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The impact of Brexit on the activity of banks: 2013-2021 country by country reporting data

Bachelor's thesis

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Abstract

The withdrawal of the United Kingdom from the European Union marks one of the most important events in recent history. The consequences of Brexit, particularly the loss of passporting rights in the services sector, have had severe adverse effects on British trade because it created barriers and challenges for British businesses to access the EU market and vice versa. This thesis aims to contribute to the existing literature on the impact of Brexit on financial services, specifically focusing on the banking sector. I use the country-by-country reporting data spanning from 2013 to 2021 to investigate the activity of 44 European banks. Using the turnover of the banks as a substitute for measuring banking activity, I estimate the gravity model employing the PPML and OLS estimators.

The results indicate a negative effect of 24% on the turnover of British banks abroad relative to the domestic turnover. This suggests that the loss of passporting rights and the subsequent regulatory changes decreased the international operations of UK-based banks. In contrast, EU-based banks experienced 30% higher turnover in partner countries than domestically.

JEL Classification	F21, F23, H25, H26, F32,
Keywords	Brexit, banks, CbCr, gravity model, Poisson Pseudo-Maximum-Likelihood

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Abstrakt

Odchod Spojeného království z Evropské unie patří mezi nejdůležitější události posledních let. Důsledky Brexitu, jmenovitě ztráta "passporting" práv v sektoru služeb, nepříznivě ovlivnili mezinárodní obchod Velké Británie. Nové regulace výrazně ztížili vstup britských podniku na evropský trh a naopak. Tato téze přispívá do existující literatury o dopadech Brexitu na finanční služby se zaměřením na bankovní sektor. Analýza využívá country-by-country reporting data o bankovní aktivitě 44 evropských bank z období 2013-2021. Bankovní obrat reprezentující aktivitu bank analyzuji pomocí gravity modelu za využití PPML a OLS metod. Analýza docházi k záveru, že obrat britských bank v zahraničí po Brexitu klesl o 24% v porovnání s obratem na území Spojeného království. Z toho vyplýva, že ztráta "passporting" práv a následné změny v regulacích přispěly ke snížení mezinárodních operací bank se sídlem ve Spojeném Království. Na druhou stranu, banky sídlíci v Evropské unii vykazaly o 30% vyšší obrat v partnerských zemích v porovnání s jejich domácím obratem.

Klasifikace JEL	F21, F23, H25, H26, F32,
Klíčová slova	Brexit, banky, CbCr, gravitační model, Poisson Pseudo-Maximum-Likelihood

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Acronyms

CbCR Country-by-country Reporting

PPML Poisson Pseudo-Maximum-Likelihood

OLS Ordinary least squares

TCA Trade and Cooperation Agreement

EEA European economic area

RTA Regional Trade Agreement

GFCI Global Financial Centres Index

Chapter 1

Introduction

[1]

After the transition period ended, the UK left the EU single market and customs union and signed Trade and Cooperation Agreement. The EU is one of the biggest trade partners of the UK, and therefore, the agreement is essential to maintain this relationship. The new agreement extends free trade mainly within the goods market. Services and financial services, in particular, are not part of the deal as the UK would be required to align the regulations to the rules of the EU, which was against the wishes of the British government.

A report by ONS 2021 investigated the consequences of Brexit and the COVID pandemic on British trade in the market of services. Comparing the data on financial services from 2019 and 2021, they found that exports and imports of financial services fell by 9.7% and 6.3%, respectively. This fall could be attributed to the exclusion of financial services from the trade agreement. Because of the loss of passporting rights, the UK became a third country in the eyes of the EU. The access to the Single Market is now based on the equivalence rulings.

Being one of the main parts of financial services, it is likely that the banking sector was affected. In this thesis, I investigate the impact of Brexit on banking activity. I make use of the CbCr data hand collected by a group of researchers under the supervision of Petr Janský. Spanning from 2013 to 2021, the dataset comprises 49,616 observations containing information on 44 European banks in 128 countries. This is the first empirical paper that uses the extended version

[1] This thesis used ChatGPT by OpenAI and Grammarly to assist with LaTeXand R codes and grammar. Nevertheless, it is crucial to note that all the notions and concepts introduced in this thesis are either the author's original creations or have been appropriately referenced from relevant sources.

of the dataset that originally covered only the period until 2019 and partially 2020.

I collected the missing observations for the years 2020 and 2021. Hence, the dataset contains years prior to the announcement of the Brexit referendum, during the negotiation period, and post-Brexit, encompassing the transition period and the period following the signature of the Trade and Cooperation Agreement that enforced the new regulations. The main variable of interest is the reported turnover of banks that acts as a proxy for banking activity.

In this thesis, three different hypotheses are tested to estimate the effect of Brexit on banking activity. Since the data captures the turnover of banks with headquarters in 14 European countries, I decided on three different models. The first model focuses on all of the banks, no matter where the headquarters are based. The second model captures the effect on the UK-based banks, and the last model estimates the impact on the EU-based banks. Below, I present the three respective hypotheses.[2] It is important to mention that the effect on turnover refers to the turnover reported in partner countries compared to the domestically reported turnover.

1. Brexit negatively affected the reported banking turnover of European countries.

2. After Brexit, British banks reported lower turnover.

3. Banks with EU-based headquarters reported higher turnover after Brexit.

To test these hypotheses, I created a gravity model with turnover as a dependent variable. The gravity model is commonly used to estimate trade flows, while the variable distance acts as a proxy for transportation costs. In the context of financial services, the meaning is somewhat different. As most of the transactions occur digitally, the increased distance does not incur additional costs in terms of gas, transport fees, or tariffs. Instead, distance represents the informational asymmetry in the market.

Anderson and Wincoop (2003) advise on including importer and exporter dummy variables to create a fixed-effect estimator, thus, accounting for the multilateral resistance terms. Nonetheless, this estimator cannot be applied to a panel dataset because all of the time-invariant variables would be omitted. As proposed by Baldwin and Taglioni (2006), by including importer-year

[2] Note that similar hypotheses were estimated by Moravec (2022) but instead of the actual Brexit, the paper focused on the impact of the announcement of the British referendum.

and exporter-year in the models, both issues, the multilateral resistance terms, and the panel data structure are solved. Furthermore, to account for perfect collinearity, Moravec (2022) suggests adding a dummy variable representing international trade, thus distinguishing between domestic and foreign operations.

I estimated the gravity equation by both the OLS and the Pseudo Maximum Likelihood method. Until recently, the OLS was the most common estimator of the gravity model. There are certain issues with using OLS on trade data because the dependent variable contains observations with zero values, and thus, log-linearization becomes a problem. One option is to leave out all of these observations or, alternatively, to add a small positive constant and estimate $log(turn + 1)$ instead. However, Silva and Tenreyro (2006) emphasize that in the case of heteroskedasticity, the disturbances are correlated with the covariates leading to biased estimates. This stems from the implications of the Jensen's inequality about the expectation of logarithms and the logarithms of expectations. I performed the Breusch-Pagan test, and while the alternative model $log(turn+1)$ exhibited heteroskedasticity, the model with only the positive observations of turnover did not. This likely occurred due to a smaller dataset. As such, I disregard the results of the alternative OLS model as it produces inconsistent estimates. It is essential to mention that in all of the models, I used clustered standard errors to avoid a possible correlation that could have occurred within a banking group.

The findings of the two methods are somewhat consistent. However, in case of a contradiction, the results of PPML will prevail. Because the OLS model was constructed using a smaller dataset and a relatively low R^2, any conclusions drawn from its analysis act only as a supporting basis for the PPML results.

To comment on the first hypothesis, I found no evidence that Brexit had an effect on the turnover reported abroad to the domestic turnover. After I specified the country of origin, I found that following Brexit, the turnover in partner countries compared to the domestically reported turnover decreased 24% for British banks and increased 30% for banks with headquarters based in one of the EU member states.

The structure of this thesis is as follows. First, I describe the literature on Brexit and its consequences, trade agreements, and the gravity model. In the next section, I focus on the data and the description of the sample. Then I move to methodology, discussion of results, and robustness procedures. In the last section, I summarize my findings.

Chapter 2

Literature review

2.1 Brexit and its development (timeline)

Since its creation, the European Union has fostered greater integration among European countries, a trend that has become increasingly more apparent in recent years with the accession of new member states and the establishment of a common currency in the European Monetary Union. The withdrawal of the UK marks the first time the EU is getting smaller. The UK had always been reluctant to be a part of the EU and was one of the countries that joined the EFTA only later on. As such, it was not unexpected when on 23 June 2016, the UK held a referendum to leave the European Union, where 52% of the voters voted to leave the EU. In March 2017, Article 50 was triggered, setting the initial withdrawal date for two years later. However, in 2019, the UK asked for an extension which was granted until October 2019. After several hearings of the Parliament, the UK left the EU on 31 January 2020. As agreed in the Withdrawal Agreement, a transition period followed until 31 December 2020, allowing the UK and the EU to sort out the future arrangements. On 24 December 2020, Trade and Cooperation Agreement was finalized and came into effect on 1 January 2021. This agreement aims to provide a tariff and quota-free market in the trade of goods and to ensure fair competition. Moreover, it sets guidelines on air and road transport regulations and environmental protection. Financial services, foreign policies, and external security and defense matters are not part of the deal as the UK did not wish to include them. A study published by CEPR (2022) pointed out that one of the reasons that may have contributed to this omission is the division of opinions concerning domestic financial regulation. While the providers of the banking services would favor staying a part of the EU, the hedge funds and other participants of the financial sectors preferred to leave.

2.2 Trade Cooperation Agreement

It has been over a year since the end of the transition period after the UK left the EU more than three years ago and six years since the Brexit referendum was announced. After implementing the Trade Cooperation Agreement (TCA) in January 2021, both sides have taken a different approach to its application. While the EU Member states started to adopt the full customs checks for UK exports immediately, the UK postponed the full customs checks for imports from the EU until January 2022.

The recent report published by the Office for budget responsibility 2021, which focused on the impacts of Brexit on UK trade, discovered that as the transition period was coming to an end, there was a substantial decline in the trade intensity of the UK compared to that of the other countries. When analyzing the effects separately, it was found that there was a sharper decline in British imports of goods from the EU than in British exports of goods to the EU.

Moreover, the UK may be falling behind due to the effects of the pandemic on the service sector, particularly the travel sector, which was hit the most heavily. Over the past years, a substantial part of the UK trade comprised services (36% in 2021). ONS (2021) published an analysis of the combined impact of Brexit and the COVID pandemic on the service trade and claimed that service exports and imports in the second quarter of 2021 were down 14.2% and 29.3%, respectively, compared with the same quarter in 2019. Both exports and imports of financial services fell by 9.7% and 6.3%, respectively. This decline could have been at least partially foreseen due to the limited provision for access to financial services as agreed upon in the TCA. Due to the loss of passporting rights, the UK can no longer provide services across the entire EU, resulting in a decline in exports. This is in line with the findings of this thesis that suggest banks with UK-based headquarters experienced a lower turnover in partner countries relative to the turnover reported in the UK. The study by ONS shows that large EU countries such as the Netherlands, France, Germany, and Ireland experienced declines in exports of financial services in the second quarter of 2021 compared to Q2 2019 and Q1 2021 when the UK-EU trade agreement entered force. However, I observed a positive effect on the turnover of the EU banks in the partner countries in comparison to turnover reported by the exporting country, indicating that the overall exports of banks based in the EU increased after Brexit or the domestic turnover decreased.

2.3 Non-tariff barriers

After the United Kingdom left the single European market on 31 December 2020, it became a third country in the eyes of the European Union. UK-based banks wishing to serve EU customers lost their passporting rights. Thus, they can no longer provide services to EU Member states without the required authorization, i.e., free cross-border services or opening local branches under favorable terms are not possible anymore. As a result, many institutions shifted their focus to the EU and created a distribution chain there. Consequently, more business was happening in countries such as Germany or Poland, resulting in a decline in the British economy.

The EU is very bureaucratic in its nature, and there is one set of rules regarding the movement of goods, services, capital, and labor for all Member States. Non-tariff barriers kept the UK behind a wall, leading to a slowdown in business investments. There is a certain ambiguity on how much of this effect on economic growth can be attributed to Brexit, considering the COVID pandemic and the ongoing conflict in Ukraine. A Office for National Statistics report (November 2021) focuses on analyzing these events and distinguishing between their effects on the projected annual GDP. Compared to other countries, the UK is falling behind, essentially not growing at all, with Russia being the only country that is worse off.

2.4 London as a financial center

Before Brexit, London supplied the EU with a sizable percentage of its financial services. Donnelly (2022) suggests that a significant number of services were moved to the EU under the pressure of the European Central Bank (ECB).

ECB issued an opinion regarding the UK's decision to leave the EU, explicitly addressing the possible risk that may arise from insufficient supervision. As there was an increased volume of requests to relocate from the UK to one of the EU member states within a short time, the recommendations provided were meant to ease the convergence across the EU. ECB made an effort to keep the EEA transactions within the EU and under the supervised control of the EU institutions to ensure smooth regulation (European Systemic Risk Board, 2021). Because the Commission had the same preference, regulatory measures were set in place to force migration from the UK to the EU. From 2017 through 2021, the UK-based financial businesses gradually moved their assets, personnel, and transactions to the EU. Most of the financial services relocation was to Paris and Frankfurt, resulting in an extensive stock market shift.

Several international banks decided to move operations from London to their branches within the eurozone, which are independent EU legal entities operating under the Single Supervisory Mechanism. Some of the banks instead chose to have third-country branches subject to supervision on the national level and, subsequently, have to comply with both home and host regulations. The nature of such regimes prevents operating across the whole of the EU, and as such, it was not used often.

The following figure illustrates how the GFCI index for London, Paris, and Frankfurt changed over time. GFCI stands for the Global Financial Centres Index and is regularly updated twice a year, in March and September, by Z/Yen. The index evaluates the competitiveness of the financial centers, providing valuable insights for policymakers and investors.

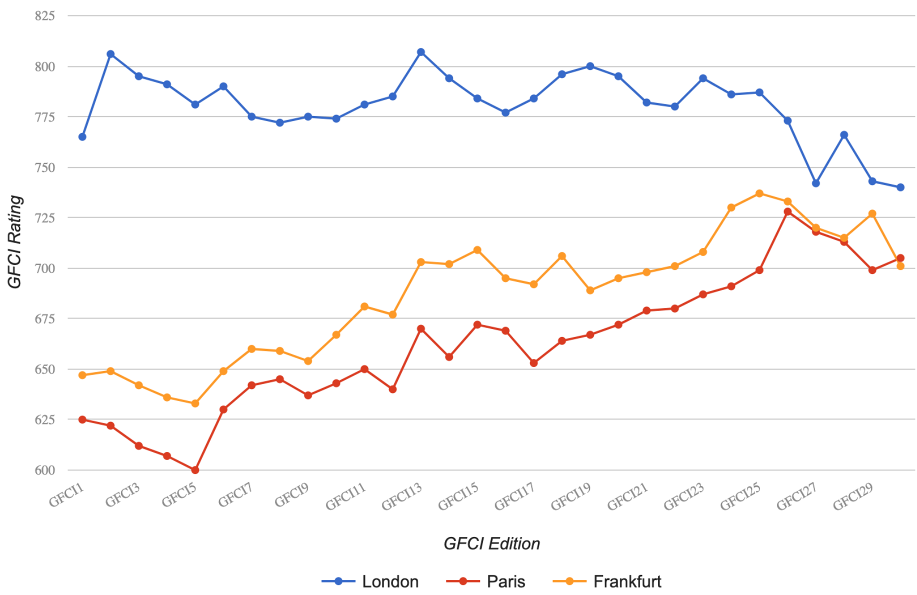

Figure 2.1: GFCI ratings, 2007-2021
Source: Z/Yen, The Global Financial Centres Index

Analyzing the graph, it becomes evident that London's ratings had been relatively stable until the announcement of the results of the British referendum in 2016, denoted as *GFCI19* on the graph, after which it experienced a downward trend. On the contrary, Paris and Frankfurt exhibited a significant upward trend that persisted until 2019, after which the ratings began to decline. The event of the actual withdrawal in 2020 is represented by *GFCI27*. Interestingly, London witnessed a temporary increase in its GFCI score following Brexit, while the trends for Paris and Frankfurt continued to decline.

A recent study by Demski et al. (2022) showed that even though London remained the world's leading center in international banking, the cross-border ties with the continent had weakened. Prior to the great financial crisis, London held about one-third of the international banking positions, but in the past years, it decreased to one-fifth, which is still well above any of the financial centers in the entire euro area. As highlighted in the study, based on the trade data from 2018 through 2021, exports of financial services from the UK to the EU fell by 19%. At the same time, exports to the rest of the world increased by 4% (UK, House of Commons Library 2022). Given that only 7000 jobs in the financial sector were reported to have relocated from London to the euro area, this decline seems rather large in comparison (UK, House of Lords, European Affairs Committee (2022, p 15)).

2.5 EU sentiment

From 2016 through 2017, the European Social Survey conducted a survey across the EU Member states on whether the citizens believe their country should follow the example of the UK and leave the EU. The same study was conducted again in the period from 2020 to 2022, and the results were vastly different. Support for leaving the EU fell in every Member state, indicating that the EU is stronger than ever. One of the reasons for the shift in public opinion might be the underlying political instability and piling of economic issues in the UK since the announcement of Brexit in 2016. Moreover, since 2016, the EU has faced multiple crises, which are widely regarded as having been managed rather effectively. The response of the EU to the COVID crisis made smaller countries feel more secure, and the war in Ukraine was met with a relatively unanimous and coordinated response to the situation, with sanctions and supplies distributed at the EU level. Compared to the past couple of years, the EU is now perceived as a means to national security, and the EU cohesion appears to be much stronger than in the years before Brexit (Busse et al., 2020).

2.6 Brexit referendum

A paper by Moravec (2022) studies the impacts of the British referendum on banking activity, using the turnover of the banks as an indicator of whether there was any treatment effect on banking activity. The study concludes that after the announcement of Brexit, there was an adverse effect on the collective pool of European banks. The banks reported lower turnover abroad compared to domestic turnover. While there seems to be no significant impact on UK banks relative to the rest, there appears to be a difference between EU and non-EU banks.

The paper focuses on the banking activity between 2013 and 2019, and thus it does not capture the effect of the actual Brexit. Many researchers believe the loss of passporting rights in the services sector, which allowed firms to provide their services within the EEA without any special authorization, is the most significant consequence of Brexit. During the transition period, it was unclear whether the UK would opt for an "optimistic" or more "pessimistic" scenario when it comes to trade restrictions (Barret et al., 2015).

Samitas et al. (2018) conducted an agent-based simulation of the short and long-term consequences of Brexit on financial stability. In the "optimistic" scenario, the UK would follow the Norwegian example and aim for more restrictive measures to continue the trade, such as signing GATS or FTA agreements. Despite not being a member state, Norway has been given full access to the European single market. Therefore, after signing the agreement, the only effects of Brexit would stem from the banking sector segmentation and non-tariff barriers to trade. However, because of the additional bureaucracy, even with the free trade deal, trade of financial services would become much more restricted. The paper suggested that should the financial institutions based in the UK choose not to relocate to the EU, there would be a surplus of financial assets not consumed in the domestic economy. The banking sector in the UK seemed to be better prepared to face a potential banking crisis as a possible consequence of Brexit. Similarly to the study by Moravec, they also claim that there is a much more substantial impact of Brexit on the EU economy because the total deposits in EU banks are decreasing. On the other hand, the number of total deposits in UK banks remains relatively stable.

However, if many UK-based banks relocate to the EU, the effects on the British economy could be more severe. Therefore, policy measures should be implemented to alleviate the negative consequences of Brexit. As the study suggests, the calculated optimum point for both UK and EU banks would be if approximately half of the UK-based banks were to transfer to the EU to avoid overcrowding of the financial sector while simultaneously fully utilizing the financial services available.

Following the Trade and Cooperation Agreement with the EU, the UK should be allowed to trade as previously, at least in terms of goods. However, prior to signing the agreement, there was a time of uncertainty in which the citizens had to rely on their expectations about what would be the new arrangements between the UK and EU.

Douch and Edwards (2022) analyzed the referendum's effects on trade and concluded that the uncertainty associated with this period was one of the main reasons for the trade decline. The lack of impact on the UK banks discovered by Moravec (2022) may have been mitigated because most banks expected the UK to remain part of the EEA. The vast majority of researchers agreed that the potential loss of passporting privilege could cause market disruptions and diminish London's influence as one of the most important financial centers. Nonetheless, most British banks either assumed passporting rights to be renewed or their decisions were not swayed by their expectations during the transition period.

It had become apparent that British providers of financial services would stop enjoying passporting rights into the Single Market after the Political Declaration of October 2019 that was signed by the UK and the EU together with the Withdrawal Agreement. Furthermore, it was clarified that no replacement for these rights would be included in the TCA, and the access to the Single Market would be based on the equivalence rulings.

The main focus of the TCA is on the goods market. The UK has a large surplus of financial services that are not subjected to the new agreement. However, their trade would require a much closer alignment of rules and substantial regulations that would have to be on par with the EU's, which the British government did not wish for.

2.7 Gravity model

This thesis uses the gravity model to estimate the effects of Brexit. The gravity equation was first used by economist Jan Tinbergen in 1962. The idea behind its creation stemmed from Isaac Newton's law of gravity, which states that the force of gravity by which two objects are attracted to each other is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. In the economic sense, it says that the further away two countries are, the smaller the volume of trade. In its simplest form, the gravity equation looks as follows:

$$Trade_{i,j} = G\frac{M_i M_j}{Dist_{i,j}}$$

where the subscripts i and j represent the importing and exporting countries. M stands for the size of each respective economy, and is often represented by variables such as population, GDP, or GDP per capita. Lastly, G for a simple constant and *Dist* stands for the distance between the trading countries. Intuitively, as the distance increases, the volume of trade falls.

In the following years, more variables were recognized to have a significant influence on trade. Notably, the bilateral characteristics of country pairs, such as sharing a common border, language, or a history of the colonial relationship, seem to impact the trade.

However, the basic form of the equation was criticized by Anderson and Wincoop (2003) as it does not account for the multilateral resistance terms such as non-tariff barriers or cultural differences. They introduce importer and exporter dummy variables to the model.

In the past, it was a common practice to log-linearize the equation and then estimate it using the OLS. Silva and Tenreyro (2006) suggest that this approach can lead to inconsistent estimates, and they propose PPML as a better estimator to use. This is due to the nature of the trade flow data that contains a lot of zero observations that would have to be either left out or processed in an alternative way. However, because the trade variable in the PPML model is not in a logarithmic form, there is no need to drop these observations.

I use both the OLS and the PPML estimators. After performing the Breusch-Pagan test to detect the presence of heteroskedasticity, the errors for the OLS models with the positive turnover fulfill the homoskedasticity assumption, which allows for consistent estimates of the parameters. Moreover, in the context of the PPML models, I use heteroskedasticity-robust standard errors. This is because the standard errors might still be affected by heteroskedasticity, even though the points estimates are heteroskedasticity-robust.

Chapter 3

Data

3.1 Data background

Since 2014, under the CRD IV Directive, banks within the EU jurisdiction with revenues over €750 million must disclose specific information on a country-by-country basis. The required information includes net banking income, profit and loss before tax, number of full-time employees, tax on profit or loss, and public subsidies received. The inclusion of CbCr framework aims to limit tax avoidance and profit shifting and ensure greater transparency in a corporate environment.

To determine the effect of Brexit on the activity of banks, I used the CbCr dataset hand-collected by a group of researchers under the supervision of doc. Petr Janský. The primary source of the data were the annual reports published by the banks themselves. This data includes information about 44 European banks, their headquarters and subsidiaries abroad, turnover, profit/loss before tax, amount of tax paid, and the number of employees. The sample consists of the years 2013-2021, of which I collected the data for 2021 and filled in the missing data points for 2020.

Net banking income or turnover is the primary variable of focus for this thesis and acts as a proxy variable for the banking activity. While it captures just one aspect of the performance and health of a bank, the turnover reflects the total value of the traded goods and services and captures the volume of loans, deposits, and other financial transactions. Additional financial indicators, such as profits, assets, and liabilities, could provide useful insight and help to evaluate the banking activity, but that is outside of the scope of this thesis.

3.2 Contribution

There has been limited interpretation of the Country-by-Country reporting data for the years 2020 and 2021 in the existing literature. This study aims to bridge this gap by analyzing and providing insights specifically for these years. This expanded dataset allows for a more comprehensive examination of the trends and implications of the CbCr data, providing valuable insights into the activities, financial performance, and tax contributions of the 44 European banks included in the study. By incorporating these previously unexplored data points, this thesis contributes to the existing literature on the CbCr and banking activity, offering a deeper understanding of the dynamics within the banking sector during the years 2020 and 2021.

This study uses turnover (*turn*) as the primary dependent variable to investigate the potential impacts of Brexit on banks' financial performance and operational activities. Analyzing turnover provides insights into revenue changes and fluctuations, offering valuable findings on the consequences of Brexit for the banking sector.

3.3 Additional variables

Along with the turnover, I incorporated additional variables into the analysis. Geographical variables were obtained from the GeoDist database provided by CEPII. These variables capture inter-country relations, including factors such as distance between the most populated cities, information on shared languages, borders, and colonial status. By incorporating these geographical variables into the analysis, a more extensive understanding of the contextual factors behind the impact of Brexit on banks' activities can be attained. As Baier and Bergstrand (2007) state in their study, these country-pair dummy variables are particularly important, absorbing the unobservable factors regarding the relationship between the endogenous trade policy and the error term. The GeoDist database is available at http://www.cepii.fr.

Furthermore, the World Economic Outlook database from October 2022 was utilized to incorporate macroeconomic variables into the analysis. This database provides essential indicators, including GDP, GDP per capita, and population. Access to the database can be obtained through the official website of the International Monetary Fund at https://www.imf.org.

Following the study on profit shifting into tax havens conducted by Hines and Rice (1994), a dummy variable *taxheav* was created. The authors identified 41 tax havens, which formed the basis for constructing the variable.

Next, I included a dummy variable for the Regional Trade Agreements (RTA)[1] to better understand the role of free trade and international relations between countries. This variable takes the value of one if, at the given time, there is an active trade agreement between two countries and zero otherwise. The study by Cardamone (2007) on the impact of trade agreements on trade suggests that the effects of RTAs can vary but, in general, have a favorable influence on trade flows, leading to increased trade among participating countries. Since countries tend to trade more within a free trade area, a potential omitted bias phenomenon could result from not including this variable.

Additionally, I included a dummy variable *GFCI* that is equal to one whenever one of the financial centers is located within the country, based on the Global Financial Centres Index. [2]

The main variable of interest is a dummy variable *brexit*, equal to one if the year corresponds to 2020 or any subsequent year. For the purpose of testing the last two hypotheses, i.e., the effect of Brexit limited to either the banks with their headquarters in the UK or the EU, the variables *eubank* and *ukbank* were created to differentiate between UK and EU banks. On top of that, I added interaction terms *isuk_brexit* and *iseu_brexit* to each of the respective models. These variables were created as a result of a multiplication of the variables *eubank* and *ukbank* with the variable *brexit*. Finally, the dummy variables *ref* and *TCA* were introduced to represent the post-referendum period and the period after the Trade and Cooperation Agreement came into effect. The purpose of the last variable is to provide insight into whether the expectation of banks about the potential loss of passporting rights played any part in their decision-making.

Altogether, the entire dataset contains information on 44 banks in 128 countries with headquarters in 14 different countries over the course of 9 years, amounting to 49,617 observations. Understandably, multiple banks did not report any turnover in certain countries as they do not operate there. Moreover, some banks did not start reporting in 2013 but only later, resulting in fewer observations for this year.

[1] The source for this variable was the Regional Trade Agreements database which provides data for both active and inactive agreements. See: http://www.rtais.org

[2] GFCI index, created by Z/Yen and updated biannually, serves as an evaluation tool of the future competitiveness of the financial centers. The list of the financial centers is available here: GFCI report 2021

Chapter 4

Methodology

The following section describes the models and methodology used to analyze the chosen variables. Two different methods were employed to estimate the parameters of the gravity equation. Firstly, I used the Poisson Pseudo Maximum Likelihood estimator (PPML) because it offers a robust estimation technique for the gravity model. Secondly, despite the general recommendation against using OLS to estimate a dependent variable with numerous zero observations, the data was also estimated using the OLS model, which will be discussed further in this section. The reasoning behind this estimation was to confirm the results obtained from the PPML estimation.

4.1 Hypotheses

I tested three different hypotheses to estimate the effect of Brexit on different groups of countries. Firstly, I created a model with all countries available in the dataset. Next, I divided the data based on the location of the bank's headquarters. Altogether, there are 14 different headquarters, which can be divided into EU and non-EU countries. For the sake of testing the last two hypotheses, I added an additional category for the UK.

1. EU countries - Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden

2. United Kingdom

3. Norway, Switzerland

The last two hypotheses focus on the first two categories. Starting with the impact on British banks, I created a dummy that is an identity whenever the headquarters of a bank resides in the UK. To avoid its overestimation, I added an interaction term to isolate the effect after Brexit.

Analogously, I estimated the model for the banks with their headquarters based in the EU. The motivation behind the last two models is to determine whether being in an official trade agreement of sorts, having a similar cultural background, or close geographical proximity plays a role in the volume of trade among the banks. In the past, the UK has been somewhat hesitant to be in the EU, and this kind of hostility could have transferred to the trade and affected the banking activity.

4.2 Accounting for panel data

From the structure of the dataset, it is clear that we are dealing with panel data. As such, necessary transformations must be made to account for methodological aspects used in research. The first problem arises from accounting for the multilateral resistance terms that could otherwise result in an omitted variable bias. While doing so, it is still necessary to account for the panel data structure. One solution would be to create an augmented "fixed-effect" estimator. Creating an importer & exporter dummy variables for the country where the bank resides and its headquarters would solve the problem of multilateral resistance terms. However, including the country-pair dummy variables is not sufficient, and using a fixed effect estimator on panel data could prove problematic. The main issue with this estimator is that it omits the time-invariant variables because they are perfectly collinear with the fixed effects. Every variable that does not vary over time for the importer & exporter dummy variables, such as the distance, will be omitted. Baldwin and Taglioni (2006) propose different methods to deal with the panel data structure and to control for MRTs. They use various combinations of dummy variables, and in this case, exporter-year and importer-year dummy variables are the most appropriate solution.

Prior to that, it is necessary to multiply all of the explanatory variables by a dummy variable denoted as INT that takes the value of one when dealing with international trade, i.e., the country and the headquarters variables are different. INT takes the value zero in the case of domestic, intracountry trade. This method was suggested by Heid et al. (2017) and Moravec (2022) as a solution to avoid perfect collinearity. Therefore, all of the explanatory variables are transformed into the interaction terms and are, thus, interpreted as the effect of the original variables for observations concerning the foreign operations in comparison to the domestic ones.

Before Silva and Tenreyro (2006) suggested that the PPML method is the preferred method in the context of gravity models, OLS was the most commonly used estimator of gravity models. Their study compares the OLS and PPML methods and shows that due to the nature of the independent variable, PPML is more suitable for estimating the trade flow data. Due to the multiplicative form of the gravity equation, log-linearization is required to allow for using the OLS method. The log-linear transformation can result in overestimating the effect of certain variables compared to the PPML method. It happens because many countries do not trade with each other, or in the case of this thesis, many banks do not have branches in all countries. As such, the value of the banks report zero turnover.

Another problem that the OLS estimation suffers from are the implications posed by the Jensen 's inequality, that is $E(ln(y)) \neq ln(E(y))$, although the variance and mean of that random variable may play a role. Based on this inequality, if the disturbances are heteroscedastic, the expectation of $log(u)$ becomes correlated with the covariates of the independent variables, directly violating one of the key assumptions of the OLS and leading to biased coefficients and inconsistent results. The study suggests PPML estimation is better as it produces unbiased estimates even in the presence of heteroskedasticity, and the interpretation of the coefficients is identical to the OLS.

In order to log-linearize the gravity equation, necessary transformations of the dependent variable have to be made to deal with zero observations that cannot be included as the log of zero is not defined. One solution is to leave out these observations and estimate the truncated dataset. Alternatively, we can add a small positive number, such as 1, and estimate $log(turn+1)$ instead, allowing for the inclusion of the zero values of the dependent variable.

Section 5 (Results) of this thesis includes two tests that assess the effectiveness of the chosen methods. First, I performed the Breusch-Pagan test to detect the presence of heteroskedasticity in the models estimated by the OLS. The second test, known as the RESET test, examines whether the functional specification of PPML or OLS is appropriately specified.

4.3 Gravity model

The suitability of a gravity model as an estimator for trade within the financial sector might be questioned as most transactions occur digitally, which undermines the significance of one of the key variables of the model, namely distance. Nonetheless, as the amount of literature covering this topic increased, this has been disproved, and the research suggests that distance represents informational and institutional friction. In the context of finance, many papers (Portes et al. (2001), Portes and Rey (2005) or Choi et al. (2014)) used the gravity model successfully. A recent study conducted by Milsom et al. (2020) analyzed the fees on the equity transactions and, upon including the institutional and informational variables in the models, concluded that the role of distance represents the institutional and information frictions. Thus, estimating the banking turnover using the gravity model is a justifiable approach.

4.3.1 PPML

The main estimator in this thesis is the Poisson Pseudo Maximum Likelihood estimator (PPML). It is typically used for count data, i.e., for data with non-negative values of the observations, such as the trade flow data, because the dependent variable is not in a logarithm.

The multiplicative form of the gravity equation is as follows:

$$turn_{i,j,k,t} = \alpha GDP_{i,t}^{\beta_1} GDP_{j,t}^{\beta_2} GDPpc_{i,t}^{\beta 3} GDPpc_{j,t}^{\beta 4} dist_{i,j}^{\beta_5} e^{\gamma D_{i,j,t} + \theta_{i,t} F_{i,t} + \theta_{j,t} F_{j,t}} \epsilon_{i,j,k,t} \tag{4.1}$$

which can be rewritten using the basic mathematical properties for logarithms:

$$turn_{i,j,k,t} = e^{log(\alpha) + \beta_1 log(GDP_{i,t}) + ... + \beta_5 log(dist_{i,j}) + \gamma D_{i,j,t} + \theta_{i,t} F_{i,t} + \theta_{j,t} F_{j,t} + log(\epsilon_{i,j,k,t})}$$

Here the subscripts i,j,k and t represent the importing country, exporting country (headquarters), individual bank, and time, respectively. In this case, t ranges from the year 2013 to 2021. Thus, the variable $turn_{i,j,k,t}$ stands for the turnover that the bank k reported in the country i with the bank 's headquarters placed in the country j. Accounting for the heterogeneity within banks, the coefficient α represents the individual effect of each bank. GDP_i, $GDPpc_i$, GDP_j, and $GDPpc_j$ represent the respective GDPs and GDPs per capita of the importing and exporting countries at time t. The variable $dist_{i,j}$ stands for the physical distance between the most populated cities of countries i and

j based on the latitude and longitude coordinates. $D_{i,j,t}$ represents the vector of dummy variables included in the model.

Accounting for the bilateral factors between the countries i and j, the model includes dummy variables for common language, borders, past or ongoing colonial relationships, and information on whether the importing country i is tax heaven or not. *RTA*, is a dummy variable equal to unity when there is an active regional trade agreement between the two countries i and j at time t. Furthermore, I included a dummy variable *GFCI* equal to unity when one of the cities in the country is considered a global financial center.

Following Moravec (2022), to take into account both the panel data structure and the multilateral resistance terms, I introduce a set of dummy variables $F_{i,t}$ and $F_{j,t}$ that represent the fixed effect of the importing and exporting countries i and j in a given year. These variables were created as a product of $i * t$ and $j * t$ and are equal to unity for a specific country and its headquarters in a given year. $\epsilon_{i,j,k,t}$ denotes the unobserved disturbances and follows the log normal distribution. Hence, provided the errors are not heteroskedastic, it holds that $E(\epsilon_{i,j,k,t}|X_{i,j,t}) = 1$ and $E(log(\epsilon_{i,j,k,t}|X_{i,j,t}) = 0$ as shown by Silva and Tenreyro.

I used similar techniques and variables as the master thesis of Moravec (2022) as well as estimated the model using the *ppml* function from the *gravity* package (version 0.9.9) developed by Woelwer et al, in the statistical software *R* in 2020. The authors of the *gravity* package have designed the *ppml* function to provide results consistent with the *ppml* function in Stata, which was initially developed by Silva and Tenreyro (2006).

4.3.2 Coefficient interpretation

As mentioned before, to avoid having perfect collinearity, all of the explanatory variables were multiplied by a dummy variable *INT*, representing international trade. As a result, the estimates are now interpreted as the effect of the original variable for the observations in partner countries compared to the domestic ones.

Two types of variables are present in the models, continuous, such as the GDP or distance, and binary, i.e. dummy variables. For both cases, the interpretation will be somewhat different. While for the continuous variables, the coefficients are interpreted as elasticities, for the dummy variables, the coefficients stand for the percentage change in the turnover when the dummy variable changes from 1 to 0.

Hence, for the continuous variables, the effect is calculated as follows (presented here for the first continuous variable $GDP_{i,t}$, for the other continuous variables analogously):

$$\beta_1 = \frac{\%turn_{i,j,k,t}}{\%GDP_{i,t}}$$

Thus, β_1 can be interpreted as a percentage change in $turn_{i,j,k,t}$ corresponding to a 1% change in $GDP_{i,t}$.

For the sake of brevity, let us assume that the model includes only one dummy variable. As the variable takes only the values 1 and 0, it holds:

$$E(turn_{i,j,k,t})|D_{i,j,t} = 1) = e^{log(\alpha)+\beta_1 log(GDP_{i,t})+...+\beta_5 dist_{i,j}+\gamma+\theta_{i,t}F_{i,t}+\theta_{j,t}F_{j,t}+log(\epsilon_{i,j,k,t})}$$

and

$$E(turn_{i,j,k,t})|D_{i,j,t} = 0) = e^{log(\alpha)+\beta_1 log(GDP_{i,t})+...+\beta_5 dist_{i,j}+\theta_{i,t}F_{i,t}+\theta_{j,t}F_{j,t}+log(\epsilon_{i,j,k,t})}$$

By subtracting the two equations and putting everything on the left-hand side, we obtain the following expression:

$$\frac{E(turn_{i,j,k,t})|D_{i,j,t} = 1) - E(turn_{i,j,k,t})|D_{i,j,t} = 0)}{E(turn_{i,j,k,t})|D_{i,j,t} = 0)} = e^{\gamma} - 1$$

Thus, as the dummy variable changes from 0 to 1, the turnover will change by $(e^{\gamma} - 1)\%$.

4.4 OLS

In order to log-linearize the gravity equation and use OLS, it is necessary to deal with the zero values observations of the dependent variable *turn*. One possibility is to limit the dataset to only those observations with positive turnover, restricting the dataset to $6,709$ from the original $49,151$ observations. Another way is to estimate $log(turn + 1)$ instead, which enables the utilization of the complete dataset without excluding any observations. Note that in case of a zero turnover, $log(turn + 1)$ is equal to zero.

The first approach leads to the following equation:

$$log(turn_{i,j,k,t}) = \alpha_k + \beta_1 log(GDP_{i,t}) + \beta_2 log(GDP_{j,t}) + \beta_3 log(GDPpc_{i,t}) +$$

$$+\beta_4 log(GDPpc_{j,t}) + \beta_5 log(dist) + \beta_6 contig + \beta_7 comlang + \beta_8 colony + \beta_9 RTA +$$

$$+\beta_{10} GFCI + \beta_{11} taxheav + \theta_{i,t} F_{i,t} + \theta_{j,t} F_{j,t} + \mu_{i,j,k,t}$$

The equation for estimating the alternative model is analogous, except the term on the left-hand side changes to $log(turn + 1)$.

$$log(turn_{i,j,k,t} + 1) = \alpha_k + \beta_1 log(GDP_{i,t}) + \beta_2 log(GDP_{j,t}) + \beta_3 log(GDPpc_{i,t}) +$$

$$+\beta_4 log(GDPpc_{j,t}) + \beta_5 log(dist) + \beta_6 contig + \beta_7 comlang + \beta_8 colony + \beta_9 RTA +$$

$$+\beta_{10} GFCI + \beta_{11} taxheav + \theta_{i,t} F_{i,t} + \theta_{j,t} F_{j,t} + \mu_{i,j,k,t}$$

where α_k stands for the logarithm of α and $\mu_{i,j,k,t}$ are the disturbances $\epsilon_{i,j,k,t}$ in logarithms. Again, the subscripts i and j refer to the partner and domestic country, respectively. The subscripts k and t stand for observations related to a bank k at time t.

All of the continuous variables are in logs and interpreted as elasticities, i.e., a 1% change in the independent variable leads to a β_m percentage change of the dependent variable, where $m = 1, ..., 5$. The interpretation of the binary variables is different. When the dummy variable changes from 0 to 1, the turnover changes by $(e^{\beta_s} - 1)\%$, where $s = 6, ..., 11$.

Chapter 5

Results

In this section, I describe the findings. Firstly I present the results obtained by the PPML estimator and then those by the OLS. The following part is dedicated to testing for functional misspecification of these models using the RESET test. Lastly, I provide a discussion of the results and limitations of the research.

5.1 Poisson Pseudo-Maximum-Likelihood

5.1.1 Interpretation of the results

I estimated four different models, and the corresponding results are presented in Table 1. To address the issue of multilateral resistance along with the panel data structure, the models are estimated using the exporter-year and importer-year fixed effects. Additionally, to avoid perfect collinearity, all explanatory variables in the models were multiplied by a dummy variable *INT*, equal to one for all of the international trade operations and zero for the domestic observations, i.e., the turnover reported in the country of the bank's respective headquarters.

Model (1) serves as the baseline model without including any variables associated with Brexit. The explanatory variables in the baseline model include the distance between the most populated cities of the country in which the bank resides and the bank's headquarters, GDP, and GDP per capita of both the exporting and importing countries, as well as a set of dummy variables. These dummy variables incorporate factors such as contiguity, common language, colonial relationship, regional trade agreement, tax haven status, and GFCI index.

In the second model, an additional dummy variable denoted as *brexit* is introduced, taking a value of one for years following Brexit (i.e., starting from 2020). The third model incorporates two dummy variables specifically associated with the United Kingdom. The variable *ukbank* takes a value of one when the headquarters are located in the UK. Furthermore, the *isuk_brexit* dummy variable represents the interaction term between *ukbank* and *brexit* dummies and is, thus, equal to one for all of the observations after the year 2020 when the exporting country is the UK.

The last model introduces two new dummy variables, *eubank* and *iseu_brexit*. Analogous to the third model, the former variable takes the value one when the exporting country is a member of the European Union, and the latter is an interaction term of said variable and *brexit*. Therefore, it is zero for three of the exporting countries: Norway, Switzerland, and the UK.

On top of that, I tried including dummy variables for the announcement of the Brexit referendum, equal to unity following the years after 2016 (2016 included) and for when the TCA came to force in 2021. However, given that both of these variables were statistically insignificant, I decided against including them in the final models.

Table 1 shows the models (1)-(4) with clustered heteroscedasticity-robust standard errors. I used Eicker-White heteroskedasticity-robust standard errors because even though the points estimates are heteroskedasticity-robust, the standard errors might still be affected by heteroskedasticity. Moreover, as the data consists of observations of 44 banks in different countries, it is mostly likely clustered. The most intuitive approach is to create clusters for each bank due to the possible correlation between the bank and its subsidiaries. For instance, a crisis that causes a bank's bankruptcy in one country may have cascading effects on branches in other countries. Alternatively, clusters for each country could also provide a sufficient solution, but this correlation is likely weaker than the one between a banking group.

By incorporating clustered standard errors into the analysis, it is possible to appropriately account for this interdependence and obtain more accurate statistical inferences.

Upon creating clusters for each bank, some explanatory variables lost their significance, including the main variables of interest. Before employing clusters, the variable *brexit* was significant in models (2) and (3), while *ukbank* and *eubank* were significant at a 1% significance level. According to the recent literature (Cameron and Miller (2015), MacKinnon et al. (2023)), when the clustered standard errors are considerably larger than the non-clustered ones, it is advisable to utilize the clustered standard errors. In our particular case, this condition is met, and, as a result, I am employing the clustered standard errors.

5.1.2 The coefficients

As anticipated, the coefficient associated with distance is negative in all four models. Across the models, if the distance increases by 1%, turnover decreases by approximately 60%, which is a somewhat smaller effect than Silva and Tenreyro (2006), who estimated the coefficient to be close to 78%. Both the GDP of the importing country and the country of the bank's headquarters are insignificant. Coefficients for the GDP per capita of the headquarters are negative and significant at 1% significance level, while for the importing country (country of destination), they are significant and positive only for the third model. This would suggest countries with lower GDP export less, while bigger countries attract more investors, possibly because they are perceived as more stable and safe in regard to investing.

Across all four models, the dummy variables maintained their significance. The dummy variables representing contiguity, tax haven countries, or countries with financial centers are all insignificant. Since most transactions occur digitally, sharing common borders may not be as important. As for the financial center index dummy variable, it might have been more suitable to include a variable that represents the rank on the list of the financial centers to show the fluctuations in ranking because most of the centers remain on the list, and thus, this variable might be inconsequential. The remaining bilateral variables for the common language, past or present colonial ties, and the regional trade agreement are positive and significant at 1%. As anticipated, these variables facilitate trade and eliminate some trade barriers. The coefficient associated with sharing a trade agreement is approximately 1.8.

The main variables of interest are all related to Brexit. In none of the models did the variable *brexit* have any effect on the turnover of banks. Not only were the coefficients very close to zero, but they were also not significant at any reasonable level.

The results of the remaining two hypotheses could provide a potential explanation for this lack of significance. Accounting for the country where the bank's headquarters reside yielded an expected outcome. Firstly, for the UK-based headquarters, the coefficient of *ukbank*, which is equal to one when dealing with a British bank, is insignificant. However, the interaction term representing the impact on British banks after Brexit has a negative coefficient which is significant at a 1% significance level. Before Brexit, the UK played a vital role in the financial sector, with London being one of the most important business centers. Nevertheless, after Brexit, new barriers to trade and regulations were imposed, and the findings confirm that the turnover of British banks in partner countries decreased by approximately 24% in comparison to the turnover reported in the UK.

In the final model, the effect on the EU banks is statistically insignificant. As for the variable *iseu_brexit*, it is statistically significant and positive at a 1% significance level. Hence, after Brexit, the banks from the EU experienced a positive shock, with approximately 30% higher turnover in their partner countries than domestically.

In conclusion, taking into account all European banks, there is no evidence that Brexit had affected the turnover reported in the partner countries compared to the domestic turnover. However, there was a negative effect on the turnover of British banks in partner countries compared to the turnover reported in the UK. Moreover, the turnover of EU banks abroad has increased compared to the domestically reported turnover.

5.2 OLS method

As mentioned before, the coefficients obtained from the OLS regression are, in general, biased for the gravity model. Nonetheless, to support the results drawn from the PPML estimation, I estimated the data using both of the techniques that are commonly used to deal with the non-negative nature of the trade data. Firstly, I limited the dataset to the positive values of turnover only, which resulted in a smaller dataset of $6,709$ observations. Alternatively, I added a small positive constant to the turnover and estimated $log(turn + 1)$. While the second model exhibits signs of heteroskedasticity, the first one does not, as proven by the Breusch-Pagan test.

Judging from the relatively low R^2 (approximately 0.4), this model does not explain the variations of the dependent variable very well, even with the absence of heteroskedasticity.

5.2.1 Breusch-Pagan test

As mentioned in section 4.2, the error terms must be homoskedastic for the OLS estimator to be consistent because of the implications posed by the Jensen's inequality. To detect heteroskedasticity, I performed the Breusch-Pagan test. The null hypothesis for the test states that the variance of residuals is constant, indicating no heteroscedasticity in the regression model. The alternative hypothesis suggests a presence of heteroskedasticity as the variance of the residuals differs across the levels of the independent variables.

Model	**Method**	**BP statistic**	**df**	**p-value**
Baseline	log(turn)	964.24	1,010	0.8459
	log(turn+1)	10,571	1,116	$< 2.2e-16$
Brexit	log(turn)	965.36	1,011	0.8451
	log(turn+1)	10,625	1,117	$< 2.2e-16$
UK_Brexit	log(turn)	993.72	1,013	0.6614
	log(turn+1)	10,766	1,119	$< 2.2e-16$
EU_brexit	log(turn)	983.41	1,011	0.7272
	log(turn+1)	10,721	1,119	$< 2.2e-16$

Figure 5.1: Breusch-Pagan test results

The table shows the results of these tests for all three methods. Because the p-values are close to 0, it is evident that the OLS model with an alternative dependent variable $log(turn+1)$ suffers from the presence of heteroskedasticity. Following Silva and Tenreyro (2006), the model is inconsistent, and the resulting parameters are biased. On the contrary, the OLS model, which included only the positive turnover, shows no heteroskedasticity at any reasonable significance level. Thus, the null hypothesis cannot be rejected.

Many studies advise against regressing the log-linearization of the gravity model as trade flow data generally exhibit heteroskedasticity, which leads to inconsistent estimates of β. However, provided the disturbances are not heteroskedastic, the results of the OLS estimator should be valid. Nevertheless, the OLS model excludes all of the zero turnover observations, resulting in a shrinkage of the dataset from 49,401 to 6,709 observations. As such, the PPML method is a much better estimator of the gravity model because it not only includes these observations but is also robust to heteroskedasticity.

5.2.2 Interpretation of the coefficients

Tables 2 and 3 present the results of the models estimated by the OLS method. As with the PPML models, I utilized clustered standard errors in the OLS analysis because they were substantially larger than non-clustered standard errors. The first table displays the results for a truncated dataset with 6,709 observations, including only those with positive turnover. These results exhibit some similarities to the findings obtained from the PPML method, although there are a few notable differences. In order to conduct a thorough comparison of the two methods, it is essential to first emphasize their shared similarities before exploring the differences.

Starting with the baseline variables that are present in all of the models, the distance and GDP per capita of the origin country, as well as the colonial dummy variable, are significant and of the same sign with approximately the same magnitude as the PPML models, although the significance of the GDP per capita decreased from 1% to 5% for the first two models. On the other hand, the GDP of the exporting and the importing countries and the importing country's GDP per capita remain insignificant. The dummy variables for common borders and tax havens show no significant effects. The dummy variable for the global financial centers is significant only in the last model.

Moving on to the differences, the common language and the regional trade agreement, which are positive and significant at 1% in the PPML models, have lost their significance in the OLS models.

Most importantly, the variables associated with Brexit exhibit slightly different coefficients. The *brexit* variable remains insignificant and close to zero for all models, except the fourth one, where it becomes significant at a 1% significance level with a coefficient of 0.279.

However, the dummy variable *iseu_brexit*, which is significant at the 1% level in the PPML model, is insignificant at any significance level. Nevertheless, the sign remains positive, supporting the conclusion drawn in section 5.1.2. Both variables representing either UK or EU banks remain insignificant. Most importantly, the variable *isuk_brexit* in the third model is significant, although the significance dropped from 1% to 5%, and of the same sign as in the PPML.

Moving on to the alternative OLS model, the obtained results diverge to a certain extent from the previous estimation methods. However, it is crucial to acknowledge the presence of heteroskedasticity, as confirmed in section 5.2.1, that could introduce bias to the parameter coefficients. As mentioned in section

4.2, if a model suffers from heteroskedasticity, the error terms become correlated with the covariates of the explanatory variables, thereby rendering the OLS estimation invalid. Consequently, given this limitation and the relatively low R^2, I will not delve into much detail when interpreting the coefficients and instead focus only on the variables related to Brexit, as the model is not suitable for explaining the variations in turnover.

In short, the *brexit* variable is significant in all four model specifications, suggesting there was a negative effect of Brexit on the reported turnover. Again, the dummy variables *ukbank* and *eubank* are insignificant. The interaction terms *isuk_brexit* and *iseu_brexit* have both lost their significance.

In conclusion, the first set of the OLS models partially supports the results carried out by the PPML estimator, while the alternative set yields markedly different results. However, the alternative models were disregarded due to the present heteroskedasticity. Therefore, there is no evidence that the event of Brexit had any impact on the average turnover of European banks in all of their partner countries relative to the domestically reported turnover. Moreover, there is a negative effect on the British banks, and their turnover in partner countries decreased compared to the turnover reported in the UK. Contrary to the results drawn from model (4) of the PPML models, OLS finds no statistical evidence of a positive effect of Brexit on the turnover in partner countries of the EU member states compared to their domestically reported turnover.

It is important to note that the first set of OLS models exhibits a relatively low R^2 (approximately 0.4) and is based on a restricted dataset comprising only observations with positive turnover. The disparities between the methods could stem from using a considerably smaller dataset or potential model misspecification.

5.3 Reset test

To test for a correct model specification or omission of important variables, a RESET test was employed. The null hypothesis of the test states that the model is correctly specified. Silva and Tenreyro (2006) used this test to compare different types of models, such as OLS and PPML, by adding the fitted values $\hat{y}$ and $\hat{y}^2$. The paper concludes that the PPML model was favored over the OLS model and suggests that rather than from the truncated dataset, the differences in the results stem from heteroscedasticity.

Figure 5.2 shows the results of the RESET test for three methods. The first

Model	Method	RESET statistic	p-value
Baseline	log(turn)	15.58	$8.004e-05$
	log(turn+1)	235.93	$< 2.2e-16$
	PPML	9,839.3	$< 2.2e-16$
Brexit	log(turn)	15.585	$7.983e-05$
	log(turn+1)	235.2	$< 2.2e-16$
	PPML	9,886.7	$< 2.2e-16$
UK_Brexit	log(turn)	27.937	$1.3e-07$
	log(turn+1)	218.95	$< 2.2e-16$
	PPML	9,687.4	$< 2.2e-16$
EU_brexit	log(turn)	28.603	$9.233e-08$
	log(turn+1)	235.2	$< 2.2e-16$
	PPML	9,917	$< 2.2e-16$

Figure 5.2: RESET test results

two, $log(turn)$ and $log(turn + 1)$, were estimated by OLS, and the last model was estimated by PPML. The first row represents the results for the baseline model, without any variables associated with Brexit. The second model was used to test the first hypothesis, i.e., the impact of Brexit on all European banks. The last two rows show the results of the tests for the models estimating the impact of Brexit on the banks with their headquarters based in the UK and the EU countries.

The last column of the figure presents the p-value for each model. Unfortunately, none of the models passed the RESET test, as the p-value is very close to zero. Although the OLS with positive turnover has the best results, the p-value is nowhere near a reasonable threshold. One of the possible explanations why this model performed the best is the absence of heteroscedasticity. Furthermore, the model used a markedly smaller dataset, but as mentioned before, heteroskedasticity is much more likely to cause discrepancies in the results. However, this explains only the differences between the two OLS methods, as the PPML used heteroskedasticity robust standard errors.

5.4 Discussion of results and limitations

In contrast with the master thesis by Moravec (2022) that focused on the effects of the Brexit referendum, the results were different. The thesis implemented similar techniques and sets of variables, as well as the dataset, except the thesis focused on the period until 2019. I included two additional dummy variables, RTA representing the regional trade agreements and GFCI, which is equal to unity in case one of the financial centers is located in the importing country, derived from the list of the global financial centers that is published biannually.

Moravec argues that, on average, following the announcement of the results of the British referendum, banks reported lower turnover in their partner countries relative to the domestically reported turnover. Based on the analysis of the extended dataset, I find no evidence supporting that the actual Brexit had any impact on the turnover abroad relative to the domestic one.

Additionally, there was a negative effect of Brexit on the British banks. The turnover in partner countries, in comparison to the domestic turnover, decreased by 24%, while there was no reaction of these banks to the referendum. This likely stems from the loss of passporting rights, as the financial services and services, in general, were not part of the new trade agreement that came into effect in January 2021. The fact that the trade of services will not be included in the new deal was officially confirmed upon signing the Political Declaration together with the Withdrawal Agreement by the UK and the EU in October 2019.

On the other hand, the study confirms that following the referendum announcement, the banks with their headquarters based in the EU reported higher turnover compared to the non-EU banks. After the UK left the EU in January 2020, this trend continued. However, the referendum had a much larger impact, increasing the turnover by approximately 55.5%, while the effect of the actual Brexit was close to 30%.

The RESET test rejecting model specification puts into question the validity of our inference, but there is no more appropriate model for the purposes of our analysis. In addressing this issue, an alternative method, such as Synthetic Difference in Differences, could prove more suitable for estimating the effect of Brexit on different countries, as demonstrated in a study by Moravec, who employed both the Synthetic Difference in Differences and PPML techniques. By following his example, we may find more robust results for our research, but such an endeavor is beyond the scope of this thesis.

Chapter 6

Conclusion

After the UK's departure from the EU on 31 January 2020, a transition period ensued until the end of 2020, allowing both parties to sort out future arrangements. The Trade and Cooperation Agreement, which took effect on 1 January 2021, provided new regulations and guidelines to facilitate a tariff-free market in the trade of goods. However, this agreement did not cover financial services, as the UK wanted to avoid being subjected to EU regulations in this sector. As such, the UK lost its passporting rights and became a third country, leading to the implementation of new regulations and sector-specific rules. One consequence of losing passporting rights is the potential impact on London's status as a major financial center. London had previously served as a hub for financial services in the EU, but the new regulations and barriers to trade have raised concerns about its diminishing importance in the financial sector.

The banking sector accounts for a big part of the financial services. I analyzed the CbCr data of 44 European banks to investigate the effects of Brexit on banking activity. I used the reported turnover of banks as a proxy for banking activity. To explore this effect, I employed a gravity equation, a common approach used to estimate trade flows. Within the context of financial services, the variable distance served as a proxy for informational asymmetry.

As is now a common practice, following Baldwin and Taglioni (2006), I included importer-year and exporter-year fixed effects to account for multilateral resistance terms and panel data structure. Additionally, as in the study by Moravec (2022), I added a dummy variable representing international trade in order to distinguish between the turnover reported in partner countries and the domestically reported turnover. By multiplying all independent variables with the dummy variable, I avoided perfect collinearity. To ensure there was no correlation within a banking group, I used heteroskedasticity-robust clustered standard errors.

I employed PPML and OLS models to estimate the gravity equation. The log-linearization of the equation was necessary for the utilization of OLS. To be able to do that, necessary transformations of the dependent variable had to be made. Turnover, as a trade flow variable, contains zero observations that cannot be put into logarithms. To address this issue, it is possible to either keep only the observations with positive values of turnover or to estimate $log(turn + 1)$ instead. Both approaches were tested using the Breusch-Pagan test to detect heteroskedasticity. The first model passed the test, but the alternative model rejected homoskedasticity. A study by Silva and Tenreyro (2006) emphasizes that in the presence of heteroskedasticity, the disturbances are correlated with the covariates leading to biased estimates. They suggest it is better to use the PPML over OLS. As such, I disregarded the findings of the alternative model.

The results from PPML and the first OLS model are somewhat consistent. However, within the context of the gravity equation, PPML is commonly regarded as a more appropriate choice. Furthermore, the OLS was estimated with a truncated dataset and has a relatively low R^2. As such, the OLS serves only as a supporting basis in confirming the results of PPML.

In examining the similarities between PPML and OLS, I find evidence that following Brexit, British banks reported lower turnover in partner countries relative to the turnover reported in the UK by approximately 24% to 27%. On the other hand, the PPML estimated that the banks with their headquarters located in the EU countries reported higher turnover in partner countries relative to their domestic turnover by approximately 30%. The OLS did not identify any significant difference for EU-based banks, and instead, it estimated that post-Brexit, not only the EU-based but all of the European banks (including the UK) reported a higher turnover in partner countries relative to the home country by approximately 32%. Nonetheless, given that this finding, unsupported by other models, may be caused by the truncated dataset, it necessitates cautious interpretation.

Future research should take advantage of the newly extended dataset and explore alternative techniques, such as Synthetic Difference in Differences, to yield more robust results on the impact of Brexit on banking activity. Moreover, the inclusion of non-European banks as well as a further extension of the dataset beyond the year 2021, might be useful for studying the long-term consequences of Brexit.

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Appendix A

Models specification and robustness check

Table A.1: GLM models with clustered standard errors, 2013-2021

	(1)		(2)		(3)		(4)	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
(Intercept)	11.182***	3.045	11.254***	3.049	11.424***	3.107	11.621***	3.256
log(dist)	-0.617***	0.237	-0.619***	0.236	-0.612***	0.228	-0.617***	0.23
gdp_o	0.169	0.228	0.168	0.229	0.128	0.252	0.132	0.248
gdp_d	0.24	0.273	0.256	0.278	0.259	0.276	0.264	0.278
gdp_pc_o	-1.996**	0.831	-2.001**	0.83	-2.065**	0.83	-2.107**	0.855
gdp_pc_d	1.3	0.833	1.299	0.829	1.38*	0.831	1.44	0.881
contig	0.108	0.437	0.108	0.437	0.197	0.397	0.2	0.38
comlang_off	0.742***	0.243	0.744***	0.243	0.658***	0.253	0.65***	0.244
colony	1.525***	0.361	1.524***	0.361	1.483***	0.301	1.485***	0.304
RTA	1.798***	0.526	1.779***	0.526	1.809***	0.53	1.817***	0.53
GFCI_dummy	-0.168	0.26	-0.225	0.295	-0.221	0.296	-0.227	0.3
taxheav	0.227	0.805	0.267	0.801	0.189	0.832	0.17	0.843
brexit			0.125	0.098	0.164	0.1	-0.09	0.105
ukbank					0.266	0.658		
isuk_brexit					-0.271***	0.105		
eubank							-0.275	0.617
iseu_brexit							0.259**	0.104
Observations	49,151		49,151		49,151		49,151	
Positive turn obs.	6,709		6,709		6,709		6,709	
Pseudo R^2	0.75		0.75		0.751		0.751	

Note: Gravity model estimated by PPML $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table A.2: OLS models with clustered standard errors, 2013-2021

	(1)		(2)		(3)		(4)	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
(Intercept)	13.324***	1.784	13.321***	1.809	13.647***	1.802	14.544***	2.172
log(dist)	-0.578**	0.24	-0.578**	0.24	-0.544**	0.24	-0.578**	0.238
gdp_o	-0.001	0.193	-0.001	0.193	-0.085	0.206	-0.071	0.202
gdp_d	0.301	0.252	0.3	0.257	0.3	0.259	0.269	0.268
gdp_pc_o	-1.232*	0.654	-1.232*	0.654	-1.362**	0.646	-1.554**	0.708
gdp_pc_d	0.703	0.673	0.704	0.672	0.874	0.656	1.146	0.752
contig	0.338	0.38	0.338	0.38	0.519	0.325	0.509	0.339
comlang_off	0.305	0.279	0.305	0.279	0.226	0.282	0.178	0.276
colony	1.244***	0.327	1.244***	0.327	1.048***	0.306	1.087***	0.293
RTA	0.391	0.919	0.393	0.924	0.429	0.936	0.541	0.667
GFCI_dummy	-0.318	0.329	-0.315	0.378	-0.333	0.378	-0.332**	0.149
taxheav	0.805	0.525	0.803	0.536	0.726	0.551	-0.547	0.54
brexit			-0.007	0.149	0.034	0.16	0.279*	0.155
ukbank					0.59	0.587		
isuk_brexit					-0.32*	0.165		
eubank							0.188	0.507
iseu_brexit							0.47	0.417
Observations	6,709		6,709		6,709		6,709	
R^2	0.400		0.400		0.405		0.405	
Adjusted R^2	0.294		0.294		0.299		0.299	
Residual Std. Error	1.835 (df = 5698)		1.835 (df = 5697)		1.828 (df = 5695)		1.828 (df = 5697)	
F Statistic	3.764*** (df = 1010; 5698)		3.760*** (df = 1011; 5697)		3.831*** (df = 1013; 5695)		3.832*** (df = 1011; 5697)	

Note: Gravity model estimated by OLS — *p<0.05; **p<0.01; ***p<0.001

Table A.3: OLS models estimating log(turn+1) with clustered standard errors, 2013-2021

	(1)		(2)		(3)		(4)	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
(Intercept)	10.606***	2.208	10.436***	2.231	10.59***	2.254	10.729***	2.36
log(dist)	-0.867***	0.208	-0.867***	0.208	-0.88***	0.211	-0.877***	0.209
gdp_o	0.066	0.089	0.067	0.089	0.045	0.092	0.053	0.093
gdp_d	0.1	0.514	0.043	0.529	0.041	0.528	0.051	0.531
gdp_pc_o	-0.277	0.24	-0.276	0.24	-0.297	0.231	-0.35	0.287
gdp_pc_d	-0.27	0.322	-0.245	0.328	-0.208	0.311	-0.158	0.353
contig	0.428	0.363	0.427	0.363	0.463	0.33	0.451	0.336
comlang_off	0.008	0.115	0.007	0.115	-0.006	0.119	-0.007	0.118
colony	0.996***	0.279	0.996***	0.279	0.943***	0.209	0.967***	0.227
RTA	0.347	1.21	0.443	1.229	0.446	1.23	0.45	1.229
GFCI_dummy	-0.141	0.799	0.076	0.883	0.068	0.883	0.06	0.883
taxheav	5.579***	2.16	5.446**	2.182	5.436**	2.178	5.417**	2.176
brexit			-0.498**	0.235	-0.49**	0.236	-0.526**	0.236
ukbank					0.172	0.307		
isuk_brexit					-0.045	0.076		
eubank							-0.108	0.236
iseu_brexit							0.041	0.06
Observations	49,151		49,151		49,151		49,151	
R^2	0.392		0.392		0.393		0.393	
Adjusted R^2	0.378		0.378		0.379		0.378	
Residual Std. Error	1.358 (df = 48034)		1.358 (df = 48033)		1.358 (df = 48031)		1.358 (df = 48031)	
F Statistic	27.754*** (df = 1116; 48034)		27.739*** (df = 1117; 48033)		27.783*** (df = 1119; 48031)		27.735*** (df = 1119; 48031)	

Note: Gravity model estimated by OLS — *p<0.05; **p<0.01; ***p<0.001

Appendix B

Turnover statistics, figures and tables

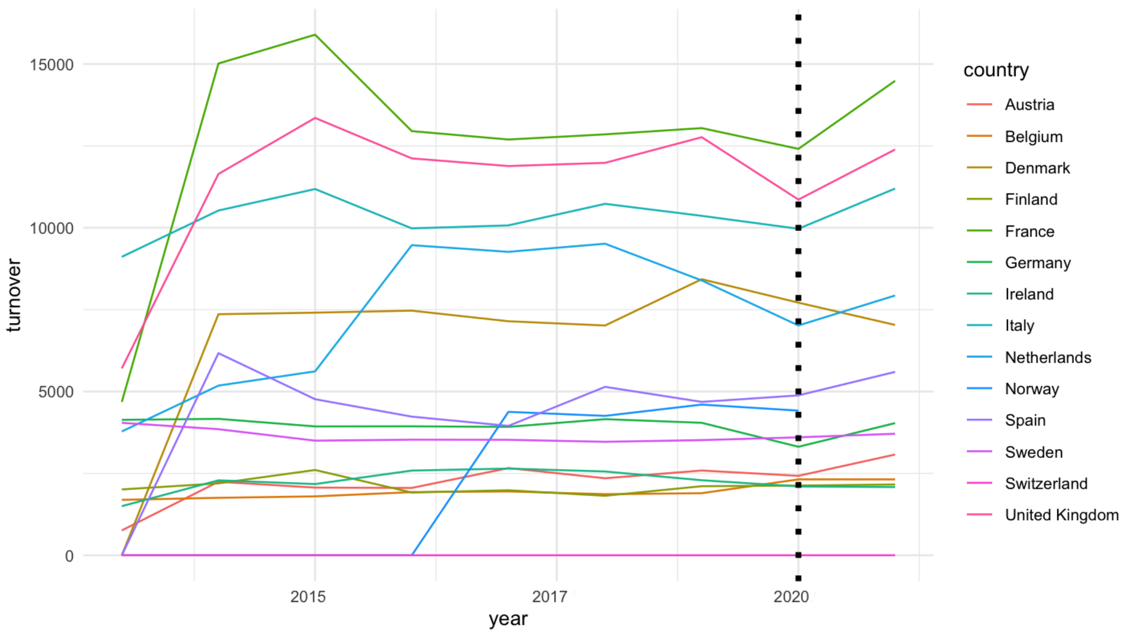

Figure B.1: Average domestic turnover, 2013-2021

Note: Displayed in the graph are the average turnovers of the 44 banks, each with their headquarters situated in one of the 14 countries, as shown in the graph. The data reflects the average turnover in EUR millions reported by the banks in their respective domestic headquarters.

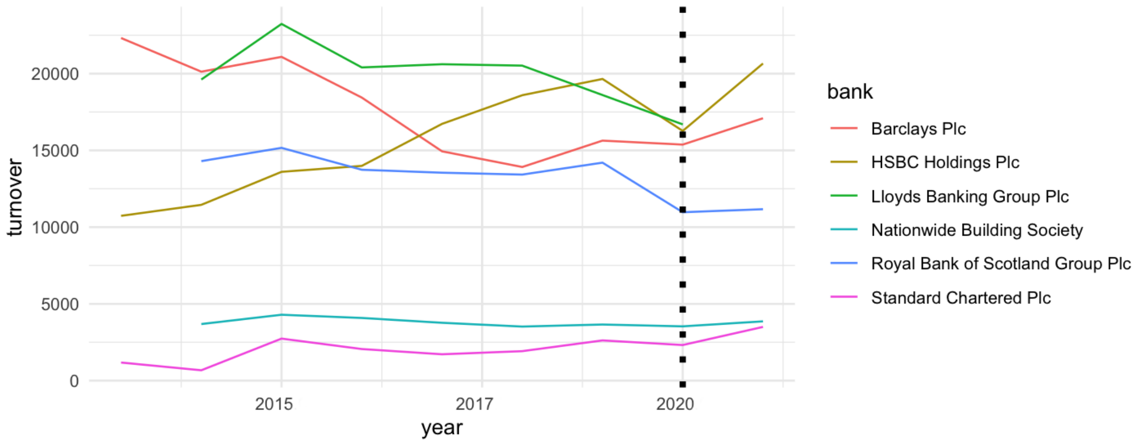

Figure B.2: Turnover of the British banks in the UK

Note: The graph shows the total turnover of the British banks in the UK in EUR millions.

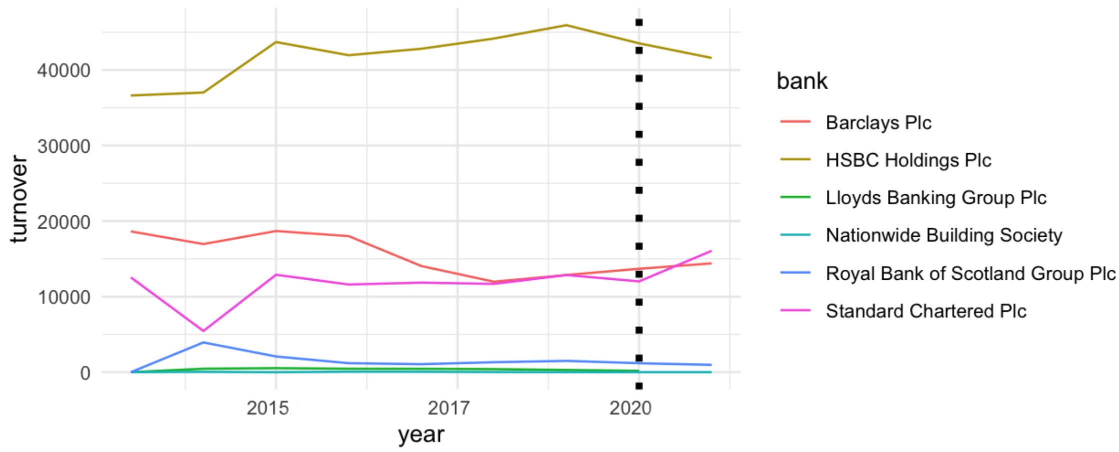

Figure B.3: Turnover of the British banks in partner countries

Note: The graph shows the total turnover of the British banks in all of the partner countries (the UK excluded) in EUR millions.

Table B.1: List of banks

	headquarters	turn_d	turn_o	year_in	par_2013	par_in	par_2021
HSBC Holdings Plc	United Kingdom	41, 924	15, 742	2, 013	20	20	52
Barclays Plc	United Kingdom	15, 475	17, 660	2, 013	25	25	24
Lloyds Banking Group Plc	United Kingdom	391	19, 996	2, 014	0	4	5
Royal Bank of Scotland Group Plc	United Kingdom	1, 655	13, 313	2, 014	0	38	16
Standard Chartered Plc	United Kingdom	11, 888	2, 079	2, 013	46	46	46
Nationwide Building Society	United Kingdom	25	3, 800	2, 014	0	1	0
UBS Group AG	Switzerland	2, 065		2, 013	12	12	11
Credit Suisse Group AG	Switzerland	1, 218		2, 014	0	4	1
Skandinaviska Enskilda Banken AB	Sweden	2, 931	4, 887	2, 013	7	7	17
Swedbank AB	Sweden	1, 039	3, 315	2, 013	4	4	5
Svenska Handelsbanken AB	Sweden	1, 502	2, 714	2, 013	5	5	11
Banco Santander SA	Spain	40, 814	7, 148	2, 014	0	31	30
Banco Bilbao Vizcaya Argentaria SA	Spain	17, 202	6, 094	2, 014	0	19	25
Banco de Sabadell SA	Spain	1, 079	4, 066	2, 014	0	1	3
Bankia SA	Spain	31	3, 355	2, 014	0	2	0
Banco Popular Espanol SA	Spain	105	3, 098	2, 014	0	2	0
DNB ASA	Norway	795	4, 414	2, 017	0	7	0
Rabobank	Netherlands	7, 253	17, 070	2, 013	36	36	32
ING Groep NV	Netherlands	11, 664	5, 830	2, 014	0	34	30
ABN AMRO Group NV	Netherlands	1, 418	6, 836	2, 013	17	17	11
NIBC Bank NV	Netherlands	64	358	2, 014	0	3	3
Intesa Sanpaolo SpA	Italy	4, 946	18, 984	2, 013	27	27	28
UniCredit SpA	Italy	10, 025	8, 806	2, 013	30	30	17
Banca Monte dei Paschi di Siena SpA	Italy	38	3, 663	2, 014	0	8	2
Allied Irish Banks Plc	Ireland	308	2, 248	2, 013	2	2	1
Deutsche Bank AG	Germany	18, 340	10, 966	2, 013	12	12	43
DZ Bank AG	Germany	1, 480	8, 404	2, 013	13	13	13
Commerzbank AG	Germany	2, 448	6, 842	2, 014	0	9	9
Landesbank Baden-Wuerttemberg	Germany	267	2, 676	2, 014	0	8	7
Norddeutsche Landesbank Girozentrale	Germany	287	2, 407	2, 013	6	6	5
Bayerische Landesbank	Germany	171	2, 087	2, 014	0	6	4
Landesbank Hessen-Thueringen Girozentrale	Germany	239	1, 832	2, 014	0	4	5
DekaBank	Germany	219	1, 493	2, 013	4	4	2
KfW	Germany	14	491	2, 014	0	1	1
BNP Paribas SA	France	28, 582	13, 869	2, 013	59	59	56
Crédit Agricole Group	France	21, 532	11, 670	2, 013	13	13	67
Groupe BPCE	France	4, 576	19, 198	2, 014	0	53	35
Nordea Bank AB	Finland	8, 108	2, 104	2, 013	15	15	19
Danske Bank A/S	Denmark	3, 352	7, 447	2, 014	0	13	11
KBC Group NV	Belgium	3, 018	3, 504	2, 013	17	17	14
Belfius Banque SA	Belgium	19	2, 339	2, 013	5	5	3
Dexia SA	Belgium	256	9	2, 018	0	5	0
Erste Group Bank AG	Austria	2, 825	2, 859	2, 013	5	5	4
Raiffeisen Bank International AG	Austria	3, 534	1, 843	2, 014	0	13	12

Note: The table contains a list of the 44 banks used in the analysis, the average turnover in the importing (destination) and exporting (origin) countries, and the number of partner countries in the initial year of reporting and the last year of the dataset.