

The Analysis of Impact of Brexit on the Post-Brexit EU Using Intervented Multivariate Time Series

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Abstract The UK is the most important partner of the EU in terms of economic and other fields due to the geographical proximity. It was one of the largest economies in the EU and its per capita income is higher than the EU average, so it is a net contributor to the EU. With UKs membership of the EU ended on 31 January 2019, there are concerns that the Brexit may have a significant impact on the EU, resulting in social, economic, political, and institutional changes, etc. in EU. While the impact of Brexit on the UK has always been the subject of considerable scholarly interest in recent years, there is relatively little literature on the impact of Brexit on the EU. This paper focuses on the evaluation of the impact of Brexit on the EU economy and other relevant aspects along three dimensions: GDP, PPP, Quarterly GDP growth. Employing powerful quantitative analysis technology that includes vector autoregression model, multivariate time series model with intervention variables, and autoregression integrated moving average, this paper obtains the important and novel evidence about the potential impact of Brexit on the EU economy, pointing out that Brexit is of far-reaching significance to the EU. This analysis uses several statistical models to screen out several key influencing factors, which can be used to predict the total GDP of EU in the next five years. The results show that EU economy will react negatively to “no-deal” Brexit, and its growth rate of economy will slow down significantly in next 5 years. Finally, we put forward relevant policy suggestions on how to deal with the negative impact of Brexit on EU.

Keywords intervention multivariate time series model; Brexit; economy; gaping Brexit hole; no-deal Brexit; post-Brexit EU

2000 MR Subject Classification 62G08; 62J02

1 Introduction

1.1 Brexit

Britain’s exit from Europe lasted for a long time, probably going back to 2016. David Cameron, the former Prime Minister of the UK, proposed the goal of leaving Europe^[8]. On June 23, 2016, Britain held a referendum on whether to remain in the EU. The data showed that 52% of voters voted to leave the EU and 48% voted to remain in the EU^[21]. The result of the vote indicated that the number of votes in favor of Brexit defeated that of “remaining Europe” by a slight margin, and Britain will leave the EU^[10]. On December 8, 2017, Britain and the European Union reached a historic agreement to leave Europe, paving the way for trade negotiations^[29].

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It is argued that even if the UK had the third referendum, the result would almost be the same as the UK Parliament voted result^[18]. On November 25, 2018, at a special summit in Brussels, the heads of EU member states adopted a treaty on Britain's withdrawal from the EU and issued a political statement on future bilateral relations. According to the treaty, Britain will remain in the EU's internal market and customs union until the end of 2020 as a transitional period^[4]. Boris Johnson officially succeeded Teresa May as the British Prime Minister on July 24, 2019. In this critical junction, he gave up any chance of negotiation with the EU and strongly insisted on that the UK must no-deal Brexit. On January 31, 2020, the UK officially left from the EU with many things to be negotiated with the EU. The UK's membership of the EU ended forty-seven years after UK joined^[4]. The argument here is that although the UK has agreed on the conditions for its exit, the EU needs to decide what the future relationship with the UK will look like, so it has a long way to go. Brexit will be detrimental to the European Union, and the EU will have endless friction with UK in the future citeupJohn2019.

1.2 The Impacts of Brexit on EU

The impacts of Brexit will lead to social and economic changes in the EU, as well as the long term political and institutional changes. Until the precise terms of EU's relations with the UK are established in post-Brexit Era, all these effects are still somewhat theoretical. With the economic benefits and disadvantages given by the UK, the obvious impacts and consequences of Brexit on EU can be seen soon.

Perhaps de-integration is the beginning of the collapse of the European Union. As a global actor, the EU plays an important role in the world or competition. The challenge that Brexit may pose to the EU is that its strength will decline, it will be replaced by potential emerging countries, and its role as a global actor will be decline^[1].

Now the Brexit has come into true and thus the EU must face new challenges in the future. In the case of Brexit, EU needs to consider more factors than just the promise of certain political elites. Recently, Britain's new prime minister Boris Johnson has put more pressure on the EU. No-deal Brexit would create more chaos in the EU.

The impact of Brexit on the development of enterprises and economy in the EU has been highlighted. All this will change after Brexit. Some factors, such as investment, transportation, taxation, customs, currency, and transnational corporation activities, would be the key factors affecting EU enterprises^[13]. In addition, businesses seriously affected by the Brexit include supply chains, currencies (chartered accountants, tax, and business consultants). Increased costs of decoupling have led to fluctuations in transport prices, tariff payments, and shrinking supply chains.

In social, political, economic, military, cultural and other fields, economy bears the brunt. Hence, in this section, we focus on the economical impacts of the Brexit on EU, along the 3 dimensions: population, budget, and gross national product (GDP).

(1) Population and Strength Reduction

The first impression of Brexit: Europe will reduce its population and strength. After Brexit, the EU will reduce by 66 million (British population), accounting for 13% of the total EU population. As a result, the number of EU citizens will be 447 million, and the EU population will still exceed that of the United States, but far below that of China and India.

Another reason for the decline in the EU population is immigration. The impact of this would be felt most on eastern European member states who have approximately 1.2 million workers in the UK by the end of 2015; the largest groups from Poland (853,000), Romania (175,000) and Lithuania (155,000)^[25]. The Polish government encouraged young migrant workers to return to Poland, but for regulatory or political reasons, many are still staying in the UK^[24].

(2) Huge Gaping Brexit Hole in EU Coffer

The other difficulty is that Brexit will increase the financial difficulty of the budget within the EU, and the difficulty is quite large. The UK accounts for 12.3% of the total EU member contributions, and the UK contributes 12.3% to the EU financial budget. Especially, the UK is a net contributor to EU finance, that is, the UK pays more to the EU than the funds obtained from the EU^[27].

Until 2020, it will not there is too much of a problem with EU because the UK has promised to keep paying until the end of 2020, but it will be a bit cumbersome since the beginning of 2021. In fact, the European Council currently is working out a long-term budget plan from 2021 to 2027. According to the conclusion of the European Council, it needs to find 75 billion euros to fill the gap of Brexit, which means that other EU member states must pay more money from their pockets. The discussion about the details is omitted here. It is just known that some countries must pay more than others. For example, Germany and the Netherlands are about to face a substantial increase in their contributions to the EU, so the relevant consultations in Brussels was very tense in terms of different countries and different payment rates^[27].

The European Union leaders summit was held in Brussels, Belgium, on February 21, 2020. The 27 remaining EU countries had to discuss the EU's long-term budget for 2021–2027, Unfortunately, EU leaders clashed on the Summit over the next long-term budget for 2021–2027 after intense talks over the Brexit loophole in their joint coffers. As poor countries demand more aid, the frugal countries such as Austria, Denmark, the Netherlands, and Sweden, are determined to rein in spending. Until April 2020, the debate between member states that want to budget no more than 1% of their GDP and those that want to budget 1.074% is continuing^[26].

(3) GDP Reduction

GDP refers to the comprehensive strength index of a country or group^[5, 11]. After leaving Europe, the EU's GDP will be lower than before^[16], which is not good for the EU. They hope to remain stable or increase during the break-out period.

From an economic point of view, the GDP of the EU will be reduced by 15% to US \$15922 billion, with a total reduction of US \$2828 billion, that is, the proportion of the UK in the EU at present. If we look at these figures from a larger perspective, it means that the gap between the EU and the United States has widened since then. The GDP of the United States was US \$20494 billion, and what is shown here was the situation in 2018. Since then, the economic growth of the United States has been better than that of the European Union. At the same time, it should be noted that China's GDP was 13407 billion US dollars, which was also the figure in 2018. As we all know, China's economic growth is strong, so the importance of the EU in geopolitical population and economy will be reduced^[26].

To my opinion, the EU's position in international relations will be reduced, especially in international trade, in negotiations involving tariffs, investment, intellectual property protection, etc., such as in the face of the U.S. GAF A (Digital tax) negotiations, of course, the larger the population, the stronger the strength, the more favorable. Therefore, the EU after Brexit has trouble in this regard.

There are main challenges facing the post-Brexit EU. As far as the relationship between UK and the EU is concerned, it is difficult to see the immediate consequences of Brexit. There are many outstanding issues. The most difficult problem now is to redefine the relationship between the EU and the UK. Negotiate one area after another to minimize obstacles in price, value-added tax, customs duty, etc., and to minimize the damage to the free movement of people. Every challenge is enormous. For example, UK imports from EU account for 53% of its total imports, which is particularly important for EU enterprises^[26]. If the EU and the UK can reach an overall agreement, they may reduce the losses caused by Brexit, but this requires that the UK must commit to strictly abide by a series of rules, including social, environmental, health, personnel, as well as difficult fishing issues. In short, this is a huge project. Is British Prime Minister Boris Johnson ready to make concessions? It's still a problem. But it can be

confirmed that, according to all the current analysis, in a short period of time, the loss of Brexit to the UK is greater than that of the EU^[26].

1.3 Hard and Soft Brexit

“Hard Brexit” here means that the UK leaves the EU and the EU Single Market with no deals, it is also called “no-deal Brexi”. On the contrast, “Soft Brexi” ensures that the UK retains its membership in the European Single Market and some free movement of people by the European Economic Area (EEA) rules^[3].

“Hard” and “soft” Brexit determines the future relationship between Britain and the EU. A hard exit from the EU without an exit agreement (no agreement) means that the EU cannot continue to cooperate with the UK. On the other hand, the soft separation means that the EU can continue to cooperate with the UK. In the past few years, Britain and the EU have cooperated in business and economy in the face of a series of crises such as debt and slow economic growth. In the past few years, Britain has also experienced a crisis^[1]. So, Brexit is of profound significance to the EU. There seems to be a “preferential relationship” between soft decoupling and hard and soft decoupling.

Whenever Britain leaves Europe, the EU must take measures to cope with it. For example, financing organizations (EUROD) will reduce their financial support for British enterprises or cancel their support for British business plans^[28]. On the other hand, no-deal Brexit will face risks because no exit agreement is reached. After this incident, the comprehensive strength of the European Union was weakened^[7].

The disorderly situation would lead to a significant slowdown in the EU economy. Trade will suffer additional friction and we expect the Euro to depreciate significantly. Loose monetary and fiscal policy could mitigate this impact, but we would expect, the GDP level from 2020-2024 to be lower than the benchmark forecast.

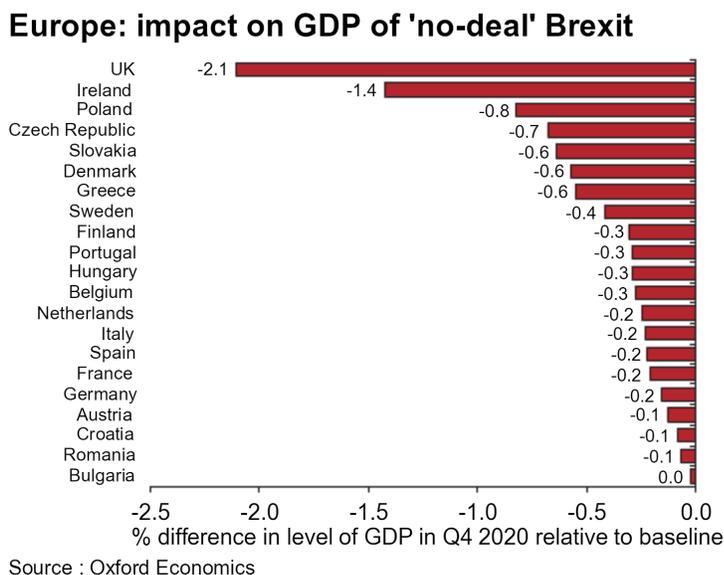


Figure 1.1. The impact on GDP of “no-deal” Brexit. The source of the figure is Oxford Economics.

The Figure 1.1 shows the impact on GDP of ‘no-deal’ Brexit. The difference (in percent “%”) in level of GDP in Q4 2020 relative to baseline is presented. We can see clearly from the figure that a no-deal Brexit would result in the level of GDP of EU countries being below the baseline forecast at the end of 2020. Specifically, that is, Ireland (−1.4), Poland (−0.8),

Czech Republic (−0.7), Slovakia (−0.6), Denmark (−0.6), Greece (−0.6), Sweden (0.4), Finland (−0.3), Portugal (−0.3), Hungary (−0.3), Belgium (−0.3), Netherlands (−0.2), Italy (−0.2), Spain (−0.2), France (−0.3), Germany (−0.2), Austria (−0.1), Croatia (−0.1), Romania (−0.1), and Bulgaria (0.0), respectively.

Increased trade frictions would result in much lower exports and imports. Consumer spending and business investment would also be hit, but government consumption would be higher. Ireland would also be hit hard but the impact on larger Eurozone economies would be much more modest^[2].

In short, a no-deal Brexit will cause more momentous trade frictions between the EU and UK. Financial markets will react negatively to “no-deal” Brexit. Monetary and fiscal policy will be relaxed, and EU economic growth will slow down significantly in 2019–2020.

1.4 Will the Post-Brexit EU Disintegrate?

The Brexit has brought a significant change to the EU. It may have a major impact on the future of the EU: a continuing chaotic EU may eventually fall apart^[22]. European integration was plagued by for example, the crises in the Eurozone and Schengen Area, tensions with Russia and the United States, and a wave of illiberalism in European countries and around the world^[9, 23].

The research and other evidence suggest that Britain’s departure from the EU may have a demonstrative effect on other EU member states, similar referendums will be triggered elsewhere in the EU, which will accelerate the disintegration of the EU. For a long time, because Britain often hinders the process of integration and requires special treatment or withdrawal, it is naturalizing a British identity as the awkward partner^[14] and a stranger in Europe^[30].

On the other hand, is it possible for Brexit to strengthen the EU by promoting further integration? For a long time, Britain has been described as an awkward partner because it often hinders the integration process and demands special treatment or withdrawal. Its withdrawal may remove this obstacle and provide much-needed impetus for those countries seeking to promote the process of European integration. Euro-skepticism is not an isolated phenomenon, it must be interpreted as a problem of party competition rooted in socio-cultural and socio-economic conflicts^[6]. There are still many debates and speculations about the impact of Brexit on the future of European integration. It is not clear whether the EU has overcome the high degree of skepticism or uneasiness about the idea of transferring new powers to the EU by many people^[6]. This has been a major obstacle to proposals for further integration in recent years, see for example, [15] and the references therein.

2 Research Methodology

To address the topic of this paper quantitatively, this section presents data sources, research methods, and tools, which seeks to answer the research questions: what does Brexit mean for the economy of EU?

2.1 Data Sources

The GDP Data are available from the official website: the World Bank Website:

<https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2018&locations=CN-EU-GB&start=1960&type=points&view=chart>

Other data website for reference is as follows:

<https://tradingeconomics.com/european-union/gdp>

The World Bank Group, with 189 members, staff from more than 170 countries and offices in more than 130 locations, is a unique global partnership: five institutions committed to reducing poverty and building sustainable solutions for common prosperity in developing countries. Hence, the data down load from the World Bank Group website is more authoritative.

2.2 Models

In this section, the analysis of the impact of Brexit on the Post-Brexit EU Uses Vector autoregression (VAR) model, time series model with intervention variables, and autoregression integrated moving average.

2.2.1 Vector Auto Regression

Vector autoregression (VAR) model explores the interdependencies among dynamic multivariate time series. It is an extension of the univariate autoregressive (AR) model to the multivariate case. In this section, VAR model is used to study the interdependencies among the economic development of the EU and that of the UK. VAR model is composed of a system of equations. In each equation, one of the endogenous variables is regressed on all its lag terms. Let $\mathbf{Y}_t = (Y_{1t}, \dots, Y_{mt})^\top$ denote an $m \times 1$ vector of time series variables. The p -th order VAR model is expressed as

$$\mathbf{Y}_t = \boldsymbol{\alpha} + \boldsymbol{\beta}_1 \mathbf{Y}_{t-1} + \dots + \boldsymbol{\beta}_p \mathbf{Y}_{t-p} + \boldsymbol{\varepsilon}_t, \quad t = 1, \dots, T, \quad (2.1)$$

where $\boldsymbol{\beta}_j$ ($j = 1, \dots, p$) are $m \times m$ coefficient matrices, $\boldsymbol{\varepsilon}_t = (\varepsilon_{1t}, \dots, \varepsilon_{mt})^\top$ is a $m \times 1$ white noise vector process with zero mean and serial indenpendency.

The above VAR model is designed to model stationary multivariate time series \mathbf{Y}_t . However, in real data analysis, there is usually a certain trend in time series. For such a nonstationary time series, it is necessary to take into consideration of the cointegrating relations.

There are various applications of the VAR model in the field of economic. For example, we can use VAR model to predict GDP of multiple countries and further take exogenous variables into the VAR model to improve the model performance:

$$\mathbf{Y}_t = \boldsymbol{\alpha} + \boldsymbol{\beta}_1 \mathbf{Y}_{t-1} + \dots + \boldsymbol{\beta}_p \mathbf{Y}_{t-p} + \boldsymbol{\gamma} \mathbf{Z}_t + \boldsymbol{\varepsilon}_t, \quad t = 1, \dots, T, \quad (2.2)$$

where \mathbf{Z}_t is a vector of exogenous variables at time t and $\boldsymbol{\gamma}$ is the corresponding coefficient vector. There are multiple choice of the exogenous variables, such as the inflation rate and the interest rate.

2.2.2 Time Series Model with Intervention Variables

In this section, the Prediction of EU Quarterly GDP Growth Rate is Based on ARIMA Intervention Model. The autoregressive moving average model (ARMA model), is one of the commonly used models in time series. ARMA model analyzes stationary sequences without seasonal variation. It represents the current sequence value as the weighted sum of the past sequence values and the past perturbation terms. ARMA(p,q) Model takes the following form:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \dots + \beta_p Y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \dots + \theta_q \varepsilon_{t-q},$$

where Y_t is the time series of interest, ε_t is a white noise sequence, p and q are the orders of autoregressive and moving average respectively, β_i and θ_j are the parameters to be estimated.

The above model can be abbreviated as:

$$Y_t = \frac{\theta(B)}{\varphi(B)} \varepsilon_t,$$

where B is the lag operator, $\theta(B) = 1 - \theta_1 B - \dots - \theta_q B^q$ and $\varphi(B) = 1 - \varphi_1 B - \dots - \varphi_p B^p$ correspond to the coefficients of moving average and autoregressive coefficients respectively, $\omega(B)$ and $\delta(B)$, having similar forms, measure the influence magnitude of the intervention event, and their lag orders can be generally specified according to the actual situation. It is noteworthy that ARMA model requires the time series to be stationary, while ARIMA model can analyze the nonstationary time sequences by differential operation.

In the intervention model, the most important part is the intervention variable, which has two forms of expression. The first form can be represented by a step function as follows:

$$S_t^T = \begin{cases} 0, & \text{before the intervention, that is, } t < T, \\ 1, & \text{after the intervention, that is, } t \geq T. \end{cases}$$

It indicates that there is a continuous effect after the intervention event occurs at time T .

The second form can be represented by a pulse function, which is:

$$P_t^T = \begin{cases} 0, & \text{others, that is } t \neq T, \\ 1, & \text{when the intervention occurred, that is } t = T. \end{cases} \tag{2.3}$$

It indicates that the intervention event occurs at time T , but only has an impact on that time point, which is not persistent.

In general, time series models with intervention variables have the following form:

$$Y_t = \frac{\theta(B)}{\varphi(B)} \varepsilon_t + \frac{\omega(B) B^b}{\delta(B)} I_t, \tag{2.4}$$

where I_t is the intervention variable and can be taken as S_t^T or P_t^T , according to the specific influence of the event, $\theta(B)$ and $\varphi(B)$ correspond to the coefficients of moving average and autoregressive coefficients respectively.

The concrete steps of the intervention model include the following:

- First, a univariable time series model is established by using the data before the intervention event. Then we can use the model to extrapolate and get the predicted value without intervention.
- Second, the actual value is subtracted from the predicted value to obtain the influence of the intervention event, and the parameters of the intervention part can be estimated by using the above data.
- Third, exclude the intervention impact on the data according to the estimation results of Step 2 and then use the "purified-data" to identify the univariate time series model without the influence of the intervention.
- Fourth, the time series model obtained in step 3 is combined with the formula of the intervention part to find out the final ARIMA intervention analysis model.

2.2.3 ARIMA (p, d, q)

ARMA (Autoregression Integrated Moving Average) model was developed by George Box and Gwilym Jenkins in the 1970s, which is a time series model consists of AR (Autoregression) model and MA (Moving average) model. A well-known special model of ARIMA is ARMA (Autoregression Moving Average). Because ARMA is only suitable for stationary time series, ARIMA model can deal with time series data more flexibly by introducing difference to make

data satisfy the stationary conditions. Generally, for time series $X(t)$, $t \in \mathcal{T}$, ARMA(p' , q) is defined as

$$X(t) - \alpha_1 X(t-1) - \cdots - \alpha_{p'} X(t-p') = \varepsilon(t) - \theta_1 \varepsilon(t-1) - \cdots - \theta_q \varepsilon(t-q), \quad (2.5)$$

where p' is the order of AR model and q is the order of MA model. Under $X(t-1) = BX(t)$, (2.5) is equivalent to

$$\Phi(B)X(t) = \Theta(B)\varepsilon(t), \quad (2.6)$$

where

$$\Phi(B) = 1 - \sum_{i'=1}^{p'} \alpha_{i'} B^{i'}, \quad \Theta(B) = 1 - \sum_{j=1}^q \theta_j B^j.$$

Suppose $\Phi(B)$ has a unit root of multiplicity d , then

$$\Phi(B) = 1 - \sum_{i'=1}^{p'} \alpha_{i'} B^{i'} = \left(1 - \sum_{i'=1}^{p'-d} \phi_{i'}\right) (1-B)^d.$$

Thus, ARMA(p' , d) can show as

$$\left(1 - \sum_{i'=1}^{p'-d} \phi_{i'}\right) (1-B)^d X(t) = \left(1 - \sum_{j=1}^q \theta_j B^j\right) \varepsilon(t), \quad (2.7)$$

which is the expression of ARIMA($p' - d, d, q$). Using $X(t-1) = BX(t)$, one can realize that $(1-B)^d X(t)$ is the result of d -difference of $X(t)$. Thus, it can be seen as a special case of ARMA(p' , q), with $\Phi(B)$ owning a unit root of multiplicity d .

Formally speaking, ARIMA(p, d, q) is defined as

$$\left(1 - \sum_{i=1}^p \phi_i\right) Y(t) = \left(1 - \sum_{j=1}^q \theta_j B^j\right) \varepsilon(t), \quad (2.8)$$

where $Y(t) = (1-B)^d X(t)$. In practice, some approaches can be used to determine p, d and q . Here we respectively use ADF (Augmented Dickey Fuller) test method to find optimal d , the figure of ACF (Autocorrelation Function) to distinguish p , and the figure of PACF (Partial Autocorrelation Function) to recognize q .

2.3 Statistical Analysis of GDP

(1) Total GDP of EU, UK and (EU-UK)

We first consider the trends of GDP (in US dollar) of EU, UK and (EU-UK) from 1960 to 2018, where (EU-UK) means the GDP of EU after the removal of British GDP. The line charts of GDP (in US dollar) of EU, UK and (EU-UK) from 1960 to 2018 are as follows:

The source for 2.1: The estimation is based on World Bank (WDI) data. As can be seen from the Figure 2.1, during 1960–1990, Britain's GDP grew steadily and slowly, while the overall economy of the EU maintained sustained growth before 1980 and experienced a short period of stagnation between 1980 and 1985. The related world background is the second oil crisis in the second half of 1979, which caused the market demand to shrink due to the rising oil price. In 1980, the Bank Act of 1980, which was implemented by the United States, accelerated the process of financial globalization. The cross-border flow of huge capital has impacted the financial market and macro-economy of emerging market countries, and various types of financial risks occur frequently.

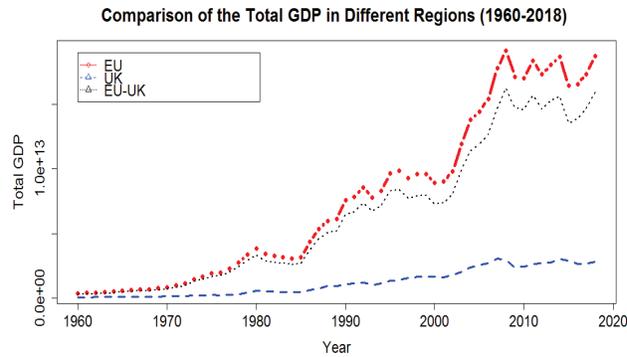


Figure 2.1. Comparisons of the Total GDP of EU (—in red), UK (—in blue) and (EU-UK) (—in black) between 1960 and 2018, where (EU-UK) means the GDP of EU after the removal of British GDP.

In the years before and after the establishment of the EU in 1993, the economy of UK and EU showed a trend of rapid growth; in 1995, the economic growth of developed countries slowed down due to the severe turbulence of the international financial market, and the EU economy showed a marked downward trend; in 2001, the EU economy showed a strong growth momentum again, benefiting from it. The expansion of the world market and the continuous growth of the U.S. economy have played a positive role in promoting the export of EU countries. After 2010, the EU economy fluctuated continuously, but basically kept the same trend as in previous years. The British economy also entered a period of sluggish development.

(2) The Growth Rate of GDP of EU and (EU-UK) In order to analyze the impact of Brexit on the overall economic development of the EU, we draw a histogram of GDP of the EU and the UK from 1992 to 2018 and impose the line charts of the growth rate of GDP of the EU before and after the removal of that of the UK. See the Figure 2.2 as follows:

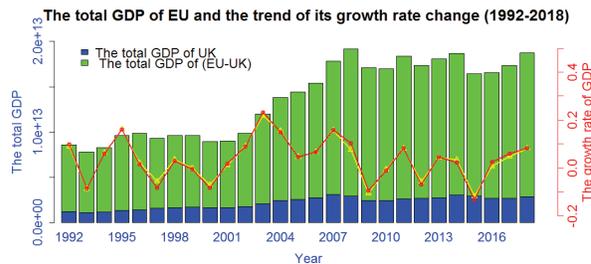


Figure 2.2. The histograms for the GDP of UK (in blue) and (EU-UK) (in green); the imposed line charts for the growth rate of GDP of EU (—in yellow) and the growth rate of GDP of (EU-UK) (—in red).

The estimation shown in 2.2 is based on World Bank (WDI) data. From the Figure 2.2, we can see that from 1992 to 2002, the total GDP of EU and UK maintained steady growth and steady development; from 2003 to 2008, the EU economy entered the fast lane and experienced a rapid development stage, with GDP growth rate between 10% and 20%. After 2010, the EU and UK economies recovered steadily, and the total GDP remained unchanged or a slight decline. Overall, due to the close connection of the fate community of the EU, the total GDP

of Britain keeps pace with that of the EU.

However, the line chart in Figure 2.2 shows that the GDP growth rate of the 27 EU countries has slightly declined after the removal of British GDP.

(3) The Ratio of UK's GDP to EU's GDP and EU's GDP to Major economies

In order to see more clearly the changes in the position of the British economy and the EU economy, two broken-line maps are drawn to reflect the changes in the proportion of the British economy in the EU as a whole and that of the EU economy in the major economies of the world. Among them, the world's major economies here include the United States, China, Japan and the European Union.

The estimation shown in 2.3 is based on World Bank (WDI) data. From the Figure 2.3, the proportion of the EU in the world's four major economies has shown a downward trend. Only in 2000–2008, the proportion rose to the largest, about 45%, and then continued to decline, until 2018, about 30%. The UK's share of EU GDP fluctuated between 10% and 20%, rising from 1993 to 2007, and then may be affected by the global financial crisis and fall back to about 15%. The decline in the EU's share of the world economy may lead to a gradual decline in its attractiveness to Britain, making “Brexit” an option for more people.

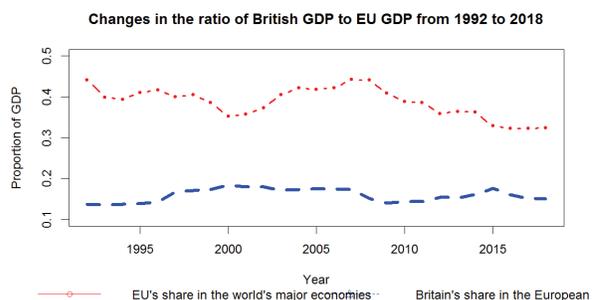


Figure 2.3. The Line Charts of the Proportion of GDP(1) Changes in the ratio of British GDP to EU GDP from 1992 to 2018(—in blue); (2) EU's share of GDP in that of the world's major economies (—in red).

Obviously, the overall trend of the EU's share in the world economy is declining. Britain's share of EU GDP has always been very large (about 20%). Hence, it can be predicted that the EU's share of the world's economy will become smaller after Brexit.

2.4 Statistical Analysis of PPP

The GDP is often recognized as the best indicator to measure the economic situation of a country. However, the GDP of different countries and regions cannot reflect the differences between their economic conditions very well. Therefore, it requires considering PPP in this section. We draw the PPP curve further.

The estimation shown in 2.4 is based on World Bank (WDI) data. Figure 2.4 shows that both EUs and UKs PPP trends in terms of current US dollar prices are increasing year by year, but both are decreasing in 2008, and corresponding to the lowest PPP growth rate in Figure 2.4, in 2008, the reason may be the world economic crisis from 2007 to 2009. Overall, PPP changes are relatively stable, and there is no excessive fluctuation compared with GDP in Figure 2.1. The proportion of British PPP in EU PPP and GDP shows the same trend of change, showing the characteristics of “decline, stability, high and fluctuation”.

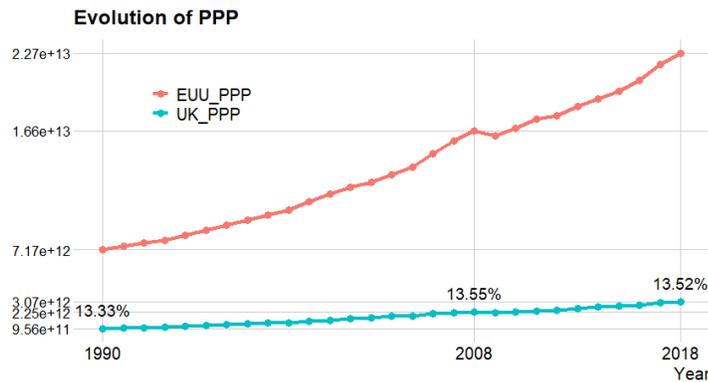


Figure 2.4. Evolution charts of PPP of EU and UK from 1990 to 2018. The EU's PPP (—in blue); The UK's PPP (—in blue).

(2) The Growth Rate of PPP of EU and UK

Tendency charts of PPP growth rates of EU and UK from 1991 to 2018 are shown in Figure 2.5. The estimation shown in 2.5 is based on World Bank (WDI) data. From Figure 2.5 we can see that the PPP of EU after the removal of British GDP is decreasing after 2017. This can also be seen as one of the impacts of the Brexit.

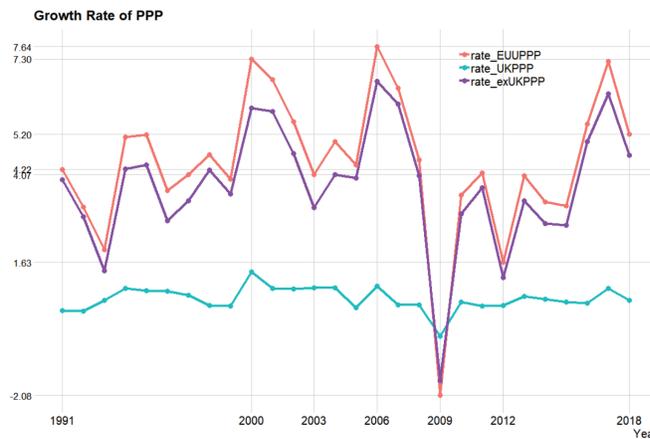


Figure 2.5. Tendency charts of PPP growth rates of EU and UK from 1991 to 2018. The rate of EU's PPP (—in blue); The rate of UK's PPP (—in blue); The rate of (EU-UK)'s PPP (—in purple).

2.5 GDP Forecast

The ARIMA (P, D, Q) model is employed in this subsection. The so-called model recognition is to determine the values of parameters P, D and Q according to the statistical characteristics of the data sequence to be processed. As mentioned above, the trend of GDP growth will be eliminated after the first-order difference, so $d = 1$. It is necessary to try many times to recognize ARIMA (P, Q) model. It is possible that more than one set of (P, Q) values can pass

the recognition test. Obviously, increasing the order of P and Q can increase the goodness of fit, but at the same time reduce the degree of freedom. The final prediction results are shown in Figure 2.6 and Tables 1–2.

Table 1. The predicted GDP for the EU (with UK) (in US dollars) as the baseline forecasts. The nominal level is 95%.

Year	Predicted GDP	Lower bound	Upper bound
2020	2.46×10^{13}	2.38×10^{13}	2.54×10^{13}
2021	2.54×10^{13}	2.36×10^{13}	2.71×10^{13}
2022	2.62×10^{13}	2.33×10^{13}	2.91×10^{13}
2023	2.70×10^{13}	2.27×10^{13}	3.13×10^{13}

Table 2. GDP forecasts for the post-Brexit EU (in US dollars). The nominal level is 95%.

Year	Predicted GDP	Lower bound	Upper bound
2020	2.13×10^{13}	2.06×10^{13}	2.19×10^{13}
2021	2.20×10^{13}	2.05×10^{13}	2.35×10^{13}
2022	2.27×10^{13}	2.02×10^{13}	2.52×10^{13}
2023	2.34×10^{13}	1.97×10^{13}	3.71×10^{13}

The source for the estimation and prediction in Tables 1–2 is based on World Bank (WDI) data. It can be seen from Tables 1–2 that, on the whole, the baseline of GDP of EU (EU including the UK) is increasing by an average of 8.0×10^{11} \$ per year, while that of the post-Brexit EU is increasing by an average of 7.0×10^{11} \$ per year. Overall, Brexit has brought about a sustained negative impact on the economic development of the EU.

The estimation shown in 2.6 is based on World Bank (WDI) data. From Figure 2.6, we can find that the baseline of EU GDP forecast has a more obvious upward trend and a wider confidence band. This means that the fluctuation range of the baseline of EU GDP forecast in the future is larger than that of the post-Brexit EU. It shows that Brexit has significant impact on the post-Brexit EU economy. The modelling suggests that Brexit would reduce the level of the post-Brexit EU GDP compared with the baseline forecast.

2.6 GDP Growth Rate Forecast

This section will forecast the EU's quarterly GDP growth from 2020 to 2021. The GDP growth rate of 8 quarters is predicted. In the case of Brexit and no-Brexit (the hypothetical case), the quarterly growth rates are shown in Table 3. It can be seen from the data in Table 3 that the Brexit process has a significant negative impact on the overall economic development of the post-Brexit EU. Specifically, after the Brexit, the GDP growth rate of the post-Brexit EU in the first quarter of 2020 will drop by 0.1 percentage points. Later, with the entry into force of various Brexit agreements, the negative impact on the EU will continue to deepen, and the growth rate in the second quarter and the third quarter will drop by 0.3 and 0.2 percentage points, respectively. From the forecast results, the Brexit event will weaken the development momentum of EU economy for a long time in the future.

The forecast shown in 3 is based on World Bank (WDI) data. Using ARIMA (5,1,2) model to extrapolate the GDP growth data from the first quarter of 2018 to the fourth quarter of 2019, and then subtract the predicted value from the actual value, the difference is the intervention effect produced by the process of Brexit. After testing, ARIMA (4,1,1) model is fitted to the purification sequence.

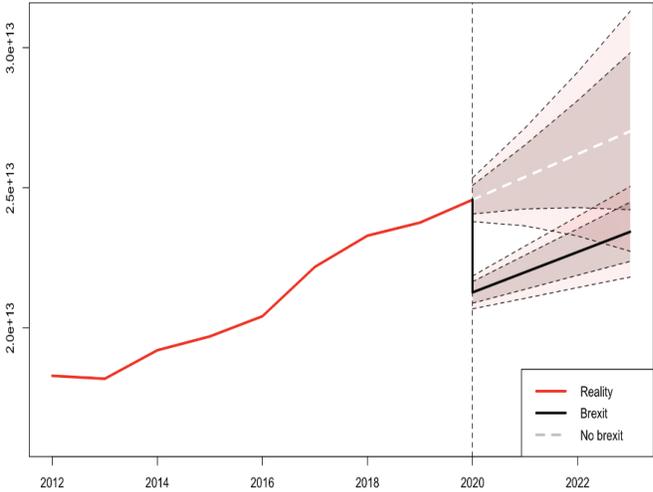


Figure 2.6. EU GDP forecast results using ARIMA (0,2,0) model, in which the red solid line represents the actual GDP of EU from 1995 to 2019, the white dotted line (the baseline) represents the EU GDP forecast including the UK from 2020 to 2023, and the black solid line represents the post-Brexit EU GDP forecast. The confidence level of the gray confidence band close to the prediction results is 80%, and that of the far pink confidence band is 95%. It is clear that the post-Brexit EU GDP is below the baseline forecast from 2020 to 2023.

Table 3. Forecast of EU’s quarterly GDP growth in 2020–2021

Quarter	Baseline (%)	Post-Brexit (%)
2020-Q1	1.1578568	1.0521248
2020-Q2	1.1176354	0.8132734
2020-Q3	0.9926506	0.7872021
2020-Q4	1.1233835	0.8686781
2021-Q1	1.1616314	0.9314550
2021-Q2	1.2544464	1.0120551
2021-Q3	1.2968925	1.0605839
2021-Q4	1.2849940	1.0456567

The forecast shown in 2.7 is based on World Bank (WDI) data. As can be seen from Figure 2.7, the quarterly growth rate of GDP of the EU as a whole began to decline from the end of 2017, and then showed a downward trend of fluctuation, which has continued to decline in the past two years. According to the forecast after 2020, Brexit will make the economic development of the post-Brexit EU worse. Without the cooperative development with Britain, the economy of the post-Brexit EU will face a series of challenges in the future, so it is urgent

to take strong measures to inject new vitality into the economic development of the post-Brexit EU.

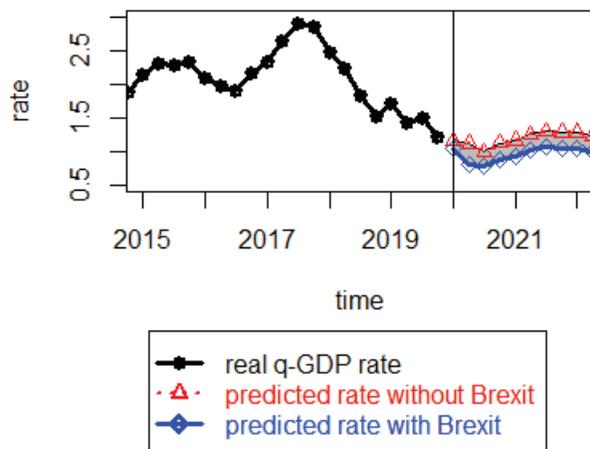


Figure 2.7. Forecast of the impact of Brexit on the post-Brexit EU's quarterly GDP growth from 2020 to 2021. The black solid line represents the actual situation of quarterly GDP growth of 28 EU countries in 2015–2020; the red dotted line represents the prediction of quarterly GDP growth of the EU in 2020–2021 when the UK does not leave the EU (hypothetical); the blue solid line represents the GDP growth prediction of the post-Brexit EU. The gray shadow indicates the negative influence of Brexit on EU.

3 Results

Empirical analysis in Section 3 shows that the Brexit means a great economic recession for the EU. Specifically,

- (1) It can be seen from the Figure 2.1 that the cross-border flow of huge capital has impacted the financial market and macro-economy of emerging market countries, and various types of financial risks occur frequently. After 2010, the EU economy fluctuated continuously, but basically kept the same trend as in previous years.
- (2) The line chart in Figure 2.2 shows that the GDP growth rate of the 27 EU countries has slightly declined after the removal of British GDP.
- (3) From the Figure 2.3, it can be seen that the proportion of the EU in the world's four major economies has shown a downward trend as a whole. Obviously, the overall trend of the EU's share in the world economy is declining. Britain's share of EU GDP has always been very large (about 20%). Hence, it can be predicted that the EU's share of the world's economy will become smaller after Brexit.
- (4) Figure 2.4 shows that both EUs and UKs PPP trends in terms of current US dollar prices are increasing year by year, but both are decreasing in 2008, and corresponding to the lowest PPP growth rate in Figure 2.4, in 2008, the reason may be the world economic crisis from 2007 to 2009. Overall, PPP changes are relatively stable, and there is no excessive fluctuation compared with GDP in Figure 2.1. The proportion of British PPP in EU PPP and GDP shows the same trend of change, showing the characteristics of "decline, stability, high and fluctuation".

- (5) From Figure 2.5, we can see that the PPP of EU after the removal of British GDP is decreasing after 2017. This can also be seen as one of the impacts of the Brexit.
- (6) As for economic growth forecast, we can see From Figure 2.6 and Table 1 that in 2019, after leaving Europe, the total GDP of the EU will decrease US\$ 0.2×10^{13} .
- (7) From Tables 1–2 and Figure 2.6, it shows that Brexit has significant impact on the post-Brexit EU economy. The modelling results suggest that Brexit would reduce the level of EU GDP compared with the baseline forecast
- (8) From Figure 2.7, the quarterly growth rate of post-Brexit GDP of the EU as a whole began to decline.

Through the study of the whole paper, we can find that Britain's Brexit will have a potentially significant impact on the European Union. The Brexit will prevent the EU's ambitious plans. Because a powerful country likes the European Union cannot tolerate its decline in world status. When the EU is unable to recover from the crisis, the financial sector is particularly important to the EU. Britain's finance is quite developed. That's why London is called the world financial center. The EU is heavily dependent on British finance. We think the EU wants to replace Britain as a global financial city in other ways. As a new global financial city, it may be one of the European Union cities^[31].

Brexit has two sides. One is the devaluation trend of the EU currency, the other is the insufficient fiscal revenue^[20]. Britain is the EU's largest trading partner. 48% of imports come from the EU. EU will adopt restrictive measures in response to Britain's restrictive response. In my opinion, this measure is not friendly based on long-term cooperation^[32]. After Britain's exit from Europe, more troubles have arisen and the relationship between the two sides has ensued. Friction is unavoidable^[12].

4 Discussion

The analysis employs several statistical models, for example, The ARIMA models, the ETS models in forecasting the total GDP of EU with or without UK. The findings show that how Brexit may change the EU in its economy and others, and summarize the possible impacts of Brexit on the future of the EU: from a chaotic EU to a disintegrated EU. The conclusion outlines several key factors that will shape how the EU responds. Empirical analysis in Section 3 shows that the Brexit means a great economic recession for the EU.

In addition, what we want to say is that Britain's exit from Europe was full of uncertainty, and there was no clear common goal between the two parts at that time. Britain's position in the European Union is particularly important. The core content of EU's Brexit mainly revolves around "withdraw agreement, transition, new relationship after Brexit". "For the EU itself, it is concerned with rebalancing the EU and world commercial trade in the world or Europe".

These are crucial to the future development of the EU. According to the previous information, we can conclude that the decline of Europe is unfavorable to the competition of the European Union in the world. Recently, America's new business policy imposed taxes on imports and exports. Britain's withdrawal from the EU has a negative impact. The two countries can defeat the EU in both ways. The EU is in trouble.

Britain will form a stronger alliance with the United States after Brexit. The American model is what Britain wants to buy. It is worth mentioning that in recent years, President Donald Trump has liked to get more money from commercial advertisements in other countries. This is a potential danger for the EU. The United States is Britain's largest cooperation partner. They have a common agreement in favor of each other's terms of trade.

The relationship between Britain and the United States is special. Their economic model is called the Anglo-Saxon economic model. Both Britain and the United States benefit from this economic model^[17]. We think Britain will work closely with the United States after Brexit. Compared with the European Union, we can understand history. The real cooperation between Britain and the United States is more due to geographical constraints. Another reason, and a typical example, is that the Prime Minister, Tony Blair, had a close relationship with the United States before the cold war, and then a series of cooperation with the United States. All these prove that Britain has a great chance to join the United States.

On the other hand, the new British Prime Minister has expressed friendship with China. He really wants to do more trade with China. He plans to do more trade with China. I think Britain rarely has any chance join in the One Belt One Road like Italy. If it joins, it will be another challenge for the EU. The One Belt One Road is not popular in the European Union. China's rise will bring risks or benefits to EU. Joining will bring other European countries. This competition has no advantage for the EU. There are more developing countries in Europe. They are the charm of oboe. These countries penetrate around this strategy. This will reduce the EU's trade activities. This is also one of the reasons why the EU has been affected by the EU's decoupling.

We think the relationship between the EU and the UK will deteriorate because the UK acts in its own way. Britain's forced withdrawal from the EU is a violation of EU rules. It breaks through the bottom line of the European Union. In the view of the EU, Britain has lost its responsibility as a member of the EU. A withdrawal without an agreement will exacerbate the crisis within the EU. Today, it is difficult for the EU to minimize risk. In business, the EU exports more to Britain, such as fruits, daily necessities, and other useful things. A sudden halt would lead to losses in the EU, particularly in agriculture, cars, and unsalable goods with short maturities. This action may lead to EU salesmen unable to sell out. Conflict will break out soon.

The EU and the UK have common financial institutions, but they use different currencies. With Britain leaving the EU, the common system will change. The exchange rate of people's income in the European Union was lower than before. At that time, the European Union suffered a crisis. We mean social problems. There are products from foreign investment. When businessmen leave the EU, prices will rise. Stocks in the European Union and the United Kingdom will fall. This is a common phenomenon when the crisis comes. However, more and more people are leaving the EU. This is the EU's biggest loss. The reduction of foreign investment will not promote the development of the EU economy. In short, Brexit has significant impact on the post-Brexit EU economy. The growth rate of post-Brexit GDP of the EU will be to decline.

5 Conclusions

Britain is an important partner of the EU in the economic and other fields. Britain's departure from Europe will change the EU's organizational structure or bring far-reaching impact. On the basis of a strong quantitative analysis, this paper studies the potential impact of Brexit on the EU from the economic point of view, and focuses on other areas involved, pointing out that the impact of Brexit on the EU is enormous.

It is of great significance to the European Union. Next, the EU will face more trouble. This paper uses a variety of statistical models, such as ETS (error, trend, seasonal) model, to predict the EU's total GDP with or without the UK. The results show that Britain's exit from Europe will change the EU, especially in economic aspects, and summarize the possible impact of Britain's exit on the future of the EU: from the chaotic EU to the disintegrated EU.

Britain has really had an impact on the EU. We don't think it's a good thing for Brexit. It

has potential hazards in the future. As mentioned above, the database shows that UK exports, imports, and investments account for a larger share of the EU market. Geographical location is close to Britain. Britain is the world's largest economy. The EU can benefit more from Britain. The cost is cheaper other country. Britain is particularly important to the EU. We compare it in two parts. One is the EU with UK data, the other excludes the UK. By and large, UKs contribution to the EU is not less.

The data tells us that Britain's withdrawal from the EU, even if the UK's GDP remains stable in the EU, will lead to a decline in the EU's economy. Britain's demanding that Britain leave Europe will inevitably sacrifice the interests of the EU. For example, the EU welcomes Britain's reference to other special country models, but needs to make concessions beyond the bottom line so that the EU will not change before the EU recovers from the crisis^[28].

The EU is willing to discuss the issue of Brexit with Britain. These are not exactly what Britain requires. We think Britain may replace other new members. Joining the EU will bring new opportunities and development. This is a loss that the EU can make up for after new members join. Recently, the slogan of the new British Prime Minister's rebels is that no-deal will take place on October 31, 2019 who acts the same as President Trump. This series of actions led the EU to consider him a dangerous people. Maybe one day it will cause trouble like the United States. In short, Brexit means that it has significant impact on the post-Brexit EU economy. And it slow down the growth rate of GDP of post-Brexit EU.

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