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Master´s Thesis

Brexit and Stock Market Comovements of UK and Europe

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Declaration of Authorship

The author hereby declares that she compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, May 11th 2018 Signature

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Abstract

The referendum organised in United Kingdom on June 23rd, 2016 led to an unexpected decision to leave the European Union. Since Brexit announcement, uncertainty about the economic prospects of the United Kingdom and of the EU has increased, and multiple research has been conducted to estimate the economic implication of Brexit for the UK as well as for the rest of Europe. The thesis addresses this topic from the point of view of financial markets correlation, and assesses how did the Brexit announcement and the outcome of the 2016 referendum influenced the cointegration of the UK stock market with those of continental Europe.

Using a multivariate DCC-GARCH model, and European stock markets data, the thesis concludes that correlation of UK and European stock markets decreased since the referendum announcement, and further decrease has been observed after the vote took place.

JEL Classification: C01, C39, D89, F15, F30, F36, G19

Key words: Brexit, uncertainty, stock market cointegration, European Union, financial markets

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Abstrakt

Referendum uspořádané ve Velké Británii dne 23. června 2016 vedlo k nečekanému rozhodnutí opustit Evropskou Unii. Jedním z dopadů odchodu členského státu je zvýšená nejistota na trhu jak Velké Británie, tak i Evropy. Bylo publikováno mnoho výzkumů které měli za cíl odhadnout ekonomické a sociální dopady tohoto rozhodnutí. Diplomová práce se zabývá tímto tématem z hlediska korelace finančních trhů, a pokouší se zhodnotit, jak výsledek referenda a oznámení Brexitu ovlivnily kointegraci britského akciového trhu a zbytku Evropy.

Použitím DCC-GARCH modelu a dat jednotlivých akciových trhů členských států, diplomová práce dochází k závěru že korelace mezi Velkou Británií a zemí kontinentální Evropy se snížila po oznámení referenda, a dále i po tom, co se referendum odehrálo.

Klasifikace JEL: C01, C39, D89, F15, F30, F36, G19

Klíčová slova: Brexit, nejistota, kointegrace akciových trhů, Evropská unie, finanční trhy

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Acronyms

UK – United Kingdom

EU – European Union

US – United States of America

LSE – London Stock Exchange

Thesis Proposal

Author:	Táňa Bedrichová
Supervisor:	Prof. Roman Horváth Ph.D
Proposed Topic:	**Brexit and Stock Market Comovements of UK and Europe**

Motivation: Evidence suggest that the integration of the European countries lead to increased interdependence of their markets, especially after the introduction of the European Monetary Union (Hallgren and Rehn, 2011; Kim, Moshirian and Wu, 2005; Mylonidis and Kollias, 2010). Thus, it may be expected that events in one market, such as the Brexit referendum in the United Kingdom, may influence foreign economies – although with different magnitude.

Since Brexit announcement, uncertainty about the economic prospects of the United Kingdom as well as of the EU has increased. Economic Policy Uncertainty Index (EPU index) indicates that near-referendum time is associated with high uncertainty, surpassing previous spikes. Reenen (2016) summarises these effects as higher trade costs for Europe as well as for the UK, implying lower trade and foreign investment, and a welfare losses varying from 1,3-9,5 percent.

Alongside with the financial globalisation, a question of the portfolio diversification arises. It has been shown that an investor can benefit from the diversification of his portfolio through investing in two different markets, however the benefit of diversification is dependent on the degree of cointegration between the particular markets (Driessen and Laeven, 2003). Considering the hypothesis that the cointegration of the UK and European stock markets became non-significant after the Brexit event, UK market may represent a diversification option for investors.

Although Brexit is a relatively new event and its long-term effects are still ambiguous, the thesis tries to analyse how did the market cointegration changed since the UK citizens voted to leave the integrated market. At the same time measures the extent of its implications on both, EU and UK market. Assuming that the UK stock market was cointegrated with the EU, the thesis rationales that the investors may benefit from Brexit through better diversification.

Hypotheses:

1. Correlation between UK stock market and continental Europe has changed after the announcement of Brexit.

2. Under the presumption that the UK stock market was cointegrated with EU markets, cointegration has lowered after the announcement of Brexit.

Methodology:

I will test the cointegration on the European stock market data (i.e. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom). To assess the political uncertainty in the UK market I will use the Economic Policy Uncertainty index developed by Baker, Bloom and Davis (2016). EPU index tracks the uncertainty related to Brexit by reporting a share of newspaper articles in the Financial Times and Times of London that discuss "Economics", "Policy", "Uncertainty". This index is highly correlated with the Brexit uncertainty index during the pre-referendum period, and data are available for after-referendum period. Using this index thus allows an estimation of uncertainty triggered by Brexit.

To assess the level of UK and continental Europe cointegration I will use a multivariate GARCH model. According to Bauwens, Laurent and Rombouts (2006), multivariate GARCH model is mostly used to test relations between volatilities and co-volatilities of several markets, and to determine the spreading of volatilities from one market to another. I will follow the approach of Karolyi (1995) who tests the multivariate GARCH model on transmission of volatility in case of United States and Canada, and Horvath and Petrovski (2013) using the multivariate GARCH on international stock market comovements between West and Central Europe.

Expected Contribution:

Multiple research was conducted in the pre-referendum period, as well as during the (present) negotiation time. I will address the Brexit topic from the point of view of market correlation, and assess how did the cointegration of the UK market changed since Brexit announcement. I believe that a quantitative analysis will help to track the development of market conditions, allowing the comparison with the pre-referendum period, and thus will represent a contribution to this relatively new topic.

Outline:

1. Introduction and literature review.
2. Data: description of the data used for the analysis.
3. Method: description of the methodology used for the analysis.
4. Results: Results presentation and summarisation.
5. Conclusions.

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1. Introduction

During the past decades the European countries became more and more integrated, and this trend became even stronger after the introduction of European Monetary Union and common currency. Due to this increased integration (and globalisation in general), one may expect that an event in one country – such as Brexit - will influence not only domestic, but also foreign markets (Dörry, 2017; Burdekin, Hughson and Gu, 2017).

The referendum organised in United Kingdom on June 23rd, 2016 led to a surprising decision to leave the European Union. This event is the first time in the history of the European Union that a country has decided to leave, and raised lot of interest. Economic Policy Uncertainty Index (EPU Index) suggests that near referendum time is associated with high level of political uncertainty, even surpassing previous spikes (for example uncertainty associated with 9/11 attacks and Second Gulf War). Multiple studies have been conducted to investigate implications of Brexit event and spread of Brexit-induced policy uncertainty to European countries - ranging from impact on country's GDP, trade, and investment to potential harm of EU's reputation (Hartwell and Horvath, 2017; Burdekin, et al., 2017).

The thesis summarises previously assessed aspects of Brexit, and tries to analyse how did the market cointegration changed since the UK citizens voted to leave the European Union. Examining the European stock markets data, the results suggest that the correlation of stock markets has been gradually decreasing since the referendum announcement. The market participants did not immediately relocate their operations into remaining EU countries in order to keep benefits of a single market, but rather incorporated the Brexit outcome into their expectations. At the same time, the decreasing correlation trend may be seen between United States and European stock markets. Decrease of correlation after the referendum took place is (among the selected markets) highest for UK stock market. This may suggest an overall decrease of cointegration among the stock markets, where Brexit even fostered this trend.

Even though the negotiations are still not finished, it is likely that the cointegration between UK and continental Europe will not be a sudden sift, but it will rather change because the collaboration between UK and continental Europe will be different.

The rest of the thesis is organised as follows: Section 2 discusses the recent integration of European financial markets. Section 3 analyses the event of Brexit, and summarises its possible implications for UK and the EU in different economic areas. Section 4 summarises the literature on the measures of integration of countries, and briefly reasons the selection of the chosen method to measure the change in comovements. Section 5 describes the chosen method more closely. The approach and results are presented in Section 6. Section 7 concludes.

2. Integration of European countries

European countries became more cointegrated in the past two decades, and this trend has been fostered by the introduction of the common currency and European Monetary Union (EMU). Multiple research has been conducted to assess integration in general, from different perspectives. Studies focused on financial markets range from examination of spillover effects within Union, through assessment of similarities between member countries (e.g. homogenisation of economies), to examination of countries' dynamic relationships (i.e. cointegration).

Kim, Mosirian and Wu (2005) examine the influence of the European Monetary Union (EMU) on the dynamic process of stock market integration before 2003, and show that there has been a clear regime shift in European stock market integration with the introduction of the EMU. Horvath and Petrovski (2013) analyse the Central Europe and South-Eastern Europe markets comovements and linkages with Western Europe and find high degree of integration between Central Europe markets and the euro area. Wang and Moore (2008) examine interdependence between Czech Republic, Hungary, Poland and aggregate euro area market, concluding that the enlargement of the European Union and financial crisis have increased the correlation among the chosen markets and euro area market. Baele (2005) uses price-based and news-based measures to assess the homogenisation of European financial market in the five key areas (money market, corporate-bond market, government-bond market, credit, and equity markets), and provides evidence of increased uniformity of EU markets since late nineties. Similarly, Campos and Macchiarelli (2016) conclude that business cycles in EU follow similar path. Hallgren and Rehn (2011), assessing the cointegration relationship of euro area, come to the conclusion of better integrated markets. The evidence of increased interconnection of markets implies that an event in one country will probably not influence only the domestic market, but the effects will spread to neighbour countries through different links.

2.1. Core of the EU

Campos et al. (2016) define a "core-ness" of a country as a measure of economic symmetry between individual European states. By measuring the correlation of member states' business

cycles, they identify the common currency as one of the most important factors that make the country a "core state" of the EU.

Taking the evidence from the supply and demand shocks, European countries fall into one of the two groups: the "core countries" which become more homogenised over time, or periphery countries that rather follow their own path and are becoming more heterogenous. Looking at the evolvement in time, some countries vary between the two groups. The core countries - based on the path of their business cycles in the period 1990 – 2015 are UK, Sweden, Denmark, Germany, Austria, France, Netherlands, Slovenia, Belgium, and Italy. Among periphery countries we may count (in decreasing order) Latvia, Ireland, Lithuania, Estonia, Luxembourg, Czech Republic, Greece, Portugal, Slovakia, Poland, Hungary, Finland, and Spain. The "varying" countries are Denmark, UK, Sweden and Spain.

Among the factors that contribute to the "core-ness" of the country are before all euro-adoption, whilst product market regulation makes countries rather "periphery" (Campos et al., 2016). This is in accordance with finding of multiple studies arguing that the cointegration pattern was strengthened especially after the introduction of EMU (Baele, 2005, Hallgren et al., 2011, Kim, Moshirian and Wu, 2011). Despite the classification of UK as the "varying country", its economy was not immune to this strengthened integration – UK business cycles became more correlated with the euro area as whole. Implying from Campos et al. (2016) research, despite a deeper cointegration of its members, the UK exit does not necessarily represent a threat, as it is not among the core countries. The specificities of the UK will be discussed in the later in this chapter.

2.2. Financial market homogenisation

Integration of the economies in the eurozone area, associated with unified standards in the financial sphere necessarily leads to homogenisation of the key areas of financial markets - money market, corporate-bond market, government-bond market, credit, and equity markets (Baele, 2005). This evolvement implies that the country specific factors, such as interest rate and exchange rate, causing the difference of yields diminish with unification. Taking this assumption, Baele (2005) uses the *law of one price* definition to assess the convergence of the financial market: "In financially integrated markets, assets generating identical cash flows

should be priced identically, irrespective of where they are transacted". Apart from the "returns homogenisation" measure, the news spillover effect points to European integration: as the countries converge, the local news become less decisive in the asset-price fluctuations, and foreign news will become more important driver.

Baele's results confirm that since the introduction of the common currency, European countries have become more homogenised. Evidence from corporate bond market show that the country of issuance is of relatively small importance, and the biases of bond portfolios has reduced dramatically. Government-bond market integration has swiftly converged in all selected countries, and has been relatively high since the introduction of euro. Government bond returns are driven by local news only to a small extent, and are rather influenced by common news. Equity market for the period of 1990 until 2003 shows rising homogeneity, and, similarly to government bonds, yields are driven by common news factors. Price differential remains high for banking market, even though this area seems to be quite advanced from a legal point of view. Degree of integration varies across banking segments: corporate lending market seems to be more integrated for medium- and long- term segment in comparison to short-term lending segment. Mortgage segment seems to be more homogenous than in the past, however the consumer credit segment is fragmented (Baele, 2005).

Due to homogenisation of European financial markets, the country specific factors of the economies have declined, as the interest rate is equal for all the EMU members (Baele, 2005). Exchange rate with *foreign* currencies is the *same* for all countries using Eurocurrency. Investment barriers still exist, although they are expected to lower over time. Other country specific factors that may have an impact on the economy still remain *specific*, such as inflation rate, tax regime, legislation, economic activity, or natural events (for instance flooding or a hurricane (Moerman, 2008)). Establishing how the degree of cointegration is changing over time is important from the point of view of diversification. And vice versa, the trends in diversification strategy may offer a look on how did the cointegration evolved in the past (Caporale et al., 2016).

2.2.1. Shift to industry diversification

Diversification is considered an effective investment strategy to minimise risk when investing. Several studies find evidence that diversification of domestic portfolio through international investment provides a significant reduction of risks (Jorion, 1985; Grubel, 1968). With markets becoming more homogenized, the international diversification does not offer the best way of offsetting risk (Hallgren et al., 2011). One of the approaches how to to determine whether the investment diversification benefits arise from particular markets is cointegration analysis. Therefore the examination of the degree of cointegration in time matter from this point of view (Caporale et al., 2016). Baele's (2005) hypothesis implies that increase of market integration should lead to a convergence in cross-country returns, as some countries specific factors are expected to homogenise over time. Benefits of international diversification within Europe would diminish, as they hold due to non-perfect comovements of the returns.

In order to minimise the risk, a better strategy for an investor operating in integrated markets is to spread her portfolio across different industries. The impact of industry shocks is not expected to change much with homogenisation of countries' economies, and industry factors usually influence the price of individual stocks. Among the factors of influence we usually count investments into R&D, mergers acquisitions, or possibly bankruptcies of companies within the industry, returns of firms and their market value of particular companies. As their evolvement is rather depending on the specific industry or firm, we may expect that their evolvement will not significantly change over time in Europe (Moerman, 2008).

Switch of the investor's diversification strategy from international to industry diversification may therefore be seen as an evidence of previously mentioned homogenisation of European financial markets. The relative importance of country diversification is expected to decrease, and industry diversification may be considered a better strategy as the countries are becoming more unified (Moerman, 2008). Studies focusing on benefits of portfolio diversification confirm this evolvement (Hallgren and Rehn, 2011; Kim, et al., 2005; Mylonidis and Kollias, 2010).

Meric and Meric (1988) focuses on co-movement paths of international stock markets during the period 1973-1987, and finds evidence that diversification across countries results in a greater risk reduction and therefore benefits the investor more than diversification across industries. Since the eighties, we have witnessed a shift in the perception of diversification, and roughly around the middle of the nineties, industry factors begun to be more dominant within diversification. Multiple studies confirm that countries have become more correlated, and the the international diversification strategy was rather outdated in early 2000. Industry diversification yields better results even when accounting for information technology-hype and sky-high internet stocks around the turn of the millennium (Moerman, 2008). According to theory, the diminished advantages of international diversification correspond to change in country risk premium (Driessen and Leaven, 2007), although some authors attribute this reduction rather to homogenisation than reduction in risk (Adjaoute' and Danthine, 2001). Either way, this shift toward industry diversification may be considered a consequence of a more homogenised countries in the EU.

To summarise, the increased uniformity of the European market, fostered by the shift from international to industry portfolio diversification, can be considered a sign of increased integration of EU financial markets. Because multiple regulatory barriers still exist, and influence of market forces can vary across segments, the level of homogenisation does not need to be uniform across regions. Nonetheless, EMU as a single currency union may represent a single area of financial opportunity from investor's point of view (Baele, 2004; Kim, et al., 2005).

2.3. Specificity of the UK

Throughout the history of the EU, UK has been referred to as an "awkward partner" vis-à-vis EU. This term was originally created by George in 1998, in his analysis of overall relationship with the Union. As mentioned in previous section, UK does not form the stable "core" as defined by Campos et al., and similarly Raddant (2016) remarks that the UK was somewhat of an outlier to the rest of EU. Henökl (2018) in his analysis of the future arrangements between UK and EU refers to Brexit as "permanent and total differentiation" which will "complete and enshrine Britain's role as an awkward partner".

Raddant's (2016) analysis of stock market comovement between UK and continental Europe confirm UK's specificity. Its comovement patterns have always been weaker than between other member states, and this had even intensified since Brexit vote. Raddant accents that this is a result of differences in industrial structure. The table below may offer a hint about different structure of the indices of chosen companies. Almost a half of the 100 companies with highest market capitalisation listed on LSE is formed by Financial or Consumer Cyclicals sector. Financial companies account for relatively large part in other indices as well, however in general the companies from Industrial sector or Consumer Cyclicals are prevalent.

	UK FTSE100	Germany DAX30	Italy FTSE MIB	Spain IBEX 35	France CAC 40
Total stocks	100	112	38	77	101
Energy	5	4	4	4	0
Basic Materials	9	8	2	9	16
Industrials	13	27	4	16	16
Consumer Cyclicals	24	25	7	10	20
Consumer Noncyclicals	11	6	1	2	4
Financials	23	17	14	19	18
Healthcare	6	8	1	6	10
Technology	2	9	1	2	9
Telecommunication Services	2	5	1	3	4
Utilities	5	3	3	6	4

Table 1: Number of companies by sector in the respective index

Source: Raddant (2016)

Size of the UK's financial market and London's position among the largest stock exchanges in the world is a possible explanation of the exogenous properties of the UK. Masih and Masih (2002) examine the market capitalisation implications to the stock market independence, referring to differential information hypothesis. According to this theory, if the cost of information search is the same regardless the size of the market, the larger market

will have more incentives to search for mispricings, and thus have access to more information than a small market at any point in time. Asset prices in the larger market will reflect information to a larger extent. Superior size of the UK market thus offers a possible explanation of its exogenous character.

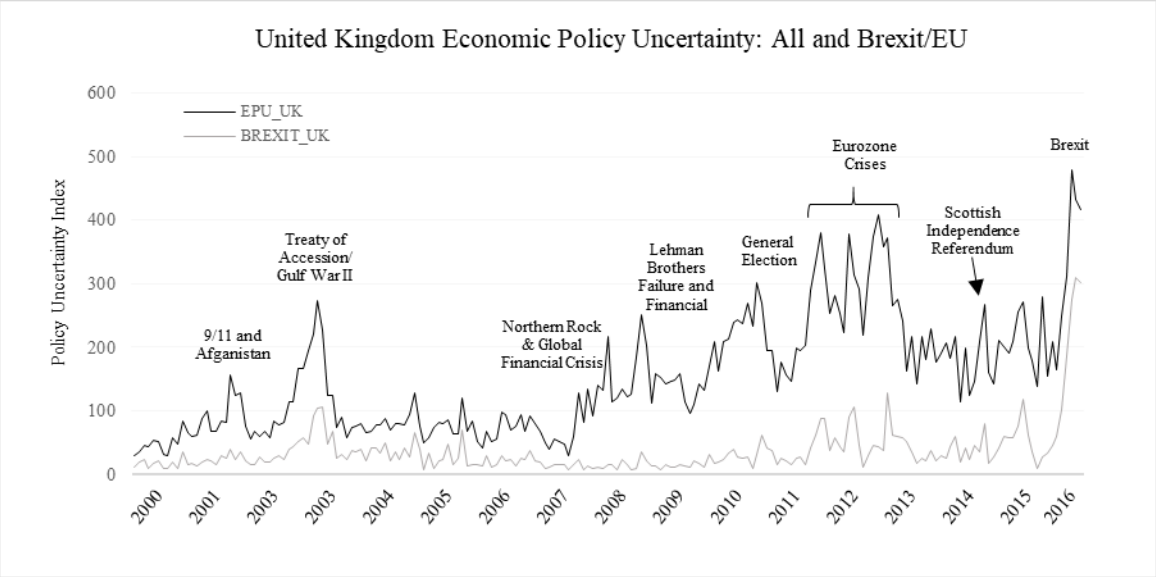
Masih et al. (2002) show influential importance of the UK stock market to stock market indices across the Europe and in the world. Particularly strong linkages exist with the US economy, where the shock from the US is likely to influence European markets through Britain. The spread of an exogenous shock from the UK is particularly strong in France, Austria and Netherlands markets[1] (Hallgren et al., 2011; Masih et al., 2002).

Following Brexit, the leading position of UK in the financial is seen as *endangered*, as UK may lose one of its competitive advantages if it leaves the single market. Some studies suggest that approximately 35% of London wholesale activities may relocate to remaining EU countries, once the UK leaves (Sapir, Schoenmaker, Véron, 2017; Batsaikhan, 2017).

[1] The closeness of the UK and US economy could be seen during the financial crisis in 2011, when UK was the first among the other countries to be hit first by the crisis.

3. Brexit

Vote of the UK citizens on June 23rd 2016 to leave the European Union - *Brexit* - spun political, economic, as well as social concerns. Economic Policy Uncertainty Index (EPU) [2], developed by Baker, Bloom and Davis (2016) shows that near-term effects of the Brexit are associated with high uncertainty, surpassing the spikes around 9/11 attacks or the uncertainty associated with Gulf War[3].



Graph 1: Economic Policy Uncertainty Index

Source: Baker, Bloom and Davis (2016)

3.1. Immediate impact

Market reacted relatively swiftly to the Brexit announcement: FTSE100 dropped down by 2.6%, FTSE 250 slid 2.2%, and FTSE 350 dropped by 7% over the first two trading days

[2] The index tracks the policy-related uncertainty in the United Kingdom through the "share of newspaper articles in the Financial Times and Times of London that discuss Economics (proxied by the words *economy* or *economic*), Policy (proxied by *tax*, *policy*, *regulation*, *spending*, *deficit*, *budget* or *Bank of England*) and Uncertainty (proxied by *uncertain* or *uncertainty*)".

[3] Another proxy for uncertainty is VStoxx volatility index. Contrary to EPU, VStoxx exhibited greater volatility after the fall of Lehman Brothers rather than after the referendum on Brexit. Brexit being a greater anomaly for media could have caused this effect: "uncertainty may increase rapidly, feeding in on itself, and strongly propagate initial economic shocks, serving as amplification mechanism" (Hartwell and Horvath, 2016).

after Brexit announcement (Davies et al., 2017). In general, Brexit vote had similar effect on Germany, France, Italy and Spain during the period of one month after the referendum took place. Higher volatility after the vote took place may be observed not only in the UK's stock market but also in other European stock markets. A peak in correlation between UK and several countries occurring at the date of Brexit vote indicates that Brexit had an impact not only on domestic economy (Raddant, 2016). Raddant's estimates suggest that France's correlation with the UK is the highest (varying above 0,9) among European countries, whilst Italy is the least correlated among selected countries.

In the following three weeks, the volatility was falling, and by the end of the month the market was relatively recovered.

Lin and Zhuo (2017) investigate the impact of British referendum on equilibrium relationships and spillover effects between the UK and European countries' sovereign bond markets, and concludethat there has been a shift in cointegration associated with the referendum, indicating a transit in the market emotion from cooperation to separation. Their results confirm that there exist long-run cointegration between the UK and European countries, and the Brexit changes their long-run equilibrium with significant period shifts.

3.2. Effects of Brexit to UK economy

Political impact of Brexit associated with uncertainty has a potential to influence the economy of the UK as well as the EU. In the next section I will discuss the recent trends of the key areas of UK's economy: GDP, trade, and foreign direct investment. Given that the vote to leave was an unexpected outcome of the referendum, and because if novelty of the situation (UK is the first member in the history to leave the EU), the market is experiencing an unprecedented uncertainty which may influence the financial markets even in the long run (Hartwell et al., 2017).

Although the exit decision was sudden, one should not expect the correlation between the UK and the EU to change from day to day. The negotiations between UK and EU are still not over, and it takes some time for the firms to relocate their operations (if they decide to do so). The change in linkages between UK and European economies is therefore expected to be gradual and take some time.

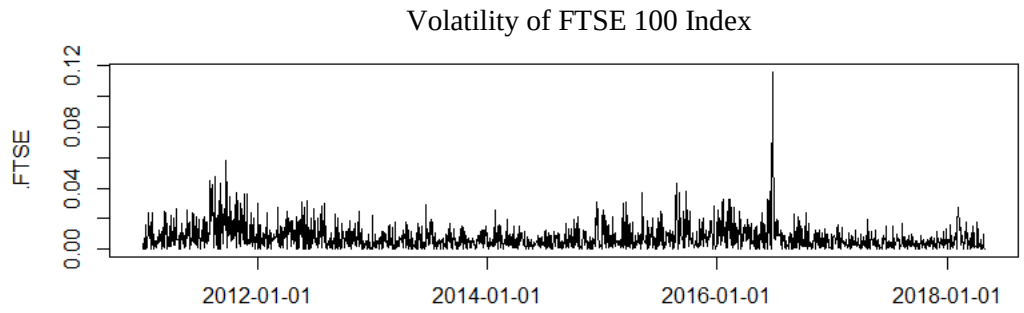
3.2.1. Increased uncertainty

A policy uncertainty may be defined as a decision of a policymaker that influence economy of particular country, outcomes or impacts of which could influence consumption, investment or households' behaviour as such. In Pastor and Veronesi's theory (2012, and 2013) a reasonable investor observes political signals and uses them to update his beliefs about the government's future policy decisions. Political risk is usually associated with higher volatility in the financial markets (Boutchkova et al., 2016), which often leads to decrease in market returns. Only when the uncertainty is resolved stocks tend to increase again (Brogaard et al., 2015, Pantzalis et al., 2000).

The vote of the UK citizens on June 23rd 2016 leading to an unexpected decision to withdraw from the EU increased the uncertainty to historical highs (Baker et al., 2016; see the EPU index above). According to Bloomberg survey (2016), the outcome of referendum was not anticipated by majority of capital market participants, even on the day of referendum. As this is the first time in the history that a member will be leaving the Union, the event had aroused lots of interest and questioning on how the Article 50 process will play out. Euro area became relatively interconnected in past decades, and an uncertainty caused by an event such as Brexit may influence the other member countries significantly (Lin et al., 2017).

If uncertainty is present only during a short time period, associated market volatility usually affects only employment. However, a persisting uncertainty increases economic costs, and has an effect not only on employment, but on investment as well. In case of the US, a persisting policy uncertainty even lead to a "volatility puzzle" where the volatility is experiencing its historical lows despite present high uncertainty. This anomaly may be explained by difficult interpretation of the administration actions for the investors (Pastor et al., 2017).

As the graph below shows, the volatility of the FTSE 100 index in June 2016 has been somewhat higher than in the previous period. In the following months the volatility lowered, however it took different time for different industries to recover. Evidence suggest that whilst industrial sector recovers relatively fast, consumer cyclical sectors need longer period of time, and slowest recovery experience the financial sectors (Davies et al., 2017).



Graph 2: Volatility of FTSE 100 Index (absolute log returns)

Source: Reuters Eikon Database - FTSE 100 Daily Close (2018)

Lower investment in the short term, and its postponement in the Eurozone is seen as one of the main Brexit implications (Hartwell et al., 2017; Baker et al., 2016). Foreign direct investment to UK may be weaker in addition to internal investment dynamics (Reenen, 2016).

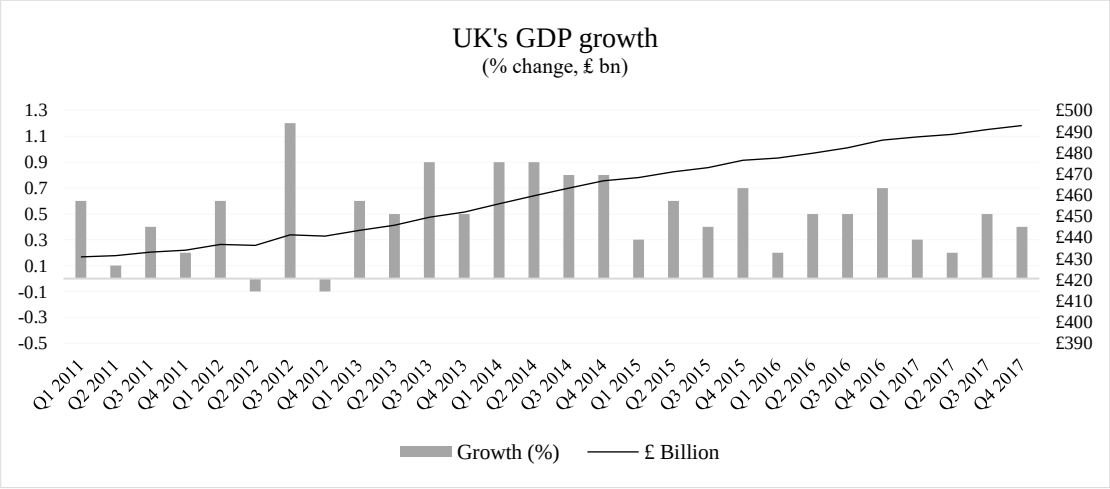
3.2.3. GDP growth

One of the immediate impacts of Brexit that affects (not only) GDP was the weakened pound. Statistical bulletins summarising the effect of Brexit on pound (2017) state that July 2016 sterling Exchange Rate Index (ERI) dropped by 6.6% comparing to June, and 15% lower in comparison to July 2015. The theory suggest that depreciation of the currency increases the trade balance of the country, by making the goods produced abroad more expensive whilst domestic goods' prices fall relative to the foreign goods. Domestic goods in turn become more competitive from the view of foreign buyers (Hardie, Jowett, et al., 2013). Hence, the weaker sterling is likely to boom UK's exports, and through reduced trade deficit increase the GDP in the short run. This pattern may have been observed in 1992 after sterling's exit from the European Exchange Rate Mechanism (Hardie et al., 2013). The weakening of the currency following the referendum can temporarily have a positive influence, serving as a "cushion" for adverse shocks to the UK economy Hartwell et al. (2017).

In the long run, however, the weaker sterling is likely to be accompanied by economic slowdown due to the exports from EU to UK. As the domestic producers import materials

from foreign economies, there is a pressure for domestic prices to rise in order to cover the production price (Hardie et al., 2013). Most studies conclude that long term effect of Brexit will influence the UK economy through trade, investment, and pervading uncertainty. (Hartwell et al., 2017). Impact on imports, exports and FDI will be discussed in more detail in following chapters.

The data published by Office for National Statistics suggest relatively low GDP growth rate since the referendum. Since the beginning of the 2016 growth rate has been increasing and in the fourth quarter almost achieved previous year level, but slowed down to 0.2% in the following year due to rising prices. Especially construction and manufacturing sectors' rate showed a little increase in 2016, whilst business and finance sectors continued to grow strongly. The household spending grew by 1.8% between 2016 and 2017, the slowest rate since 2012. The GDP growth during the 2017 was driven mainly by services. One may observe a (relatively small) decrease of the business investment growth to 0.2% in the end of the 2017 (Office for National Statistics, 2017c).



Graph 3: Seasonally adjusted gross domestic product (£ billions) and quarter-on-quarter growths (%)
Source of data: Office for National Statistics (2018)

Studies focusing on the impact of political integration on country's growth conclude that political integration seem to have a positive impact on economic performance (Campos et al. 2014, Born et al., 2017). Benefits of being a member of the Union has been quantified in

terms of GDP by Campos et al. (2014), who estimates that the UK's GDP per capita would be approximately 24% lower if the UK did not join the EU.

Multiple studies tried to estimate the impact of Brexit on UK's GDP. Swati et al (2017) and Booth et al. (2015) estimated that the Brexit will have negative effect on the UK's GDP – up to 3% of GDP per year. It is difficult to estimate how the British economy would have been evolving had it never entered the EU, or (contrarily) had not leave it. With time, it is possible to quantify the impact of being a part of the Union using the synthetic control method: create a *doppelganger* of the economy where an event has never happened (Abadie and Gardeazabal 2003). This method lets an algorithm to determine the combination of other economies that match the evolution of (let's say) GDP in the UK before the particular event with highest possible accuracy. Born, Müller, et al. (2017) uses this pure data-driven approach to calculate the GDP loss after the withdrawal from the Union, and find that at the end of the third quarter of 2017 the costs attributable to Brexit reached almost £20 billion or 1.3% of GDP.

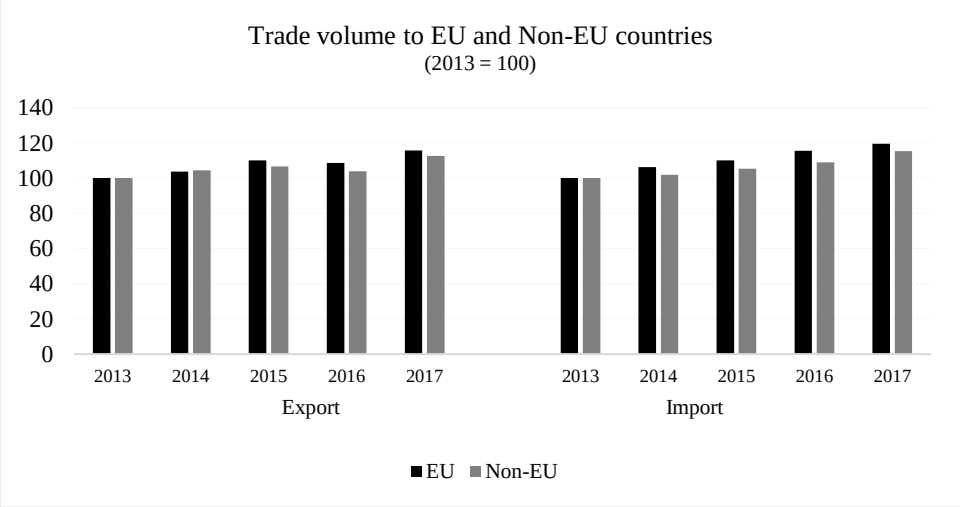
However, the use of synthetic control method has a few shortcomings. As previously discussed, UK economy has its specificities comparing to European countries, and assumption that the economic development of one country can be modelled accurately by weighted average of other countries' economic development, may seem a little *too straightforward*. Brexit itself will influence the UK's economy and may pivot multiple economies' evolvement - this is something that synthetic control method cannot capture. Especially political integration may be underestimated, as the method does not account for *second rounds* related effects and effects of uncertainty (Hartwell et al., 2016). Nonetheless, this approach offers a rough idea what could have been.

3.2.4. Trade

Positive effects of being in the union on trade and foreign investment have been conclusion of multiple studies (Baier et al., 2008; Swati et al, 2017). Baier et al. (2008) examines the effects of the union membership on biliterate trade, and concludes that being a member of a union increases countries' trade between 127-146% after 10 to 15 years. Membership affects the trade volumes mainly through easier access to the market, whereas the effects are fostered by self-selection of the trading partners (Baier (2008) argues that large number of studies

underestimate the effect of membership as they do not account for self-selection factor). Low trade barriers and easy access to the partner countries' market, implying low export costs make an attractive environment for the foreign investors (Swati et al., 2017).

Although no single state in the EU can be highlighted as the Britain's main importer, EU as a whole is the top destination for the UK export. Given its location, Europe is a natural trading partner for the UK and especially over-seas countries may see the easy access to the EU market through Britain as a competitive advantage (Swati et al., 2017). The share of trade with the members of the EMU area in terms of value accounts for more than a half of the UK trade, although one may see a slight decline in the value of trade with EMU in the past two years. As for the volume, the latest data published by Office for National Statistics show increasing trend in terms of trade volume import to the EU over the last 5 years. Exports volume has been increasing as well, despite showing slowdown in 2016 (Office for National Statistics, 2018a).



Graph 4: Exported and imported trade volume to EU and Non-EU countries – comparison to 2013
Source of data: Office for National Statistics (2018)

The top (single state) destination of UK exports in 2017 were the United States, accounting for approximately 14% of all exports (£48.6 billion). US was followed by Germany, France, and Ireland, together summing up to £84.3 billion of imports, and roughly 25% of all the exports. Among the top 10 destinations, China and Hong Kong accounted for approximately for 7% of total exports with the value of over £18 billion. Among the first ranks among

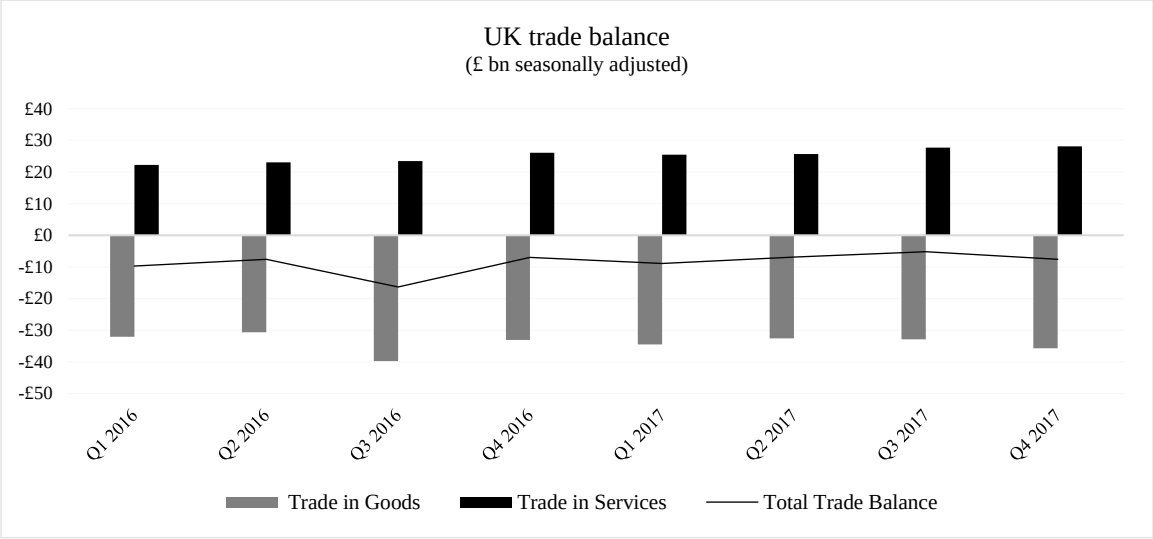
importing countries, the Germany, China, Netherlands and USA, accounting for 40% of UK total imports with the value of £192.4 billion (Office for National Statistics, 2018d).

EXPORT SOURCES				IMPORT SOURCES			
	Value £ million	% of Total of UK Exports	Cumulative percentage		Value £ million	% of Total UK Imports	Cumulative percentage
1. United States	48 569	14.2	14.2	1. Germany	69 505	14.5	14.5
2. Germany	37 252	10.9	25.1	2. China	43 140	9.0	23.5
3. France	25 604	7.5	32.6	3. Netherlands	40 879	8.6	32.1
4. Netherlands	21 458	6.3	38.9	4. United States	38 915	8.1	40.2
5. Ireland	19 678	5.7	44.6	5. France	27 300	5.7	45.9
6. China	18 531	5.4	50.0	6. Belgium & Luxembourg	25 832	5.4	51.3
7. Belgium & Luxembourg	14 102	4.1	54.1	7. Norway	19 793	4.1	55.4
8. Italy	10 767	3.1	57.2	8. Italy	18 993	4.0	59.4
9. Spain	10 464	3.1	60.3	9. Spain	15 680	3.3	62.7
10. Hong Kong	7 640	2.2	62.5	10. Irish Republic	14 933	3.1	65.8

Table 2: Top trade export and import countries by value (2017, seasonally adjusted)
Source: Office for National Statistics (2018d)

Services form a large part of UK's trade, as shown in the figure below. UK is a net exporter of services with net balance of £107 million, and a net importer of goods, balancing to a deficit of £135.6 million (as of the end of 2017). One may observe a widened trade balance deficit in the quarter following the referendum (Q3), accounting to £14.8 billion – almost double comparing to previous quarter. This increased deficit was due significant increase in imports in comparison to exports. Data suggest that mostly erratic commodities, such as aircraft, ships, precious metals and non-monetary gold had a significant impact on trading balance in this period. Services exports followed a rather steady, slightly growing trend in the past two years (Office for National Statistics, 2017d). Latest Data published by the Office for National Statistics (2018d) suggest that the trade in goods and serviced deficit widened

with the EU and narrowed with non-EU countries in the last twelve months to February 2018 (Office for National Statistics, 2018d).



Graph 5: UK trade balance 2016 – 2017 (£ million seasonally adjusted)

Source of data: Office for National Statistics (2018)

The implications of Brexit concerning trade focus mainly on the increased trade barriers. It is likely that the increased costs will reduce trade and investment flows into the UK economy and thus make it somewhat poorer (Hartwell et al., 2017; Swati et al., 2017). Uncertainty associated with future arrangements between UK and rest of the Europe could have been seen in a large negative impact on valuation of logistics companies in 2016 (Tielman et al., 2016). The magnitude of the effect will depend on the outcome of negotiations between UK and EU, and UK's negotiation capabilities to come to trade agreements with non-EU countries.

Regardless of the model that will be put in place for the UK-EU collaboration, withdrawal from the Custom Union will lead to higher trade barriers and possibly higher costs of shipping causing the trade volumes to lower. Apart from this "quantitative" impact on the economy, the companies may encounter a more difficult coordination between headquarters and local production plants, especially if the migration controls will be put in place (Swati et al., 2017).

The more difficult collaboration between headquarters and production plants would especially influence the industries with complex global value chains (GVC) (Davies et al., 2017). As mentioned above, the commodities such as aircraft or ships had a relatively large impact on the increased trade deficit in 2016 (Office for National Statistics, 2016d). Companies with complex GVC are considered to be crucial to the UK economy: firms participating in the complicated GVCs, may profit from UK's competitive advantage in certain processes or inputs of production. Davies and Studnicka (2017) examine the impacts of Brexit through GVC structure and find that the greater is the firm's GVC exposure to the UK or EU (i.e. more fragmented production and bigger the outsourcing from current EU members), bigger the potential of Brexit to influence company's operation. Investors did not react equally to companies in the wake of Brexit and were rather bearish on firms with European focused value chain.

At the same time, Brexit has a potential to decrease trade UK-EU trade flows through indirect trade effects. Some potentially strong spillover effects may occur through the complex trade structure of the EU market. There is a possibility that Brexit will impact trade of the countries which are not directly in connection with the UK. Halpern (2016) shows on the Hungary – Germany – UK trade example that despite low integration between UK and Hungary, the Hungarian exports may be hit by Brexit because of disintegration between UK and Germany. This effect may be especially strong if the export patterns between Germany and UK are similar to those between Hungary and Germany.

3.2.5. Foreign Investment (FDI)

Multiple research has been conducted focusing on the effects of EU membership on its belonging countries' FDI: According to Swati et al. (2016), increase of FDI ranges between 14-38% (depending on used statistical method), Campos and Coricelli (2015) estimate an impact of 25-30%, estimation of Straathof et al. (2008) suggest an increase in inward stocks by 14%. Alfaro et. Al. (2004) argue that increase of FDI has especially impact on GDP of countries that have a highly developed financial sector – such as UK.

According to theory, investment flows between two countries depend mainly on their geographical distance, their respective market size, and GDP per capita, although the

potential customers' purchasing power is considered of secondary importance (Anderson, 2011). UK's geographic location, and access to the EU single market – in terms of export as well as an access to skilled market force - has been considered one of the main advantages of the UK (Sapir et al., 2017). Investing and locating production in the UK provide firms entry to the market of over 440 million potential consumers with GDP per capita over US$ 39 000 (OECD, 2018). Passporting rights allow financial services firms to operate seamlessly across Single Market (Swati et al., 2016).

Research conducted shortly before Brexit suggested that the FDI would fall after the exit of the UK because of potential higher tariff costs and non-tariff barriers, more difficult communication between headquarters and local branches or plants, and due to uncertainty over the shape of agreements that UK would negotiate after the exit. Swati et al. estimates that through FDI, the real income could lower by 3.4% (2016). Special concern is of financial services which is the main component of FDI accounting for around 45% of UK inward FDI, 8% of GDP, and constituting 12% of tax receipts (Tyler, 2015). EU is the world's largest exporter of financial services, and half of the cross-border lending originates in the EU (Sapir et al., 2017).

One of the biggest advantages that EU offers to companies in financial sector are passporting rights. These allow a bank based in any of the EU country to set up a branch in another EU country, whilst being regulated by authorities in the homeland. This advantage can be applied to any Swiss or American bank through a branch or a subsidiary in the EU. Losing the passporting rights is considered be one of the most crucial loss for the UK, and, at the same time an opportunity for other European financial centres, such as Paris or London, to grab a bigger share of the financial market in Europe through offering an alternative for London within EU market[4] (Sapir et at., 2017).

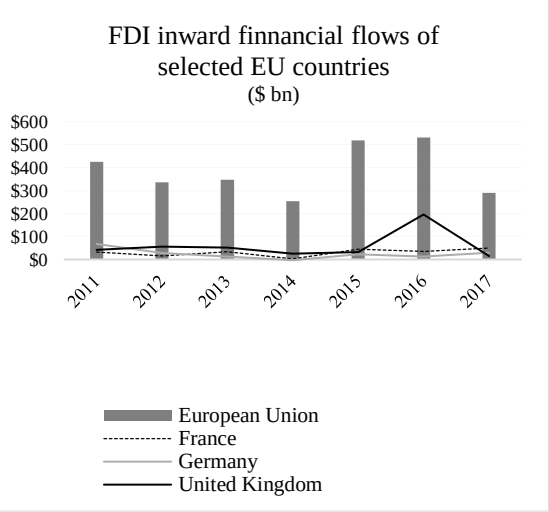
Apart from financial services, UK has a competitive advantage in mining and transport equipment sector, and sectors with high local demand such as food and beverages. To ease their access to the British market and be close to their customers, some production and

[4] This is rather questionable, as it is difficult to guess how will London as financial center function "on its own". London became one of the leading financial centers during the UK's membership.

manufacturing firms may relocate their operations, and those areas may experience an increase of FDI after Brexit (Swati et al, 2017).

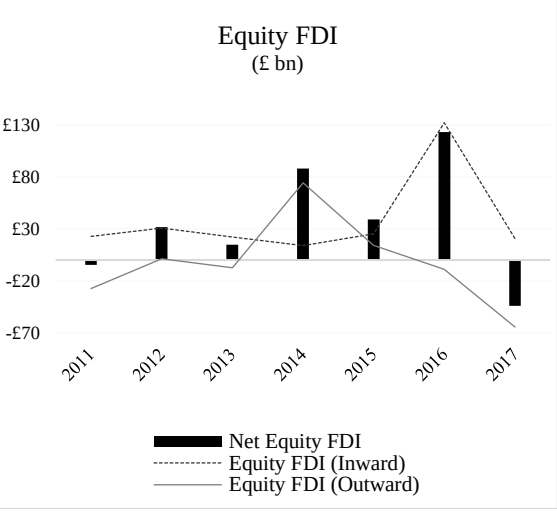
The largest destination for UK's FDI is EU, second largest is the United States. The net income from both partners has decreased for both since 2015, being more significant for the EU – from the value of over USD 42 billion, to over USD 27 billion in 2016. US may be seen as an equivalent partner in terms of net income in 2016, valuing to over USD 26 million.

According to research investors have been attracted by three main advantages of the UK market: skilled labour, business-friendly rule of law and geographic location (The Global Financial Index 23, 2018). Looking at the history data, UK has been an attractive investment partner for the past decades, and the country has been profiting from its advantages implying from the EU membership. This is reflected in positive UK's net position of FDI in terms of value. Comparing to other EU economies, UK receives the most of FDI in the region. Despite the pre-Brexit expectations, as the data published by Britain's National Statistics Office in the end of 2017 show a record high in net foreign direct investment into UK. FDI inward flows reached £145.6bn in 2016, up from £ 25.3bn in 2015. This steep increase in 2016 was caused mainly due to increase in equity investment. Large value of FDI flows were dominated by merger and acquisition (M&A) deals, including for example acquisitions of SABMiller, ARM Holdings or BG Group (Office for National Statistics, 2018b,d).



Graph 6: Inward FDI of selected countries ($ bn)

Source of data: OECD (2018)



Graph 7: Equity foreign investment flows (£ bn)

Source of data: Office for National Statistics (2018)

The reason for decrease in net FDI income in recent period was due to higher change in earnings of UK's investors in foreign countries (i.e. credits), than the earnings of foreign investors' assets in the UK (i.e. debits). Within EU, UK's credits fell by £15.3 billion, whilst debits increased by £1.4 billion, lowering the UK's net position in the FDI market. Since 2011 the implied rates of returns[5] have been constantly decreasing for UK's assets, whilst the rates of liabilities remained relatively flat (Office for National Statistics, 2017b).

A sharp decline in the exchange rate after a period of appreciation between 2011 and 2015, has probably lowered the value of FDI denominated in the foreign currency in sterling terms. Office for National Statistics confirm that the exchange rate movements were not found to influence the change of value of the UK assets in the period 2011-15, however the depreciation of sterling in the first three quarters of 2016 seem to have a positive impact on the value of UK assets and credits, through increasing the value of UK assets and credits denominated in the foreign currency increases (even with no change in the underlying performance of assets). Foreign investors' assets in the UK ands are usually denominated in sterling, and exchange rate fluctuations are expected to have lesser impact. The impact of the fluctuation of exchange rate differs between those two groups (Office for National Statistics, 2017b).

To summarise the overall effect the economy, UK has been experiencing a slower growth following Brexit. In the short term, weakening pound had influenced the export and import prices of the UK goods and services, causing a decrease in trade deficit, partially making up for effects on trade and FDI. By the end of 2016 the rate of growth has been comparable to previous years, trade deficit narrowed, and equity investment soared. Looking at the evolvement in 2017, weak currency effect seems to be of lower strength – net equity investment has been negative, and GDP growth rate has been lower comparing to previous years (Office for National Statistics, 2017 and 2018).

[5] Implied rate captures how much income is generated per one pound of investment.

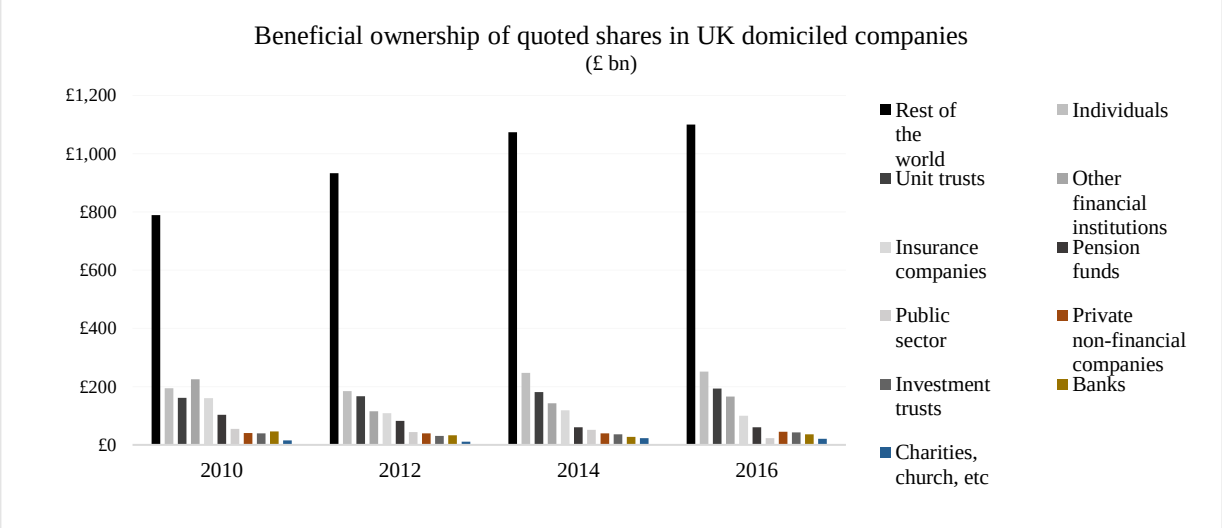
3.2.6. Overview of UK quoted shares

In line with the focus on the financial markets and how did the unexpected UK withdrawal from the EU influenced them, in this section I will briefly discuss the ownership of UK quoted shares and sector of companies listed at LSE in the year of Brexit vote. EU membership with all its advantages have been attracting overseas investors (Swati, 2017). The previous section discussed that the following Brexit, UK will no longer have the right to enjoy passporting rights, and thus may become less attractive for investors (Sapir et al., 2017).

As of the end of 2016, over the 50% of the value of holdings of quoted shares by the beneficial owner[6] on the LSE was owned by non-UK companies. Of those, most were owned by North America region (over 50%), followed by European investors (26%) and Asian investors (16%). This ratio has been slowly increasing since 2011. In terms of absolute values, by the end of 2016, non-UK investors held over £1.1 trillion of quoted shares. Next largest group were individuals with approximately 12% of holdings (equivalent to £251.5 billion). The value of UK domiciled companies was worth a total of £2.04 trillion in the end of 2016 (Office for National Statistics, 2017e).

The evolution of the all share index since the nineties reflects the increasing internationalism of the UK stock market, and to certain extent an easier access to trading on the foreign market (for example electronic trading (Office for National Statistics, 2017e)).

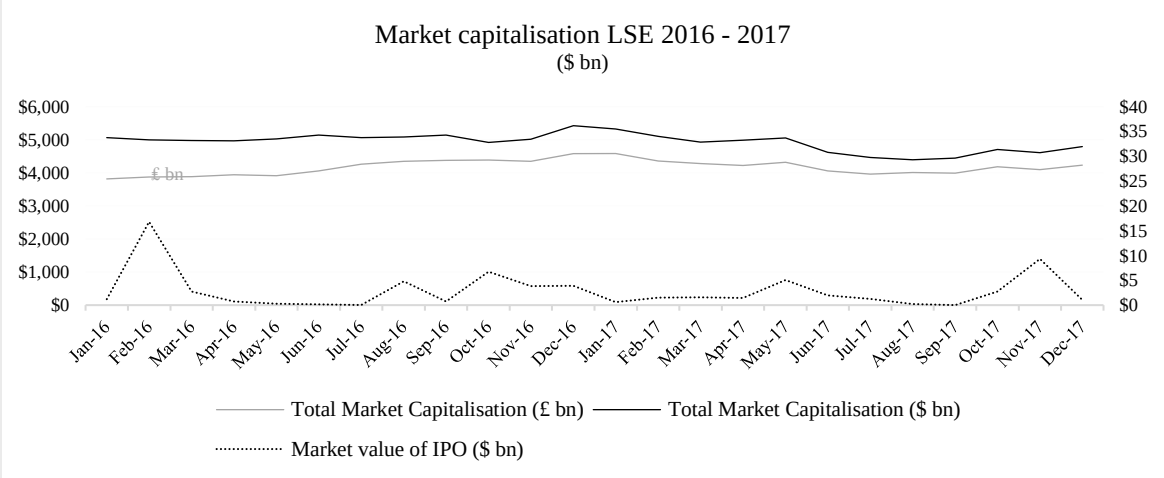
[6] By the definition of Office for National Statistics, the beneficial owner is the underlying owner, i.e. a person or entity who receives the benefits of holding the shares (e.g. dividends). (Office for National statistics, 2017e)



Graph 8: Beneficial ownership of UK companies

Source: Office for National Statistics (2017e)

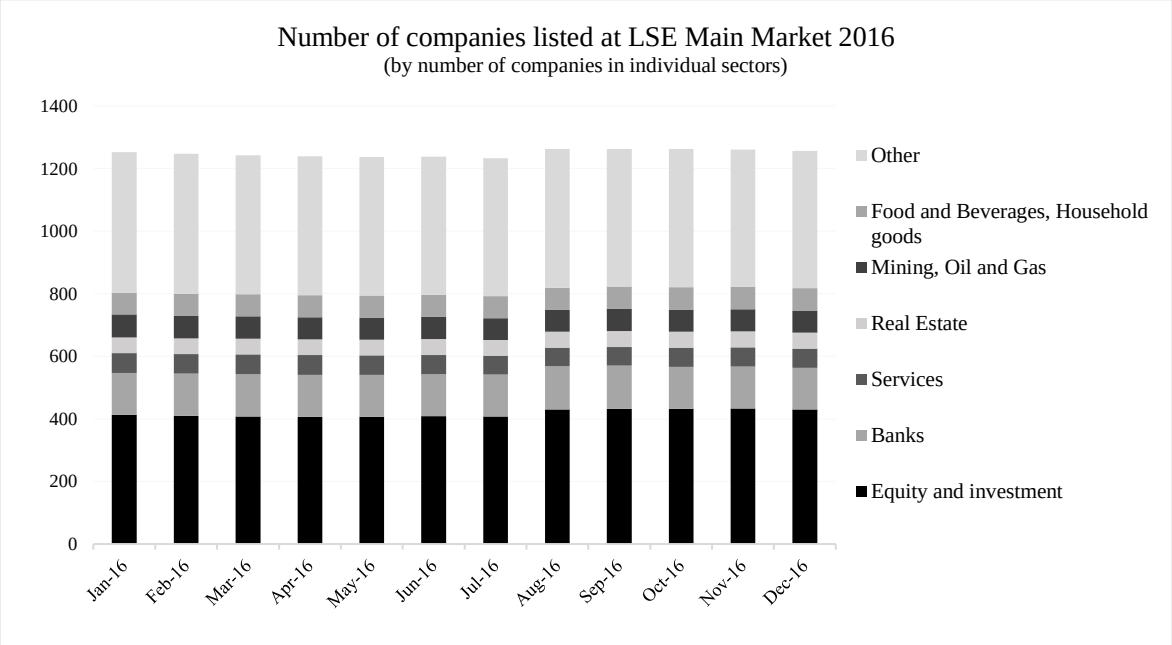
Looking at the change in the total market capitalisation and number of companies quoted on London Stock Exchange, the London financial market seem to be holding its position. Despite the drop of number of listed companies at the beginning of 2017, the total market capitalisation experienced only a slight drop since 2016, and the number of new IPOs seemed to be relatively stable. In the end of 2017 the London Stock exchange group stated that the exchange became even more international in 2017, attracting 106 companies, rising up 164 % by value of IPOs compared to 2016 (London Stock Exchange Group, 2017).



Graph 9: Total market capitalisation of companies listed at London Stock Exchange in 2016 - 2017

Source: London Stock Exchange (2018)

As for the number and sectors of companies listed on London Stock exchange, the composition did not significantly change – by number of companies the financial services companies were on the leading position and number of companies from equity investment sector slightly increased in in the third quarter. Similarly in 2017, financial services companies account for around 20% and with Industrial Goods and Services and Real Estate account for roughly one third of the number of companies listed. By market capitalisation, Banks, Industrial Goods and Services together with Oil and Gas companies are on the top rank, Banks accounting for around 14% of total value traded.



Graph 10: Number of listed companies on London Stock Exchange in 2016 by sector

Source: London Stock Exchange (2018)

Value of all share index quoted on the LSE has increased by 2% between 2014 and 2016, although in the evolution of the index value, one may observe the impact of the UK withdrawal. The increasing trend continued throughout the 2017 (London Stock Exchange, 2018). Hence, at least for now, London Stock Exchange does not seem to be less attractive for investors.

To summarise, the effect of the withdrawal from the Union, especially by affecting trade flows, investment, and attractivity of London for investors. As the previous brief analysis of the trade, FDI and UK stock ownership do not indicate a sudden change of the UK-EU

dynamics after Brexit. As it takes certain amount of time for firms to relocate their production, it is possible that some of them will do so in the future. Mainly the firms with more affiliates, or more complex global value chain structure are vulnerable to the effects of Brexit, especially the increased trade barriers (Davies and Studicka, 2017). For now, the research by EY, a consultancy, suggests that in the next three years the majority of questioned firms do not have the intention to leave UK (EY, 2017).

In the long term, all depends on the outcome of negotiations with EU, and ability of UK to negotiate agreements with non-EU countries.

3.3. Effects of Brexit to EU

A persistent trend of mistrust in the EU since 2010 had taken a substantial hit by the withdrawal of the UK. UK's unexpected vote to exit the union came at the time where the EU was propagating "ever closer union". Despite this sudden decision, trust polls by Eurobarometer suggest that the frustration about EU politics (or membership) did not begin with Brexit, but with crisis. Brexit was only another knock (Hartwell et al., 2017).

Hartwell et al. (2017) argue that the criticism of the EU is not EU itself, but rather about its institutional development, including EU policy making and its focus on euro area project. The self-withdrawal thus may be at least partially due to institutional metrics of the EU. Multiple research conducted on the advantages of single market on trade and FDI, Schengen area or free movement of its citizens concluding that being part of the EU has in fact positive effect on the economy. The institutional design of the euro area did not change in 2016 with Brexit, but it was rather driven by Greece and euro-area periphery longer time ago. Several studies suggest that Euro area membership has become less attractive than in the mid-2000s (Hartwell et al., 2017).

European institutions became more oriented towards the euro area and tend to favour the Euro-currency states (Hartwell et al., 2017). This shift was one of the key points of critique from the UK side: David Cameron, former prime minister of UK, has often highlighted the different treatment of "ins" and "outs". As several studies confirm, UK has been a specific state within EU (see previous section; Raddant, 2016; Campos et al., 2017), and most probably was never going to accept euro as its own currency. The self-withdrawal of one of

the most important non-core member (as defined by Campos et al., 2017) may signify that that EU will be more and more identified by an expanded euro-area. At the same time this may represent an opportunity to the EU as it offers some flexibility in its institution-building across various euro area projects (i.e. banking/capital markets union, or fiscal harmonization). Impact on the large financial centres in Europe will be discussed in the next chapter.

In the short term, Brexit may undermine the EU, but the challenge is to restore the growth in order to keep EU interesting for its members in the long term. The Union should be forging the institutions that will drive convergence only where it is possible. Issues in the euro area associated with growth – like investment – are structural, not monetary (Hartwell et al., 2017). As Hartwell (2016) puts it: "The EU's reputation may be momentarily tarnished by the fact that one of its Member States has decided to leave, but the economic clout of the EU remains and will do more for reputation of the Union in the long-run. […] in the longer term, stability of the EU and the euro area will be almost wholly in the hands of the EU itself."

3.4. Financial geography Brexit – UK as financial centre

Multiple research has been conducted seeking to grasp finance in all its complexity, across established disciplines[7]. London's financial centre has grown over time in terms of competitiveness, through its ability to transform itself, attracting new finance activities, constituting organisational power relationships across space, and managing structural changes in finance over time. This financial *ecosystem* contains multiple synergistic relationships between specific activities, and cannot be simply re-built elsewhere (Dörry, 2017). According to some studies this leading position among the EU financial markets makes the UK even a specificity in the European convergence (Masih and Masih, 2002; see Section 3.3.). Recent events shed a light on the intricacy and interconnections of all the elements that make London a specificity. Although the withdrawal of the UK from EU will surely not influence all of them, due to the complexity of the market one cannot be sure what will be the position of London's financial hub outside the Europe. Chairman of HSBC

[7] Such ambition has for example a geographical research program recently formulated by the *Global Network of Financial Geography* (FinGeo).

compared the ecosystem of London to a Jenga tower: “We don’t know if you pull one small piece out, whether nothing happens or indeed there is a more dramatic impact” (The Daily Telegraph, 2017, online). This section tries to analyse the impact of Brexit on London’s position as the leading financial centre of Europe, its ties towards European financial centres, and US and Asia financial markets.

3.4.1. London – European financial centre

London market is a base for operations in clearing businesses, including stock exchanges, clearinghouses and asset managers, and financial passporting. By number of companies and market capitalisation of over USD 3.6 billion, London Stock Exchange is the leading financial centre in Europe. Global Financial Centres Index (GFCI), an index evaluating the competitiveness of financial centres, has been ranking London as a leader among world financial centres in multiple areas of competitiveness - such as business environment or infrastructure (GFCI, 2018). Looking at the over-the-counter transactions, London handles biggest volume of US dollar clearing outside US, and dwarfs other European *large* financial centres (Frankfurt or Paris) in figures related to clearing euro derivates ($US 928tn comparing to $US 88tn and $US 141tn, respectively (Dörry, 2017)).

The size of the market has proven to be one of the competitive advantages of a financial centre. London financial sector, apart from its size, benefits from multiple advantages (Dörry, 2017; Schiereck et al., 2016) which may be in stake following Brexit:

- Giving its location, London links Shanghai with New York, while English being the national language foster this position. Access to single market attracts firms worldwide, since it offers a possibility to manage operations across the EU from a London base, taking the advantage of passporting rights. The withdrawal from the EU may mean losing this advantage, and therefore not being able to operate seamlessly in any member state. According to Hall and Wojcik this may be crucial, as approximately one fifth of financial services activity relies directly on EU passports (New Financial 2017). Similarly, Samitas, Polyzos and Siriopulos (2017) through an agent-based simulation conclude that this would influence the banking

sector in particular, where practitioners may lose the ability to operate in some member countries.

- One of the pro-Brexit arguments suggested that UK companies will no longer be subject of the EU regulations. This point is rather blurry since if the UK companies will want to do business with EU members, they will probably have to comply with set standards, making them subject of double requirements. (Financial Times, 2018). Moreover, the UK will no longer be at the decision table to influence the implementation of regulations or norms.
- From the geo-political point of view, UK – EU relationship is quite specific: the largest financial centre meets world's second largest financial market. London and UK-based financial services are disproportionally important to the euro area, handling roughly 40% of Europe's assets under management, and UK-based banks holding approximately 60% of Europe's capital markets. British banks provide over £1.1tn of loans to the EU member states. This large size of London Stock Exchange, may give London an edge in negotiations (Dörry, 2017).

  At the same time, London dominated the clearing and settlement of Euro-denominated financial products over the last 20 years. The trading volume of euro-denominated transaction is enormous comparing to European stock exchanges (US$ 928 vs. US$ 141 on Paris stock exchange and US$ 88 on Frankfurt stock exchange). If the euro market is managed outside the EU, the ECB, as the lender of the last resort, cannot seize the control in a crisis (Dörry, 2017).

  The EU recently tried to push more transparency into OTC derivative clearing through the introduction of The European Market Infrastructure Regulation hoping to boost the business and importance of both exchanges and their clearinghouses. (Dörry, 2017). Losing its easy access to the European market, financial markets in Frankfurt or Paris may be a preferred choice for some investors (Sapir et al. 2017).
- The size of the UK financial sector made it a strategically important economic sector. Regardless of the form of Brexit, the UK financial sector will no longer be afforded the privileges of the UK Government (Hall and Wójcik, 2018).
- London has a leading position from technological perspective. In the heterogenous finance sector, it is able to "built on matching processes that innovatively combine

existing activities across companies and sectors in order to create new activities that generate income, as the novel blending of finance with technology (FinTech)" (Sapir et al., 2017). One may see the technological edge simply by looking on the clearing house services: despite vast trading volume, the industry employment numbers are relatively modest – technology and automation rule the settlements. To keep its leading position, London need to maintain and keep attract the pool of talent. In case of lower demand for clearing services, resulting from allocation of the business may diminish the technological leadership of London (Dörry, 2017).

- On the other side, Hall and Wójcik (2018) argue that London built itself into the leading financial centre that is today and that is what makes it extraordinary that may not be destroyed by one event. Quick recovery of the financial and business services, followed by attraction of asset managers and ability of London to reinvent itself is not just something that can be taken away. Thus, the exit from the Union may be seen rather as an opportunity for London's financial hub – despite the uncertainties associated with the Brexit impact on the complex industry system.

To summarise, one may expect decrease in the financial integration with continental Europe, but this does not mean that London as a financial centre will become less attractive for the investors. Given the complexity of the industry, and the fact that London build itself into its today's shape whilst being in the EU, it is difficult to guess how the position of London as a financial centre of Europe will change. By its size, capacity, and technology edge, London currently has a leading place in the world financial markets among New York, Singapore and Hong Kong. The Global Financial Centres Index published in March 2018 lists London as number one in its ranks and ratings tables. Together with New York, London kept being on the top since 2015. Bottom line, fact that London was able to build itself into one of the top players may indicate that Brexit represents an opportunity to even strengthen its position among key players.

3.4.2. New European financial center – a Challenge for EU

Comparing London to other large centres in EU, the former may seem like a giant: London overweighs Frankfurt or Paris in terms of value added to the country's GDP (over 52% in 2015), trade balance (over 12 times higher than Frankfurt with £ 6.5bn in 2015) or tax revenue

(₤ 25.5 billion comparing to £ 0.3 billion for Frankfurt). In banking industry UK hosts more assets, capital and reserves than other EU country (Batsaikhan et al., 2017).

As the withdrawal of the UK will become effective in March next year (2019), from this date the main financial centre of Europe will be outside the EU. Here lays an opportunity for other large financial centres of Europe – apart Frankfurt and Paris, also Dublin and Amsterdam. Although comparing to London they are all relatively small and host fewer large European-headquartered companies, with London being outside of the single market area, those centres may attract a larger share of the European financial market (Batsaikhan et al., 2017). GFCI Index (2018) already shows rile in ratings of European financial centres, especially in Germany. Analysing the clearing market - a backbone of modern finance, Batsaikhan, et al. (2017) estimate that due to London exogeneity, roughly 35% of its wholesale banking activities would migrate to other financial centres within EU. This share of business equals to around ₤ 1.6 trillion of all UK banking assets. Brexit may mean to relocate about 10,000 banking positions, and further 18-20,000 positions related to professional services such as legal, accounting or consultancy. This *inflow of business* at the same time represents a challenge for current size and capacity of the EU finance market.

London is a base for the biggest FinTech and financial innovation centre in Europe (followed by Germany), leads in market size, and (behind the US) is the second largest in terms of investment and employment. Departure of financial firms from London thus may in short term cause a disruption in the financial markets (Sapir et al., 2017). Particular challenge for the EU thus lies in being able to develop FinTech within finance industry, and extend the capacity of current trading centres in order to being able to handle the amount of activities in the EU financial market. Sapir et al. (2017) argues the Brexit may be an opportunity for European financial market to accelerate its development and increase the resilience against shocks.

In order to increase the capacity, it is crucial to minimize the financial market fragmentation in EU, implying a lower borrowing costs within remaining states. In an integrated market for financial services, there may not be a need for current financial firms to move their location, and thus reducing the need for all facilities to be located in only one city (Sapir et al., 2017). Hence, the policy challenge for the EU lies in making more market-based financial system

within the Europe, where the participants would share benefits as well as risks (Batsaikhan et al., 2017).

Estimate is, that UK's share of total European market would drop from current 90% to only 60% following the withdrawal. Batsaikhan et al. (2017) assume that Frankfurt will become dominant within Europe acquiring approximately 45% of the market, Paris around 20%. Negotiations are still not over, but it is likely that financial system of Europe will be hosted in location (or locations) within euro area (Sapir et al., 2017).

3.5. Brexit and non-Europe markets:

Examining the shifts in comovements also outside the Euro region, Kim et al. (2005) conclude that the introduction of EMU has also influenced cointegration of the EU vis-a-vis Japan and the US. The economic ties between the countries may influence their financial sector and cause a shift in correlation not only within Europe, but within other world regions as well.

3.5.1. US:

Several studies find cointegration between US and European markets: Gerrits and Yuce (1999) find evidence that US stock market is correlated with Germany, UK and Netherland market, Syrioupoulos (2007) find cointegration between US stock market and Central Europe. Caporale et al. (2016) provide evidence that US and European market (using Stoxx Index) were cointegrated during the pre-crisis period (until March 2009), however the cointegration lowered afterwards, as US and European markets followed a different recovery paths from the crisis.

Nonetheless, the event of Brexit did cause a drop in the stock prices in the US market. Schiereck et al. (2016) examine the similarities of unexpected withdrawal of UK with events in 2008 and fall of Lehman Brothers – which was as well associated with high uncertainty on the financial market. His results suggest that the similarity of the two events is low, as the source of uncertainty was different – in case of Brexit the source is mainly unclear arrangements between UK and EU collaboration, and uncertain regulatory environment. Differently, after the Lehman Brothers fall, the reason for uncertainty was coming from the question whether there would be government bailouts to avoid further bank failures. Brexit

therefore is not another Lehman Brothers event, even though the bank's share prices fell even further then following the fall in 2008.

Regardless of Brexit, US economy is currently facing a big uncertainty. As previously mentioned, political uncertainty is usually associated with higher volatility. However, in the US, the volatility index is experiencing its historical lows despite present high uncertainty. Pastor and Veronesi examine the coexistence of the two, and come to the conclusion that this phenomenon occurred due to difficult interpretation of US administration's acts, when political signals have become less precise in recent months. The ratio of policy uncertainty to market volatility - two factors where the former should influence the latter, and thus should be moving in the same direction – has been rising and higher than ever before. Since the US presidential election, the ratio almost doubled. (Pastor and Veronese, 2017).

It is therefore difficult to separate the effect of uncertainty associated with Brexit and uncertainty associated with the US administration's unpredictability. Taking the uncertainty aside, the impact of the Brexit on US had similar effects on the EU countries: weaker pound influenced the trade (making the export to UK more expensive and the imports to US cheaper, thus making the domestic products less attractive), and possible trade barriers are likely to complicate the business of the companies with complex value chains. As for the financial markets London's loss could be New York's gain, as some activities may be relocated to New York (Batsaikhan et al., 2017).

3.5.2. Asia:

Among European countries, UK has the largest stock investment from China, who sees UK as a "gate" to Europe. Following Brexit this relationship could become more complicated, and Chinese companies may reconsider their local strategies. Given that the China is the largest economy in Asia, and second largest in the world, its demand may impact global financial activities. London being outside of EU may allow Frankfurt or Paris to absorb some of the Chinese investment in Europe (Lain and Pan, 2017).

Influence of Brexit on Hong Kong financial market would be more severe comparing to China or EU countries. Hong Kong played the role of the platform for foreign firms to invest in China and Chinese firms going abroad. Following Brexit, there is a possibility that the

firms will favour China financial market, replacing Hong Kong as the trading platform (Lin and Pan, 2017; Pan and Brooker, 2014).

Impact of Brexit on Singapore would be most visible through FDI and pound depreciation due to which the UK would become a better competition for Singapore. There has been a rising concern over competitiveness of Singaporean exports and "of manufactured goods and services, which might lead to lower demand for treasury, foreign exchange and insurance services out of Singapore". On the other side, if the outcome of negotiations leads to shift of financial market activities toward continental Europe, it could benefit Singapore's growth in financial activities in the longer term" (Lai and Pan, 2017).

One may see the shift of big global banks from international operations to the domestic market. This may be less attractive for smaller financial centres in Asia, (like Kuala Lumpur, Bangkok, Mumbai or Taipei), greater financial centre may consider this shift to be a good opportunity to cover these prime locations (Lai and Pan, 2017). Again, the outcome shall depend on outcome of negotiations and changes in business orientation of British and European banks.

Previous chapters summarized several areas that had some interconnection with Brexit. European Union became closer and this trend was fostered by the introduction of the Monetary Union. UK, even if staying in the EU, was probably never going to accept this common currency (Campos et al., 2016), and given its several specificities it rather followed its own path within the EU (Raddant, 2016). Its self-withdrawal can offer the EU more flexibility in various euro area projects, and be a trigger point for the European financial market to accelerate its development of FinTech (Harwell et al, 2017; Sapir et al., 2017).

One of the most significant features that make UK different from the rest of the Europe is its financial industry, which forms a significant part of GDP. London, among Hong Kong or New York, belongs to one of the key stock markets in the world. This is a result of years of evolvement, and London's ability to adapt itself, transform and keep up with current trends by attracting skilled labour force (Dörry, 2017). Large number of financial international institutions placed their headquarters in London due to its developed financial market (Tielman, 2016). Without a doubt, being a member of the EU had fostered this position, and

London financial hub profited from Single Market advantages, such as the ease of access to European markets. Despite Brexit, UK's financial market with its nature may strengthen its position among world's largest players (Hall et al., 2018). At the same time, EU financial centres may be able to cut a larger share of financial business within Europe. The *inflow of financial business* into remaining financial centres is one of the challenges for the EU – despite relatively developed finance centres in Frankfurt or Paris, the new *London* does not need to necessarily be in one location, but the activities and benefits (and risks) may be rather shared among remaining members. In order to fulfil this, EU should focus on integrated, more market-based financial sector (Sapir et al., 2017).

The negotiations are still not over and it is not clear what will be their outcome. Brexit is expected to shape the powers and change the co-operation structure between EU and UK. After triggering Article 50 in March 2017, Brexit will become effective next year (March 2019). However, Brexit is rather a complex set of actions with multiple outcomes, not a snap-time act, therefore we expect already to see the shifts in the co-movements of the correlation between UK and eurozone markets due to market participants' expectations. Uncertainty, firms preparing their operations for exit, where multiple scenarios are still a possibility, affects the correlation paths even before referendum itself (Raddant, 2016).

4. Measurement of convergence of the European financial markets

In general, it is possible to divide the literature about European integration into two groups: The first category treat convergence as a static concept rather than as a gradual and an on-going process. Those studies calculate the number of common stochastic trends over pre-specified sample periods using cointegration techniques. The model which will be used in this thesis – multivariate GARCH, belongs to this group. The second may be referred as volatility spillover literature, and concentrates on volatility linkages between individual stock markets.

Autoregressive conditional heteroskedasticity (ARCH) models are nowadays commonly used to describe and forecast volatility changes in financial series (Bauwens, Laurent and Rombouts, 2006). Multivariate GARCH models are ordinarily used to study relationships between the volatilities and co-volatilities within several markets (Karolyi, 1995), to assess the correlation changes between returns over time (Bollerslev, 1990; Longin and Solnik, 1995), or assess the impact of volatility of financial market on variables like growth rate, and export (Kim, 2000).

4.1. Summary of studies using GARCH to evaluate comovement of stock market:

Multiple studies use different GARCH models to examine change in comovement of stock markets and identify patterns of their dependencies (Cmiel, 2016). Raddant (2016) analyses change in correlation of the stock indices using multivariate GARCH model and finds evidence of relatively high, although constant correlations among chosen indices (i.e. Germany, France, Spain, Italy and UK). Horvath and Petrovski (2013) analyse the Central Europe and South-Eastern Europe markets correlations and linkages with Western Europe using BEKK-GARCH model concluding increasing cointegration within membership time period. Similarly, Wang and Moore (2008) – using DCC-GARCH and Kasch-Haroutounian et al. (2001) - using BEKK- and CCC-GARCH model, examine Central and Eastern Europe stock markets providing evidence of increased correlation within selected countries within examined time periods. Scheicher (2001) uses the vector autoregression (VAR)–CCC model on the data of European emerging markets (Czech Republic, Poland and Hungary) to find evidence of global shock transmissions through returns (rather than volatility shocks).

Inspired by the previous research approach, and GARCH models' properties as such, I will examine the cointegration between selected European markets using GARCH model. In the next part, I will briefly describe the model which will be later implemented on selected stock market data - DCC-GARCH.

5. Methodology

As discussed in the previous chapters, multiple studies use heteroskedastic models to determine how did the cointegration between two markets changed oved time. In the following sections the GARCH model will be explained more precisely. Throughout the whole chapter I will refer to Tsay (2010) and Francq and Zakoian (2010).

5.1. Univariate GARCH

Bollerslev (1986) proposed a generalisation of the ARCH model. We assume that the mean equation of the log return series r_t may be adequately described by an ARMA model.

A process (ϵ_t) is called GARCH (p, q) process if its first two conditional moments exist and satisfy:

(1) $E\ (\epsilon_t \mid \epsilon_u, u < t) = 0,\ t \in \mathbb{Z}$.

(2) There exist constants ω, α_i, i = 1, …, q and β_{ji}, j = 1, …, p such that

$$\sigma_t^2 = \mathrm{Var}\ (\epsilon_t \mid \epsilon_u, u < t) = \omega + \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2, \qquad t \in \mathbb{Z}. \quad (5.1)$$

By definition, the innovation process ϵ_t^2 is defined as $v_t = \epsilon_t^2 - \sigma_t^2$. By substitution of the variables σ_{t-j}^2 by $\epsilon_{t-j}^2 - v_{t-j}$, in (5.1), we obtain:

$$\epsilon_t^2 = \omega + \sum_{i=1}^{r} (\alpha_i + \beta_i) \epsilon_{t-i}^2 + v_t + \sum_{j=1}^{p} \beta_j v_{t-j}, \qquad t \in \mathbb{Z}, \quad (5.2)$$

Where r = max (p, q), with the convention α_i = 0 and β_j = 0 if $i > q$ and $j > p$ respectively. Assuming that ϵ_t^2 is stationary, and (ϵ_t) is GARCH (p, q) process, we can state that (ϵ_t^2) is an ARMA (r, p) process. The ARMA representation will be later useful for identification and estimation of a GARCH processes.

Thus, a strong GARCH model is defined by equations:

$$\begin{cases} \epsilon_t = \sigma_t \eta_t \\ \sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2 \end{cases} \tag{5.3}$$

where ω is a strictly positive constant, α_i and β_j are non-negative constants such that $\beta_j \geq 0$, and $\sum_{i=1}^{\max(q,p)} (\alpha_i + \beta_i) < 1$. The last condition implying that the unconditional variance of σ_t^2 is finite.

5.2. Properties of GARCH model

Excess Kurtosis

The kurtosis coefficient is defined as the ratio of the fourth-order moment (assuming it exists), to the square second moment. Kurtosis coefficient for a normal distribution (equal to 3) serve as benchmark for the other distributions.

Kurtosis coefficient for GARCH (1, 1) model is defined as:

$$\kappa_\epsilon = \frac{1 - (\alpha_1 + \beta_1)^2}{1 - (\alpha_1 + \beta_1)^2 - \alpha_1^2(\kappa_\eta - 1)} \kappa_\eta, \tag{5.4}$$

where $\kappa_\eta = E\eta_t^4$. η_t is independent of its past and (η_t) is iid centered.

The excess kurtosis coefficient of ϵ_t and η_t, relative to the normal distribution, is:

$$\kappa_\epsilon^* = \kappa_\epsilon - 3 = \frac{6\alpha_1^2 + \kappa_\eta^* \{1 - (\alpha_1 + \beta_1)^2 + 3\alpha_1^2\}}{1 - (\alpha_1 + \beta_1)^2 - 2\alpha_1^2 - \kappa_\eta^* \alpha_1^2}, \qquad \kappa_\eta^* = \kappa_\eta - 3. \tag{5.5}$$

The excess kurtosis of ϵ_t increases with that of η_t, and when GARCH coefficients approach to the zone of non-existence of the fourth moment.

As financial time series are characteristic by its heavier tail distribution than that of a normal distribution, and excess kurtosis, GARCH model provides a simple parametric function that can be used for describing the volatility evolution.

Volatility clustering

Given its definition, the GARCH structure allows the noise ϵ_t to be a function of ϵ_{t-1}, implying that a high value of ϵ in time *t-1* tend to be followed by high value in time *t*. The large absolute values are not normally distributed through the whole period, but rather form clusters. GARCH models thus capture the volatility clustering of the financial time series.

Autocovariance and autocorrelation

For a GARCH (1, 1) model, where $E\epsilon_t^4 < \infty$, the autocorrelations of the squares are defined as:

$$\rho_{\epsilon^2}(h) := \text{Corr}(\epsilon_t^2, \epsilon_{t-h}^2) = \rho_{\epsilon^2}(1)(\alpha_1 + \beta_1)^{h-1}, \qquad h \geq 1, \tag{5.6}$$

where

$$\rho_{\epsilon^2}(1) = \frac{\alpha_1\{1 - \beta_1(\alpha_1 - \beta_1)\}}{1 - (\alpha_1 + \beta_1)^2 - \alpha_1^2}. \tag{5.7}$$

The equations (5.6) and (5.7) show that for a GARCH (1, 1) process, the autocorrelations of the squares decrease.

Covariance of the model is then:

$$\gamma_{\epsilon^2}(h) = \text{Cov}(\epsilon_t^2, \epsilon_{t-h}^2) \geq 0, \qquad \forall h, \tag{5.8}$$

And if $\alpha_1 > 0$, then $\gamma_{\epsilon^2}(h) > 0, \forall h$.

5.3. Multivariate GARCH

Similarly to the univariate GARCH case, the multivariate GARCH may be specified by their first two moments. An $\mathbb{R}^m$-valued GARCH process (ϵ_t), with $\epsilon_t = (\epsilon_{1t}, \dots, \epsilon_{mt})'$, must then satisfy, for all $t \in \mathbb{Z}$,

$$\begin{cases} E(\epsilon_t \mid \epsilon_u, u < t) = 0 \\ \text{Var}(\epsilon_t \mid \epsilon_u, u < t) = E(\epsilon_t \epsilon_t' \mid \epsilon_u, u < t) = H_t. \end{cases} \tag{5.9}$$

Multivariate GARCH extension is then based on following equation:

$$\epsilon_t = \text{H}_t^{1/2} \eta_t, \tag{5.10}$$

where (η_t) is a sequence of iid $\mathbb{R}^m$-valued variables with zero mean and identity covariance matrix. The chosen matrix $\mathrm{H}_t^{1/2}$ can be symmetric and positive definite, or to be triangular, with positive diagonal elements. In the latter case (i.e. $\mathrm{H}_t^{1/2}$ is lower triangular) the first component of ϵ_t depends only on the first component of η_t. When m = 2, it is possible to set

$$\begin{cases} \epsilon_{1t} = h_{11,\mathrm{t}}^{\frac{1}{2}} \eta_{1t} \\ \epsilon_{2t} = \dfrac{h_{12,t}}{h_{11,\mathrm{t}}^{\frac{1}{2}}} \eta_{1t} + \left(\dfrac{h_{11,t} h_{22,t} - h_{12,\mathrm{t}}^2}{h_{11,t}} \right)^{1/2} \eta_{2t} \,, \end{cases} \tag{5.11}$$

where η_{it} and h_{it} denote generic elements of η_t and H_t. Specification of H_t is rather delicate: the matrix should be symmetric, positive definite for all t and at the same time the specification should be parsimonious enough to enable feasible solution.

Multivariate GARCH model categories:

The multivariate models may be divided into four categories (Silvennoinen and Treäsvirta, 2009):

a) Models of conditional covariance matrix which model the matrix H_t directly. This group of models includes VEC- and BEKK-GARCH models, which were among the first parametric MGARCH models. In general, those models are flexible, however they are often computationally demanding.
b) Factor models. In this group of models, ϵ_t is assumed to be generated by several unobserved heteroskedastic factors. Motivated by economic theory, factor models assume that the observations are generated by underlying factors (which are assumed to be conditionally heteroskedastic and possess a GARCH-type structure).
c) Models built on the idea of modelling conditional variances and correlation (instead of modelling the conditional covariance matrix). Conditional correlation models decompose the conditional covariance matrix into conditional standard deviations and correlations.
d) This group includes CCC models and its extensions (i.e. DCC, as it will be explained later).

e) Semi- and non-parametric models. Last group of models rely on semi- and non-parametric approach, offsetting the loss of efficiency of the parametric estimator due to the misspecified structure of the conditional covariance matrix.

5.4. CCC- and DCC GARCH model

Given its properties, the comovements in the European stock markets will be estimated using the Dynamic Conditional Correlation model (DCC-GARCH). As the DCC- model may be considered an extension of Constant Conditional Correlation model (CCC-GARCH), I will briefly discuss constant correlation model first.

A) Constant Conditional Correlation Models CCC

CCC–GARCH model of Bollerslev (1990) is probably the simplest multivariate correlation model that is nested in the other conditional correlation models.

For a multivariate GARCH defined as in (5.10), assume that all past information on ϵ_{kt} is summarized in the variable $h_{kk,t}$, with $Eh_{kk,t} = E\epsilon_{kt}^2$. Letting $\tilde{\eta}_{kt} = h_{\mathrm{kk,t}}^{-\frac{1}{2}} \epsilon_{kt}$, we define for all *k* a sequence of iid variables with zero mean and unit variance. The variables $\tilde{\eta}$ are generally correlated, so we let *R* = Var($\tilde{\eta}$) = ρ_{kt}, where $\tilde{\eta} = (\tilde{\eta}_{1t}, \dots, \tilde{\eta}_{mt})'$. Conditional variance of

$$\epsilon_t = \mathrm{diag}\,(h_{11,t}^{\frac{1}{2}}, \dots, h_{mm,t}^{\frac{1}{2}})\,\tilde{\eta}, \tag{5.12}$$

is written as

$$H_t = \mathrm{diag}\left(h_{11,t}^{\frac{1}{2}}, \dots, h_{mm,t}^{\frac{1}{2}}\right) R\ \mathrm{diag}\,(h_{11,t}^{\frac{1}{2}}, \dots, h_{mm,t}^{\frac{1}{2}}) \tag{5.13}$$

The conditional correlations between the components of ϵ_t are time invariant by construction:

$$\frac{h_{kl,t}}{h_{kk,t}^{\frac{1}{2}} h_{ll,t}^{\frac{1}{2}}} = \frac{E\,(\epsilon_{kt}\epsilon_{lt}|\epsilon_u, u<t)}{\{E\,(\epsilon_{k,t}^2|\epsilon_u, u<t)E\,(\epsilon_{l,t}^2|\epsilon_u, u<t)\}^{1/2}} = \rho_{kt}. \tag{5.14}$$

CCC model relies on the following univariate GARCH specification:

$$h_{kk,t} = \omega_k + \sum_{i=1}^{q} a_{k,i}\epsilon_{k,t-i}^2 + \sum_{j=1}^{p} b_{k,j}h_{kk,t-j}\,, \qquad k = 1, \dots, m. \tag{5.15}$$

where $\omega_k > 0,\ a_{k,i} \geq 0,\ b_{k,j} \geq 0,\ -1 \leq \rho_{k,l} \leq 1$ and R is symmetric and positive semidefinite. $h_{kk,t}$ depends not only on its own past values, but also on the past values of all the variables $\epsilon_{l,t}$. Set

$$h_t = \begin{pmatrix} h_{11,t} \\ \vdots \\ h_{mm,t} \end{pmatrix}, \qquad D_t = \begin{pmatrix} \sqrt{h_{11,t}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{h_{mm,t}} \end{pmatrix}, \qquad \epsilon_t = \begin{pmatrix} \epsilon_{1t}^2 \\ \vdots \\ \epsilon_{mt}^2 \end{pmatrix}. \tag{5.16}$$

Assuming that (η_t) is a sequence of iid variables with distribution η. A process (ϵ_t) is called CCC-GARCH (p, q) if it satisfies:

$$\begin{cases} \epsilon_t = \mathrm{H}_t^{1/2}\eta_t\,, \\ \mathrm{H}_t = \mathrm{D}_t\mathrm{R}\mathrm{D}_t\,, \\ h_t = \omega + \sum_{i=1}^{q} \boldsymbol{A_i}\epsilon_{t-i} + \sum_{j=1}^{p} \mathbf{B}_j h_{t-j}\,, \end{cases} \tag{5.17}$$

where R is a correlation matrix, $\underline{\omega}$ is a $m \times 1$ vector with positive coefficients, and the $\mathbf{A}_i$ and $\mathbf{B}_j$ are $m \times m$ matrices with nonnegative coefficients. The conditional correlation matrix is time invariant.

We have $\epsilon_t = \mathrm{D}_t\tilde{\eta}_t$, where $\tilde{\eta} = R^{1/2}\eta_t$ is a centered vector with covariance matrix R. The components of ϵ_t may be expressed like $\epsilon_{kt} = h_{kk,t}^{\frac{1}{2}}\tilde{\eta}_{kt}$, however, the conditional variance $h_{kk,t}$ depends on the past of all the components of ϵ_t.

B) <u>Dynamic Conditional Correlations Models (DCC)</u>

CCC model previously described have several limitations: (a) nonstability by aggregation, and (b) the assumption that conditional correlations are constant.

DCC-GARCH models may be considered an extension of CCC-GARCH models, obtained by introducing dynamic conditional correlations. The matrix R introduced in (5.17) is replaced by a matrix R_t which varies in time and is measurable with respect to the past variables $\{\epsilon_u, u < t\}$. Hence the DCC-GARCH model relies on following:

$$\mathrm{H}_t = \mathrm{D}_t \mathrm{R}_t \mathrm{D}_t \tag{5.18}$$

For the parsimonious reasons, it is reasonable to choose diagonal matrices $\boldsymbol{A_i}$ and $\mathbf{B}_j$ in (5.17) corresponding to univariate GARCH models for each component.

Depending on the specification of R_t, different DCC models may be obtained.

6. Estimation

6.1. Dataset & Approach

The main focus of this thesis is to explore how did the cointegration of the European stock market changed during past couple of years, since UK voted for a withdrawal from the European Union. Due to the promoted integration of the EU, the UK and continental Europe have become more interconnected, and it should not be expected that a one-time event such as Brexit will cause a sudden drop in stock market correlation between two countries. A change in correlation should rather be gradual, than sudden.

However, there is a possibility that this decrease was not caused purely by Brexit. In recent times one may have observed an increase in nationalism – in Europe as well as in the United states (Economist, 2016; Financial Times, 2017). The most commonly mentioned reasons for the outcome of the referendum was the increased immigration in UK[8] (Economist, 2016). It is therefore possible to assume that the increased nationalism was in fact behind decrease of stock market correlation. To explore this more closely, the I will estimate not only the correlation between UK and USA, but UK-USA and USA-EU correlation dynamics as well. Assuming that the decrease in correlation is a consequence of raising nationalism, it might be expected that the correlation with the American market will decrease for both, EU and the UK. A stable correlation between USA and the EU might imply that Brexit had to do with the decreased correlation between UK and continental Europe.

To explore the market integration shift in the post-Brexit period, I use the stock market indices of following countries: Netherlands (AEX), Austria (ATX), Belgium (BEL20), France (CAC40), Italy (FTSE MIB), Germany (DAX), Spain (IBEX 35), Ireland (ISEQ20), Norway (OBX), Sweden (OMX Stockholm 30), Denmark (OMX Copenhagen 20), Finland

[8] As one of the most mentioned reasons for leaving the EU is the immigration. When looking at different geographic regions in which pro-brexiteers won, and account for change in numbers, this reason become more obvious. Non-metropolitan cities experienced an enormous increase in foreign-born population. In case of increase by more than 200% between 2001 and 2014, a Leave vote followed in 94% of cases (Economist, 2016).

(OMX Helsinki 25), Portugal (PSI-20), Switzerland (SMI), United States (S&P500) and United Kingdom (FTSE100).

I use log returns of daily closing values for the period span from January 1st 2011 to April 30th 2018 from Reuters Eikon database. When data was not available for particular day, the closest previous closing value available was used.

The thesis focuses mainly on comparison of following three periods: pre-Brexit, mid-Brexit and post-Brexit. Pre-Brexit period is defined as the period before January 23rd 2013 (i.e. the date of Brexit announcement), mid-Brexit refers to the period from January 24rd until the Brexit referendum (June 23rd 2016), and post-Brexit period refers to the time since the vote took place until end of April 2018[9].

Table 3 provides some descriptive statistics of the return time series. The expected return through selected period varies around zero for all indices. As it is typical for financial time series, selected variables are not normally distributed - kurtosis indicating fat tails, suggesting extreme daily returns for data to demonstrate normality.

Prior to the estimation of model, I employ Augmented Dicky-Fuller (ADF) test (Dickey and Fuller, 1979) to test the stationarity of individual stock indexes, and then I use autocorrelation function (ACF) together with Ljung-Box statistics to detect serial correlation[10].

The log returns show no, or very small evidence of autocorrelation, however squared log returns and absolute returns are serially correlated. Similarly, the Ljung-Box statistics suggest, that data are serially correlated. Market index returns have serial dependence. The test results suggest that the data may be modelled using an autoregressive conditional heteroskedasticity model (ARCH model).

To test for the statistical significance of the estimated correlation decrease over time, I will employ the equality of means tests (Bartlett and Fligner-Killeen test).

[9] The two milestones – referendum announcement and vote - were proposed by Lin and Zhuo (2017)
[10] Tests p-values may be found in the Appendix

Index	Country	Obs.	Mean	median	St. Dev.	Min	Max	Kurtosis	Skewness
AEX	Netherlands	1,878	0.0002	0.001	0.012	-0.083	0.058	3.552	-0.406
ATX	Austria	1,878	0.0000	0.000	0.014	-0.097	0.077	3.945	-0.462
BEL	Belgium	1,878	0.0002	0.000	0.012	-0.090	0.061	4.200	-0.364
CAC	France	1,878	0.0001	0.000	0.014	-0.108	0.082	4.827	-0.382
FT MIB	Italy	1,878	0.0000	0.000	0.018	-0.157	0.081	5.290	-0.595
FTSE	UK	1,878	0.0001	0.000	0.011	-0.116	0.053	8.738	-0.866
DAX	Germany	1,878	0.0003	0.000	0.014	-0.095	0.073	4.108	-0.392
IBEX	Spain	1,878	-0.0001	0.000	0.016	-0.156	0.075	7.002	-0.578
IETP	Ireland	1,878	0.0004	0.000	0.012	-0.114	0.059	8.618	-0.855
OBX	Norway	1,878	0.0002	0.000	0.015	-0.079	0.067	2.445	-0.349
OMXS30	Sweden	1,878	0.0000	0.000	0.015	-0.136	0.075	7.278	-0.732
OMXC20	Denmark	1,878	0.0003	0.000	0.012	-0.065	0.058	2.652	-0.273
OMXH25	Finland	1,878	0.0002	0.000	0.014	-0.120	0.076	5.484	-0.426
PSI	Portugal	1,878	-0.0002	0.000	0.014	-0.096	0.046	2.247	-0.492
SMI	Switzerland	1,878	0.0001	0.000	0.010	-0.060	0.081	5.083	-0.128
S&P	USA	1,878	0.0004	0.000	0.009	-0.069	0.046	5.461	-0.600

Table 3: National Stock Indices – summary statistics

6.2. Results

The estimated correlations between UK, US and selected European countries show that the overall cointegration with UK stock market is higher than that of the US market (varying around 0.75 before the referendum announcement in case of UK, and 0.57 in case of US).

After the referendum announcement (i.e. after January 23rd 2013), and since the vote took place the drop of correlation was overall lower between UK and European markets – varying around 0.03 points (comparing to US – Europe market decrease varying around 0.05 points). In all cases, the drop in correlation has proven to be statistically significant, using equality of means test.

Correlation of most of the selected markets spiked shortly after the vote took place. This spike was most probably associated with the unexpectedness of the prevalence of the "out"

vote – as Bloomberg survey shows, the outcome of the referendum was unanticipated by majority of the capital market participants, even on the day of referendum (Bloomberg, 2016). In most of stock indices, the correlation dropped after the spike, and seemed to move up roughly to its previous level. The Swedish- and Finnish - UK stock markets correlations seem to follow a different path. The decrease in correlation after the Brexit referendum announcement and further decrease after the vote took place were around the same (0.03 and 0.04 points), whereas the rest of the selected countries seem to be influenced more by the announcement comparing to the vote itself (the drop varies around 0.02).

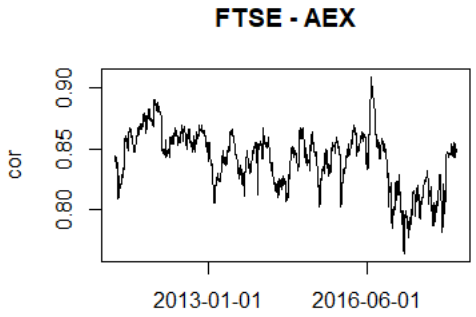
The correlation changed the least between UK and Ireland, which may be explained by the closeness of the two economies. One may observe even a slight increase in correlation between UK and Switzerland, possibly due to the fact Switzerland's stock market is an *outsider* to the EMU.

As expected, the results suggest that Brexit was not a sudden one-time shock to the economy, the date of referendum (or its announcement) is not associated with sudden shift in integration. Correlation of national stock markets decreased gradually over time.

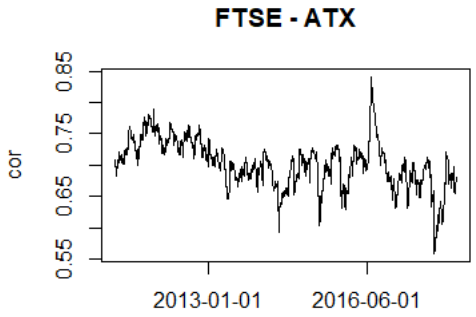
Estimated correlations means within respective period are summarised in table 4 (correlation of European stock markets with UK), and table 5 (correlation of European stock markets with US).

Correlation:		pre-Brexit	mid-Brexit	post-Brexit	Equality of means[11]
FTSE - AEX	(UK - Netherlands)	0.859	0.841	0.823	***
FTSE - ATX	(UK - Austria)	0.737	0.691	0.683	***
FTSE - BEL	(UK - Belgium)	0.808	0.778	0.765	***
FTSE - CAC	(UK - France)	0.834	0.811	0.797	***
FTSE - FT MIB	(UK - Italy)	0.755	0.724	0.710	***
FTSE - GDAXI	(UK - Germany)	0.820	0.790	0.768	***
FTSE - IBEX	(UK - Spain)	0.742	0.730	0.712	***
FTSE - IETP	(UK - Ireland)	0.753	0.706	0.703	***
FTSE - OBX	(UK - Norway)	0.748	0.696	0.680	***
FTSE - OMXS30	(UK - Sweden)	0.754	0.722	0.690	***
FTSE - OMXC20	(UK - Denmark)	0.662	0.617	0.593	***
FTSE - OMXH25	(UK - Finland)	0.753	0.723	0.678	***
FTSE - PSI20	(UK - Portugal)	0.671	0.641	0.634	***
FTSE - SSMI	(UK - Switzerland)	0.737	0.695	0.704	***
FTSE – S&P	(UK – US)	0.637	0.595	0.569	***

Table 4: Change in correlations of selected European markets (results summary). P-value refers to results of equality of means test. *** indicates statistical significance at 1% level.

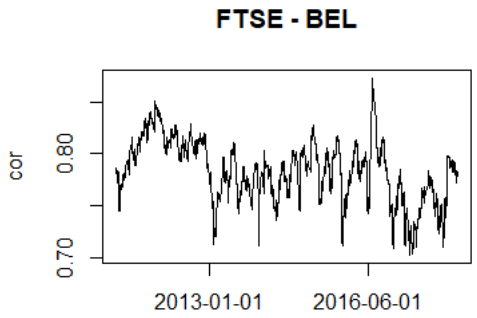


Graph 11: Correlation between UK and Netherlands

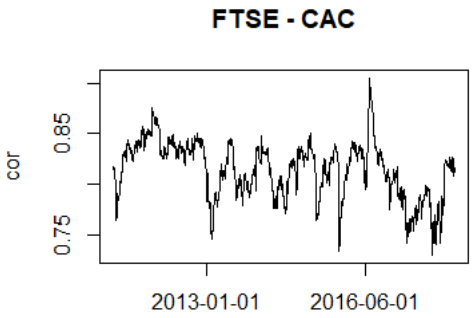


Graph 12: Correlation between UK and Austria

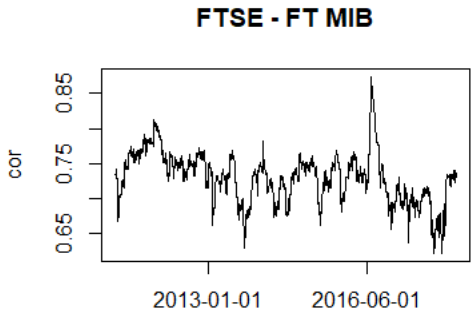
[11] Both, Bartlett and Fligner-Killeen test p-values showed same level of statistical significance



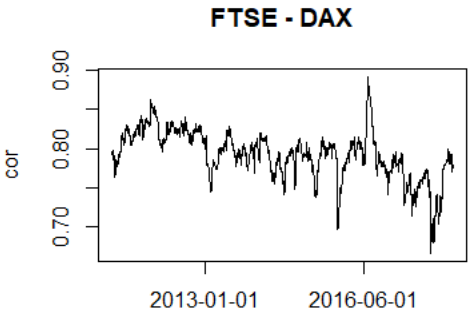
Graph 13: Correlation between UK and Begium



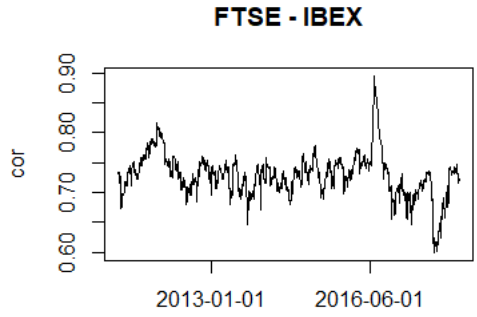
Graph 14: Correlation between UK and France



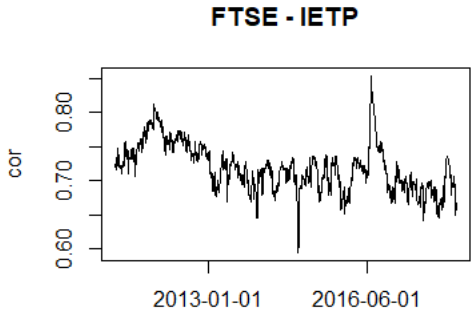
Graph 15: Correlation between UK and Italy



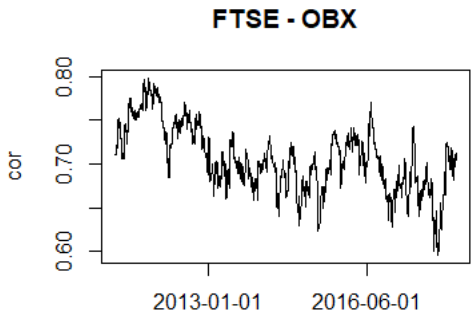
Graph 16: Correlation between UK and Germany



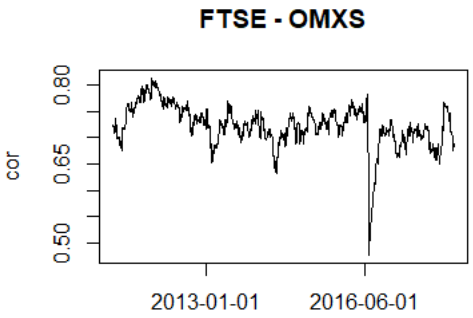
Graph 17: Correlation between UK and Spain



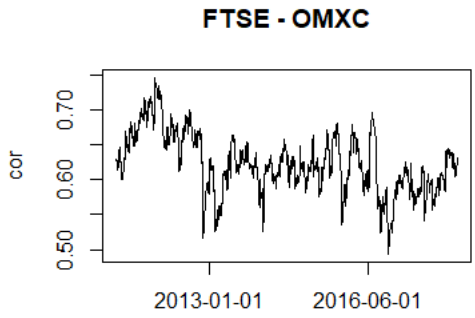
Graph 18: Correlation between UK and Ireland



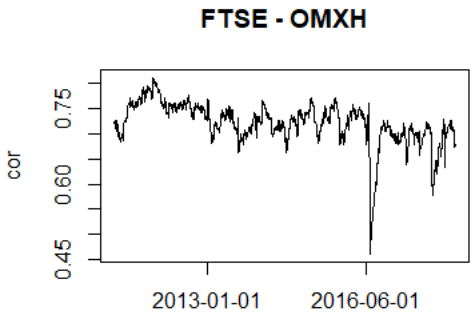
Graph 19: Correlation between UK and Norway



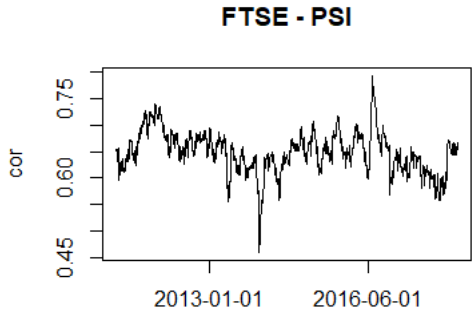
Graph 20: Correlation between UK and Sweden



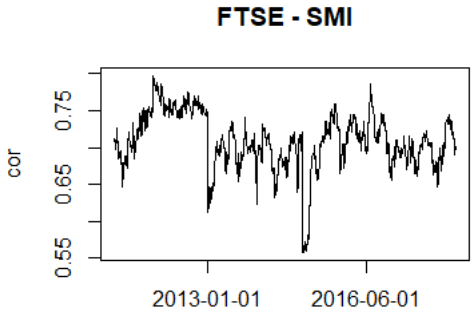
Graph 21: Correlation between UK and Denmark



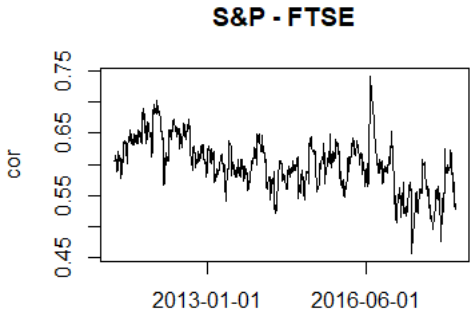
Graph 22: Correlation between UK and Finland



Graph 23: Correlation between UK and Portugal



Graph 24: Correlation between UK and Switzerland



Graph 25: Correlation between UK and US

As for the correlation between UK and US level, UK's stock market was the second most correlated among the selected stock markets (after Netherlands), in the pre- and mid- Brexit period.

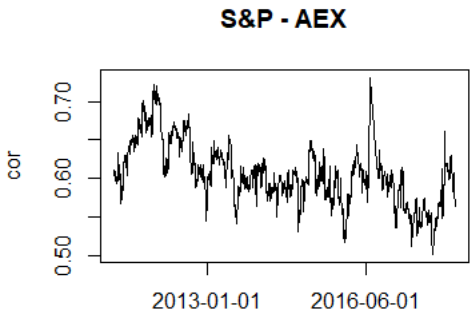
The thesis estimates the correlation between US and other European markets as well, in order to examine possibility that correlation between markets is decreasing overall, not only due to Brexit. The results suggest that this, at least partially, may be the case. Since the announcement, the overall correlation between US and European markets decreased, although on a lower extent than in case of the UK (where the decrease varies of around 0.05). Higher decrease can be observed in the mid-Brexit period, and decrease in the post-Brexit period was rather low – around 0.01 points. In case of Ireland, Denmark and Switzerland the correlation even slightly increased (by 0.0058, 0.0003 and 0.109 respectively).

To sum up, the selected markets seemed to be influenced by the Brexit event, especially by its non-expectance. The quick *recovery* of the correlation level shows that the cointegration of UK and EU markets will not change suddenly, but rather over time.

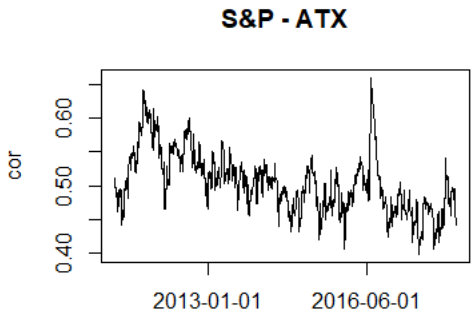
The results suggest that the correlation between markets had been experiencing a decreasing trend in all three examined periods associated with UK referendum. The decrease of correlation between European markets and UK being higher than the decrease in correlation with the US may suggest, that Brexit indeed played a role and reinforced this trend. It is important to mention that, given the used model, this thesis cannot to precisely determine to which extent Brexit caused the decrease in correlations, or what additional factors played a role.

Correlation:		pre-Brexit	mid-Brexit	post-Brexit	Equality of means[12]
S&P - AEX	(US - Netherlands)	0.642	0.597	0.582	***
S&P - ATX	(US - Austria)	0.543	0.496	0.475	***
S&P - BEL	(US - Belgium)	0.603	0.554	0.536	***
S&P - CAC	(US - France)	0.634	0.588	0.573	***
S&P - FT MIB	(US - Italy)	0.581	0.537	0.530	***
S&P - GDAXI	(US - Germany)	0.631	0.579	0.565	***
S&P - IBEX	(US - Spain)	0.567	0.534	0.515	***
S&P - IETP	(US - Ireland)	0.557	0.478	0.484	***
S&P - OBX	(US - Norway)	0.544	0.472	0.450	***
S&P - OMXS30	(US - Sweden)	0.577	0.523	0.509	***
S&P - OMXC20	(US - Denmark)	0.482	0.422	0.422	***
S&P - OMXH25	(US - Finland)	0.566	0.512	0.484	***
S&P - PSI20	(US - Portugal)	0.514	0.464	0.453	***
S&P - SSMI	(US - Switzerland)	0.497	0.429	0.440	***
S&P - FTSE	(US - UK)	0.637	0.595	0.569	***

Table 5: Change in correlations of US and selected European markets (results summary). P-value refers to results of equality of means test. *** indicates statistical significance at 1% level.

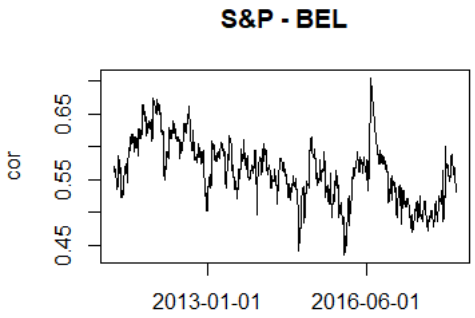


Graph 26: Correlation between US and Netherlands

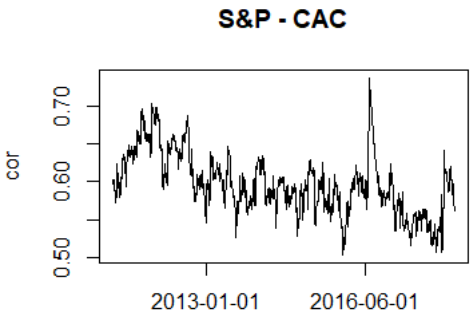


Graph 27: Correlation between US and Austria

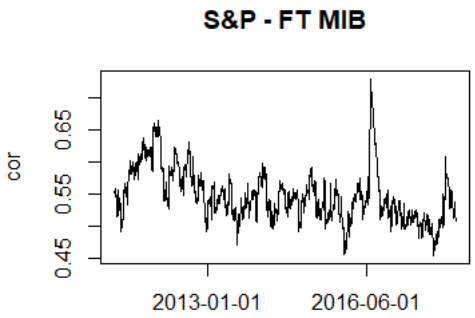
[12] Both, Bartlett and Fligner-Killeen test p-values showed same level of statistical significance



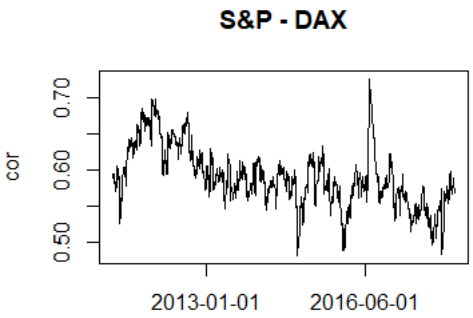
Graph 28: Correlation between US and Begium



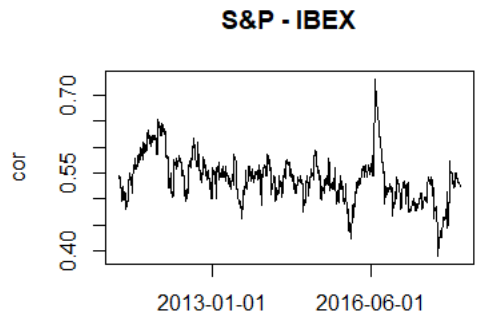
Graph 29: Correlation between US and France



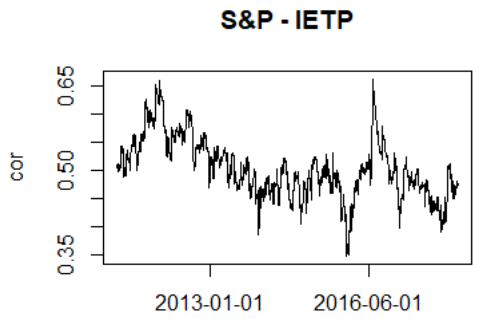
Graph 30: Correlation between US and Italy



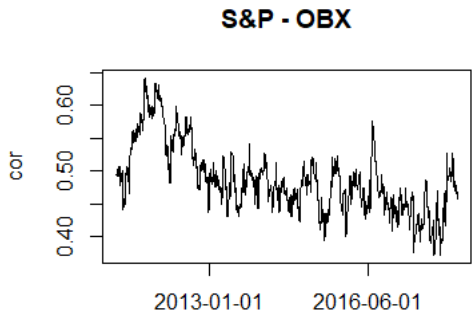
Graph 31: Correlation between US and Germany



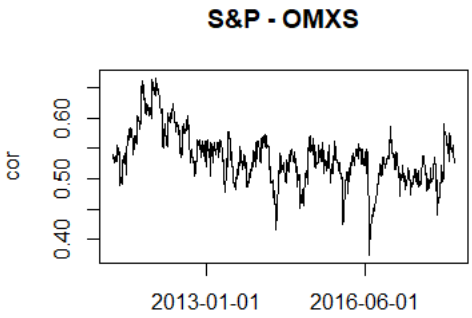
Graph 32: Correlation between US and Spain



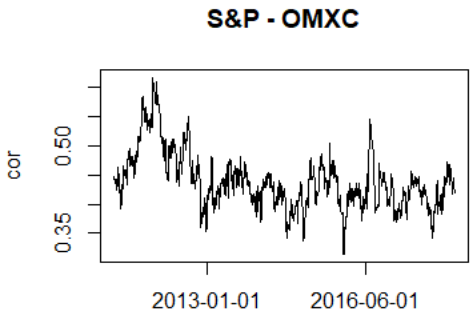
Graph 33: Correlation between US and Ireland



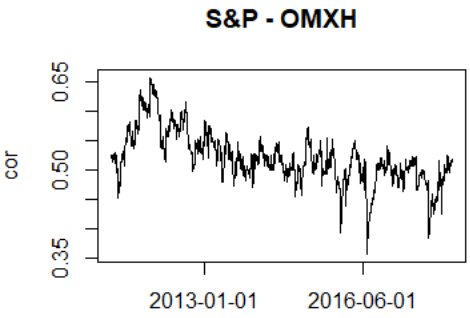
Graph 34: Correlation between US and Norway



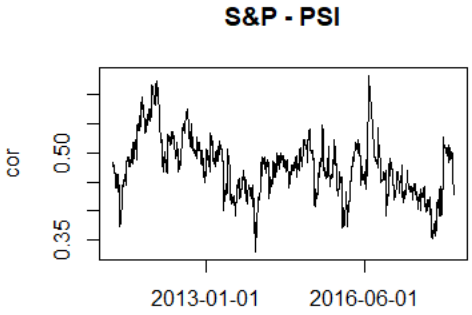
Graph 35: Correlation between US and Sweden



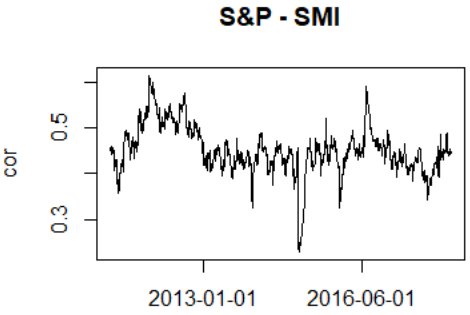
Graph 36: Correlation between US and Denmark



Graph 37: Correlation between US and Finland



Graph 38: Correlation between US and Portugal



Graph 39: Correlation between US and Switzerland

7. Conclusion

Surprising decision to withdraw from the Union, triggered reactions all over Europe, and spurred discussions what will be the effects on UK as well as the EU. This thesis focused mainly on the possible impact of Brexit to UK's position as European leading financial centre, and examined the change in European stock markets comovements since 2011.

Large number of studies focus on how the Brexit will damage the economy and possible negative impact. Given that UK is considered the financial centre of the EU, relying to a large extent to financial products and services, financial market seems to be endangered the most (Dörry, S., 2017). Leaving EU means losing its advantages as well. Especially passporting rights, free movement of goods and services are considered to be a big advantage attracting foreign investors (Batsaikhan et al., 2017).

By collecting the evidence from different economic areas, including financial geography, it is possible to conclude that leaving EU may be a possibility for London even strengthen its position among world stock markets. Although it may be difficult to forecast how London will function outside Europe, it has managed to promote itself into a leading position in the past, and this ability is not something that may be taken away. At the same time, Brexit may represent an opportunity for other European financial centres such as Paris or Frankfurt to attract a larger share of the market. This area also represents a challenge for the EU. It is possible that not only one city will become a new EU financial centre, but multiple cities will share this *post*. In order for this to work, the EU thus should focus on integrated financial market, where members share not only costs, but benefits as well (Sapir, 2017).

Examining the cointegration between European markets, there is a trend of weakening relationship between UK and continental Europe economies. The gradual decrease in correlation suggest that the cointegration between UK and EU will not be a sudden shift, but will differ because the collaboration between UK and continental Europe will change.

US and European economies correlation has been decreasing as well, although to a lower extent. This may suggest that the correlation between markets is has taken a downward path in general, whereas in case of UK, the withdrawal from the Union even fostered this trend. The methodology chosen in this thesis to estimate recent trends in the stock market

cointegration is rather unsuitable to quantify to what extent is Brexit causing the decrease in their correlations. Further research is needed to investigate the possible causes of decreasing cointegration of European stock markets.

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9. Appendix

	ADF test p-value	Ljung Box p-value
AEX	< 0.01 ***	0.01139 *
ATX	< 0.01 ***	0.00257 **
BFX	< 0.01 ***	0.00007 ***
FCHI	< 0.01 ***	0.00170 **
FTMIB	< 0.01 ***	0.00452 **
FTSE	< 0.01 ***	0.00001 ***
GDAXI	< 0.01 ***	0.00689 *
IBEX	< 0.01 ***	0.00024 ***
IETP	< 0.01 ***	0.00000 ***
OBX	< 0.01 ***	0.07908 *
OMXS30	< 0.01 ***	0.00381 **
OMXC20	< 0.01 ***	0.05599 *
OMXH25	< 0.01 ***	0.00022 ***
PSI20	< 0.01 ***	0.00038 ***
SSMI	< 0.01 ***	0.05174 *
S&P	< 0.01 ***	0.00000 ***

Table 6: test results of ADF test and Ljung-Box test.

* indicates statistical significance at the 10% level

** indicates statistical significance at the 5% level

*** indicates statistical significance at the 1% level