Supervised by Kevin Cullinane

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Quantifying the Impact of Potential Brexit Scenarios Utilising a Double-Logarithmic Gravity Equation

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Jacqueline Karlsson
Helena Melin

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Quantifying the Impact of Potential Brexit Scenarios Utilising a Double-Logarithmic Gravity Equation

By Jacqueline Karlsson and Helena Melin

This Master of Science thesis was submitted to the School of Business, Economics and Law at the University of Gothenburg (Vasagatan 1 P.O. Box 600 SE-40530 Gothenburg, Sweden). The thesis was equivalent to 20 weeks of full time studies.

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Abstract

Purpose. The purpose of this research report was to project if the Brexit would negatively impact the export quantities of passenger cars from Germany to the UK. The automotive industry is highly interconnected and barriers could severely impact the supply chain networks of automotive manufacturers. The topic was of particular interest due to the estimated implications of the Brexit and the substantial passenger car quantities that Germany exports.

Methodology. The authors studied the current market structure through the use of a double-logarithmic gravity equation. The gravity model provided the foundation for a quantitative forecasting model which projected future trade quantities under different Brexit scenarios. The model was based on a sample representing 98 per cent of Germany's total export quantity of passenger cars. Diagnostic tests suggest that the model was robust and efficient in estimating trade quantities.

Findings. All Brexit scenarios were estimated to negatively impact the export quantities of passenger cars from Germany to the UK. Lower tariffs were projected to benefit export quantities of passenger cars from Germany, nevertheless, a weaker economy in the UK due to the Brexit is estimated to reduce demand for passenger cars and offset the benefits of trading with low tariffs. The most pessimistic scenario in 2030 forecasts a reduction of 15,4 per cent in exported cars compared to a scenario in the absence of the Brexit.

Originality. By being the first to project the impact of the Brexit on German export quantities of passenger cars, the results provide valuable insights for automakers as well as supply chain planners and other professionals.

Research limitations. The authors have narrowed their focus to the export of complete cars and do not take into account interactions between countries and industries before or after complete cars are exported.

Key words. *Automotive Industry; Brexit; Gravity Equation; Trade Costs*

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Abbreviations

ACEA	European Automobile Manufacturers' Association
CETA	Comprehensive Economic Trade Agreement
EEA	European Economic Area
EEC	European Economic Community
EFTA	European Free Trade Association
ERM	Exchange Rate Mechanism
EU	European Union
EUR	Euro
FDI	Foreign Direct Investment
FTA	Free Trade Agreement
GBP	Great Britain Pound / Pound Sterling
GDP	Gross Domestic Product
HM Treasury	Her Majesty's Treasury
HS	Harmonized Commodity Description and Coding System
IMF	International Monetary Fund
LTEU	Lisbon Treaty / Treaty of the European Union
MFN	Most Favoured Nation
OECD	Organisation for Economic Co-operation and Development
OICA	Organisation Internationale des Constructors d'Automobiles
OLS	Ordinary Least Squares
PTA	Preferential Trade Agreement
PwC	Pricewaterhousecoopers
SMMT	Society of Motor Manufacturers and Traders
U.S	United States
UK	United Kingdom
USD	United States Dollar
VDA	German Association of the Automotive Industry
VIF	Variance Inflation Factor
WTO	World Trade Organization

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1. Introduction

The United Kingdom (hereinafter the UK) has one of the largest economies of the European Union (hereinafter the EU) (World Bank, 2017a). However, the relationship between the two has been historically difficult (BBC News, 2016a). The EU itself started as a customs union (Bayoumi & Eichengreen, 1995) but has grown more politically and economically integrated and power has become increasingly centralised (eur-lex.europa.eu, 2015; European Union, 2015). Scholars suggest that the UK has not approved of the development of the EU[1].

In 2013, Prime Minister David Cameron declared that if the Conservative Party won the following election, they would pursue negotiations with the EU and allow Britons a choice of whether or not to stay in the union (BBC News, 2016a). The Prime Minister claimed that he had no choice but to offer a public vote in the matter since the EU negatively impacted the politics in the UK (Parker, 2016). The referendum took place on June 23rd, 2016 where the leave campaign won a surprising victory. That the UK leaves the EU has been commonly referred to as the *Brexit* (Hunt & Wheeler, 2017).

The election outcome had immediate consequences. The very next day, David Cameron announced his resignation as Prime Minister in favour of a new leadership (BBC News, 2016b). The new leadership, under Theresa May, formally invoked Article 50 of the Lisbon treaty of the EU (hereinafter LTEU) on March 30th, 2017 which started a two year process of leaving the EU (Castle, 2017). According to several scholars (HM Treasury, 2016a; PwC, 2016; European Union Committee, 2016), there are three Brexit scenarios that potentially could follow the negotiations with the EU: that the UK becomes a member of the European Economic Agreement (hereinafter EEA); that the UK negotiates a bilateral agreement with the EU; or that the UK trades with the EU under World Trade Organization (hereinafter WTO) terms. These scenarios would result in different tariffs on goods and services and are estimated to impact the UK gross domestic product (hereinafter GDP) accordingly (OECD, 2016).

[1] See chapter 2.1 The historical relationship for a detailed review.

The outcome of the Brexit referendum could have noteworthy consequences on the UK and its trade partners. Germany is one of their most important trade partners[2] and is mainly exporting passenger cars to the UK where 39 per cent of the total number of imported units in the UK is of German origin[3] (United Nations, 2017a). 77 per cent of all manufactured passenger cars in Germany were sold abroad in 2016 (VDA, 2017) and the German economy is heavily reliant on its exports (Williams & Theil, 2016).

1.1 Problem description

The automotive industry has traditionally been characterised by forecast driven production, yet, vehicle manufacturers have increasingly established build-to-order strategies (Holweg et al., 2004). Manufacturing networks are challenged by the mass customisation that customers demand. This has increased the complexity of production systems (Mourtzis, 2016) and, as a result, supply chains in the automotive industry have been largely restructured in the past decades. The production of passenger cars has moved due to production costs and to enable companies to be in closer proximity to the end costumer. Foreign companies have proven that they can avoid tariffs by producing locally (Pavlínek, Domański & Guzik, 2009) and being closer to the market can lower transportation costs (Krugman, 1980).

Through a global presence, automotive manufacturers have increased production quantities in order to capitalise on economies of scale (von Corswant & Fredriksson, 2002). Truett and Truett (2017) explain that German manufacturers operate in the output range of economics of scale, which is important since it allows the industry to reduce unit costs. The German automotive industry is the biggest car industry in Europe, representing 34,9 per cent of the total assembly of 16,3 million passenger cars (OICA, 2017). The industry is important and contributes to the overall economic growth of the region (ACEA, 2016a). Germany exported 7,8 million passenger cars in

[2] The UK's biggest import partners in 2015, in terms of value for all products, were Germany (15,0%), China (10,0%), the U.S (9,2%), the Netherlands (7,5%) and France (6,1%) (United Nations, 2017a).

[3] Germany was the biggest importer in terms of quantity measured as number of cars (39,0 %) in 2015 followed by Spain (12,3%). Germany was also the biggest import partner of passenger cars in terms of value representing 48,1 per cent followed by Belgium (13,3%), Spain (10,2%), France (4,7%) and Japan (4,1%) (United Nations, 2017a).

2015, of which 1,4 million passenger cars were to the UK[4] (United Nations, 2017a).

Nevertheless, the automotive industry is particularly vulnerable to tariffs due to its international supply chains. Automotive manufacturers' supply chains are delicate to interruptions and reliant on the Single Market (Campbell, 2016). The BMW Group argues that they import over 150 000 new passenger cars into the UK from the EU each year and that barriers could result in higher costs if they would not be granted free trade with the EU (Johnston, 2016). In addition to the tariff cost, the time which additional customs checks would cause could in itself be significant, since it may well increase costs in the supply chains (Monaghan, 2016). Furthermore, O'Grady (2016) explains that tariffs in the automotive industry would be administratively difficult.

The Brexit is a new phenomenon and little research has been conducted in the field. However, articles have been published in a more comprehensive manner about the overall Brexit and referendum (Butler, Jenson & Snaith, 2016; Glencross, 2015; Menon & Salter, 2016a; Hobolt, 2016; Vasilopoulou, 2016), the reasons behind the Brexit (Menon & Salter, 2016b; Thielemann & Schade, 2016), the result (Goodwin & Heath, 2016), the negotiations or legal implications following it (Jensen & Snaith, 2016; Łazowski, 2016; Kroll & Leuffen, 2016; Gordon, M., 2016; Chalmers, 2016), EU-related future challenges (Biscop, 2016; Simón, 2015) and estimated financial implications (Boulanger & Philippidis, 2015). Some scholars have also focused on the Brexit's impact on a particular sector or industry such as the marine environment (Boyes & Elliot, 2016), the agriculture or food sector (Swinbank, 2016; Grant, W., 2016; Matthews, 2016) and the pharmaceutical industry (Song, 2016; Baker, Ali & Thrasher, 2016). Nevertheless, to the authors' knowledge no academic article has yet been published in regards to the impact of the Brexit on the automotive industry in general and the export of passenger cars from Germany in particular. This makes it a highly relevant topic, and consequently, this research report will contribute to filling this gap in scientific knowledge and practice.

[4] Germany biggest export partners, in terms of quantity of passenger cars, in 2015, were the UK (17,4%), the U.S (15,9%), China (7,8%), France (6,5%) and Italy (5,5%) (United Nations, 2017a).

1.2 Purpose and research question

The purpose of this research report is to project if the Brexit will negatively impact the export quantities of passenger cars from Germany to the UK. The automotive industry is highly interconnected and barriers could severely impact the supply chain networks of automotive manufacturers. The topic is of particular interest due to the estimated implications of the Brexit and the substantial passenger car export quantities that Germany represents.

To estimate the impact that different factors have on export quantities of passenger cars from Germany to the UK, this research report will apply a gravity equation which is a model that is derived as a reduced form from a general equilibrium model of international trade in final goods. This model will provide the foundation for a quantitative forecasting model that will project the impact of the Brexit on export quantities of passenger cars from Germany to the UK.

In order to fulfil the purpose, the following research question has been formulated:

RQ: What is the estimated impact of the Brexit on the export quantities of passenger cars from Germany to the UK?

1.3 Delimitations

In order to estimate the impact of the Brexit, several delimitations have been made in this research report. First, the authors have narrowed their focus to the export of complete cars. The industry is highly international and, consequently, components often have another origin than the actual car. Moreover, the research report does not take interactions between countries into account, as well as industries, before or after the complete car is exported. This also means that the forecasted quantities do not address whether export quantities of passenger cars from Germany change in other countries due to the Brexit or from where the UK would import cars in the future in case the export quantities from Germany decline. Furthermore, the forecasts by segment and brand assume that everything will stay the same in the future. Hence, the research report does not take into account trends in regards to for example electric

cars which are estimated to disrupt the current market structure. Finally, this research report does not distinguish between new and used passenger cars.

1.4 Disposition

The remaining research report will be structured as follows. It will start by describing and elaborating on the background of the Brexit and what is expected to follow the negotiations with the EU. This chapter reviews important background information of the causes leading up to the Brexit and how it could come to affect trade for both the UK and its partners.

Thereafter, this research report will provide a methodological background. The chapter includes a description of the methodology behind the literature collection and presents the research philosophy and approach of this research report. Furthermore, it describes the quantitative gravity model that was applied to the dataset.

The methodological chapter will be followed by an analysis of the model, variables and observations. The chapter reviews the systematic elimination of variables and diagnostic tests in regards to the sample and the regression technique.

Thereafter, this research report will present the results from the extensive data modelling. The chapter covers the results from the gravity equation, the results from the forecasting model and a breakdown of the forecasted quantities by segment and brand.

Finally, the report will draw some conclusions and provide guidance for future research.

2. The Brexit

The first chapter of this research report will give an overview of the Brexit. It will start by providing a brief review of the UK's role in the EU, with a particular focus on the development of the union to offer a broader understanding of the support for the Brexit. It will continue by describing and elaborating on the referendum and, finally, present likely exit scenarios.

2.1 The historical relationship

The Treaty of Rome was created in 1956 and became the foundation of the European Economic Community (hereinafter EEC) known as the common market. The EEC became the EU under the Maastricht Treaty in 1993 and the collaboration became closer than it had been before in that a Single Market was created (European Union, 2017a). A Single Market is a deeper form of free trade area that seeks to remove both tariff and non-tariff barriers (BBC News, 2017).

Economic and political factors such as greater stability within the EU region and furthering of trade and investments in trade partners has brought many countries to seek agreements with the EU in order to gain access to the European market (Francois, McQueen & Wignarja, 2005). The European Free Trade Association (hereinafter EFTA) with members such as Norway and Switzerland is a free trade area in Europe and the EU has free trade agreements with many other countries too (BBC News, 2017).

A free trade agreement (hereinafter FTA) is a trade pact between nations which eliminates tariffs, quotas or other potential barriers to trade in regards to specific goods or to all goods and services traded. The purpose of an FTA is that by reducing trade barriers, trade increases between the involved parties (Kepaptsoglou, Karlaftis & Tsamboulas, 2010). However, even though there are many trade agreements, Baier and Bergstrand (2007) argue that international trade economists have struggled to find empirical evidence to support an average positive correlation between FTAs and increased bilateral trade (Baier & Bergstrand, 2007). Even so, several governments

have declared that they envision FTAs and bilateral agreements to be in line with their goal of trade liberalisation (Levy, 1997).

Nobel laureate Tinbergen (1962) was the first to measure the effect of FTAs on bilateral trade flows through the use of a gravity model. The gravity model has since then become the foundation to measure the effects of FTAs and customs unions on bilateral trade flows (Bayoumi & Eichengreen, 1995). Inspired by Tinbergen, Aitken (1973) used a cross-sectional model with a special focus on the EEC and EFTA membership. He concluded that both the EEC and the EFTA had seen growth cumulatively in the gross trading creation and that it was greater in the EEC than in the EFTA.

Building on Aitken's work, Brada and Méndez (1985) evaluated whether the results from the EEC and EFTA were applicable to developing countries. Their research proved that both developed and developing countries can be successfully integrated, but that factors such as policy and system can prevent the trade scheme from reaching its full potential (Brada & Méndez, 1985). The EU has expanded and come to cover countries with greater diversity. There are also candidate countries that are transposing their national law to enable membership in the union, such as Albania and Macedonia (European Union, 2017b), which are countries with relatively undeveloped economies (World Bank, 2017a).

The UK joined the EEC in 1973 (European Union, 2017a). It had wanted to join the common market as early as 1961 but was vetoed by the French President Charles de Gaulle (Wilson, 2014). This was the start of a complex relationship between the UK and the EU which offers a broader understanding of the support for the Brexit.

2.1.1 Financial context

The EEC became the EU under the Maastricht Treaty in 1993. The collaboration became closer and a Single Market was created consisting of the four freedoms, namely the movement of goods, services, people and money (European Union, 2017a). The Maastricht Treaty also led to the creation of the common currency, the euro, and set out the criteria for joining the Economic and Monetary Union (European

Commission, 2017a). The currency was in 2017 adopted by 19 of 28 member countries (European Union, 2017c).

The UK has not adopted the common currency and an opt-out clause was settled for them when the Maastricht Treaty was concluded. The UK has agreed to introduce the currency if the UK Government and Parliament make a decision in this respect and the UK meets certain convergence criteria. These criteria refer to five economic tests including convergence of business cycles; flexibility; investments; financial services; and growth, stability and jobs. According to the UK Government, it was not in their national interest to adopt the common currency since the criteria has not been met (eur-lex.europa.eu, 2006).

The Exchange Rate Mechanism (hereinafter ERM) seeks to avoid volatility in the exchange rates of member states which have not adopted the euro. It is a framework that attempts to ensure price stability and participation is voluntary (European Commission, 2017b). The UK joined the ERM in 1990 but exited in 1992, since rising inflation at the end of the 1980s led to an increase in short-term interest rates, which in turn led to sharp deflation. To tackle the challenges that the German unification posed on the ERM, real exchange rates rose to stimulate domestic demand. In order to keep price stability in Germany, short-term interest rates outside Germany increased to keep inflation down. This increase of interest rates was higher than what was appropriate for the UK economy and the country decided to leave the ERM in 1992 (King, 1997). In 2017, the ERM only covered the Danish currency (European Commission, 2017b).

Furthermore, each member state makes financial contributions to the EU budget (European Union, 2017d). However, Prime Minister Margaret Thatcher renegotiated the UK's contributions in 1984 (Wilson, 2014) and the rebate is still in place. The rebate was EUR 6,1 billion in 2015, which reduced the contribution by 34 per cent to EUR 18,2 billion (European Parliament, 2017). The budget determines expenditures and priorities and has to be approved unanimously by leaders of every member country. Many member countries would like to reduce or remove the UK rebate (Kovacevik, 2016) and the mechanisms to correct the budgetary contributions have

been criticised for making the finances more complicated, less transparent, unfair and harder to modify (D'alfonso, 2016).

2.1.2 Integration and centralisation

The EU has also become increasingly centralised. The creation of the LTEU in 2007 was "inspired by" the Constitutional Treaty and most institutional and policy reforms in the Constitution were also included in the LTEU but in diverse forms. The LTEU reformed the EU institutions and changed the decision making processes; strengthened the democratic dimension of the EU; reformed internal policies; and strengthened external policies. Due to the greater number of members of the EU, the voting in the Council under the LTEU is based on a qualified majority and a President and High Representative for Foreign Affairs and Security Policy were created. The LTEU amended the treaties which formed the constitutional basis of the EU (eur-lex.europa.eu, 2015).

Ireland had a referendum regarding the LTEU and rejected the treaty. The UK Labour Party promised a referendum on the Constitution in the UK in the general election but no referendum was held. Some have questioned whether there should have been a referendum in the UK as well before ratifying the treaty due to its considerable changes to the EU (Kirkup, 2008).

Furthermore, the European Commission created a new regulatory framework after the financial crisis. The global financial crisis evolved into the euro debt crisis which, according to the Commission, required a deeper integration of the banking system. The EU institutions agreed to establish a Single Supervisory Mechanism and a Single Resolution Mechanism for banks. In addition to this, the Commission put forward a proposal for a European deposit insurance scheme which would create a more uniform insurance cover in the Banking union. The Banking union applies to countries which have adopted the euro, but non-euro countries also have the possibility to join (European Union, 2015).

According to the European Union (2015) the Banking union was a large step in the integration of the EU and helped restore financial stability. Peston (2012) argues that

the Banking union has centralised decision making power and might be the most significant move towards federalism since the euro debt crisis.

The Banking union is especially relevant for the UK. Magnus, Margerit and Mesnard (2016) explain that London is a major financial centre both in Europe and globally. The revenue from the financial sector accounted for 11 per cent of the UK GDP in 2015 and 24 per cent of all financial services inside the EU. However, the think tank Open Europe (2017) suggests that the biggest potential impact of the Banking union for the UK would be if the framework would impact treaties. Germany has argued for the construction of a new architecture for the euro zone which would require treaty changes.

2.1.3 Balancing interests

The collaboration between the United States (hereinafter U.S) and the UK has been phrased as a special relationship. This special relationship was created during Prime Minister Winston Churchill's regime and some suggest that the UK under Prime Minister Tony Blair supported the U.S in the wars in Iraq, Afghanistan and Kosovo due to this relationship, and hence, risked the UK's relations with the EU by doing so (Porter, 2010).

It has been argued that the UK has struggled to balance its dependence on the U.S and the EU after the union's creation. According to Morris (2016) the country leaned too far away from the interests of the EU and was therefore rejected by the community in the 1960s. In the 1970s, on the other hand, they were too close to the EU and therefore joined on unfavourable terms. After the 1980s there has been a trend of leaning away from Europe again, which is illustrated by the development referred to in this chapter.

2.2 The referendum

The referendum was a matter that cut across political lines. This section will start by describing the purpose behind each of the campaign groups involved in the election and the outcome of the referendum. It will continue by reflecting over the reasoning

behind the outcome, as well as offer some insights about the process of exiting the EU.

2.2.1 The remain campaign

The former Prime Minister David Cameron took a clear stand in the Brexit by leading the campaign to remain. The Prime Minsister was in a precarious situation, leading the campaign against several members of the Conservative Party, as well as members of his Cabinet (Jackson, Akhtar & Mix, 2016). The official campaign on the remain side was 'Britain stronger in Europe' (Noble, 2015) and the Prime Minister spent a great deal of time in the months previous to the election communicating his vision of a stronger UK as part of the EU (BBC News, 2016c).

The remain campaign focused on three central topics. The first one was in regards to jobs and opportunities (Britain Stronger in Europe, 2017a). The campaign claimed that inside the Single Market, businesses had the opportunity to grow and prosper freely which would create more jobs and financial security for the people. They also stated that about 10 per cent of all jobs in the country were directly linked to the EU (Britain Stronger in Europe, 2017b).

The second central point concerned lower prices. The campaign claimed that being part of a union with no tariffs ensured lower prices for several commodities, such as food and fuel. It was also claimed that competition within the EU pressured prices on goods and services, ensuring a bigger selection and higher living standards for Britons. Moreover, they argued that by leaving the EU the country could go into recession (Britain Stronger in Europe, 2017c).

The third central point involved labour rights. EU laws regulate labour rights that cannot be ignored by any government. These regulations were claimed to protect Britain's workers, and by leaving the EU it could become competitive for companies to dissolve these regulations, thus lowering working conditions for employees (Britain Stronger in Europe, 2017d).

2.2.2 The leave campaign

The official campaign group for the leave campaign was 'Vote Leave'. Vote Leave had support and donors from the Conservative Party, the Labour Party and the United Kingdom Independence Party. The purpose of their campaign was to convince voters to vote for the UK to leave the EU so that the UK could instead make a new trade agreement which would be based on free trade (BBC News, 2015).

The first central point of the leave campaign was to halt contributions to the EU budget (Vote Leave, 2017). According to the Economist (2016a) there were claims from those supporting the Brexit that the contribution of the UK to the EU budget was an unfair portion compared to other countries in the EU. Vote Leave (2017) argued that by leaving the EU, savings of GBP 350 million a week could be made.

Another important issue for the campaign was to take back border control, both in regards to national security but also in order to halt unrestricted immigration from the EU. By withdrawing from the EU, the country could decide who would be allowed into the UK on its own terms, based on skills criteria rather than on their nationality (Vote Leave, 2017).

The third central point was in regards to bringing sovereignty back to the UK (Vote Leave, 2017). Some Britons blame the EU for imposing regulations on businesses which potentially hurt their profits and restrict their employment rules. Similarly, some business owners claim that following standardised EU rules for conducting business is sometimes difficult and causes additional strains on their operations (Gordon, S., 2016a).

2.2.3 The outcome of the referendum

On a national level, 51,9 per cent voted for the UK to leave the EU while the remain side received 48,1 per cent, indicating a majority of 1,3 million votes for the leave campaign with a total of 17,4 million to 16,1 million votes. All in all, 46 million people were allowed to vote and the turnout rate was 72,2 per cent (BBC News, 2016d).

On a country level, England and Wales both supported the leave decision with 53,4 per cent and 52,5 per cent respectively. Scotland had high numbers supporting the remain cause, in total 62,0 per cent, while 55,8 per cent of the voters in Northern Ireland voted to remain as well (Hunt & Wheeler, 2017). The strong remain figures in Scotland could be due to several factors. Many Scots who voted to remain in the UK in their independence referendum in 2014 did so for economic reasons and, consequently, because they wanted to remain in the EU and the process of reapplying as a new country looked troublesome (Economist, 2017a). Furthermore, Scots are less concerned about immigration (O'Leary, 2017) and all major political parties in the country supported the remain side in the referendum (Economist, 2016b). Scotland's First Minister described the Brexit as an "undemocratic process" since Scotland voted to stay in the EU. The Minister also expressed that it is likely that a second referendum would be held in regards to Scotland's independence from the UK (Hunt & Wheeler, 2017). The Scottish Parliament approved a second independence referendum on March 28th, 2017 but approval is still required from the UK Government (Dickie, 2017).

2.2.4 The reasons behind the outcome of the referendum

Many politicians as well as financial experts expected the remain side to win. Duff (2016) states that the remain campaign had accused those supporting a decision to leave the union during the campaign for not having a coherent plan in case they actually would win, which he believes to be true. Prime Minister David Cameron had promised to invoke Article 50 of the LTEU if the votes were in favour of doing so, but his government had not made any contingency plan (Duff, 2016). According to the Financial Times (2016), several voters were pushed to the leave side due to frustration at the EU's influence on the UK's policies and laws. Immigration was also a contributing factor, as well as struggling local economies.

However, it was not only domestic factors that influenced the late spur of voters to the leave side. Chris Lockwood, a former advisor to Prime Minister David Cameron, claimed that the EU did not do enough to keep the UK content in the union, especially in regards to immigration-related topics. In the final negotiations with the EU before the referendum, Prime Minister David Cameron managed to put a hold on in-work

benefits for EU migrants. Nevertheless, the EU declined to defer any further on the principle of free movement, which provoked many voters (Mance & Packard, 2016).

The BBC News (2016e) mentions a better run campaign and convincing slogans as the main reasons for the success of the leave campaign. Payne (2016) supports this by suggesting that the leave side was more disciplined, had a better message as well as better front personalities. Furthermore, the remain campaign considered themselves as having the winning argument in terms of the economic advantages, with strong expert opinions such as the International Monetary Fund (hereinafter IMF) and Her Majesty's Treasury (hereinafter HM Treasury) supporting their cause. However, they did not capitalise on the fact that the discussion took new turns, concerning immigration and the inclusion of Turkey into the EU (Payne, 2016).

About two months before the referendum, a HM Treasury report was issued on the topic of the financial implications of leaving the EU. The Chancellor of the Exchequer, George Osborne, also stated to the public that if the UK was to leave the EU, it would be an irreversible step which would cause financial instability and in turn leave the country without an economic plan. This would, according to Osborne, require increased taxes as well as less public spending in order to fill the GBP 30 billion gap that would arise in the national budget (BBC News, 2016f).

Nevertheless, the BBC News (2016f) claims that this was not a popular announcement. As a counter statement, 57 members of the parliament issued a statement in regards to this announcement, which claimed that it was "absurd" to promise to "punish voters" in such a way. Gilbert (2016) argues that Osborne's tactics were wrong too. He states that even though Osborne may have been right about the fact that the Brexit vote could cause an economic shock that would in fact force the government into making adjustments, this was not the way to get the message across.

Another public figure, Mark Carney, the governor of the Bank of England made similar statements in May of 2016. During a presentation of the bank's inflation report, he stated that leaving the EU could force the UK into a "technical recession" and "destabilise financial markets" (Economist, 2016c). While Prime Minister David Cameron said that this warning was a clear message in regards to the dangers of the

Brexit (Robertson, 2016) some found this statement to be of a political nature and thereby compromising the bank's independence as a financial institution (Economist, 2016c).

In addition to these two statements, the IMF claimed in May of 2015 that the Brexit could lead to a stock market crash as well as reduced housing prices. The IMF managing director, Christine Lagard, also supported Mark Carney's claims regarding the financial markets. Lagard concluded that with all possible scenarios of the Brexit, the IMF had yet to find a positive aspect with it. The Vote Leave campaign responded by claiming that the UK Government was involved in these statements since the IMF received funding from both the EU and the UK Government (Inman, 2016).

2.2.5 The process of leaving the EU

Article 50 of the LTEU is the withdrawal clause that applies if a member country of the EU decides to voluntarily withdraw from the union (Article 50:1 LTEU). The Article is invoked when a member country notifies the European Council about its intentions to withdraw. The country then has two years to reach an agreement with the EU in regards to the arrangement of the withdrawal. An agreement is reached if the Council, acting by a qualified majority, has obtained the European Parliament's consent (Article 50:2 LTEU). The country is considered withdrawn when the withdrawal agreement enters into force, but no more than two years after the member state triggered the Article. However, the Council may decide to extend that period unanimously (Article 50:3 LTEU). The member state does not take part in the discussions in regards to the European Council or in decisions concerning the exit (Article 50:4 LTEU) (eur-lex.europa.eu, 2012).

Prime Minister Theresa May, the successor to Prime Minister David Cameron, stated that she intended to trigger the Article by the end of March of 2017. However, the UK Supreme Court ruled that the UK Parliament had to be consulted in the matter (Gostyńska-Jakubowska, 2017). The Parliament approved the bill on March 13th, 2017 and it became an Act of Parliament on March 16th, 2017. Consequently, Prime Minister Theresa May formally invoked the Article on March 29th, 2017 (New York Times, 2017) which was an irreversible act (Economist, 2017b). The negotiations are

complicated and to complete a comprehensive trade agreement in 2 years seems unrealistic (Economist, 2016d).

The Prime Minister also announced a new general election in the UK on April 18th, 2017 and it has been argued that the main reason behind the election was the Brexit. Through the election to be held on June 8th, 2017, some believe that Prime Minister Theresa May hopes to ensure a larger majority in the UK to make it easier to agree on what stance the UK will take in the negotiations with the EU (Economist, 2017c).

2.3 The future relationship

Prime Minister Theresa May invoked Article 50 of the LTEU which started a two year period of negotiations in order to untangle the UK from the EU. During this process, the UK and the EU must decide how they want its future trade relations to be shaped. This section will generate plausible outcomes of such discussions and what potential economic implications these could have for the UK[5]. The plausible outcomes discussed in this chapter will form the basis of a forecasting model which will quantify what impact the Brexit will have on the export of passenger cars from Germany to the UK.

One of the main challenges with the Brexit is that it is an unprecedented event which has caused uncertainty. The Economist (2016e) suggests that the strong decrease in the value of the sterling pound, which has been down almost 20 per cent against the U.S dollar since the referendum, might result in higher inflation. Moreover, Pricewaterhousecoopers (hereinafter PwC) (2016) estimates that the risk premium of the cost of goods will increase due to this uncertainty, which is believed to have a large economic impact in the short run. HM Treasury (2016b) suggests that the process of leaving the EU could bring forth a decade of uncertainty which, consequently, could affect the economy and Gordon, S. (2016b) claims that several businesses in the UK are already starting to feel the impact caused by the uncertainty.

[5] For the purpose of this research report, the section will mainly focus on factors related to the trade in goods. However, the UK has a large financial services industry that could be greatly affected by the Brexit, especially in regards to clearing of euro denominated securities.

The future financial and trade-related uncertainties in regards to the Brexit will depend, to a large extent, on whether the UK would have access to the Single Market. Open Europe (2015) argues that the best case scenario would be for the UK to develop an FTA with the EU. They estimate that the UK GDP would be 1,6 per cent higher in 2030 under such a scenario compared to if they would have stayed in the EU (Open Europe, 2015). Gros (2016) expects that the negative effect of the Brexit on the GDP would be long-term and that this would likely lead to a weaker currency which could positively impact export competitiveness, as well as mitigate the financial impact of leaving the Single Market.

Others are more pessimistic. According to the HM Treasury (2016a), trade would be lower in many goods sectors if the UK would trade under an FTA with the EU. This is due to an estimated negative impact on production which would be restricted by the decreasing inflow of foreign direct investments (hereinafter FDI). Open Europe (2015) has developed a worst case scenario where the UK fails to develop a trade deal and loses access to the Single Market. Under such a scenario, they have estimated that the UK GDP would be 2,2 per cent lower in 2030 compared to if they had stayed in the EU (Open Europe, 2015).

In case the UK would lose access to the Single Market, the Organisation for Economic Co-operation and Development (hereinafter OECD) (2016) estimates that the UK's export would drop by 8 per cent due to its lack of preferential treatment, not just with the EU but also with other trade partners. Supply chains in both the UK and the EU, which have developed over a long time, would become more untangled and production costs could increase for both parties. Similarly, HM Treasury (2016a) has calculated that the UK's total trade quantities would decrease by 17 to 24 per cent by not having access to the Single Market. These figures are also affected by less access to the EU market, as well as not having any FTA with other countries in place.

Moreover, the HM Treasury (2016a) estimates that the total UK trade flows would decrease by 9 per cent over a period of 15 years. During this period, trade flows would first decrease quite dramatically due to the introduction of customs borders towards the EU. After that, when participation into the EEA would take place, it is

estimated that trade with other EEA members would increase from 35 to 53 per cent which would cease the downward spiral.

Finally, OECD (2016) explains that by not being a member of the EU, the UK would not be able to influence EU standards and regulations and regulatory regimes are likely to develop over time. New trade costs could emerge on goods since the UK would be expected to achieve half of the cost savings from the common market if concluding an FTA with the EU. The OECD (2016) also argues that the UK would become less attractive to invest in if they no longer had access to the Single Market. Such consequences could weaken stable investments, decrease the capacity for export and hinder technical innovation and productivity. The FDI could instead be directed to EU members who can ensure access to the Single Market (OECD, 2016).

According to several scholars (HM Treasury, 2016a; PwC, 2016; European Union Committee, 2016), there are three Brexit scenarios that are more likely than others to follow the negotiation with the EU after the invocation of Article 50 of the LTEU:

- UK becomes a member of the EEA;
- UK negotiates a bilateral trade agreement with the EU; or
- UK trades with the EU under WTO terms.

There are also some that argue for a transition deal between the EU and the UK before the negotiations are finalised. The EU has communicated that such an agreement would require the UK to accept the four freedoms and EU rules (MacDonald, 2017).

2.3.1 Membership of the EEA

Being a member of the EEA would entitle the free movement of goods, capital, services and people, and non-member states are treated as members of the Single Market as if they were part of the EU (European Union Committee, 2016). The UK would in this scenario not be a part of the customs union which would enable them to seek other trade partners as well and sign FTAs with them separately (Emerson,

2016). Traditionally, this type of agreement has suited smaller countries such as Norway, Iceland and Liechtenstein (OECD, 2016).

A non-member country must, however, pay into the EU budget. While EEA members do not contribute to the overall budget as EU members do, they are obliged to contribute funds to decrease social and economic disparities, meaning that it is a form of grant to poorer EU members based on the contributor's economic situation (HM Treasury, 2016a). The House of Commons (2013) explains that the UK's net contribution was GBP 128 per capita in 2011 compared to Norway's contribution which was GBP 108 in the same year.

Moreover, regulations set by the EU must also be followed as a member of the Single Market. Legal enforcement is supervised by designated institutions and cannot contradict the EU Court of Justice. Moreover, the UK would not be allowed to take part in future decision making processes in the EU (Emerson, 2016).

One of the advantages of being a member of the EEA would, on the other hand, be that it is a tried and functioning concept, which means that the EU already has experience of it. Such a system would reduce uncertainty since the effect on trade and FDI could be expected in advance and estimated in greater detail (Emerson, 2016). A drawback would, nevertheless, be that UK voters would not have achieved their main targets by voting leave since being a member of the EEA is not compatible with the desire to reduce, for example, immigration (Emerson 2016). Dhingra and Sampson (2016) believe that for a country such as the UK, an EEA membership would be a hard position to attain since they are used to having a strong position in the decision making processes.

2.3.2 Trade under a bilateral trade agreement

Another possible scenario would be to negotiate a bilateral trade agreement with the EU. Emerson (2016) states that one example of such a bilateral agreement is the Comprehensive Economic Trade Agreement (hereinafter CETA) between the EU and Canada. It is an advanced version of a relatively deep trade agreement, mostly limited to the goods sector (Emerson, 2016). The CETA negotiations have taken place for the

past seven years (BBC News, 2016g). The EU has been forced to seek individual approval of the agreement in each member state (Beesley, 2016).

In its quest to promote economic growth, CETA removes most tariffs between the parties as soon as it comes into effect and looks to eliminate all tariffs on industrial products (European Commission, 2017c). This agreement does not involve the free movement of labour, but simplifies the process of European companies transferring part of their workers to Canadian subsidiaries and vice versa (European Commission, 2017c). For solving international disputes, CETA has developed an Investment Court System. This court is an independent court and will therefore not be based on any other courts or tribunals and has representatives from both Canada and the EU (European Commission, 2017c).

A bilateral agreement could reduce most tariffs on goods traded, but the agreements that involve more access to the Single Market usually have the greatest obligations. Under such a scenario, the UK would, therefore, have to accept EU regulations and free movement of people as well (HM Treasury, 2016a).

Nevertheless, the EU has signalled that there may not be any "cherry picking" in the Brexit negotiations. The Single Market, based on the four freedoms, reduces both tariff and non-tariff barriers and are indispensible (Economist, 2016f). There is a fear that if the UK was to get a special deal with the EU, other countries would follow the same path (Grant, C., 2016).

2.3.3 Trade under WTO terms

The third likely scenario would be that the UK would do trade with the EU according to the rules set out by the WTO. According to the Economist (2017d), it would be the scenario that would take place if no other agreement could be reached between the parties (Economist, 2017d). Prime Minister Theresa May has, however, indicated that she is prepared to walk away from any deal, which would result in applying WTO standards, rather than accepting an offer that she does not believe acts in the UK's best interest (Parker & Barker, 2017). Nevertheless, Bown (2016) argues that the

WTO option would put the UK in a situation where they are worse off than being part of a bilateral trade agreement.

The WTO standards are based on the concept of the Most Favoured Nation (hereinafter MFN). This means that all countries have to be treated equally and countries cannot discriminate between trading partners. Hence, if a country would like to change the tariff for one partner it has to change it for all other trading partners as well (World Trade Organization, 2017a). Furthermore, future tariffs and customs are negotiated among member countries of the WTO. According to Beattie (2016), each member has a schedule of commitments that covers its rights and obligations for each agreement, including such sectors as agriculture, industrial goods as well as services, which provides the terms on which the country would trade. Member states of the EU have this negotiated for them (Beattie, 2016) and the WTO exclude most services (Economist, 2016g). Services are an important part of the UK economy, and while they are experiencing a trade deficit in goods, the UK has a surplus in services. As members of the EU, the UK is allowed to set up branches of their businesses anywhere within the union in areas such as banking, law and financial services. All of which would face uncertainties under WTO rules (Bown, 2016).

One of the positive aspects of trading under WTO rules would be that it is argued as being the only existing option that would free the UK from the obligations associated with access to the Single Market (HM Treasury, 2016a). Nevertheless, there are several disadvantages for the UK to operate under WTO rules. The tariffs on some goods could be high. For example, in regards to passenger cars, where the tariffs reach up to 10 per cent (Economist, 2016g). There are many German-manufactured passenger cars in the UK, which could potentially face these high tariffs (Bown, 2016).

2.4 Concluding remarks

The historical relationship

The EU has grown to become a Single Market which eliminates tariff and non-tariff barriers. It has also grown more economically integrated through the creation of the common currency and has increasingly centralised its decision making power. Scholars suggest that the UK has not approved of the development of the EU.

The referendum

The election in regards to whether or not the UK should stay in the EU, took place on June 23rd, 2016 and the leave side won with a margin of 52 to 48 per cent. England and Wales both supported the leave cause, while Scotland and Northern Ireland voted in favour of remaining in the EU. Some of the reasoning behind why the leave side won are derived from a broad discontent with the EU; a better run leave campaign; and a general perception that the remain side, as well as other public figures supporting the remain campaign, engaged in unprofessional argumentation.

The future relationship

Since the UK voted to leave the EU in the referendum, the exit clause under Article 50 LTEU was formally invoked, starting a two year process of leaving the union. The implications of the Brexit for the UK and its trade partners is argued to depend on under what form the UK and the EU will do trade in the future. There are three likely trade-related scenarios that could follow the negotiations with the EU: that the UK becomes a member of the EEA; that the UK negotiates a bilateral agreement with the EU; or that the UK trades with the EU under WTO terms.

These scenarios would involve different tariff rates and, hence, are estimated to impact the UK economy to a different, but large, extent. There is also a political element where there is pressure from the UK population to not accept a trade relationship where the four freedoms of the EU is a prerequisite.

3. Methodology

The purpose of this research report is to project if the Brexit will negatively impact the export quantities of passenger cars from Germany to the UK. A literature review was conducted with a particular focus on the Brexit and likely exit scenarios. Furthermore, a gravity model provided the foundation for a forecasting model that was applied to historical data in order to estimate the impact of the Brexit on passenger car exports under the scenarios identified in the literature review.

This chapter will be structured as follows. It will start by describing the methodology behind the literature collection in regards to the Brexit. It will continue by presenting the research philosophy and approach of this research report and, finally, describe the quantitative model that was applied to the dataset.

3.1 Literature collection

Walliman (2011, p.78) states that no research "appears in a vacuum" and means that a researcher must first decide on a context for the research and understand relevant theories and ideas for the topic.

In order to establish a relevant timeline of events leading up to the Brexit, the authors' main focus was on reputable newspapers and media outlets from the UK such as the Economist, the Financial Times, the BBC News, and Reuters. Secondary data has the advantage of being produced by professional researchers and reduces the need for field work (Walliman, 2011).

Sreejesh, Mohapatra and Anusree (2014) describe two problems when collecting secondary data that the authors faced during this research process. First of all, there can be a lack of relevance in the data, since secondary sources could become irrelevant due to trends or changes in the market place. The authors had to address much irrelevant material for the reasons mentioned, but mainly due to the abundance of information. This was solved through constant discussions about relevancy and importance of inclusion in the timeline of events. The second problem mentioned by Sreejesh, Mohapatra and Anusree (2014) involves inaccurate data which should be

questioned, since errors often occur due to a potential bias of the writer. This was an issue that had to be addressed continuously throughout this research report since some newspapers were openly biased in the matter. Both the Economist and the Financial Times declared support for staying in the EU, even so, they were deemed credible in regards to establishing a timeline. However, great care was taken when articles regarded opinions rather than facts.

Other sources included academic articles, websites and reports. The academic articles were used to add depth when discussing FTAs or the development of the EU, but also to provide a relevant background to the gravity model. Websites from dependable sources, such as the European Commission, were utilised. Lastly, the future estimations in the literature review came from reports published by different sources such as the HM Treasury and the OECD. Consultancies, for example the PwC, were also used. There may be a certain degree of error in all of these estimations and should be considered more as general guidelines than as absolute certainties.

In order to establish the role of the UK and Germany in the international automotive industry, data and statistics were downloaded from the United Nations Trade Statistics Database (Comtrade)[6]. This was complemented with reports and articles to provide a fuller picture.

3.2 Research philosophy

When conducting a research report there are two main paradigms from which the author must choose a philosophical framework: positivism and interpretivism (Collis & Hussey, 2014). According to Burgess, Singh and Koroglu (2006), the paradigmatic stance that is chosen can have an impact on how knowledge is produced throughout the report.

Interpretivism is described as when researchers believe that people search for a deeper understanding of the world that they take part of. Additionally, these people form subjective experiences through their practices. Nevertheless, these experiences can vary from one individual to another and it is up to the researcher to untangle the

[6] See chapter 3.6 Data collection for a detailed review.

complications rather than simply categorise them. Open-ended questions are encouraged and the role of the researcher is to listen and interpret the answers (Cresswell, 2014).

Positivism is, on the other hand, a stance where causes decide outcomes. This means that the problems which are researched under such an approach should recognise the potential causes that could affect outcomes which often take place in different types of experiments (Cresswell, 2014). Furthermore, Raeling (2007) argues that positivists often have the mind-set that knowledge gathered through science is better than that gathered from values and feelings that cannot be tested empirically, due to its loyalty to objectiveness as well as its use of unbiased methods.

The objective of this research report is to measure the impact of the Brexit in regards to passenger car quantities exported from Germany to the UK. A positivistic method was deemed appropriate since such an approach according to Burgess, Singh and Koruglu (2006. p.713) “assumes the unity of the scientific method, searches for causal relationships, believes in empiricism, assumes that science (and its process) is values-free, and views the foundation of science as being based on logic and mathematics”. This combined with Collis and Husseys’ (2014) argument that interpretivism has the underlying assumptions that all findings are value-laden and that the research is subjective, justifies that choice.

Collis and Hussey (2014. p.44) go into more depth by stating that “under positivism, theories provide the basis of explanation, permit the anticipation of phenomena, predict the occurrence and therefore allow them to be controlled". This is, indeed, what has been done in this research report. Through the scenarios discussed in the literature review, the authors have attempted to anticipate different outcomes based on previous literature before testing the available data in a forecasting model which provided more insight in the matter.

3.3 Research approach

As the goal of this research is to shed light on a contemporary issue and little research had been conducted in regards to the unprecedented event in the industry chosen, the authors sought to achieve measurable results through this research report. Walliman (2011) suggests that under a positivistic approach, the most appropriate methods to reach assigned goals are to use mathematical models and quantitative analysis in order to confirm, discard or redefine the hypothesis. One advantage of a quantitative method is that data can be measured accurately since it involves magnitude, usually displayed in numbers. Mathematical models can be applied to analyse data (Walliman, 2011). For the sake of this research report, a quantitative research method was consequently chosen with a gravity model as its foundation.

Quantitative research designs often use a hypothesis as a way of predicting the future outcomes of relationships among variables and, thereafter, tests them. To test a hypothesis, statistical procedures are often used from which the researchers draw conclusions about a population based on a sample (Cresswell, 2014). In order to answer the research question for this research report, the authors developed hypotheses which will be presented in chapter 3.4.1 Hypotheses.

When conducting a research report, there are several research designs that could be appropriate. Nevertheless, in order to categorise the research design utilised in this research report, the authors used the classification by Wacker (1998). According to him, there are two major classifications of research which are presented as analytical and empirical research. Analytical research uses deductive methods to arrive at theories while empirical uses inductive. The research in this report is considered to be analytical due to its deductive nature. Collis and Hussey (2014) describe deductive research as methods where a theoretical and conceptual structure is established and tested empirically.

3.4 The model

The gravity equation is a commonly used model in economics. The gravity model has been argued as being a successful tool to estimate international trade (Anderson, 1979), a general framework to examine trade patterns (Eichengreen & Irwin, 1995) and one of the most "empirically successful" trade analytical tools in economics (Anderson & van Wincoop, 2003, p.170). The theoretical foundation of the model has been established by several scholars such as Linnemann (1966); Bergstrand (1985); Evenett and Keller (2002); and Anderson and van Wincoop (2003).

The gravity model estimates bilateral trade flows where trade is positively related to the GDP levels of the trading partners and negatively related to the distance between them. In the model, bilateral trade flows are based on the mutual gravitation force between the nations with the gravity variable GDP reflecting mass. In addition to the traditional standard model, several modifications can be made and dummy variables added (Chi & Kilduff, 2010). The gravity model has been widely used to estimate factor movement of bilateral trade flow effects from international borders (Anderson & van Wincoop, 2003) and trade agreements (Rose, 2004). In addition to its applications to international trade, it has been used in quantitative analysis of migration flows (Karemera, Oguledo & Davis, 2000), investments (Brenton, di Maurio & Lücke, 1999) and market area analysis (Baker, 2000).

The gravity model was first applied to international trade in the work of Nobel laureate Tinbergen (1962) who conducted an econometric study using the gravity model where the model included FTAs as a dummy variable. Since then, several scholars have estimated the effect that the European Community has had on bilateral trade flows among its members (Balassa, 1967; Aitken, 1973; Abrams, 1980; Brada & Mendez, 1985; Frankel, Stein & Wei, 1995). Nevertheless, the traditional gravity model often refers to the models developed by Anderson (1979) who contributed to establishing a theoretical foundation for the gravity model whereby one of his models based utility on the constant elasticity of substitution preferences and goods that were differentiated by origin.

Many authors have tried to incorporate transportation costs into the gravity model. Baier and Bergstrand (2001) distinguished the relative effects of transportation cost reductions, tariff liberalisation and other variables. Their study showed that the mean logarithmic growth of trade overall increased in their sample and that tariff rates had a larger impact on trade growth than transportation costs. Anderson and van Wincoop (2004) discussed trade costs in detail in their widely cited work and argued that all costs are not directly observable but that the total cost, consisting of distribution and international trade, is substantial and differs greatly between countries. This is in line with Hummels (2001, p.25) who concluded that transportation costs constitute a large trade barrier and that trade costs can be categorised into three groups: "explicitly measured costs (freight and tariffs); costs captured by proxies; and unmeasured costs". Anderson (2011) suggested, based on the work by McCallum (1995), that the border dummy variable in the model reflected the impact of multilateral resistance, while Feenstra (2002) argued that the multilateral resistance terms are not generally observable, but that fixed effects related to the importer and exporter can replace them.

Baier and Bergstrand (2001, p.6) suggest that Bergstrand (1985) showed that the potential distribution costs were "captured formally by a constant-elasticity-of-transformation function that allows each country's producer to treat export supplies to each market as imperfect substitutes". Baier and Bergstrand (2001) also reckon that Anderson (1979) and Bergstrand (1985) introduced trade barriers explicitly in their models. Both of them made, according to Baier and Bergstrand (2001, p.6), "bilateral trade flows influenced by the absolute level of bilateral transaction costs and the level of bilateral transaction costs relative to an income weighted average of the exporter's bilateral costs to all markets".

There is little academic agreement in terms of which variables to include in the gravity equation, and which ones that should be omitted (Yamarik & Ghosh, 2005). Anderson and van Wincoop (2003) add that bias can appear in both the estimation and the analysis through omission of the wrong variables. Still, academics believe that trade data tests empirically well in the gravity model (Feenstra, 2002) and the model has gained popularity among empirical trade literature (Yamarik & Ghosh, 2005).

The gravity equation is derived as a reduced form from a general equilibrium model of international trade in final goods. According to Chi and Kilduff (2010) the original gravity model in international trade is defined as:

$$T_{ij} = A \times \left(\frac{Y_i \times Y_j}{D_{ij}} \right) \quad \textbf{(1)}$$

where the variables are defined as follows:

T_{ij} trade flow from country *i* to country *j*;
Y_i GDP of country *i*;
Y_j GDP of country *j*;
D_{ij} physical distance between country *i* and country *j*; and
A is a constant.

Nevertheless, according to Bergstrand (1985) the gravity model in international trade commonly takes the form:

$$T_{ij} = \beta_0 (Y_i)^{\beta_1} (Y_j)^{\beta_2} (D_{ij})^{\beta_3} (A_{ij})^{\beta_4} \mu_{ij} \quad \textbf{(2)}$$

where the parameters to be estimated are denoted by β and the variables are defined as follows:

T_{ij} trade flow from country *i* to country *j*;
Y_i GDP of country *i*;
Y_j GDP of country *j*;
D_{ij} physical distance between country *i* and country *j*;
A_{ij} other factor(s) either aiding or resisting trade between country *i* and country *j*;
μ_{ij} and a logarithmic-normally distributed error term with E(ln μ_{ij}) = 0.

The gravity equation is normally specified in a double-logarithmic form and estimated with Ordinary Least Squares (hereinafter OLS) (Eichengreen & Irwin, 1995), although there are some exceptions to this general practice. Anderson and van

Wincoop (2003) used an approach to incorporate the multilateral resistance index that resulted in that the parameters became nonlinear and, hence, estimated it using a nonlinear OLS method. Furthermore, the OLS method is considered inappropriate when zero trade flows are recorded and could be measured by a maximum likelihood model (Baier & Bergstrand, 2007) or tobit (Chen, 2004). Santos Silva and Tenreyro (2006) claim that OLS could be inappropriate and leads to inconsistent estimates in the presence of heteroscedasticity and suggested using a poisson pseudo maximum-likelihood method instead (Santos Silva & Tenreyro, 2006). On the other hand, Martin and Pham (2015) argue that tobit is an appropriate method in a tobit-based data generation process when there are zeroes in the dataset and heteroscedasticity is controlled. Another practice to overcome the issue of zeroes is to construct a semi-logarithmic form, but this is considered difficult to interpret (Eichengreen & Irwin, 1995).

Despite the fact that the gravity model applied to aggregate trade flows is popular, the empirical studies on specific products are relatively few (Chi & Kilduff, 2010). Balassa (1967) suggests that the total trade is of limited interest since the aggregate results may provide results that differ from individual commodities and commodity groups.

3.4.1 Hypotheses

Hypotheses were formulated in order to guide the quantitative analysis undertaken in this research report:

H_0: The Brexit will not impact the export quantities of passenger cars from Germany to the UK.

H_1: The Brexit will negatively impact the export quantities of passenger cars from Germany to the UK.

3.5 Research design

The effect of independent variables was estimated on historical export quantities of passenger cars in number of units. A logarithmic technique was used to convert the gravity equation in this research report and the relationship between the export of passenger cars and the variables included in the model were established using a regression technique.

3.5.1 Sample

This research report used a sample consisting of all countries to which Germany exported more than 1 000 passenger cars in the designated year and data was available. Country *i* denoted Germany and country *j* the import country. The total sample consisted of more than 80 observations per year and was collected in a non-random manner. Furthermore, there was an element of selection bias by the authors where poor countries were excluded from the sample[7]. The dataset included approximately 98 per cent of the total export quantity of passenger cars from country *i* in 2015, 2014, 2013 and 2012. Appendix A presents the full list of trade partners, country *j*, which were included and excluded from the dataset in the gravity model and the quantities they represented of the total export quantity.

3.5.2 Variables

The independent variables in the gravity model initially included GDP of country *i* and country *j*; GDP per capita of country *i* and country *j*; population of country *i* and country *j*; the geographical distance between the trade partners; the quality of logistics in country *j*; and the import tariff on passenger cars moving from country *i* to country *j*. In addition to these, the gravity model included a number of dummy variables controlling for EEA membership; if country *j* had direct access to the sea; country adjacency; and if they shared a common language. An intercept vector and an error term were also included in the model. The choice of relevant variables was made by reviewing the work by, for example, Aitken (1973); Rose (2004); and Chi and Kilduff (2010) who have performed similar studies to this research report.

[7] See chapter 4.3.2 Further data analyses for a detailed review.

GDP and population. GDP was included based on the argument that exporting nations' GDP measures productive capacity, while the importing countries' GDP provides a measure of absorptive capacity (Tinbergen, 1962). The rationale behind including the GDP of country *i* was that export capacity is related to GDP where a higher income, everything else being equal, results in more exports (Abrams, 1980; Aitken, 1973). The rationale behind including the population of country *i* was that export market population is a proxy for market size. Based on the concept of scale economics, the larger the population is, the more efficient is market production (Aitken, 1973). The GDP of country *j* was assumed to impact the demand for imports (Abrams, 1980). The potential import demand in this research report was set by GDP and population as described by Aitken (1973).

Production. Production is often concentrated near its largest markets to minimise transportation costs and by concentrating production, companies may realise scale economies. As a result, countries tend to export products of which they have a "relatively large domestic demand" (Krugman, 1980, p.955). The concept 'home market effect' was established by Krugman (1980) and implied a link that did not exist in trade models that were based solely on comparative advantage. Built on his work, Hanson and Xiang (2004) discussed how the industry character impacts the level of the home market effect and concluded that trade with large transport costs and low replacement elasticity are inclined to concentrate in larger countries which, they argued, is directly related to the level of product differentiation.

Production levels in country *i* and country *j* were initially included in the gravity model. However, due to lack of data for a sufficient sample and the presence of multicollinearity, the parameter β could not be measured in a reliable and robust manner.

GDP per capita. GDP per capita for both country *i* and country *j* were included based on the Linder hypothesis. The Linder hypothesis was established by Linder (1961) and suggests that countries that have similar demand structures trade more with each other than dissimilar countries and that greater inequality has a negative effect on trade. Bergstrand (1990) argues that the relationship is present in both the supply structure, based on the Heckscher-Ohlin theorem, as well as in the demand structure,

such as in the work by Linder (1961).

Distance. Geographical distance is often treated as a proxy for transportation cost and several scholars have proved that bilateral trade flows decrease with increased distance between partners (for example, see Linnemann (1966)). Disdier and Head (2008) conducted a quantitative analysis on the distance effect and found that bilateral trade is nearly inversely proportionate to physical distance. In their dataset, an average increase of distance by 10 per cent reduced the trade between the parties by approximately 9 per cent. Chi and Kilduff (2010, p.509) explain that "a historical trend shows that geographical distance has a statistically significant and negative impact on imports as transportation costs and convenience favour closer relationships and sourcing". A distance variable was included in the model in this research report.

Total logistics costs. Due to the advancement of logistics-related technology, distance as a proxy for transportation costs has been questioned and total logistics costs argued as being more appropriate. On the other hand, for example, Disdier and Head (2008) showed that the effect of geographical distance has not declined in more recent data, indicating that technological changes has not caused a decline or reduction of the impact of distance. Distance represents resistance to trade which "has an economic element, consisting of transportation and information costs; a structural element reflecting differences in consumption patterns and resource endowments as, for example, between temperate and tropical countries; and a policy element including the effects of economic integration" (Brada & Mendez, 1985, p.550).

However, to reply to the critics, the model used in this research report also initially included a proxy for infrastructure, namely the total span of the motorway network in line with the description by Bougheas, Demetriades and Morgenroth (1999). Nevertheless, due to the characteristics of the car trade, it was later modified and the liner shipping connectivity index was used instead to reflect how connected country *j* was to the global container network. However, since the liner shipping connectivity index is null for countries which do not have direct access to the sea, and that cars often are shipped by ships with other characteristics, the variable was later replaced by a dummy variable for country *j*'s direct access to the sea. In addition to that, it included the logistics performance index reported by the World Bank (2017b).

Tariffs. All countries profit from less barriers to trade (Eaton & Kortum, 2002) and reductions of tariffs have been argued to explain about 26 per cent of the growth of trade in OECD countries between the late 1950's and the late 1980's (Baier & Bergstrand, 2001). A variable reflecting the tariff rate was included in the model.

Language commonality and country adjacency. In addition to these variables, the gravity model initially included several dummy variables. Language commonality was included to show whether country *i* and country *j* shared a language or cultural similarity (Frankel, Stein & Wei, 1995) since this makes trade easier (Bougheas, Demetriades and Morgenroth, 1999). When two countries share a language, it increases trade "substantially" (Havrylyshyn & Pritchett, 1991, p.6). In addition to the language commonality variable, the model also included a border effect dummy variable. Aitken (1973, p.882) argues that neighbouring countries can be expected to trade more with each other due to "similarity of tastes and an awareness of common interests".

EEA. Most economists argue that international trade should be free (Rose, 2004). However, the regional integration of the EU has the "potential to harm participants through trade diversion or nonparticipants nearby through worsened terms of trade" (Eaton & Kortum, 2002, p.1743). This study included a dummy variable for membership of the European Community. Baier and Bergstrand (2001) explain that it might seem unnecessary to include dummy variables to reflect preferential trade agreements (hereinafter PTA), yet, the PTA might lead to greater trade beyond the effect of no tariffs.

In summary, the proposed gravity equation was specified as follows:

$$\begin{aligned}\ln(EX_{ij}) = \alpha &+ \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(D_{ij}) + \beta_4 \ln(POP_i) \\ &+ \beta_5 \ln(POP_j) + \beta_6 \ln(GDPCAP_i) + \beta_7 \ln(GDPCAP_j) \\ &+ \beta_8 \ln(TARIFF_{ij}) + \beta_9 \ln(LOGIS_j) + \beta_{10} CA_{ij} \\ &+ \beta_{11} LC_{ij} + \beta_{12} EEA_j + \beta_{13} SEA_j + e_{ij}\end{aligned} \quad \textbf{(3)}$$

where the parameters to be estimated were denoted by β and the variables were defined as follows:

EX_{ij}	export of passenger cars from country *i* to country *j*, in units;
GDP_i	GDP of country *i*, in current USD;
GDP_j	GDP of country *j*, in current USD;
D_{ij}	physical distance between the trade centre in country *i* and country *j*, in kilometres;
POP_i	total population of country *i*;
POP_j	total population of country *j*;
$GDPCAP_i$	GDP per capita of country *i*, in current USD;
$GDPCAP_j$	GDP per capita of country *j*, in current USD;
$TARIFF_{ij}$	tariff rate that country *j* imposes on passenger cars from country *i*;
$LOGIS_j$	quality of logistics of country *j*;
CA_{ij}	country adjacency, a dummy variable with a value of 1 if country *j* shares a common border with country *i*, 0 otherwise;
LC_{ij}	common language, a dummy variable with a value of 1 if country *j* shares an official language with country *i*, 0 otherwise;
EEA_j	European Community, a dummy variable with a value of 1 if country *j* is a member of the European Community, 0 otherwise;
SEA_j	direct access to the sea, a dummy variable with a value of 1 if country *j* has direct access to the sea, 0 otherwise; and
e_{ij}	the error term.

3.5.3 Regression technique

A logarithm technique was used to convert the gravity model in this research report. The logarithm of exports of passenger cars from country *i* to country *j* in terms of number of units was the dependent variable. A value of 1 was not added before taking logarithms. Although adding 1 is a popular approach (for example, see Eichengreen and Irwin (1995)), it is inappropriate (Santos Silva & Tenreyro, 2006). The relationship between the export quantity of passenger cars and the variables included in the model was established using an OLS regression method. The method was considered suitable since the sample did not include any observations of zero trade flows and the equation was additive and linear.

MS Excel, SPSS and STATA were the statistical software used in this research report. MS Excel provided the basis due to its availability and flexibility, but the results were controlled for by using SPSS and STATA. Furthermore, several estimations were considered unfeasible to perform in MS Excel, and therefore, were complemented by estimations from SPSS and STATA.

3.5.4 Expected results

The variables that were predicted to impact demand included: GDP_j; POP_j; $GDPCAP_j$; CA_{ij}; LC_{ij}; and SEA_j. The variables expected to impact supply were: GDP_i and POP_i. The variables expected to impact transportation and logistics-related costs, hence the resistance terms, were: D_{ij}; $LOGIS_j$; $TARIFF_{ij}$; and EEA_j.

The passenger car exports from country *i* to country *j* were predicted to have a positive relationship to GDP, GDP per capita and population. A higher GDP and population in country *j* were expected to lead to a higher demand and consequently benefit passenger car exports from country *i* to country *j*. A higher GDP and population in country *i* were expected to increase the production capacity. Moreover, that a more similar GDP per capita between country *i* and country *j* would benefit trade based on the Linder hypothesis was also expected. Hence, the coefficients GDP_j, POP_j, $GDPCAP_j$ as well as GDP_i, POP_i and $GDPCAP_i$ were expected to positively impact bilateral export quantities.

The physical distance between the trade partners was expected to have a depressing effect on trade quantities reflecting higher transportation costs. The quality of logistics was expected to reduce transportation costs and consequently facilitate more trade. Hence, the variable D_{ij} was expected to be negatively correlated to bilateral export quantities and $LOGIS_j$ and SEA_j to be positive.

Tariffs, country adjacency and preferential market access could have an effect on trade quantities. The authors expected that preferential access to the import market would positively affect export quantities of passenger cars.

3.6 Data collection

According to Sreejesh, Mohapatra and Anusree (2014) the data collection process should preferably be conducted in two stages. There should be a pre-testing phase followed by the study itself. During the pre-testing phase, data should be gathered from a subsample in order to test if the data is deemed relevant for the study. In the case of this research report, that meant identifying relevant variables necessary to run the regression analysis successfully in order to establish the coefficients for the forecasting model.

The pre-testing phase can reduce errors from occurring in the actual study since the second step should be to decide how to organise the gathered data and decide whether or not the results of the pre-test are good enough to use when proceeding to the real test[8] (Sreejesh, Mohapatra & Anusree, 2014).

3.6.1 The gravity model

The independent variables in the pre-testing phase of the gravity model with the dependent variable trade included GDP of country *i* and country *j*; GDP per capita of country *i* and country *j*; population of country *i* and country *j*; the distance between the trade partners; the quality of logistics in country *j*; and the tariff on passenger cars moving from country *i* to country *j*. In addition to these, the gravity equation included a number of dummy variables controlling for EEA membership; if country *j* had

[8] See chapter 4.1 Systematic elimination of variables for a detailed review.

direct access to the sea; country adjacency; and if they shared a common official language.

Trade. The export and import quantities of passenger cars from country *i* to country *j* were collected from the United Nation's (2017a) database[9]. For the purpose of this research report, data was extracted using the 4th version of the Harmonized Commodity Description and Coding System (hereinafter HS) which is an international nomenclature. Countries that participate in this system can categorise traded goods through a common basis in order to simplify customs operations. The six-code system consists of goods classified by different granularity and was introduced in 1988, but has been revised several times since (United Nations Statistics, 2017a).

Moreover, the commodity code HS 8703 Passenger cars was used to calculate imported and exported quantities of passenger cars. The total quantities were based on the consolidated amount for all countries and not what the database refers to as *world* in line with the suggestion made by the United Nations Statistics (2017b). Due to confidentiality related issues, some countries do not report data on lower commodity code levels (United Nations Statistics, 2017b). Hence, this research report used the highest commodity code granularity level of which quantity was reported.

Furthermore, there are bilateral asymmetries in trade data where the reported export does not equal the reported import in the United Nations's (2017a) database. It is a familiar occurrence in official statistics and could be explained by several reasons: the criteria of partner attribution in import and export statistics have been applied inconsistently; the value of goods are recorded differently; the usage of different trade systems in data collection; time lag; goods being classified differently; or goods passing through third countries (United Nations Statistics, 2017c). To overcome this issue, the forecast by segment in this research report reported the results in regards to both the import of passenger cars into the UK from Germany, and export of passenger cars from Germany to the UK.

[9] See United Nations Statistics (2010) and United Nations Statistics (2013) for a detailed review about data sources, methodology and limitations of the Comtrade database.

The United Nations (2017a) provides information in regards to quantity, weight and value of trade. This research report has used quantities to measure international trade flows to overcome valuation and currency conversion issues. According to the United Nations Statistics (2010, p.45) quantities "provide a reliable indicator of international movements of goods". Furthermore, "the use of appropriate quantity units may also result in more internationally comparable data on these movements, because differences in quantity measurements between the importing country and the exporting country can be less significant than in value measurements".

The trade figures reported by the United Nations (2017a) includes trade in foreign goods, commonly referred to as re-export or re-import. Re-export is export of goods in the same state as previously imported and the trade data is included in the total export figure also presented by the United Nations (2017a). That goods are re-exported could be because of, for example, defects or cancellations of orders (United Nations Statistics, 2017d) and countries are encouraged to record the distinction (United Nations Statistics, 2010). However, this research report utilised the total export without subtracting for the re-export figures since differences in reporting practises were assumed based on the data pattern.

GDP and population. GDP, population and GDP per capita of all countries were collected from the World Bank (2017a). GDP referred to GDP at purchaser's prices in USD[10]; population the total population which was based on mid-year figures for all residents regardless of legal status or citizenship; and GDP per capita the two parameters divided (World Bank, 2017a).

The World Bank relies on international and regional sources such as the United Nations (2017b), Eurostat by the European Commission (2017d) and Prism (2017). The World Bank also uses national statistics gathered from census reports and other national sources which mean that they are reliant on those individual countries to

[10] GDP at purchaser's prices is the "sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars. Dollar figures for GDP are converted from domestic currencies using single year official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used" (World Bank, 2017c).

provide updated statistics[11]. Countries which did not report their national statistics were excluded from the sample.

Distance, country adjacency and access to the sea. Distance was measured from the capital city of country *i* to the capital city of country *j* as suggested by Yamarik and Gosh (2005) or through the "great circle distance" from the location where the largest port was situated in country *i* to the location of the largest port of country *j* (Smarzynska, 2001, p.4). The choice of measurement method was made on a country-by-country basis where countries north of Turkey or located in Europe were assumed to transport cars by land and the others by sea. If country *j* lacked a port and was assumed to transport cars by sea, the distance was measured from the capital city of country *j* to the closest port, and from the closest port to the largest port of country *i*. The measurements were made through Google Maps (2017) and Marinetraffic (2017). Google Maps (2017) was also the source of countries that country *i* shared a border with and whether country *j* had direct access to the sea.

Quality of logistics. The overall quality of logistics was reported by the World Bank (2017b). The overall quality was measured based on a survey where respondents rated countries based on several logistics performance criteria. The core components of the logistics performance quality are: "the efficiency of customs and border clearance"; "the quality of trade and transport infrastructure"; "the ease of arranging competitively priced shipments"; "the competence and quality of logistics services"; "the ability to track and trace consignments"; and "the frequency of which shipments reach consignees within scheduled or expected delivery times" (World Bank, 2014, pp.51-52). The index is only available every second year, hence, the index for 2012 was applied to the models for 2012 and 2013 and the index for 2014 was applied in 2014 and 2015. The variable was based on the country with the highest index value being the benchmark.

The quality of logistics was adjusted in the following manner:

[11] See World Bank (2017a) for detailed review in regards to data sources, methodology and limitations of the World Bank database.

$$LOGIS_j = \left(\frac{x_j}{x_i}\right) \times 100 \qquad (4)$$

where the variables were defined as follows:

$LOGIS_j$ quality of logistics of country *j* in year *t*;

x_j observed quality of logistics in country *j* in year *t*; and

x_i observed quality of logistics in the country with the highest index value in year *t*.

Tariffs. The MFN tariff rates for HS 8703 Passenger cars were downloaded from the World Trade Organization (2017b). The rates were presented as applied MFN tariff rates in weighted averages based on the sub-categories of HS 12 8703 Passenger cars. The data was compared to all of EU's PTAs and if there was a deviation, the bound rate in the PTA was applied. In case HS 8703 was not specifically referred to in a PTA, the applied MFN tariff rate presented by the World Trade Organization (2017b) was utilised.

Moreover, the latest updated tariff rates were assumed to be valid in years following it. If country *j* reported a tariff rate *x* for HS 8703 in year *t* this rate was applied in year $t + 1$ and $t - 1$ in case there was no other tariff rate presented. If there was a change of tariff rate *x* in $t + 1$, the tariff rate *z* was applied in $t + 1$ and all years following it. If tariff rate *x* was introduced and came into effect in $t - 1$, tariff rate *y* was applied in all years before $t - 1$, and tariff rate *x* in year $t - 1$ and all years following it. A value of 1 was added to all tariff rates so that logarithms could be applied.

Language commonality. The countries that shared an official language with country *i*, either as their first language or where it was recognised as an official language, was gathered from the CIA (2017).

EEA. Membership of the EEA included all member countries of the EU or EFTA and was collected from the European Union (2017b).

3.6.2 The forecasting model

The forecasted GDP figures were extracted from the statistical database OECD (2017) in forecasted form. The forecasts in the absence of the Brexit contained forecasted GDP data without making any further adjustments. However, the GDP in the scenarios were additionally adjusted for by the estimated GDP changes the different scenarios were expected to have in case of a potential Brexit. These estimated GDP changes were based on a report from the OECD (2016) where the institution presented GDP forecasts based on different severities, namely an optimistic scenario, a central scenario and a pessimistic scenario. The OECD (2016) only presents one GDP forecast for 2020 but the forecasted GDP for 2030 were based on all three severities. Consequently, this research report has estimated the impact of the Brexit in 2020 under a central scenario and in 2030 based on an optimistic scenario, a central scenario and a pessimistic scenario.

3.7 Reliability and validity

When conducting a research report, it is essential to take the reliability and the validity into consideration. The concept of reliability addresses how accurate the performed research is and whether or not the measurements are precise. In positivistic studies, replication is an important factor. This means that if the study is performed again, the same output should be expected (Collis & Hussey, 2014).

For a research report to be generalizable, meaning that the results can be used outside the report itself, it is important to look at both internal and external validity. Internal validity concludes whether or not the notions regarding cause and effect have support from the study itself (Walliman, 2011). In order to avoid risking the internal validity, Cresswell's (2014) methodology for dealing with validity issues was used. This methodology involved identifying the main threats and having countermeasures for them. One main threat that was identified by the authors was that participating countries in the model had certain characteristics that could skew the outcomes in one direction or another. A countermeasure to this was to analyse the leverage of the

observations[12]. Another threat that was identified was that due to the fact that the model was evolving during the research process, it could have changed between the pre-test and the actual test, which could have affected the outcome. This was addressed by keeping the final pre-test and the actual test exactly the same.

3.7.1 Generalizability

One of the main advantages of a quantitative research design is that it provides reliable results which are often generalizable to a larger population. External validity refers to just that, how well the results of the research report can be applied to the general population (Walliman, 2011). The ability of research to become generalizable is subject to the researcher's ability to distinguish the relevant factors from the irrelevant ones during the research process (Walliman, 2011). This was addressed by having a large sample size consisting of approximately 98 per cent of all passenger cars exported from country *i*. The model was tested in several years and proved to present consistent results.

However, the gravity model has some weaknesses that makes it hard to generalize its results. Most importantly, since the variables included in the model change depending on the objective of the research, it is not possible to conduct comparative statistical exercises (Anderson & van Wincoop, 2003). The data analysis in this research report is, consequently, case-specific. The regression was made in the context of export of passenger cars from country *i,* denoting Germany, to country *j,* denoting the import partners, and could be applied if estimating the export of passenger cars to all of country *i*'s trade partners. It is also the authors' perception that the model could be generalized to export of cars from a country with similar characteristics to country *i* in Europe. The regression analysis has included a large share of the export quantity of passenger cars from country *i* and the results have been proven consistent in several years. This justifies and supports its robustness and validity.

[12] See chapter 4.3 Diagnostic tests – the sample for a detailed review.

3.8 Concluding remarks

This research report was of a positivistic character and categorised as analytical. A literature collection was conducted in order to obtain a holistic overview of the Brexit and the potential future scenarios. A gravity model provided the foundation for a forecasting model in order to estimate the impact of the Brexit on the export of passenger cars from Germany to the UK under the scenarios identified in the literature review. The gravity model is widely used in trade theory and considered to be one of the most empirically successful trade analytical tools in economics.

The gravity equation

Several financial, trade and logistics-related regressors were tested in relation to the export of passenger cars from country *i* to country *j* in terms of number of units in order to evaluate how they affected the results and each other. A logarithmic technique was used to convert the gravity model in order to analyse it econometrically. The relationship between the export of passenger cars from country *i* to country *j* and the regressors included in the model were, moreover, established by using an OLS regression technique. Country *i* denoted variables related to Germany and country *j* variables related to the import partners.

The variables

The independent variables in the gravity model initially included GDP of country *i* and country *j*; GDP per capita of country *i* and country *j*; population of country *i* and country *j*; the distance between the trade partners; the quality of logistics in country *j*; and the tariff on passenger cars moving from country *i* to country *j*. In addition to these, the gravity equation included a number of dummy variables controlling for EEA membership; if country *j* had direct access to the sea; country adjacency; and if they shared a common language. The choice of relevant variables was made by reviewing the work by, for example, Aitken (1973); Rose (2004); and Chi and Kilduff (2010) who have performed similar studies to this research report.

4. Analysis

The purpose of this research report was to estimate if the Brexit would negatively impact the export quantities of passenger cars from Germany to the UK. A systematic elimination of variables from the initial equation was performed to establish the final gravity equation and diagnostic tests of the final equation were conducted. This chapter will start by presenting the systematic elimination of variables and introduce the gravity equation of which the forecasting model was based on. It will continue by presenting the diagnostic tests in regards to the model, and finally, report the analysis in regards to the sample and observations.

4.1 Systematic elimination of variables

All variables included in the model went through scrutiny. They were examined on an individual level through their interaction with each other to clarify their place in the model. Based on the suggestions of Yamarik and Ghosh (2005) the core of the gravity model was based on GDP and distance but a variety of variables were initially considered for inclusion. The model was initially run with the variables GDP of country *i* and country *j*; GDP per capita of country *i* and country *j*; population of country *i* and country *j*; the distance between the trade partners; the quality of logistics in country *j*; and the import tariff of passenger cars moving from country *i* to country *j*. In addition to these, the gravity equation included a number of dummy variables controlling for EEA membership; if country *j* had direct access to the sea; country adjacency; and if they shared a common language. Greene (2003) stresses that choosing the right variables is important since including irrelevant ones can lower the precision of the model while not including one that is important could include bias in the estimates.

An econometric problem can occur when the dependent variable is a component of one of the regressors. “By an accounting identity” the regressors in the model could “be correlated with the disturbance term” (McCallum, 1995, p.619). The dependent variable, export of passenger cars from country *i* to country *j*, was a component of GDP of country *i* and consequently GDP of country *i* was removed. GDP per capita and population for country *i* were also removed since they were strongly correlated

with GDP.

The results from the regressions with the remaining variables are displayed in Table 1. In line with the approach presented by Yamarik and Ghosh (2005) variables were added or removed from the regression equation one by one to see how they affected the overall model to determine the final equation.

Table 1. Systematic elimination of variables

	(1)	(2)	(3)	(4)	(5)	(6)
GDP$_j$	0,676	0,681	0,667	0,675	0,677	0,760
	(0,189)	*(0,185)*	*(0,181)*	*(0,180)*	*(0,179)*	*(0,061)*
Distance$_{ij}$	-0,376	-0,371	-0,311	-0,329	-0,361	-0,369
	(0,118)	*(0,114)*	*(0,100)*	*(0,098)*	*(0,066)*	*(0,063)*
Tariff$_{ij}$	-4,182	-4,189	-4,321	-4,263	-4,230	-3,958
	(0,986)	*(0,982)*	*(0,970)*	*(0,956)*	*(0,946)*	*(0,863)*
Logistics$_j$	2,261	2,247	2,154	2,194	2,266	1,988
	(0,831)	*(0,819)*	*(0,800)*	*(0,796)*	*(0,779)*	*(0,450)*
Population$_j$	0,085	0,083	0,095	0,086	0,081	
	(0,160)	*(0,158)*	*(0,155)*	*(0,155)*	*(0,153)*	
EEA$_j$	0,079	0,087	0,119	0,111		
	(0,243)	*(0,238)*	*(0,234)*	*(0,232)*		
Common language$_{ij}$	0,636	0,614	0,362			
	(0,135)	*(0,132)*	*(0,145)*			
Country adjacency$_{ij}$	-0,392	-0,401				
	(0,222)	*(0,219)*				
Direct access to the sea$_j$	0,058					
	(0,136)					
Observations	84	84	84	84	84	84
- of total export quantity	0,981	0,981	0,981	0,981	0,981	0,981
Significance F	0,000	0,000	0,000	0,000	0,000	0,000
R Square	0,866	0,866	0,864	0,863	0,862	0,862
Adjusted R Square	0,849	0,851	0,851	0,852	0,854	0,855

Note: Robust error terms are displayed in parentheses.

The dummy variables representing direct access to the sea and EEA membership were excluded due to their low impact on the overall explanatory power of the regression. Almost all countries in the dataset had access to the sea. Moreover, the dummy

variable EEA was removed since it was strongly correlated with distance and tariffs which suggested that the trade-creating benefits of membership in the European Community was captured by other regressors.

The two remaining dummy variables - common language and country adjacency - were excluded as well, mainly since they were statistically insignificant. Lastly, the population of country *j* was removed due its low correlation with the dependent variable, its high correlation to GDP and, therefore, its low overall impact on the model.

The remaining independent variables after conducting the systematic elimination included GDP of country *j*; geographical distance between country *i* and country *j*; import tariffs; and the quality of logistics of country *j*. The variable $TARIFF_{ij}$ was added by 1 so that the logarithms could be applied. The variable $LOGIS_j$ of country *j* was based on the country with the highest index value as defined in equation (4).

The final gravity model, denoted (6) in Table 1, was defined as:

$$\ln(EX_{ij}) = \alpha + 0{,}760\ln(GDP_j) - 0{,}369\ln(D_{ij}) - 3{,}958\ln(TARIFF_{ij}) + 1{,}988\ln(LOGIS_j) + e_{ij} \quad \textbf{(5)}$$

or more specifically:

$$\ln(EX_{ij}) = \alpha + 0{,}760\ln(GDP_j) - 0{,}369\ln(D_{ij}) - 3{,}958\ln(TARIFF_{ij} + 1) + 1{,}988\ln\left(\left(\frac{x_j}{x_i}\right) \times 100\right) + e_{ij} \quad \textbf{(6)}$$

where the variables were defined as follows:

EX_{ij} export of passenger cars from country *i* to country *j*, in units;

GDP_j GDP of country *j*, in current USD;

D_{ij}	physical distance between the trade centres in country *i* and country *j*, in kilometres;
$TARIFF_{ij}$	tariff rate that country *j* imposes on passenger cars from country *i*; and
$LOGIS_j$	quality of logistics of country *j*.

A confidence interval of 95 per cent was used to test the model. All variables were statistically significant, the results were consistent over several years and contributed to the overall explanatory power of the model. Hence, the variables were considered robust and efficient in measuring the impact of the Brexit.

4.2 Diagnostic tests – the model

The final gravity model defined through systematic elimination and expressed in equation (6) was further analysed in regards to the regression technique utilised.

The OLS linear regression analysis has four assumptions: there should be a linear or an approximately linear relationship between the independent and dependent variables; there should be no multicollinearity between the regressors; no heteroscedasticity should be present in the dataset; and the assumption of a normal distribution of errors should roughly hold[13] (Montgomery, Peck & Vining, 2012).

4.2.1 Linear relationship

The relationship between the dependent variable and the regressors was tested for using scatter diagrams and in a correlation matrix. As stated by Wegman (1990) a scatter diagram allows detection of structures such as linear or nonlinear features. All covariates in the final equation had a linear or an approximate linear relationship with the dependent variable, however, outliers were present[14]. Table 2 presents the Pearson's correlation for 2015 for all variables included in the final analysis and Figures 1 to 4 show the results graphically.

Table 2. Pearson's correlation

	Exported quantity$_{ij}$	**GDP$_j$**	**Distance$_{ij}$**	**Tariff$_{ij}$**	**Logistics$_j$**
Exported quantity$_{ij}$	1,000	0,745	-0,334	-0,285	0,765
GDP$_j$	0,745	1,000	0,127	0,225	0,581
Distance$_{ij}$	-0,334	0,127	1,000	0,482	-0,241
Tariff$_{ij}$	-0,285	0,225	0,482	1,000	-0,206
Logistics$_j$	0,765	0,581	-0,241	-0,206	1,000

[13] In time-series regression analyses, the data should also lack autocorrelation. This research report was not based on time-series data, nevertheless, a Durbin-Watson test was performed by the authors out of curiosity. Utilising a significance of α = 0,05 the range was defined at d_L = 1,53 and d_U = 1,74. According to Greene (2002) the inconclusive region is large if T is small or moderate. Based on Montgomery, Peck & Vining (2012) the authors concluded that the test was inconclusive since $d_L \leq d \leq d_U$.

[14] See chapter 4.3 Diagnostic tests – the sample for a detailed review.

Figure 1. Linear relationship – Logistics

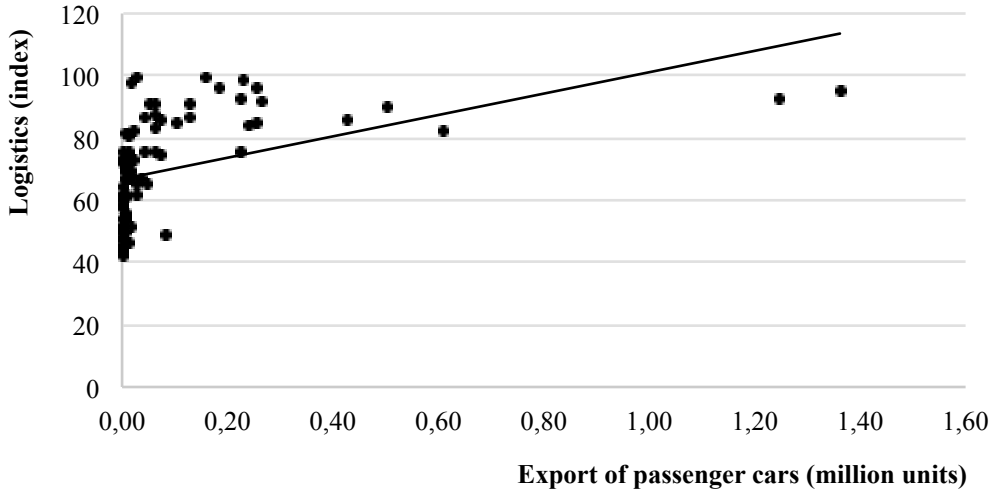


Figure 2. Linear relationship – Tariffs

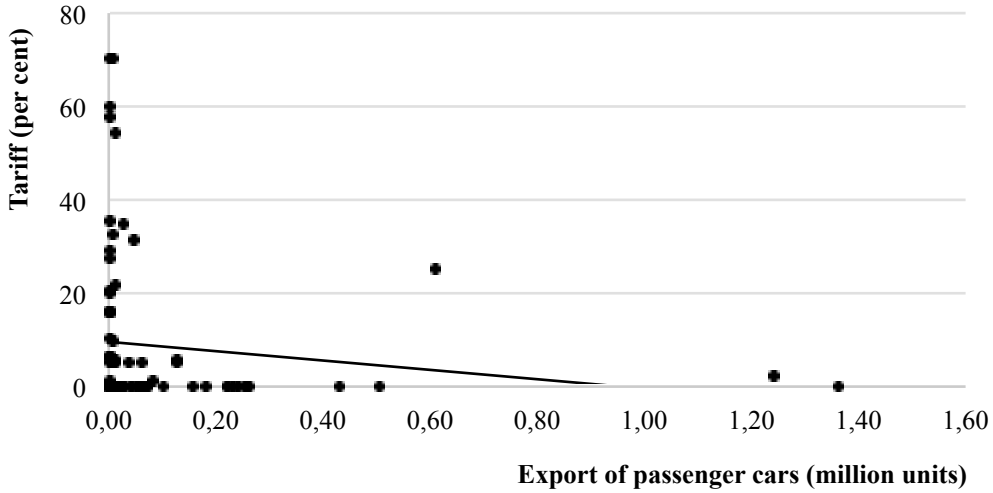


Figure 3. Linear relationship – Distance

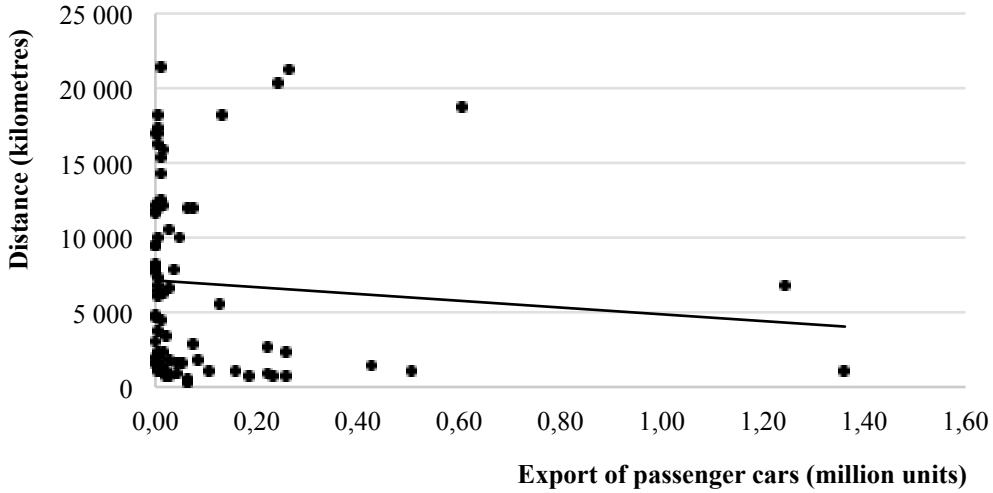
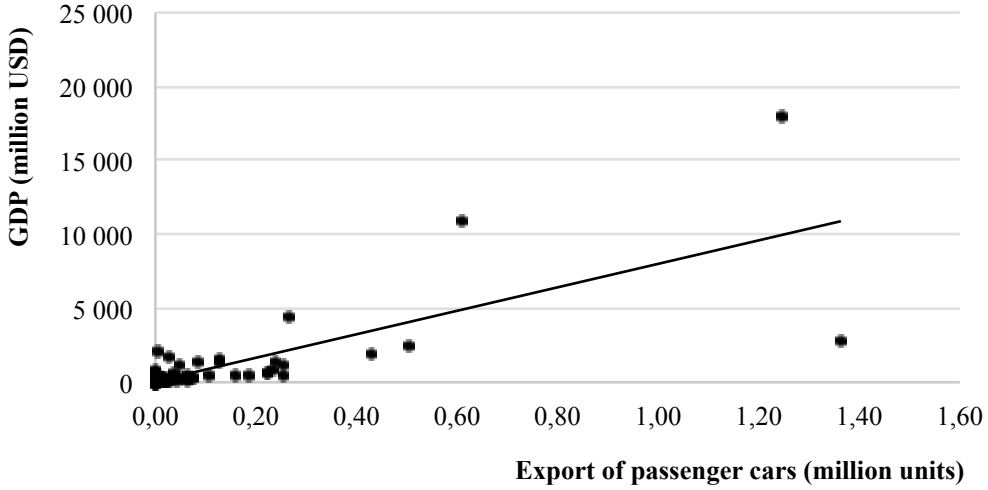


Figure 4. Linear relationship – GDP



4.2.2 Multicollinearity

There are several ways to test for multicollinearity. Nevertheless, authors such as O'Brien (2007) test it through the Variance Inflation Factor (hereinafter VIF).

According to Montgomery, Peck & Vining (2012) VIF is defined as:

$$VIF_k = \frac{1}{(1 - R_k^2)} \qquad (7)$$

where the variables are defined as follows:

VIF_k VIF for coefficient *k* in year *t*; and

R_k the coefficient of multiple determination of coefficient *k* in year *t*.

It is an indication that the coefficient has been seriously affected by multicollinearity if VIF $>$ 10 (O'Brien, 2007). Table 3 reports VIF for each variable in the dataset. All coefficients for all years tested in this research report had values lower than 3 which suggest that multicollinearity was absent in the dataset.

Table 3. Variance Inflation Factors

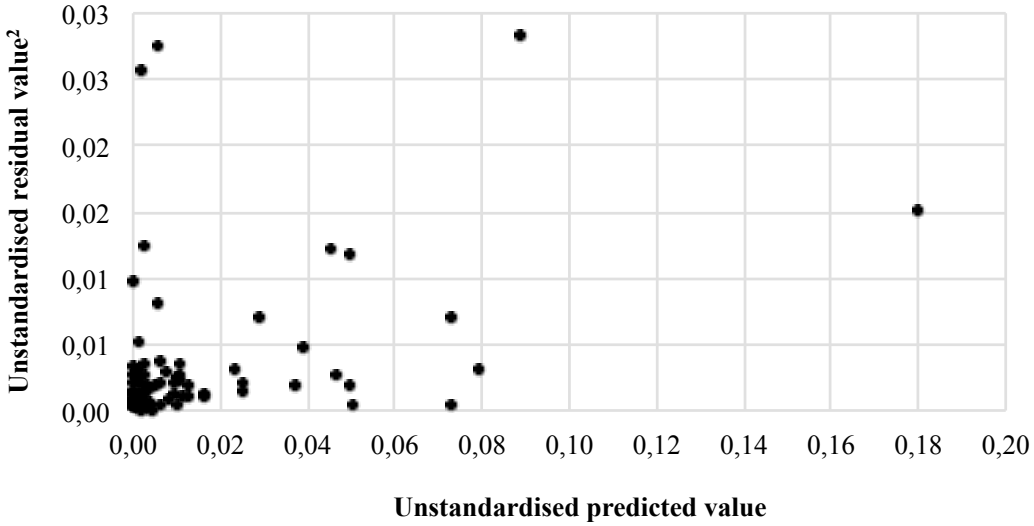
	2015	2014	2013	2012
GDP_j	1,918	1,877	1,615	2,595
$Distance_{ij}$	1,381	1,375	0,992	1,004
$Tariff_{ij}$	1,482	1,447	1,844	1,222
$Logistics_j$	1,953	1,976	1,740	2,151

4.2.3 Homoscedasticity

There are also several approaches to analyse homoscedasticity in datasets. For example, by observing a scatterplot of the squared residuals in relationship to the unstandardised predicted values, heteroscedasticity can be detected. Figure 5 presents the result from the scatterplot. The initial analysis indicated that the data in the dataset was violating the assumption of homoscedasticity.

The Breusch-Pagan (1979) and the White (1980) tests were conducted to confirm the indication from the graph. Both of these tests had probability values of less than 0,05 and heteroscedasticity was assumed in the sample. Robust error terms were introduced to deal with this in line with the approach suggested by Huber (1967) and White (1980).

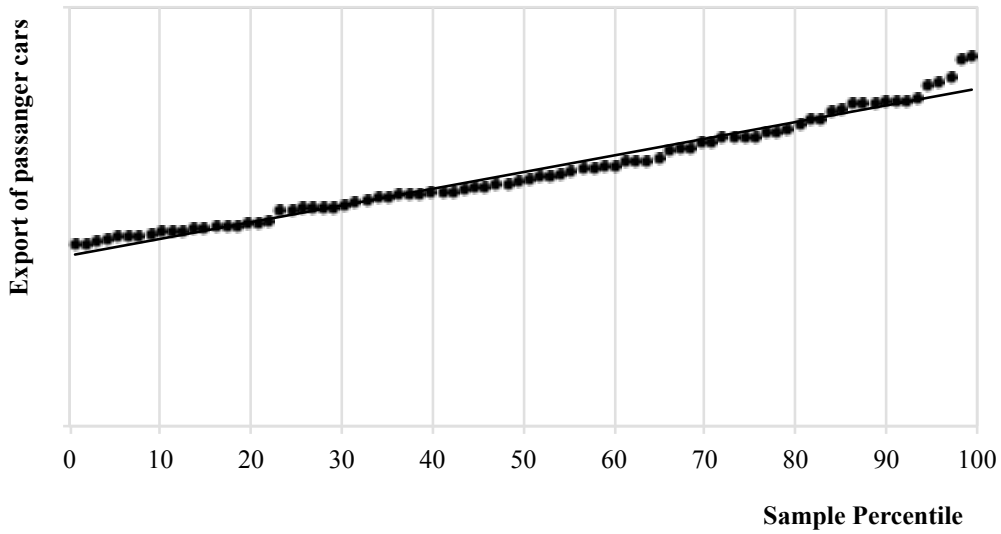
Figure 5. Heteroscedasticity



4.2.4 Normal distribution

A commonly used method to test for normality is by analysing Q-Q plots (Liang, Pan & Yang, 2004). The authors checked the variability in the dataset by comparing the normal distribution to that of the dependent variable. Figure 6 presents the probability output graphically. The graph suggests that the sample was normally distributed.

Figure 6. Normal distribution



4.3 Diagnostic tests – the sample

All countries that country *i,* denoting Germany, exported more than 1 000 passenger cars to in the designated year were included in the dataset with the exception of those that had insufficient data. The final dataset included approximately 98 per cent of the total quantity of exported cars from country *i* for all years measured.

4.3.1 Outliers and leverage

Aggarwal and Yu (2011) define outliers as one or more data points that differ from the rest of the dataset and there were some data points present which differed from the overall pattern. To validate if the outliers had leverage, the final sample was tested for by using Cook's distance in line with the approach presented by Cook (1977). The observations were also analysed in regards to leverage[15].

Cook's distance is defined in general form by Montgomery, Peck and Vining (2012, pp.215-216):

[15] See Montgomery, Peck and Vining (2012) for a detailed review in regards to definitions and theorems referred to in this chapter.

$$CD_i = (\mathbf{M}, c) = \frac{(\widehat{\boldsymbol{\beta}}_{(i)} - \widehat{\boldsymbol{\beta}})'\mathbf{M}(\boldsymbol{\beta}_{(i)} - \widehat{\boldsymbol{\beta}})}{c} \quad \textbf{(8)}$$

where $\widehat{\boldsymbol{\beta}}$ consists of all n observations and the "usual choices of **M** and c are $\mathbf{M} = \mathbf{X}'\mathbf{X}$ and $c = pMS_{Res}$". Because $\boldsymbol{W}\widehat{\boldsymbol{\beta}}_{(i)} - \boldsymbol{W}\widehat{\boldsymbol{\beta}} = \widehat{\boldsymbol{y}}_{(i)} - \widehat{\boldsymbol{y}}$ the equation may be formulated:

$$CD_i = \frac{(\widehat{\boldsymbol{y}}_{(i)} - \widehat{\boldsymbol{y}})'(\widehat{\boldsymbol{y}}_{(i)} - \widehat{\boldsymbol{y}})}{pMS_{Res}} \quad \textbf{(9)}$$

where the variables are defined as follows:

CD_t Cook's distance of the sample in year *t*;
$\widehat{\boldsymbol{y}}$ vector of the least squared estimate of all observations;
$\widehat{\boldsymbol{y}}_{(i)}$ vector of an observation (*i*=1, 2,…,*n*); and
$pMS_{Res}$the number of regressors multiplied by the marginal square.

$CD_t > 1$ is normally considered to be influential on the estimation since $F_{0,5,p,n-p} \simeq 1$ (Montgomery, Peck & Vining, 2012). All observations in the dataset for this research report had a Cook's distance of less than 1.

Moreover, leveraged observations are identified through matrix algebra where the diagonal elements of the hat matrix **H** are defined as:

$$h_{ii} = \boldsymbol{x}_i'(\mathbf{X}'\mathbf{X})^{-1}\boldsymbol{x}_i \quad \textbf{(10)}$$

where the variables are defined as follows:

h_{ii} diagonal elements of a hat matrix **H**; and
$\boldsymbol{x}_i'$ the i^{th} row of the **X** matrix.

The average size of the hat diagonal is $\bar{h} = \frac{p}{n}$. An observation is traditionally considered to have leverage if the hat diagonal exceeds twice the average size of the hat diagonal, that is $2\frac{p}{n}$ (Montgomery, Peck & Vining, 2012).

Table 4 presents the results from the calculations that were related to outliers. The calculations indicated that there were outliers present and that some of the observations had leverage.

Table 4. Diagnostic tests – the outliers

	Minimum	Maximum	Mean	Standard deviation
2015				
Cook's distance	0,000	0,180	0,014	0,027
Centred leverage value	0,005	0,168	0,048	0,033
2014				
Cook's distance	0,000	0,138	0,015	0,027
Centred leverage value	0,007	0,251	0,050	0,040
2013				
Cook's distance	0,000	0,165	0,015	0,029
Centred leverage value	0,007	0,249	0,048	0,039
2012				
Cook's distance	0,000	0,131	0,014	0,025
Centred leverage value	0,005	0,250	0,048	0,038

4.3.2 Further data analyses

To validate how the leveraged observations impacted the sample and whether the sample was robust, another diagnostic test was conducted and the results are displayed in Table 5. The choice of suitable robustness tests was influenced by Rose (2004). The 1st sample (1) excluded 3σ outliers. The 2nd sample (2) excluded 2σ outliers. The 3rd sample (3) included only those reported as *high income* countries by the World Bank (2017d). The 4th sample (4) included only those reported as *upper middle* income countries by the World Bank (2017e). The final sample (5) included

only those reported as *lower middle* income countries by the World Bank (2017f) [16].

The results from the diagnostic test indicated that excluding outliers increased the explanatory power of the regression analysis and reduced the variability of the dataset, however, excluding outliers did not impact the coefficients to a very large extent. To split the model based on income level increased the explanatory power of the regression analysis in the case of rich countries, denoted (3) in Table 5, and influenced some coefficients, most notably, increased the impact of GDP and reduced the impact of tariffs. Aggarwal and Yu (2001) argue that outliers could contain important evidence of irregular activities which the data describes and, hence, should remain in the dataset. All observations in this research report remained in the sample which provided the foundation of the forecasting model.

Table 5. Diagnostic tests – the sample

	(1)	(2)	(3)	(4)	(5)
GDP_j	0,779	0,820	0,861	0,756	0,302
	(0,057)	*(0,050)*	*(0,055)*	*(0,121)*	*(0,319)*
$Distance_{ij}$	-0,356	-0,379	-0,356	-0,767	-0,518
	(0,061)	*(0,059)*	*(0,071)*	*(0,193)*	*(0,306)*
$Tariff_{ij}$	-3,938	-3,488	-2,560	-1,809	-2,648
	(0,857)	*(0,673)*	*(2,530)*	*(0,908)*	*(2,187)*
$Logistics_j$	1,867	1,810	1,177	3,440	2,742
	(0,435)	*(0,393)*	*(0,708)*	*(1,116)*	*(3,515)*
Observations	83	80	45	25	13
- of total export quantity	0,980	0,980	0,822	0,149	0,010
Significance F	0,000	0,000	0,000	0,000	0,466
R Square	0,877	0,908	0,937	0,793	0,331
Adjusted R Square	0,871	0,903	0,931	0,752	-0,004

Note: Robust error terms are displayed in parentheses.

[16] The total sample was chosen in a non-random manner. Since GDP of country *j* was correlated with the export of passenger cars from country *i* to country *j*, there was an element of selection bias of the authors where poor countries were excluded from the sample. However, the purpose of the regression analysis was to provide the foundation of a forecasting model applied to the UK, so consequently, this element was not considered to limit the analysis.

4.4 Concluding remarks

In order to evaluate whether the gravity model was robust and would act as an efficient foundation for the forecasting model, a systematic elimination of variables as well as diagnostic tests were conducted. This chapter analysed the variables, the regression technique and the sample.

The variables

Variables were systematically eliminated in order to finalise the model. After extensive modelling, the remaining independent variables included GDP of country *j*; geographical distance between country *i* and country *j*; the import tariff; and the quality of logistics of country *j*. All regressors were statistically significant, consistent over several years and contributed to the overall explanatory power of the model. Hence, the variables were considered robust and efficient in measuring the impact of the Brexit.

The technique

An OLS regression technique was utilised in order to calculate the gravity equation which is a model that is based on several assumptions which, consequently, were tested for diagnostically. The tests indicated that there was heteroscedasticity present in the dataset and robust error terms were introduced in line with the suggestions by Huber (1967) and White (1980) to address the issue.

The sample and observations

The sample and observations were tested diagnostically as well. The results from the analysis suggested that the impact of different independent variables could differ depending on the characteristics of country *j* which were not captured in the final gravity model. Furthermore, outliers were present in the dataset and was suggested to have leverage. The results from the diagnostic tests indicated that excluding outliers increased the explanatory power of the regression analysis and reduced the variability of the dataset, however, excluding outliers did not impact the coefficients to a very large extent. All observations remained in the sample of the final gravity equation.

5. Results

The purpose of this research report was to project if the Brexit would negatively impact the export quantities of passenger cars from Germany to the UK. A double-logarithmic gravity equation was established based on historical trade data and provided the foundation for a forecasting model. This chapter will present the results from this data modelling.

It will start by reporting the results from the gravity equation and continue by presenting the rationale behind and results from the forecasting model. Furthermore, it will apply the forecasted quantities on the current market structure to estimate the effect that the Brexit is projected to have with greater granularity.

5.1 The forecasting model

The independent variables in the final gravity equation included GDP of country *j*; the overall quality of logistics of country *j*; geographical distance between country *i* and country *j*; and the tariffs of passenger cars. A double-logarithmic technique was utilised to convert the final gravity model in this research report to constant elasticity in order to analyse it econometrically. According to Greene (2002) the approach is often used to forecast demand or production.

Moreover, a confidence interval of 95 per cent was applied. The results from the final gravity model were statistically significant and explained 85,5 to 88,5 per cent of the variability of the export quantities. The sample consisted of all countries to which country *i* exported more than 1 000 units in the designated year and data was available. Hence, the sample size represented approximately 98 per cent of the total number of exported passenger cars from the export country. Table 6 presents the consolidated results from the gravity model by year.

Table 6. Results from the gravity model

	2015	2014	2013	2012
GDP_j	0,760	0,804	0,839	0,812
	(0,061)	*(0,057)*	*(0,055)*	*(0,064)*
$Distance_{ij}$	-0,369	-0,296	-0,287	-0,303
	(0,063)	*(0,064)*	*(0,062)*	*(0,060)*
$Tariff_{ij}$	-3,958	-3,576	-3,799	-4,039
	(0,863)	*(0,693)*	*(0,687)*	*(0,537)*
$Logistics_j$	1,988	1,955	1,522	1,587
	(0,450)	*(0,461)*	*(0,479)*	*(0,475)*
Observations	84	80	83	84
- of total export quantity	0,981	0,976	0,976	0,975
Significance F	0,000	0,000	0,000	0,000
R Square	0,862	0,879	0,879	0,890
Adjusted R Square	0,855	0,873	0,873	0,885

Note: Robust error terms are displayed in parentheses. All variables are in logarithms and are statistically significant.

The coefficients established in the gravity model for 2015 were applied to the forecasting model. Based on the gravity equation, defined in equation (6), a short term forecast was conducted, quantifying the effect that the Brexit is expected to have in 2020, as well as a long-term forecast, which quantified the effect that the Brexit is estimated to have in 2030. The forecasts were further broken down into different severities, reflecting the scenarios discussed in previous literature, and compared to scenarios in absence of the Brexit. In the forecasting model, country *i* denoted variables related to Germany and country *j* variables related to the UK.

The estimated GDP changes were built on a report by OECD (2016) which presented GDP forecasts based on different severities, namely an optimistic scenario, a central scenario and a pessimistic scenario[17]. The tariff rate in the pessimistic scenario in this research report was based on the MFN rate in the absence of a PTA; the central scenario was based on the most popular tariff rate in the dataset that was greater than 0; and the optimistic scenario did not apply any tariff.

[17] See chapter 3.6 Data collection for a detailed review.

In summary, the scenarios in 2020 were specified as follows:

2020 - Nothing changes: estimated a GDP reduction of 0,00 per cent and a tariff rate of 0,00 per cent. The scenario was supposed to reflect a development in which the UK did not exit the EU. It could also reflect a transition agreement.

2020 - Central scenario: estimated a GDP reduction of 3,30 per cent and a tariff rate of 5,00 per cent. The tariff rate was meant to reflect a semi-beneficial scenario and could be the tariff applied if the UK would negotiate a bilateral agreement with the EU.

The scenarios in 2030 were specified as follows:

2030 - Nothing changes: estimated a GDP reduction of 0,00 per cent and a tariff rate of 0,00 per cent. This was supposed to reflect a scenario in which the UK would not exit the EU.

2030 - Pessimistic scenario: estimated a GDP reduction of 7,70 per cent and a tariff rate of 9,70 per cent. The tariff rate was based on the MFN rate and the scenario could reflect trade under the WTO terms.

2030 - Central scenario: estimated a GDP reduction of 5,14 per cent and a tariff rate of 5,00 per cent. The tariff rate was meant to reflect a semi-beneficial scenario and could be the tariff applied if the UK would negotiate a bilateral agreement with the EU.

2030 - Optimistic scenario: estimated a GDP reduction of 2,72 per cent and a tariff rate of 0,00 per cent. This was supposed to reflect a scenario in which the UK remained in the Single Market.

The forecasts in the absence of the Brexit contained forecasted GDP data without making any further adjustments. However, under the Brexit scenarios, the forecasted GDP data was adjusted by the projected GDP reductions under the scenarios.

The GDP of country *j,* the UK, was adjusted in the following manner:

$$GDP_f = s_t \times (1 - x_f) \quad \textbf{(11)}$$

where the variables were defined as follows:

GDP_f forecasted GDP for country *j* under scenario *f*;

s_t forecasted GDP for country *j* in the absence of the Brexit; and

x_f forecasted GDP reduction for country *j* under scenario *f*.

Moreover, the distance in kilometres between London and Berlin was used; the value of 1 was added to the tariff rate; and the quality of logistics in 2016 was applied to all scenarios, no matter year and severity.

Based on equation (6) identified in the systematic elimination of variables and adjusted for equation (11), the forecasting model was defined as:

$$\begin{aligned} ln(EX_{ij}) = \alpha &+ 0{,}760 \ln(s_t \times (1 - x_f)) - 0{,}369 \ln(D_{ij}) \\ &- 3{,}958 \ln(TARIFF_{ij} + 1) + 1{,}988 \ln\left(\left(\frac{x_j}{x_i}\right) \times 100\right) \\ &+ e_{ij} \end{aligned} \quad \textbf{(12)}$$

5.1.1 Forecasted quantities

The results from the forecast showed that if there were to be no Brexit or a transition deal without changes to the current agreement would be negotiated, Germany would export 1,3 million passenger cars to the UK in 2020. Nevertheless, if the Brexit would occur and a 5,00 per cent tariff would be applied, the quantities would decrease by 7,73 per cent which represents about 102 000 passenger cars.

The forecast for 2030 was based on three different scenarios. The pessimistic scenario projected that Germany would export 15,39 per cent less cars to the UK than if no Brexit would occur; the optimistic scenario would lead to 0,92 per cent less exported

cars compared to a scenario in the absence of the Brexit; and the central scenario would lead to a reduction of 9,20 per cent exported passenger cars from Germany to the UK.

Hence, all Brexit scenarios would lead to lower export quantities of passenger cars from Germany to the UK in terms of number of units compared to if the UK would have stayed in the EU. Table 7 shows a consolidated view of the findings from the forecast, that is, the estimated impact of the Brexit on the export of passenger cars from Germany to the UK.

Table 7. Results from the forecasting model

	2020	Impact (+/-)	2030	Impact (+/-)
No Brexit				
Nothing changes	1 316 383		1 431 375	
Brexit				
Pessimistic scenario			1 211 136	-15,39%
Central scenario	1 214 595	-7,73%	1 299 636	-9,20%
Optimistic scenario			1 418 246	-0,92%

Note: The impact from the Brexit is calculated based on the scenarios in absence of the Brexit.

In summary, based on a model including GDP, distance, tariffs and the quality of logistics – capturing demand factors and logistics-related costs – there is a clear preference for trading without tariffs in terms of trade of passenger cars. However, all Brexit scenarios are estimated to reduce the German export quantities compared to if no Brexit would occur. The Brexit is projected to negatively impact the UK GDP which is positively correlated to export quantities of passenger cars from Germany and consequently estimated to offset the benefits from trading without tariffs.

5.2 The market

The projected impact of the Brexit was further applied to the current market structure by market segment and by brand. The forecasted quantities defined in equation (12) will be denoted EX_f in what follows.

5.2.1 Forecasted quantitates by market segment

The database provided by the United Nations (2017a) reports conflicting figures for import and export quantities[18]. All data presented in this section was therefore applied to two different datasets. The first dataset used the forecasted quantities in regards to the exports from Germany and the second dataset used the difference between the forecasted and observed figures and adjusted the import quantities accordingly.

The import quantities were converted to forecasted quantities in the following manner. Based on equation (12), the difference between the observed and forecasted quantities was first calculated under all scenarios:

$$Z_f = \frac{(EX_t - EX_f)}{EX_t} \qquad \textbf{(13)}$$

where the variables were defined as follows:

Z_f the difference between the observed export quantities and the forecasted export quantities under scenario *f*;
EX_t observed export quantities from country *i* to country *j* in year *t*; and
EX_f forecasted export quantities from country *i* to country *j* under scenario *f*.

Secondly, the difference between the observed export quantities and the forecasted export quantities defined in equation (13) was applied to the observed import quantities to establish forecasts under all scenarios.

[18] See chapter 3.6 Data collection for a detailed review.

The forecasted import quantities were calculated by:

$$IM_f = IM_t \times Z_f \quad \textbf{(14)}$$

where the variables were defined as follows:

IM_f forecasted import quantities from country *i* to country *j* under scenario *f*;

IM_t observed import quantities from country *i* to country *j* in year *t*; and

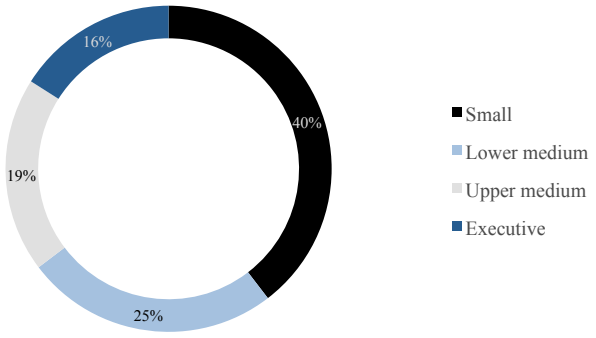
Z_f the difference between the observed export quantities and the forecasted export quantities under scenario *f*.

The forecasted export quantities and forecasted import quantities were thereafter applied to the current market structure. The European Automobile Manufacturers Association (hereinafter ACEA) presents figures in regards to new car registrations by market segment in the UK. ACEA (2017a) categorises cars in four different segments, namely *small, lower medium, upper medium* and *executive*. The segments refer to the categorisation by the European Commission (2017e) where, for example, *lower medium* corresponds to segment C and *executive* to segment E (ACEA, 2017b). Figure 7 presents the passenger car registrations in the UK in 2016 by market segment.

According to the trade association Society of Motor Manufacturers and Traders (hereinafter SMMT) (2017), who provides a detailed overview of the UK market, Volkswagen Polo was among the most popular *small* cars[19]; Volkswagen Golf and Audi A3 in the *lower medium* segment; BMW 3 Series, BMW 4 Series and Audi A4 in the *upper medium* segment; and Mercedes-Benz C-Class, Mercedes-Benz E-Class, BMW 5 Series and Audi A6 in the *executive* segment.

[19] As defined by ACEA (2017a)

Figure 7. Market segments



Source: Authors based on ACEA (2017a)

In order to forecast the export of passenger cars from Germany to the UK by market segment, the market shares of each market segment were converted to percentages and multiplied by the forecast. The forecasted export quantities by market share, where the forecasted total quantities were defined in equation (12), were calculated in the following manner:

$$M_f = EX_f \times \left(\frac{r_j}{R}\right) \quad \textbf{(15)}$$

The forecasted import quantities by market share, where the forecasted total quantities were defined in equation (14) based on equation (13), were defined as:

$$M_f = IM_t \times \left[\frac{(EX_t - EX_f)}{EX_t}\right] \times \left(\frac{r_j}{R}\right) \quad \textbf{(16)}$$

or simplified:

$$M_f = IM_f \times \left(\frac{r_j}{R}\right) \quad \textbf{(17)}$$

where the variables were defined as:

M_f forecasted quantities for market segment *j* under scenario *f*;

EX_f forecasted export quantities from country *i* to country *j* under scenario *f*;

IM_f forecasted import quantities from country *i* to country *j* under scenario *f*;

r_j observed number of registered cars for market segment *j* in year *t*; and

R observed total number of registered cars in year *t*.

Table 8 summarises the findings from the modelling by segment which assumed that all parts of the market would be equally affected by the Brexit, that the German export/UK import have the same market share in all segments and that the market shares of each part of the market would be identical in the future[20].

Table 8. Forecasted quantities by market segment

	2020	Impact (+/-)	2030	Impact (+/-)
No Brexit				
Small	519 820		565 228	
Lower medium	329 559		358 348	
Upper medium	253 879		276 057	
Executive	210 021		228 367	
Brexit				
Pessimistic scenario				
Small			478 259	-86 969
Lower medium			303 211	-55 137
Upper medium			233 581	-42 476
Executive			193 230	-35 138
Central scenario				
Small	479 625	-40 195	513 206	-52 022
Lower medium	304 077	-25 483	325 367	-32 981
Upper medium	234 248	-19 631	250 649	-25 407
Executive	193 781	-16 240	207 349	-21 018
Optimistic scenario				
Small			560 044	-5 184
Lower medium			355 061	-3 287
Upper medium			273 525	-2 532
Executive			226 273	-2 095

Note: The impact from the Brexit is calculated based on the scenarios in absence of the Brexit.

[20] The estimates are based on great simplifications of the reality and should, hence, be interpreted as guidelines rather than absolute figures.

The calculations showed that the *small* segment would register 40 195/29 454 less cars with German origin in 2020 in the central scenario compared to if there would not be any Brexit. In 2030, the pessimistic scenario shows a loss of 86 969/63 729 passenger cars compared to if no Brexit would occur; the central scenario a reduction of 52 022/38 120 cars; and the optimistic scenario a decline of 5 184/3 799 passenger cars.

5.2.2 Forecasted quantities by brand

Four of the largest German brands in the UK by market share are Volkswagen, BMW, Audi and Mercedes-Benz[21] (Statista, 2017). However, not all production of these cars takes place in Germany and there are also other brands being produced in Germany such as Ford and Opel/Vauxhall (ACEA, 2015) both of which have significant market shares in the UK (Statista, 2017). Hence, to assume that all German brands in the UK market were assembled in Germany and that all cars shipped from Germany were German would be flawed. Moreover, Germany has one of the largest ports in Europe and cars produced in other countries could well be exported from Germany.

Nevertheless, this section of the market analysis will attempt to clarify what effect the Brexit could have on brands based on the current situation. It was assumed that 80 per cent of all newly registered passenger cars in the UK with the brands BMW, Volkswagen, Mercedes-Benz and Audi were exported from Germany; that the market shares by month in the UK in 2016 will be identical to the market shares in 2020 and 2030; and that the effect of the Brexit will be the same on all cars across market segments. Consequently, the following analysis will not make a distinction between export and import figures.

The extracted market shares by brand were re-calculated as total number of units, summarised by year and then converted to market shares. This process was conducted to re-calculate monthly market shares to annual market shares by brand. The annual

[21] According to ACEA (2015) there were three assembly plants of passenger cars in the UK relevant for this analysis. BMW Group is assembling the Mini in Cowley; BMW Group assembling Rolls Royce in Goodwood; and Volkswagen producing the Bentley in Crewe. These brands were excluded from the following analysis to fully capture the effect of the Brexit on brands.

market shares were calculated based on Statista (2017) and ACEA (2016b) in the following manner:

$$MB_t = \sum_{m=1}^{12} R \times \left(\frac{r_j}{R}\right) \quad \textbf{(18)}$$

where the variables were defined as:

MB_t market share in units for brand *j* in year *t*;
r_j observed number of registered cars for brand *j* in month *m*; and
R observed total number of registered cars in month *m*.

The process of forecasting quantities by brand was further rationalised by assuming that 80 per cent of the quantities behind the market shares were exported from Germany. Hence, the market shares were applied to the total number of registered cars adjusted for this rate. Based on equation (13) and equation (18), the forecast by brand in simplified form was defined as:

$$B_f = MB_t \times Z_f \times 0{,}8 \quad \textbf{(19)}$$

where the variables were defined as:

B_f forecasted quantities for brand *j* under scenario *f*;
MB_t market share in units for brand *j* in year *t*; and
Z_f the difference between the observed export quantities and the forecasted export quantities under scenario *f*.

If there would not be a Brexit, Volkswagen, which is the brand with the largest market share, would export 159 089 passenger cars into the UK in 2020 and 172 986 cars in 2030. However, if the UK would impose a tariff of 5,00 per cent in 2020, they would export 12 301 less cars. The effect would be even larger in 2030 where the pessimistic scenario estimates a reduction of 26 617 cars; the central scenario a reduction of 15 921 cars; and the optimistic scenario 1 587 less cars. Hence,

Volkswagen would be the least affected in case the UK would not impose any tariffs. If there would be a Brexit, a scenario with low tariffs would be highly beneficial under the current trade structure. Table 9 presents the forecasted export quantities by brand.

Due to seasonality in car registrations, BMW could expect to experience the greatest impact of the Brexit in March and September. On a monthly basis, the central scenario in 2020 would reduce car registrations of BMW branded cars with German origin by approximately 2 000 units compared to if no Brexit would occur. The effect would double under the pessimistic scenario in 2030, hence, reduce registrations by approximately 4 000 units per month in the designated months.

Table 9. Forecasted quantities by brand

	2020	Impact (+/-)	2030	Impact (+/-)
No Brexit				
Volkswagen	159 089		172 986	
BMW	141 229		153 566	
Mercedes-Benz	130 942		142 381	
Audi	127 390		138 518	
Brexit				
Pessimistic scenario				
Volkswagen			146 369	-26 617
BMW			129 937	-23 628
Mercedes-Benz			120 473	-21 907
Audi			117 205	-21 313
Central scenario				
Volkswagen	146 787	-12 301	157 065	-15 921
BMW	130 309	-10 920	139 432	-14 134
Mercedes-Benz	120 817	-10 125	129 276	-13 104
Audi	117 540	-9 850	125 769	-12 749
Optimistic scenario				
Volkswagen			171 399	-1 587
BMW			152 157	-1 409
Mercedes-Benz			141 075	-1 306
Audi			137 247	-1 271

Note: The impact from the Brexit is calculated based on the scenarios in absence of the Brexit.

5.3 Concluding remarks

After extensive modelling, a double-logarithmic gravity model with strong explanatory power was created using an OLS regression technique. The results showed that all Brexit scenarios would lead to lower export quantities compared to a scenario in the absence of the Brexit. Thus, the null hypothesis was rejected.

Forecasted quantities

The estimated short term impact suggests that Germany could expect to export 7,73 per cent less cars in 2020 under a central scenario compared to if no Brexit would occur.

The long term impact under a pessimistic scenario, applying the MFN tariff rate and estimating a large reduction of the UK GDP, shows a decrease by 15,39 per cent in exported passenger cars from Germany in 2030 compared to a scenario in the absence of the Brexit. Under a central scenario, applying a 5,00 per cent tariff and estimating a moderate GDP reduction, the exported quantity was projected to decrease by 9,20 per cent. If the UK would trade with the EU without tariffs and there would be a small GDP reduction, the export of passenger cars was calculated to decrease by 0,92 per cent.

The market

The forecasted figures were further applied to the current market structure in order to calculate the effect with greater granularity. This research report attempted to estimate the effect on market segments and on the brands Volkswagen, BMW, Audi and Mercedes-Benz.

6. Conclusions

The purpose of this research report was to project if the Brexit would negatively impact the export quantities of passenger cars from Germany to the UK. The commodity category was of particular interest due to the notable quantities that Germany exports. The automotive industry is highly interconnected and the results from this research report suggest that higher barriers would negatively impact the current trade flows of passenger cars from Germany to the UK.

The automotive industry is one of the key drivers of economic growth in the EU. The German automotive industry is the biggest car industry in the region, representing 34,9 per cent of the total assembly of 16,3 million passenger cars. The UK constitutes the single largest export market for Germany where a total of 17,4 per cent of all passenger cars in terms of number of units end up. Several German brands such as Volkswagen, Audi, Mercedes-Benz and BMW have noteworthy market shares in the country where they compete in all market segments.

In order to estimate the impact that financial, trade and logistics-related factors have on Germany's export of passenger cars to the UK as well as achieve measurable results, a quantitative approach, in the form of a double-logarithmic gravity equation, was selected and provided the foundation of a forecasting model. The gravity model is widely used in economics and trade theory and traditionally used to calculate trade flows. The final gravity equation, which was defined after a systematic elimination of variables, included GDP of country *j*; the geographical distance between country *i* and country *j*; import tariffs; and the overall quality of logistics in country *j*. All variables were statistically significant and contributed to the overall explanatory power of the model. Diagnostic tests suggest that the model was robust and efficient in estimating trade quantities.

The results from the extensive modelling implied that there is a clear preference for trading without tariffs. However, all Brexit scenarios are estimated to reduce the German export quantities compared to if no Brexit would occur. The Brexit is projected to negatively impact the UK GDP which is positively correlated to export quantities of passenger cars from Germany and estimated to offset the benefits of

trading without tariffs. By being the first to project the impact of the Brexit in the automotive industry, the results provide valuable insights for automakers as well as supply chain planners and other professionals.

The research question of this research report was defined as follows:

RQ: What is the estimated impact of the Brexit on the export quantities of passenger cars from Germany to the UK?

The main conclusions from this research report were:

- The Brexit is estimated to reduce export quantities in regards to passenger cars from Germany to the UK in the *short term*. More specifically, export quantities are estimated to decrease by 7,73 per cent under a central scenario compared to a scenario where the UK would have stayed in the EU.

- All Brexit scenarios are estimated to reduce export quantities in regards to passenger cars from Germany to the UK in the *long term* as well. More specifically, quantities are estimated to decrease by 15,39 per cent under a pessimistic scenario; 9,20 per cent under a central scenario; and 0,92 per cent under an optimistic scenario compared to a scenario in the absence of the Brexit.

- Lower tariffs are estimated to benefit export quantities of passenger cars from Germany. However, a weaker economy in the UK due to the Brexit is estimated to reduce demand for passenger cars and offset the benefits of trading with low tariffs.

6.1 Implications

The automotive industry is an important industry in the EU. Germany is the largest producer of passenger cars in the region and the UK its largest market. The industry contributes greatly to the financial growth, and consequently, is an influential factor in politics and the economy.

The trade-related relationship between Germany and the UK will change when the UK leaves the EU. The effect these changes are expected to have on exports will depend, to a large extent, on the terms under which they will do trade in the future. Nevertheless, the German export quantities of passenger cars are estimated to decrease under all likely Brexit scenarios that have been identified in the literature review due to the reduced demand for passenger cars and higher logistics and trade-related costs.

The effect of tariffs is projected to be substantial and impact the export figures to a large extent. For example, if a tariff of 5,00 per cent would be applied in 2020, the German export of passenger cars is expected to decrease by 7,73 per cent compared to if no Brexit would occur. This effect would represent losses of between 10 000 and 12 000 units per year for Volkswagen, BMW, Mercedes-Benz and Audi respectively. If the UK would trade with the EU under WTO tariffs in 2030, the effect would double for the brands referred to. The automotive industry is influential and representatives should encourage politicians to develop an agreement where passenger cars would face low tariffs. Nonetheless, even if no tariffs would be applied, the German export of passenger cars to the UK is still expected to decrease, which suggests that the demand for logistics services for the designated routes could be expected to decrease as well.

There is currently no local production of these brands taking place in the UK. However, if the UK would come to trade with the EU under a scenario with tariffs, production might shift to mitigate the effect of the higher border costs and to be in closer proximity to the market. Increasing the domestic production and encouraging suppliers to enter the UK could enable manufacturers to avoid the cost, time and complexity that additional customs checks potentially would cause.

Nevertheless, even though the UK is the biggest market for Germany, they only export about 17 per cent of the total export of passenger cars to the country. In an industry where economies of scale are vital, the UK market might be *too small* and *too fragmented* to set up profitable domestic production. Furthermore, the demand for passenger cars is expected to decrease under all Brexit scenarios regardless of tariff rate.

Other large markets for passenger cars from Germany include China and the U.S. These markets are important markets, partly due to the size of their economies which offsets the negative effect distance and tariffs have on trade flows. When the UK exits the union their economy is expected to shrink which, as a result, is projected to reduce the demand for cars. Even though fewer cars would be exported to the UK, other markets for passenger cars could be expected to grow. Hence, there is a possibility that trade flows change and that the UK will be a less important partner for Germany in regards to passenger cars in the future.

Regardless of how automotive manufacturers, logistics professionals and other stakeholders choose to act, the authors of this research report encourage all actors to develop a contingency plan to respond to the substantial effect the Brexit is expected to have on the export of passenger cars from Germany to the UK. The plan should take into account the effect that the economy, distance, quality of logistics and tariffs has on demand and logistics-related costs in regards to the export of passenger cars. Furthermore, the authors advise all stakeholders to consider the long term strategic implications of the Brexit.

6.2 Future research

The topic of the Brexit is contemporary. Building on this research report, which had a narrow but deep focus, comparative studies could add transparency to this unprecedented event. Other or all types of vehicles could be considered and trade in spare parts included. This would provide a holistic view of barriers and their consequences for supply chains. The model developed in this research report focused on the demand side of passenger car exports. However, future research could take the supply side into account as well. Additionally, a modified model could be applied

across industries to trace where the biggest financial impact of the Brexit would occur, helping to prevent economic shocks.

This research report could also provide the foundation of applications to other member countries in the EU as well as within other trading blocs, to evaluate the impact membership withdrawal would have on trade in passenger cars.

Finally, this research report enumerates the impact of the Brexit in the automotive industry and provides general recommendations for manufacturers. However, presented with the forecasted reductions in the export figures, future research could focus on how the industry in general, and individual manufacturers and logistics professionals in particular, should respond to the Brexit and develop best practice in reducing the financial impact on the automotive industry.

Appendices

Appendix A

Table 10 presents the countries representing country *j* which were included and excluded from the final gravity model by year. The excluded countries were excluded because of missing data or because country *i*, denoting Germany, exported less than 1 000 units of passenger cars to the country in the year referred to.

Table 10. Sample specifications

2015		2014		2013		2012	
Observations excluded	**Volume (% of total)**	**Observations excluded**	**Volume (% of total)**	**Observations excluded**	**Volume (% of total)**	**Observations excluded**	**Volume (% of total)**
Other Asia, nes	1,07%	Other Asia, nes	1,01%	Other Asia, nes	0,85%	Other Asia, nes	0,89%
China, Hong Kong SAR	0,40%	China, Hong Kong SAR	0,49%	China, Hong Kong SAR	0,58%	China, Hong Kong SAR	0,48%
Serbia	0,06%	Morocco	0,24%	Morocco	0,25%	Israel	0,38%
Azerbaijan	0,05%	Azerbaijan	0,09%	Belarus	0,18%	Belarus	0,17%
Iran	0,04%	Belarus	0,09%	Azerbaijan	0,09%	Azerbaijan	0,07%
Belarus	0,02%	Serbia	0,06%	Libya	0,06%	Libya	0,07%
Mauritius	0,02%	Libya	0,03%	Serbia	0,06%	Serbia	0,06%
Iraq	0,02%	Iran	0,02%	Iraq	0,03%	Iraq	0,04%
Uruguay	0,01%	China, Macao SAR	0,02%	China, Macao SAR	0,02%	Sri Lanka	0,02%
Greenland	0,01%	Albania	0,02%	Brunei Darussalam	0,02%	Trinidad and Tobago	0,02%
New Caledonia	0,01%	Trinidad and Tobago	0,02%	Trinidad and Tobago	0,02%	Brunei Darussalam	0,02%
Sri Lanka	0,01%	Iraq	0,02%	Albania	0,02%	China, Macao SAR	0,02%
Jamaica	0,01%	Brunei Darussalam	0,01%	Iran	0,01%	New Caledonia	0,02%
Cote d'Ivoire	0,01%	Turkmenistan	0,01%	TFYR of Macedonia	0,01%	Angola	0,02%
State of Palestine	0,01%	New Caledonia	0,01%	Cote d'Ivoire	0,01%	C□te dIvoire	0,01%
Cambodia	0,01%	Sri Lanka	0,01%	Niger	0,01%	Togo	0,01%
Cameroon	0,01%	Cote d'Ivoire	0,01%	New Caledonia	0,01%	Cameroon	0,01%
San Marino	0,01%	Ghana	0,01%	Cameroon	0,01%	Armenia	0,01%
Ecuador	0,01%	Argentina	0,01%	Togo	0,01%	Ecuador	0,01%
Bolivia (Plurinational State of)	0,01%	Cameroon	0,01%	Armenia	0,01%	Turkmenistan	0,01%
Togo	0,01%	Jamaica	0,01%	State of Palestine	0,01%	Niger	0,01%
Turkmenistan	0,01%	State of Palestine	0,01%	Montenegro	0,01%	State of Palestine	0,01%
Montenegro	0,01%	Ecuador	0,01%	Kenya	0,01%	San Marino	0,01%
Niger	0,01%	Niger	0,01%	San Marino	0,01%	Montenegro	0,01%
Ethiopia	0,01%	Bolivia (Plurinational State of)	0,01%	Ecuador	0,01%	Cambodia	0,01%
Congo	0,01%	Armenia	0,01%	Bolivia (Plurinational State of)	0,01%	Kenya	0,01%
Senegal	0,00%	San Marino	0,01%	French Polynesia	0,01%	Afghanistan	0,01%
Armenia	0,00%	Montenegro	0,01%	Yemen	0,01%	French Polynesia	0,01%
French Polynesia	0,00%	Senegal	0,01%	Kyrgyzstan	0,01%	Senegal	0,01%
Uzbekistan	0,00%	Togo	0,01%	Senegal	0,01%	Congo	0,01%
Mali	0,00%	Cambodia	0,01%	Angola	0,01%	Bolivia (Plurinational State of)	0,01%
Kenya	0,00%	French Polynesia	0,01%	Ethiopia	0,01%	Mongolia	0,01%
Lao People's Dem. Rep.	0,00%	Kyrgyzstan	0,01%	Cambodia	0,00%	Kyrgyzstan	0,01%
Libya	0,00%	Congo	0,01%	Congo	0,00%	Iran	0,00%
El Salvador	0,00%	Myanmar	0,01%	Turkmenistan	0,00%	Lao People's Dem. Rep.	0,00%
China, Macao SAR	0,00%	Angola	0,00%	Mongolia	0,00%	Cura□ao	0,00%
Andorra	0,00%	Kenya	0,00%	Lao People's Dem. Rep.	0,00%	Ethiopia	0,00%
Cayman Isds	0,00%	Ethiopia	0,00%	Cuba	0,00%	Yemen	0,00%
Anguilla	0,00%	El Salvador	0,00%	Gabon	0,00%	Syria	0,00%
Haiti	0,00%	Lao People's Dem. Rep.	0,00%	Burkina Faso	0,00%	El Salvador	0,00%
Mongolia	0,00%	Mongolia	0,00%	Mali	0,00%	Uzbekistan	0,00%
Burkina Faso	0,00%	Yemen	0,00%	El Salvador	0,00%	Guinea	0,00%
Cura	0,00%	Uzbekistan	0,00%	Myanmar	0,00%	Mali	0,00%
Guinea	0,00%	Burkina Faso	0,00%	Uzbekistan	0,00%	Gibraltar	0,00%
Yemen	0,00%	Mali	0,00%	Cura	0,00%	Gabon	0,00%
Angola	0,00%	Andorra	0,00%	Guinea	0,00%	Burkina Faso	0,00%
Other Africa, nes	0,00%	Cayman Isds	0,00%	Syria	0,00%	Dem. Rep. of the Congo	0,00%
Saint Maarten	0,00%	Bahamas	0,00%	Afghanistan	0,00%	Barbados	0,00%
Myanmar	0,00%	Haiti	0,00%	Tajikistan	0,00%	Cuba	0,00%
United Rep. of Tanzania	0,00%	Afghanistan	0,00%	Gibraltar	0,00%	Bangladesh	0,00%
Guam	0,00%	Guinea	0,00%	Dem. Rep. of the Congo	0,00%	Cayman Isds	0,00%
Afghanistan	0,00%	Greenland	0,00%	Bahamas	0,00%	United Rep. of Tanzania	0,00%
Zimbabwe	0,00%	Barbados	0,00%	Cayman Isds	0,00%	Honduras	0,00%
Bangladesh	0,00%	Gambia	0,00%	Gambia	0,00%	Guam	0,00%
Gambia	0,00%	Sudan	0,00%	Guam	0,00%	Bahamas	0,00%
Kyrgyzstan	0,00%	Cura	0,00%	Sudan	0,00%	Gambia	0,00%
Somalia	0,00%	Honduras	0,00%	Barbados	0,00%	Madagascar	0,00%
Barbados	0,00%	Gibraltar	0,00%	Andorra	0,00%	Sudan	0,00%
Bahamas	0,00%	Guam	0,00%	Sierra Leone	0,00%	Saint Lucia	0,00%
Gabon	0,00%	Zambia	0,00%	Madagascar	0,00%	Zimbabwe	0,00%
Namibia	0,00%	Tajikistan	0,00%	Zimbabwe	0,00%	Mozambique	0,00%
Honduras	0,00%	Zimbabwe	0,00%	Djibouti	0,00%	Sierra Leone	0,00%
Gibraltar	0,00%	Madagascar	0,00%	Mozambique	0,00%	Tajikistan	0,00%
Sierra Leone	0,00%	Nepal	0,00%	Honduras	0,00%	Malawi	0,00%
Equatorial Guinea	0,00%	Gabon	0,00%	Saint Lucia	0,00%	Djibouti	0,00%
Sudan	0,00%	Sierra Leone	0,00%	Haiti	0,00%	Zambia	0,00%
Mauritania	0,00%	Other Africa, nes	0,00%	Nicaragua	0,00%	Cabo Verde	0,00%
Tajikistan	0,00%	Uganda	0,00%	Bermuda	0,00%	Haiti	0,00%
Mozambique	0,00%	Bangladesh	0,00%	Venezuela	0,00%	Myanmar	0,00%
Djibouti	0,00%	Cuba	0,00%	Faeroe Isds	0,00%	Andorra	0,00%
Nepal	0,00%	Br. Virgin Isds	0,00%	Greenland	0,00%	Nicaragua	0,00%
Guinea-Bissau	0,00%	Venezuela	0,00%	Liberia	0,00%	Liberia	0,00%
Bermuda	0,00%	Dem. Rep. of the Congo	0,00%	Zambia	0,00%	Other Africa, nes	0,00%
Dem. Rep. of the Congo	0,00%	Saint Maarten	0,00%	Aruba	0,00%	Faeroe Isds	0,00%
Nicaragua	0,00%	Mauritania	0,00%	Other Africa, nes	0,00%	Aruba	0,00%
Faeroe Isds	0,00%	Aruba	0,00%	Nepal	0,00%	Nepal	0,00%
Uganda	0,00%	United Rep. of Tanzania	0,00%	Cabo Verde	0,00%	Namibia	0,00%
Cabo Verde	0,00%	Saint Lucia	0,00%	Belize	0,00%	Equatorial Guinea	0,00%
Cuba	0,00%	Faeroe Isds	0,00%	Burundi	0,00%	Mauritania	0,00%
Aruba	0,00%	Fiji	0,00%	Mauritania	0,00%	Guinea-Bissau	0,00%
Rwanda	0,00%	Mozambique	0,00%	Saint Maarten	0,00%	Venezuela	0,00%
Suriname	0,00%	Somalia	0,00%	Somalia	0,00%	Fiji	0,00%
Saint Lucia	0,00%	Malawi	0,00%	Guinea-Bissau	0,00%	Rwanda	0,00%
Br. Virgin Isds	0,00%	Guinea-Bissau	0,00%	Equatorial Guinea	0,00%	Bermuda	0,00%
Liberia	0,00%	Djibouti	0,00%	Malawi	0,00%	Grenada	0,00%
Madagascar	0,00%	Syria	0,00%	United Rep. of Tanzania	0,00%	Belize	0,00%
Venezuela	0,00%	Belize	0,00%	Bangladesh	0,00%	Eritrea	0,00%
Malawi	0,00%	Nicaragua	0,00%	Fiji	0,00%	Burundi	0,00%
Zambia	0,00%	Cabo Verde	0,00%	Chad	0,00%	Chad	0,00%
Central African Rep.	0,00%	Equatorial Guinea	0,00%	Eritrea	0,00%	Suriname	0,00%
Chad	0,00%	Bermuda	0,00%	Namibia	0,00%	Uganda	0,00%
Fiji	0,00%	Liberia	0,00%	Uganda	0,00%	Bunkers	0,00%
Burundi	0,00%	Suriname	0,00%	Rwanda	0,00%	Timor-Leste	0,00%
United States Minor Outlying Islands	0,00%	Comoros	0,00%	Fr. South Antarctic Terr.	0,00%	Seychelles	0,00%
South Sudan	0,00%	Eritrea	0,00%	Turks and Caicos	0,00%	Botswana	0,00%
Syria	0,00%	Rwanda	0,00%	Saint Barth	0,00%	Fr. South Antarctic Terr.	0,00%
Lesotho	0,00%	Namibia	0,00%	Suriname	0,00%	Maldives	0,00%
Eritrea	0,00%	Central African Rep.	0,00%	Bunkers	0,00%	Somalia	0,00%
Dem. People's Rep. of Korea	0,00%	Burundi	0,00%	Grenada	0,00%	Central African Rep.	0,00%
Bunkers	0,00%	Fr. South Antarctic Terr.	0,00%	South Sudan	0,00%	Holy See (Vatican City State)	0,00%
Dominica	0,00%	Saint Barth	0,00%	Central African Rep.	0,00%	Lesotho	0,00%
Maldives	0,00%	Dem. People's Rep. of Korea	0,00%	Mayotte	0,00%	Turks and Caicos Isds	0,00%
Seychelles	0,00%	Bunkers	0,00%			Swaziland	0,00%
Guyana	0,00%	Holy See (Vatican City State)	0,00%			South Georgia and the South Sandwich I	0,00%
Swaziland	0,00%	Bonaire	0,00%			Greenland	0,00%
Botswana	0,00%	Chad	0,00%			Guyana	0,00%
Belize	0,00%	Maldives	0,00%			Dem. People's Rep. of Korea	0,00%
		South Sudan	0,00%			Marshall Isds	0,00%
		Botswana	0,00%			Sao Tome and Principe	0,00%

2015		2014		2013		2012	
Observations included	**Volume (% of total)**	**Observations included**	**Volume (% of total)**	**Observations included**	**Volume (% of total)**	**Observations included**	**Volume (% of total)**
United Kingdom	17,36%	United Kingdom	15,94%	USA	15,35%	USA	14,60%
USA	15,88%	USA	14,60%	United Kingdom	14,54%	United Kingdom	12,84%
China	7,76%	China	10,99%	China	10,05%	China	11,05%
France	6,45%	France	6,32%	France	6,18%	France	6,64%
Italy	5,47%	Italy	4,90%	Japan	4,53%	Italy	5,21%
Japan	3,35%	Japan	3,96%	Italy	4,49%	Japan	4,53%
Belgium	3,27%	Belgium	3,24%	Belgium	3,35%	Russian Federation	3,51%
Spain	3,27%	Spain	3,05%	Switzerland	2,84%	Belgium	3,32%
Rep. of Korea	3,06%	Switzerland	2,76%	Russian Federation	2,83%	Switzerland	3,13%
Netherlands	2,94%	Rep. of Korea	2,58%	Turkey	2,74%	Netherlands	2,71%
Switzerland	2,85%	Netherlands	2,51%	Netherlands	2,64%	Austria	2,61%
Turkey	2,84%	Austria	2,39%	Austria	2,48%	Spain	2,60%
Austria	2,34%	Turkey	2,30%	Spain	2,36%	Turkey	2,26%
Sweden	2,02%	Sweden	2,01%	Sweden	1,93%	Canada	1,95%
Australia	1,65%	Russian Federation	1,70%	Australia	1,89%	Sweden	1,94%
Canada	1,62%	Australia	1,65%	Rep. of Korea	1,88%	Australia	1,87%
Norway	1,33%	Canada	1,64%	Canada	1,76%	Norway	1,59%
Russian Federation	1,08%	Norway	1,37%	Norway	1,59%	Rep. of Korea	1,58%
South Africa	0,95%	South Africa	0,97%	South Africa	1,21%	South Africa	1,08%
Portugal	0,94%	United Arab Emirates	0,95%	Brazil	0,83%	Poland	0,92%
Denmark	0,82%	Portugal	0,80%	Mexico	0,81%	United Arab Emirates	0,71%
United Arab Emirates	0,79%	Poland	0,79%	United Arab Emirates	0,75%	Finland	0,71%
Czechia	0,79%	Denmark	0,72%	Finland	0,73%	Mexico	0,65%
Poland	0,78%	Finland	0,67%	Denmark	0,72%	Czechia	0,60%
Finland	0,65%	Czechia	0,66%	Poland	0,66%	Denmark	0,59%
Mexico	0,63%	Mexico	0,66%	Czechia	0,57%	Portugal	0,49%
Ireland	0,53%	Brazil	0,64%	Portugal	0,54%	Hungary	0,49%
Hungary	0,52%	Hungary	0,53%	Hungary	0,48%	Brazil	0,47%
Saudi Arabia	0,48%	Saudi Arabia	0,49%	Saudi Arabia	0,42%	Saudi Arabia	0,37%
Brazil	0,36%	Ireland	0,47%	Ireland	0,37%	Luxembourg	0,37%
Luxembourg	0,33%	Luxembourg	0,40%	Luxembourg	0,35%	Romania	0,36%
Romania	0,33%	Romania	0,35%	Ukraine	0,34%	Algeria	0,36%
Israel	0,31%	Singapore	0,27%	Algeria	0,32%	Ukraine	0,35%
Slovakia	0,27%	Slovakia	0,26%	Romania	0,32%	Ireland	0,35%
Morocco	0,26%	Kuwait	0,25%	Israel	0,31%	Singapore	0,33%
Slovenia	0,24%	Algeria	0,22%	Singapore	0,31%	Argentina	0,32%
Greece	0,23%	Israel	0,21%	Argentina	0,30%	Morocco	0,30%
Singapore	0,22%	Greece	0,21%	Kuwait	0,28%	Slovakia	0,26%
Qatar	0,19%	Slovenia	0,20%	Slovakia	0,26%	Kuwait	0,26%
Croatia	0,17%	Qatar	0,19%	Malaysia	0,25%	Malaysia	0,25%
Egypt	0,17%	Egypt	0,19%	Chile	0,19%	Egypt	0,17%
Latvia	0,16%	Thailand	0,18%	New Zealand	0,18%	Chile	0,17%
Tunisia	0,15%	New Zealand	0,17%	Thailand	0,17%	Qatar	0,17%
Malaysia	0,13%	Chile	0,16%	Greece	0,17%	Tunisia	0,17%
New Zealand	0,13%	Latvia	0,15%	Slovenia	0,16%	Slovenia	0,16%
Kuwait	0,12%	Croatia	0,14%	Qatar	0,15%	Latvia	0,16%
Ukraine	0,12%	Malaysia	0,14%	Tunisia	0,14%	New Zealand	0,15%
Chile	0,11%	Tunisia	0,12%	Latvia	0,13%	Greece	0,15%
Thailand	0,10%	Colombia	0,11%	Egypt	0,11%	Colombia	0,11%
Colombia	0,10%	Ukraine	0,11%	Colombia	0,10%	Croatia	0,09%
Cyprus	0,09%	Oman	0,09%	Croatia	0,09%	Cyprus	0,09%
Algeria	0,09%	Estonia	0,09%	Nigeria	0,09%	Bahrain	0,08%
Lebanon	0,09%	Bulgaria	0,08%	Estonia	0,08%	Lebanon	0,08%
Bulgaria	0,09%	Bahrain	0,08%	Oman	0,08%	Oman	0,07%
Oman	0,08%	Cyprus	0,08%	Peru	0,07%	Peru	0,07%
Lithuania	0,08%	Lebanon	0,07%	Georgia	0,07%	Estonia	0,07%
Estonia	0,07%	Lithuania	0,07%	Lebanon	0,07%	Georgia	0,07%
Jordan	0,06%	Peru	0,06%	Bahrain	0,07%	Bosnia Herzegovina	0,07%
Peru	0,06%	Nigeria	0,06%	Lithuania	0,07%	Nigeria	0,06%
Viet Nam	0,06%	India	0,06%	Cyprus	0,06%	Thailand	0,06%
Bahrain	0,05%	Bosnia Herzegovina	0,06%	Bosnia Herzegovina	0,06%	Lithuania	0,05%
Philippines	0,05%	Jordan	0,05%	Bulgaria	0,06%	India	0,05%
Bosnia Herzegovina	0,05%	Georgia	0,04%	Jordan	0,05%	Bulgaria	0,05%
Iceland	0,05%	Viet Nam	0,04%	Kazakhstan	0,05%	Jordan	0,05%
India	0,05%	Kazakhstan	0,04%	Indonesia	0,05%	Indonesia	0,05%
Indonesia	0,03%	Indonesia	0,04%	India	0,04%	Kazakhstan	0,04%
Panama	0,03%	Rep. of Moldova	0,03%	Rep. of Moldova	0,04%	Benin	0,04%
Malta	0,03%	Panama	0,03%	Benin	0,04%	Rep. of Moldova	0,04%
Nigeria	0,03%	Benin	0,03%	Viet Nam	0,04%	Philippines	0,04%
Georgia	0,03%	Philippines	0,03%	Panama	0,03%	Panama	0,03%
Benin	0,03%	Iceland	0,03%	Iceland	0,03%	Iceland	0,03%
Rep. of Moldova	0,02%	Guatemala	0,02%	Ghana	0,03%	Viet Nam	0,03%
Guatemala	0,02%	Mauritius	0,02%	Philippines	0,03%	Mauritius	0,03%
Costa Rica	0,02%	Malta	0,02%	Sri Lanka	0,02%	Guatemala	0,03%
Dominican Rep.	0,02%	Dominican Rep.	0,02%	Mauritius	0,02%	Ghana	0,02%
Pakistan	0,02%	Uruguay	0,02%	Guatemala	0,02%	Costa Rica	0,02%
Argentina	0,02%	Costa Rica	0,02%	Malta	0,02%	Albania	0,02%
Albania	0,02%	TFYR of Macedonia	0,02%	Dominican Rep.	0,02%	Paraguay	0,02%
TFYR of Macedonia	0,02%	Paraguay	0,02%	Uruguay	0,02%	Uruguay	0,02%
Trinidad and Tobago	0,02%	Pakistan	0,02%	Pakistan	0,02%	Jamaica	0,02%
Kazakhstan	0,02%			Paraguay	0,02%	Malta	0,02%
Paraguay	0,01%			Costa Rica	0,02%	Pakistan	0,02%
Brunei Darussalam	0,01%			Jamaica	0,01%	TFYR of Macedonia	0,01%
Ghana	0,01%					Dominican Rep.	0,01%

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