS GENERAL - PRICE INDEX and MALTA SE MSE - PRICE INDEX. I then applied model (3) to the UK and each of the aforementioned countries to measure changes in returns and correlation of returns due to Brexit.

The results delivered by the model are poor and uncertain. Firstly, the goodness of fit of the model is lower than 10% in most of the applications, with only Hungary, Czechia and Luxembourg obtaining R square respectively of 21, 32 and 35%. Moreover, none of these countries presents consistently significant changes in correlation of returns with the UK in the period post-Brexit. It is worth mentioning that Malta, Cyprus and Slovakia show an insignificant cross-market correlation even before the event. I concluded that Eastern Europe is only partially affected by the event also given the lower initial correlation of stock markets. Moreover, the model implemented to explain Brexit effects on Western Europe provides here a low explanatory power. For these reasons, these countries were not included in the core analysis of the study.

5.3 Study Limitations

The study presents several limitations. Firstly, when studying changes in returns and volatility and changes in correlation of returns and volatility between each country and the UK, the potential presence of confounding events was not taken under consideration. Confounding events are those events that could influence market prices creating noise that increase the difficulties for researchers to capture the effect of the specific incidence under examination. In order to prevent confounding events to bias an event study analysis and in order to reduce potential interferences, usually short event windows are chosen (Konchitchki & O'Learyrch, 2011). In this specific case, the analysis conducted is not an event study, but external occurrences could still distort empirical results given the long timespan under consideration. However, the validity of the conclusions derived from the study are strengthened by the uniformity and consistency of results. Movements of returns, volatility and correlation between the UK and each of the 16 countries present high similarities, proving that results are not jeopardized by potentially relevant country-specific confounding events.

Secondly, reliability of results could be compromised by the reduced sample size. Since Brexit effects on Western Europe are considered, the number of countries analysed is limited to 16. Sample size results to be a major limitation in the analysis of potential causes of different market reactions and changes in correlation throughout Europe. Models (4), (5), (8), and (9) are based on 16 data points, thus confidence intervals are wider and the risk to incur in statistical errors during the hypothesis testing is higher than in analysis with larger samples. Therefore, results are weaker and less reliable.

Thirdly, in the analysis of country-specific characteristics determining different market reactions, I chose seven factors as explanatory variables. They were the most relevant predictors from a pool of variables previously tested, however the potential presence of missing variables is not excluded. The problem of omitted variables was not addressed here. Omitted variables are those factors not included in the model that could influence the dependent variable and being correlated with one of the regressors. The omission of relevant explanatory variables can thus jeopardize regression results (Radaelli & Wagemann, 2018). Interpreting the analysis of potential causes correlated to country-specific market reactions to Brexit, the reader should be aware of the potential bias caused by the problem of missing variables.

Lastly, it is important to remember that the exit of the UK from the European Union has not materialized yet, it is thus risky to infer conclusions about future losses and future Brexit effects. For this reason, the present study focuses on the analysis of market movements that occurred in the last two and a half years and that mirror expectations of investors about the future, expectations that could be driven by prudence or fear and that should not be confused with analytic forecasts of Brexit consequences. Further studies will be needed in order to account for short and especially long-term effects, which will delineate more clearly with the passing of time.

6 Conclusion

The intent of this research was to investigate on Brexit effects on European financial markets. More precisely, I studied how the "exit" vote determined a change in the co-movement of the FTSE100 and the main European indexes. I found that in the two weeks after the event, many financial markets experienced a significant decline in returns and a contagion effect measured as the increase in the correlation with the British market. After a period of transition, in the last two years cross-market correlation is significantly lower than before Brexit meaning that British and European markets are going through a detachment process. Regarding the potential causes of different market reactions across the sample, different factors affect changes in the short and long term. However, being part of the Mediterranean countries increases, in absolute value, the scale of changes in returns and correlation consistently throughout time. Analysis on volatility reinforced these results. To conclude, further studies will be necessary to analyse Brexit consequences when the exit of the UK will actually materialize, in the meantime this paper provides a comprehensive picture and a key of interpretation of the developments occurred until now in the financial markets of Western Europe.

7 Appendix

Figure 1: Betas of returns before Brexit, or b_0 model (2)

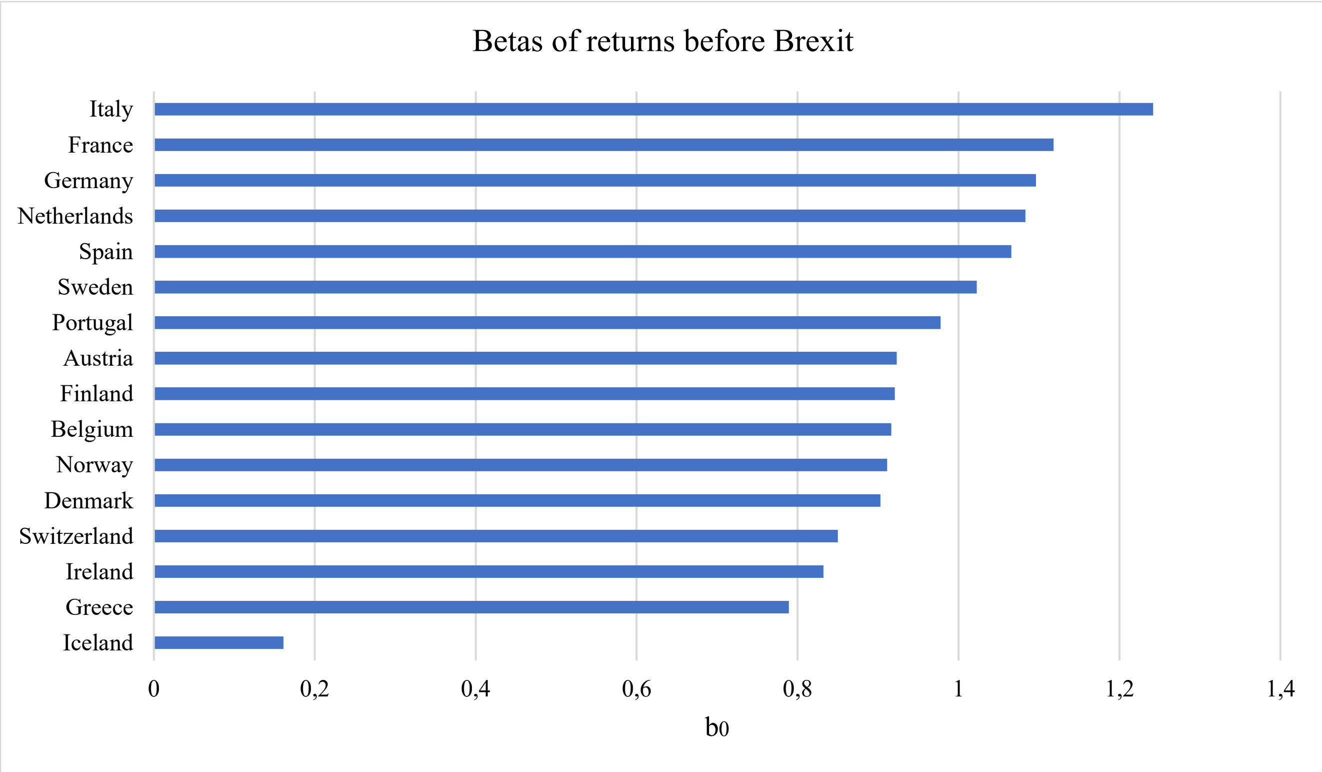

Figure 2: Brexit average effect on correlation, or g_1 model (2)

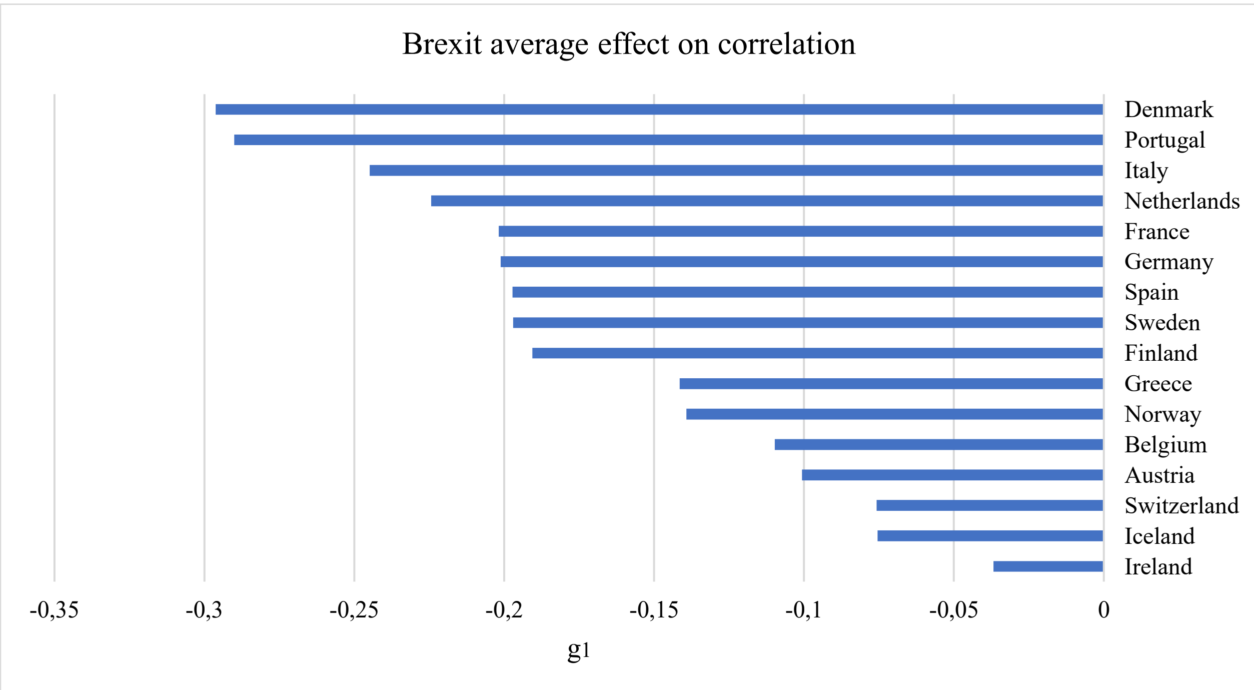

Figure 3: Linear correlation of daily returns NL-UK

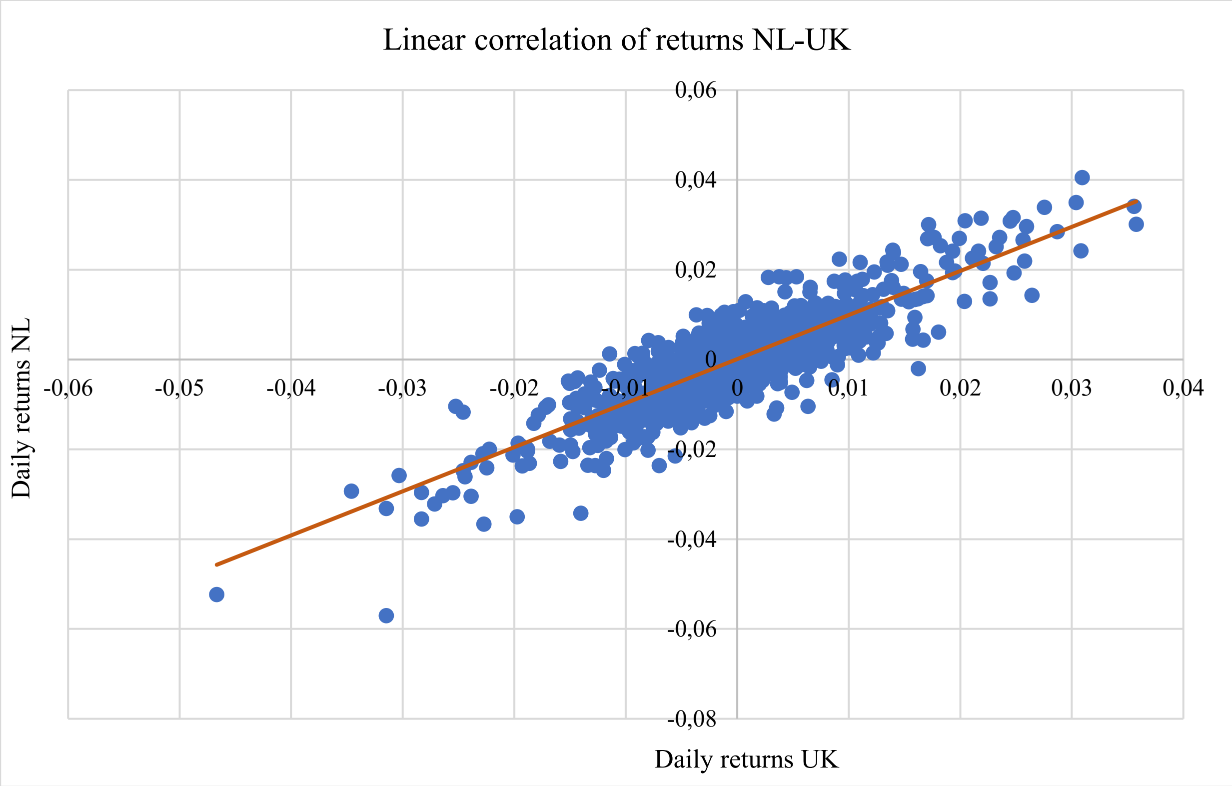

Figure 4: Residual Plot of daily returns NL

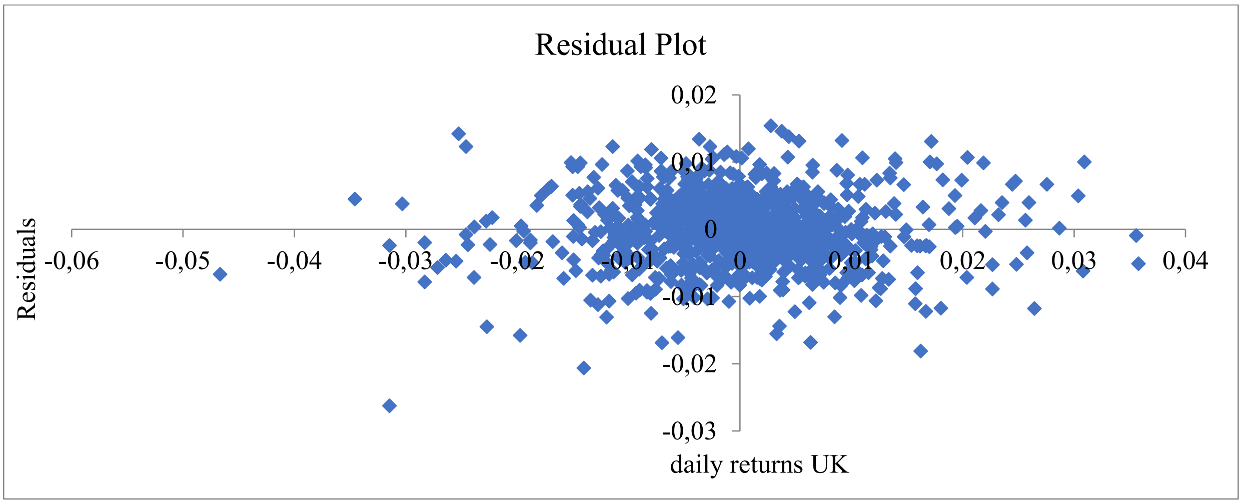

Figure 5: 2-week decline in returns, or b_1 model (3)

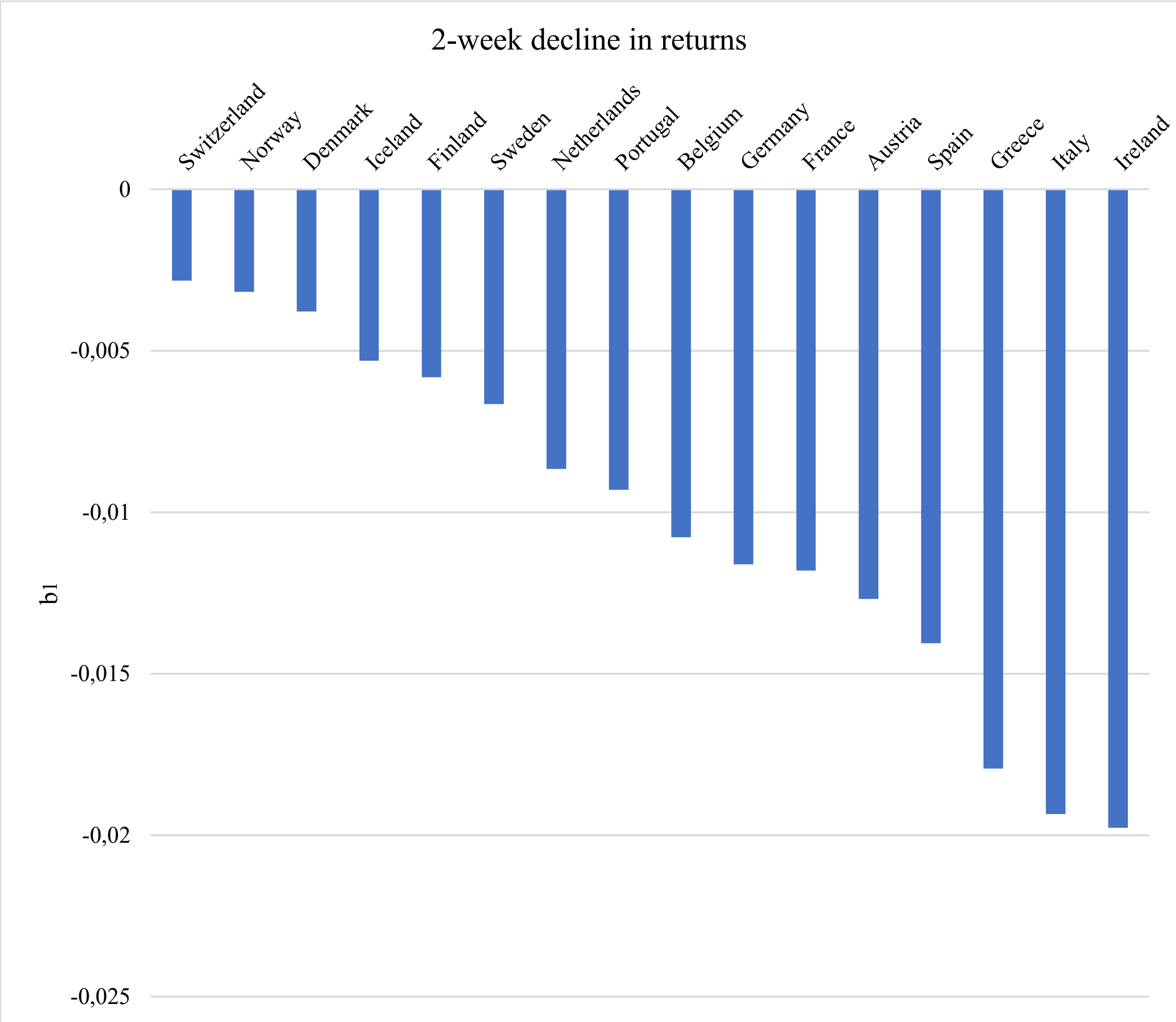

Figure 6: Change in correlation of returns, or g_j model (3)

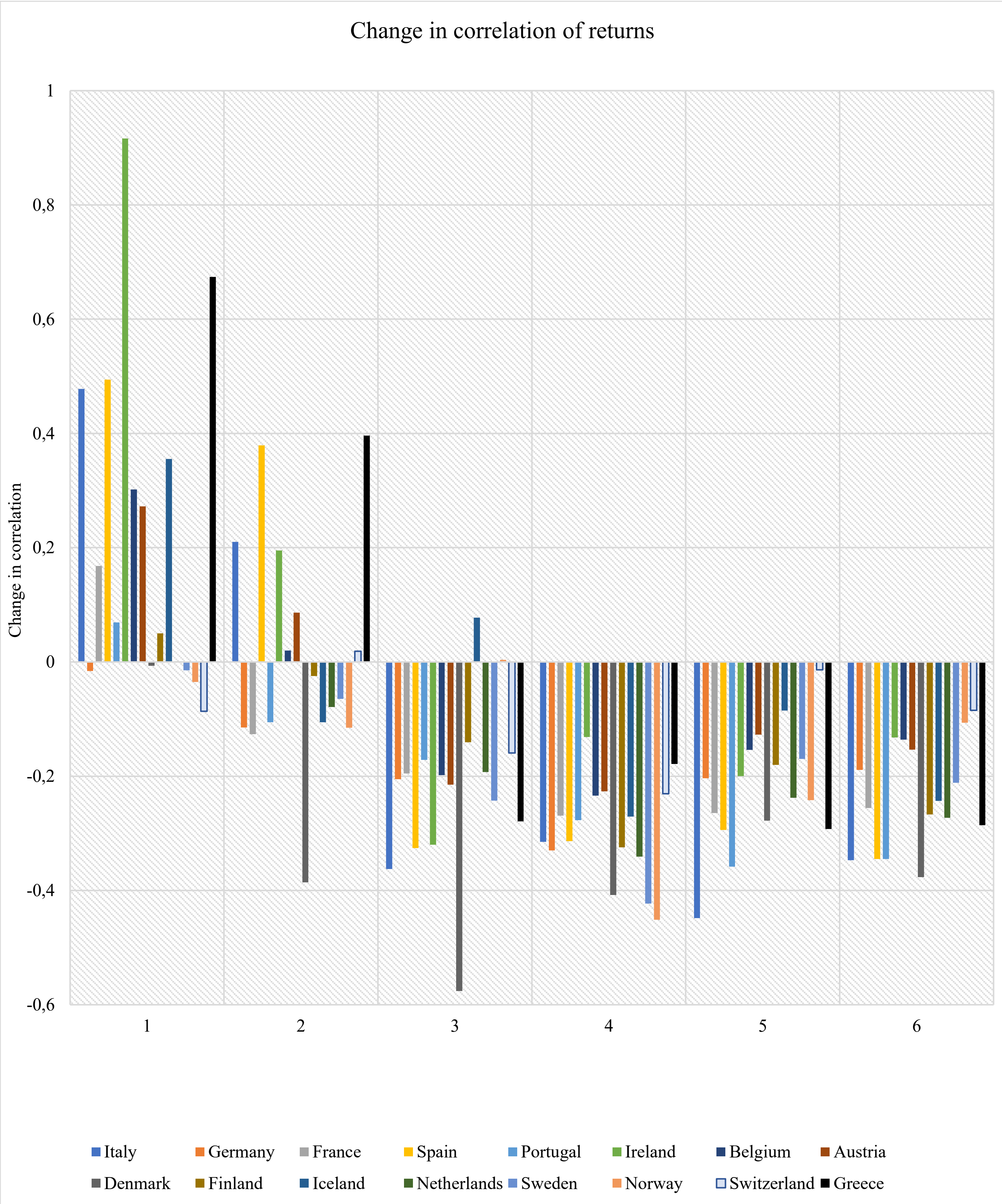

Figure 7: *Previous Beta + Change in correlation of returns 6*, or correlation of returns 6

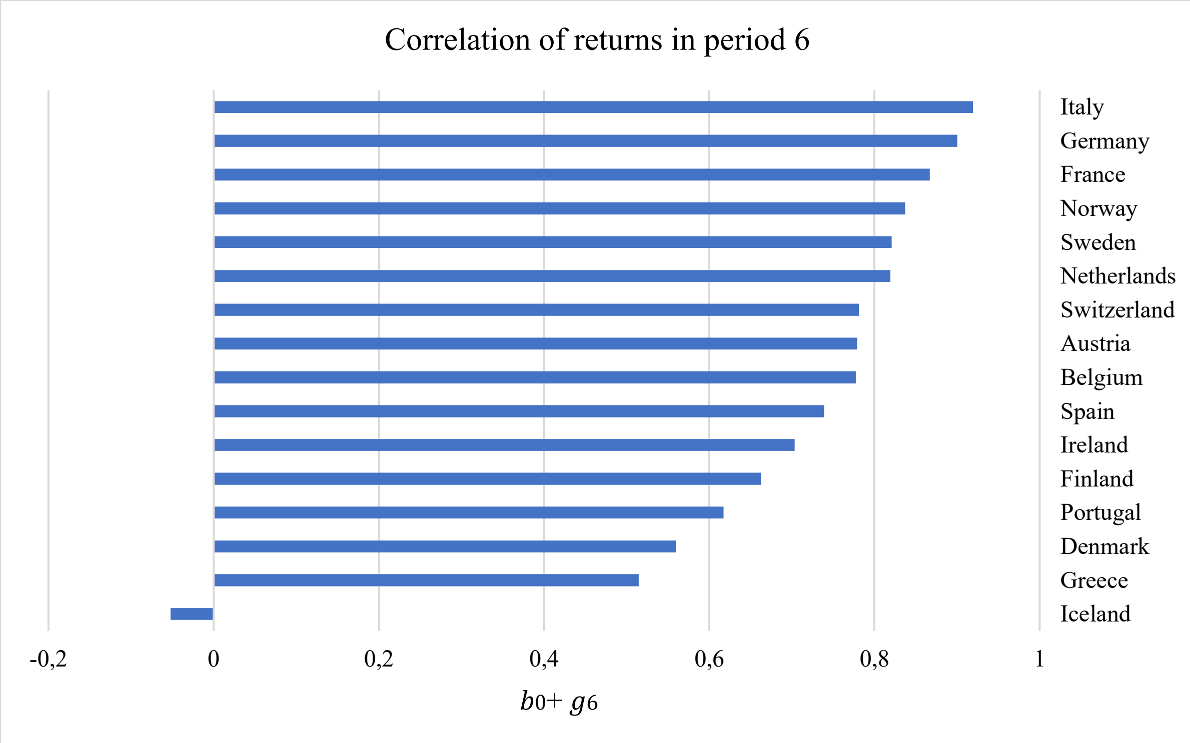

Figure 8: Estimated coefficients of country-specific numerical variables in models (4) and (5)

	2-week change in returns	Change in correlation of returns 1	Change in corr 2	Change in corr 3	Change in corr 4	Change in corr 5	Change in corr 6
Previous Beta	0.0114	-0.8769	-0.1400	-0.0934	-0.2969	-0.3583*	-0.0296
Mediterranean	-0.0044*	0.3232*	0.1123	-0.0248	0.0299	-0.1493***	-0.1079*
Northern	0.0025	-0.0011	-0.1838	-0.0649	-0.0990*	-0.0436	-0.0472
ETFA	0.0078**	-0.3241*	-0.0625	0.2018	-0.0784	0.0249	0.0968
Distance	-0.0057**	0.2497	0.2707*	-0.0105	0.0204	-0.0373	0.0025
(Exp+Imp)/GDP	-0.1006***	5.6163**	3.5720**	-0.1256	0.9775	-0.5975	0.5142
GDP	-0.0035*	0.1403	0.0736	-0.0181	0.0176	0.0273	0.0240

, **, and * indicate statistical significance at 10%, 5% and 1% level, respectively*

Figure 9: Betas of volatility before Brexit, or b_0 model (7)

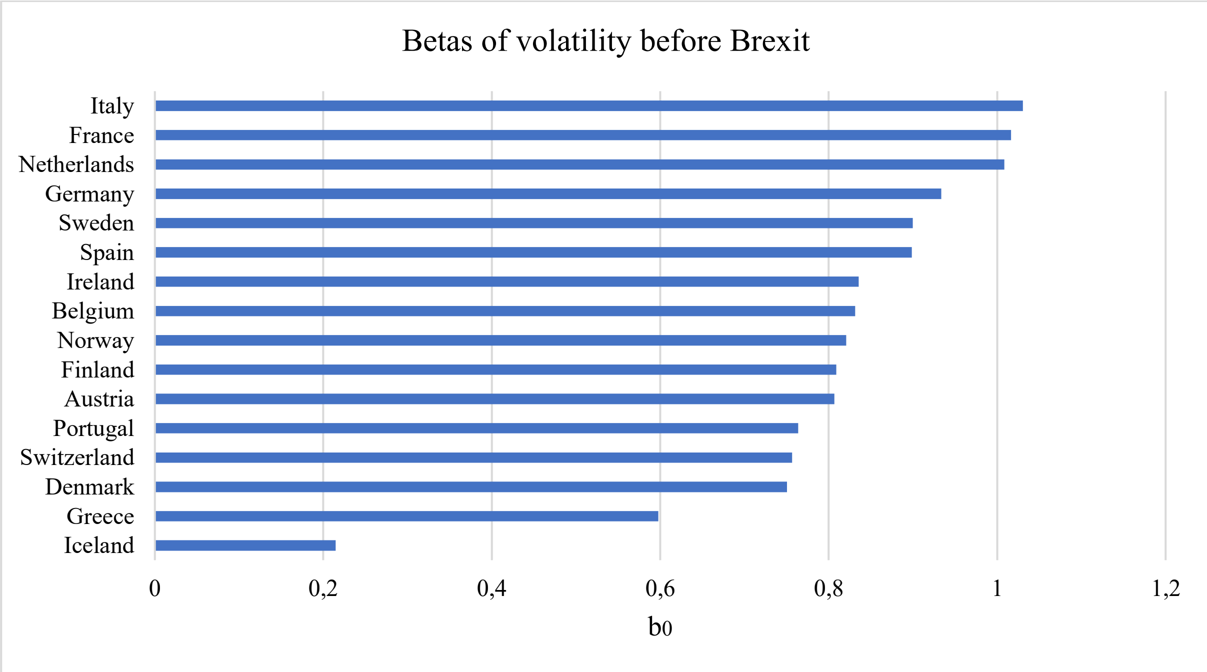

Figure 10: Linear correlation of volatility NL-UK

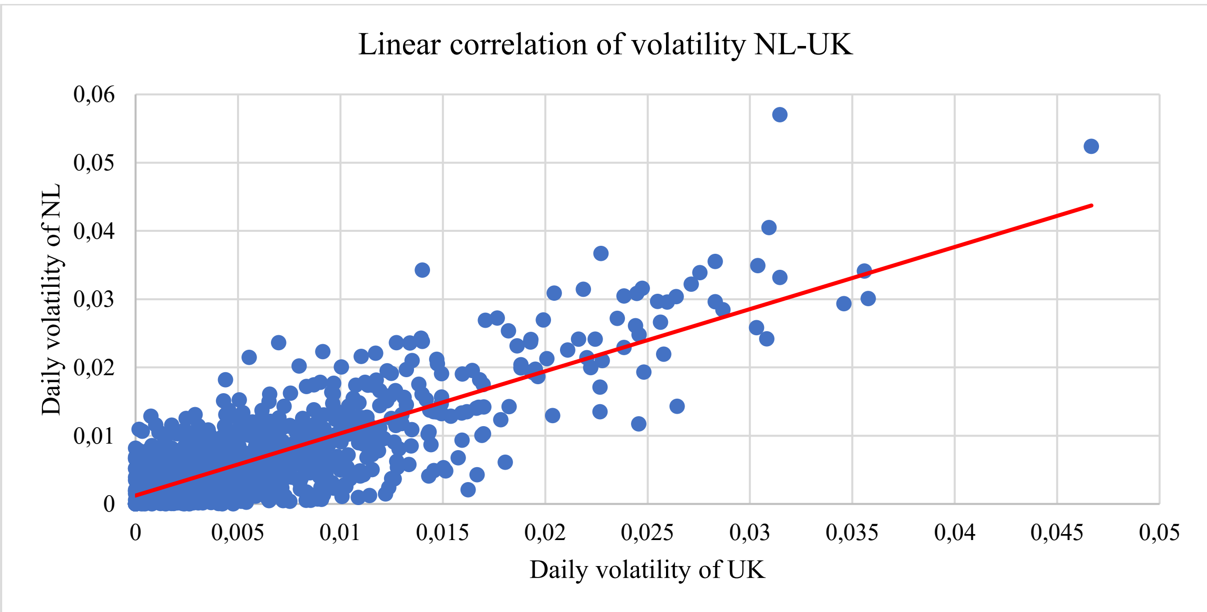

Figure 11: 2-week change in volatility, or b_1 model (7)

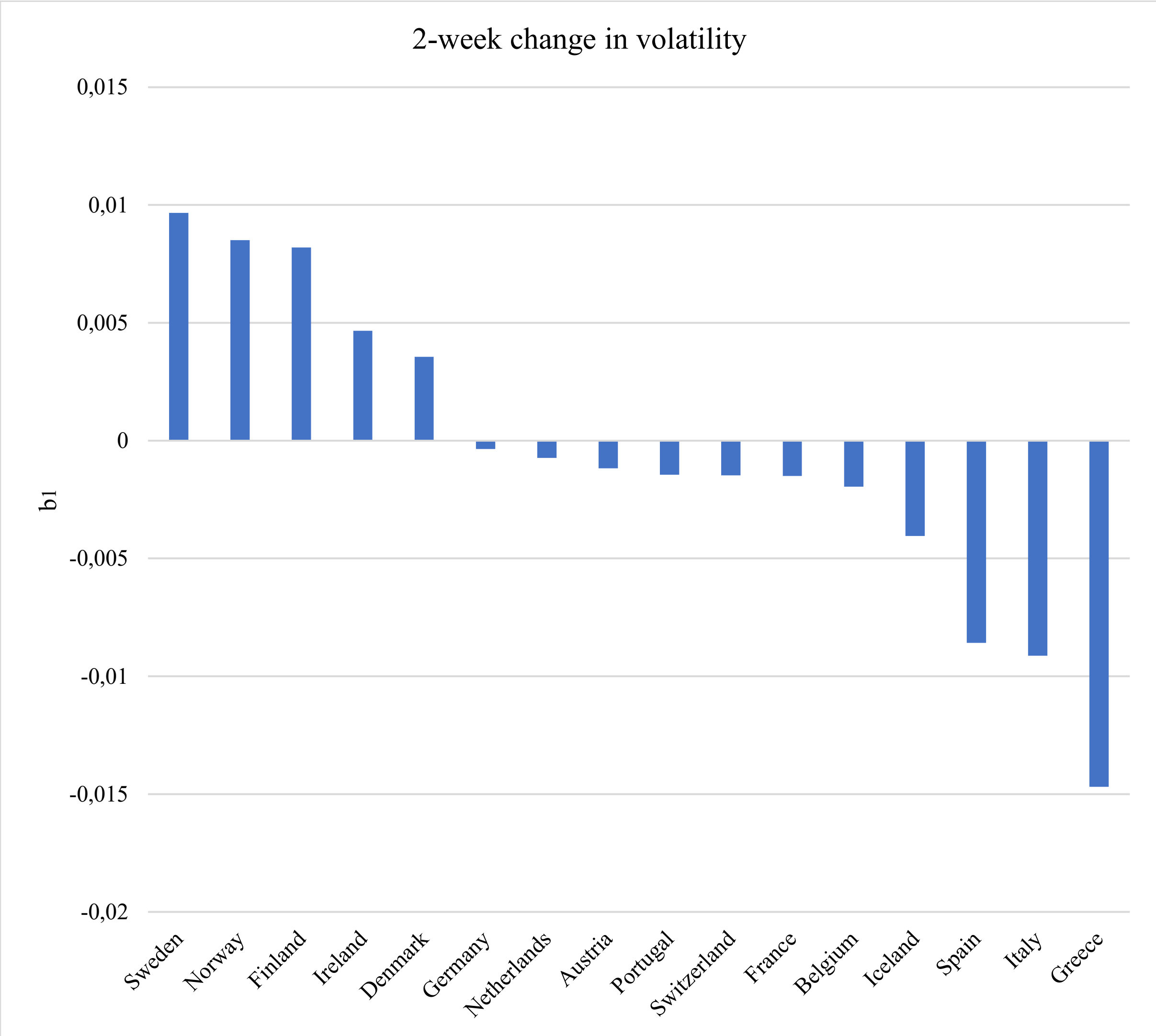

Figure 12: Change in correlation of volatility, or g_j model (7)

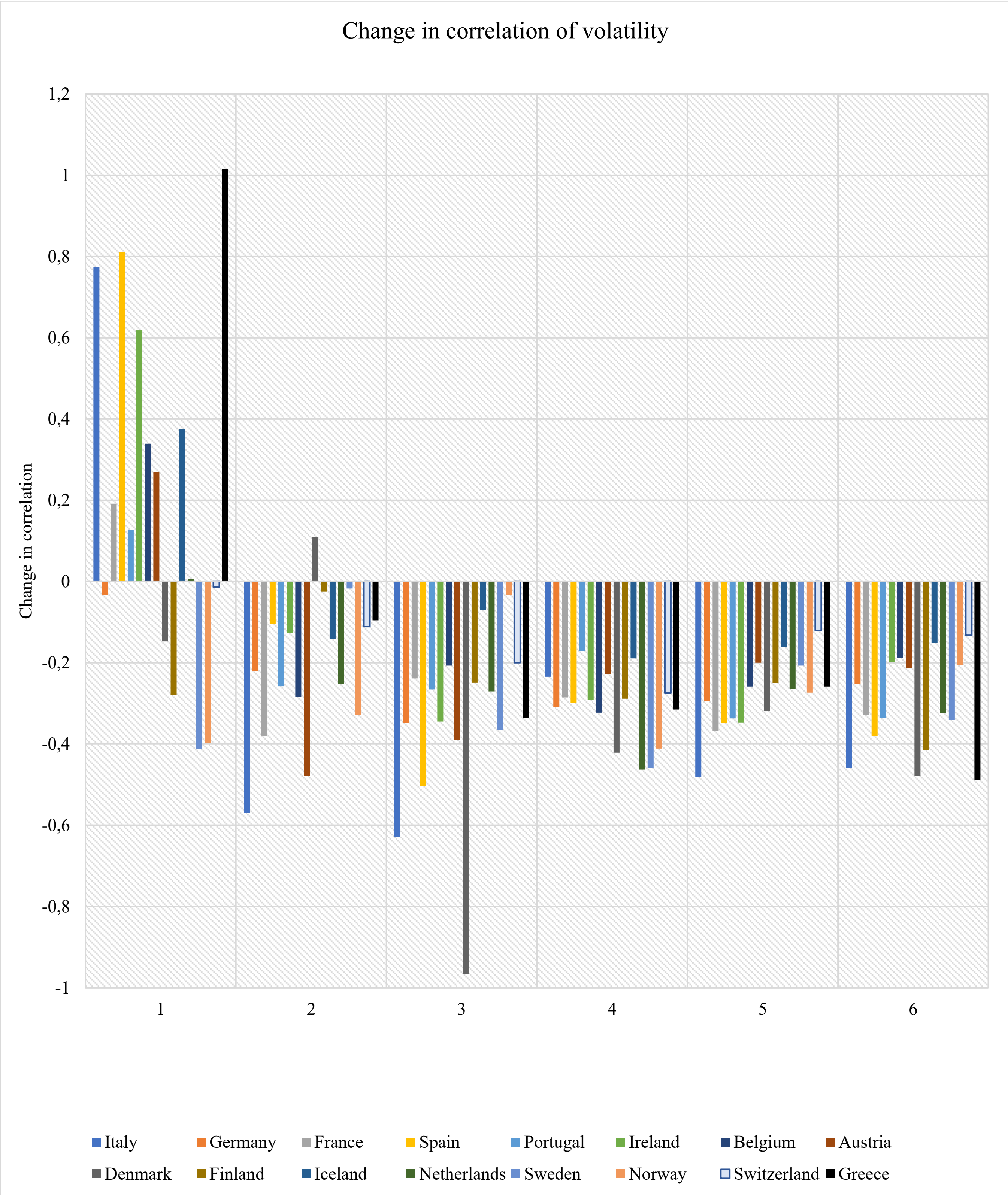

Figure 13: *Previous Beta + Change in correlation of volatility 6*, or correlation of volatility 6

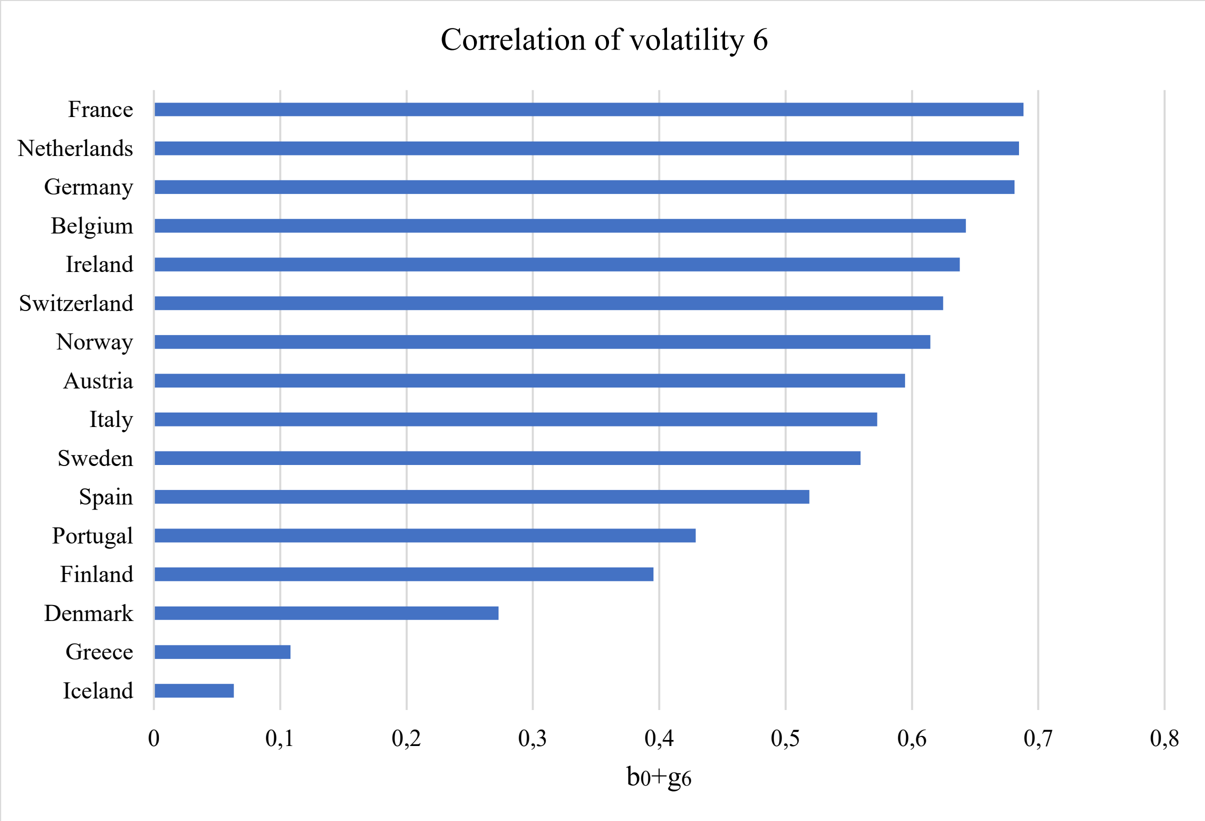

Figure 14: Estimated coefficients of country-specific numerical variables in models (8) and (9)

	2-week change in returns	Change in correlation volatility 1	Change in corr 2	Change in corr 3	Change in corr 4	Change in corr 5	Change in corr 6
Previous Beta	0.0283**	-1.7131	-0.8286	0.5296	-0.1966	-0.0979	-0.0795
Mediterranean	-0.0054*	0.4744**	-0.0294	-0.0030	0.0476	-0.1353***	-0.1028
Northern	0.0084***	-0.3110	0.2229	-0.1599	-0.0757	-0.0722	-0.0902
ETFA	0.0023	-0.3396	-0.1776	0.3429	0.0046	0.0463	0.1484*
Distance	-0.0026	0.2783	-0.0439	-0.0316	0.0322	-0.0198	-0.0218
(Exp+Imp)/GDP	-0.0453	6.9826***	-0.3384	0.5993	0.3210	-0.6659	0.7715
GDP	-0.0027	0.2075	0.0808	-0.1126	0.0004	-0.0279	0.0076

, **, and * indicate statistical significance at 10%, 5% and 1% level, respectively*

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