Essays in International Economics: the Role of Trade Liberalization, Protectionism and Pandemics in a Globalized World

Inaugural-Dissertation
zur Erlangung des Grades Doctor oeconomiae publicae
(Dr. oec. publ.)
an der Ludwig-Maximilians-Universität München

2021

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Marina Gabriele Steininger

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Für meine Familie
und Alessandro.

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Contents

Preface **1**

1 Globalization in The Time of COVID-19 **7**

1.1 Introduction 7

1.2 COVID-19 - A Production Barrier Shock 12

1.3 Theoretical Framework 14

1.4 Quantifying the Effects of COVID-19 19

1.4.1 Open Economy 21

1.4.2 Less Integrated World 27

1.5 Conclusion 33

2 Covid-19 Pandemic, Trade and Inequality **35**

2.1 Introduction 35

2.2 Methodology 39

2.2.1 The COVID-19 Shock 39

2.2.2 The Theoretical Framework 40

2.2.3 The Regional Effects of COVID-19 42

2.3 Data and Descriptive Evidence 45

2.3.1 Data 45

2.3.2 Descriptive Evidence 48

2.4 Results 49

2.5 Conclusion 56

3 Quantifying Brexit: From Ex Post to Ex Ante Using Structural Gravity 61

3.1 Introduction 61
3.2 Model 66
3.2.1 Setup 66
3.2.2 General Equilibrium 67
3.2.3 Comparative Statics in General Equilibrium 68
3.3 Empirical Model, Data, and Parameter Estimates 69
3.3.1 Empirical Model 69
3.3.2 Data Sources 70
3.3.3 The UK's Europe Exposure in Comparison 72
3.3.4 Gravity Analysis of Aggregate Data 74
3.3.5 Gravity Analysis of Sectoral Data 77
3.4 General Equilibrium Results 77
3.4.1 Counterfactual Scenarios 77
3.4.2 The Role of Treatment Heterogeneity 79
3.4.3 Effects on Real Consumption 81
3.4.4 Effects on Bilateral Trade 84
3.4.5 Effects on Overall Trade 86
3.4.6 Changes in Sectoral Value Added 86
3.5 Robustness 88
3.6 Conclusion 89

4 Revisiting the Euro's Trade Cost and Welfare Effects 97

4.1 Introduction 97
4.2 Research Design 99
4.2.1 Gravity 101
4.2.2 Comparative Statics 103
4.2.3 Construction of Confidence Intervals 103
4.3 Data and Empirical Results 104

4.3.1 Data 104
4.3.2 Gravity Analysis of Average Effects 105
4.3.3 Singling Out Germany and Allowing For Directionality 106
4.4 Counterfactual Analysis 109
4.5 Conclusion 116

5 Quantifying the EU-Japan Economic Partnership Agreement 117

5.1 Introduction 117
5.2 Descriptive Evidence of potential growth opportunities between EU and Japan 119
5.3 Theoretical Framework 123
5.3.1 Comparative Statics in General Equilibrium 126
5.4 Model Calibration and Scenario Definition 128
5.4.1 Data 128
5.4.2 Learning from EU-Korea for EU-Japan 129
5.4.3 Counterfactual Scenarios 136
5.5 General Equilibrium Results 137
5.5.1 Changes in Real Income 138
5.5.2 Welfare Decomposition 140
5.5.3 Changes in Sectoral Value Added 142
5.5.4 Changes in Trade 143
5.6 Conclusion 146

A Appendix to Chapter 1 - Globalization in the Time of COVID-19 147

A.1 Data Sources and Description 147
A.2 Additional results 151

B Appendix to Chapter 2 - COVID-19 Pandemic, Trade and Inequality 157

B.1 Fit of the Data - WIOD and Interpolated Eurostat Data 157
B.2 Technical Explanation of the Theory 161

B.2.1 List of EU Regions in the Sample 167

C Appendix to Chapter 3 - Quantifying Brexit: From Ex Post to Ex Ante Using Structural Gravity 169

C.1 The Model in Changes 169

C.2 Details on Data and Results 171

D Appendix to Chapter 4 - Revisiting the Euro's trade cost and welfare effects 189

D.1 Model Closure 189

D.2 Comparative Statics in General Equilibrium 190

D.3 Detailed Gravity Results 192

E Appendix to Chapter 5 - Quantifying the EU-Japan Economic Partnership Agreement 196

Bibliography 203

List of Figures

1.1 Decomposition of Real Income changes - Open Economy 25

2.1 Sectoral Productivity Differences across Selected Countries 46

2.2 Productivity Differences across Regions within EU28 Countries 47

2.3 Initial Value Added in bn. Euro across Europe's Regions 49

2.4 Value Added Change in bn Euro across Europe's Regions 50

2.5 Value Added Change Over Income in bn Euro across Europe's Regions . 54

3.1 Inverse Trade Frictions with Different Trade Partners, 2014 73

3.2 Change in Non-Tariff Barriers, in % 80

3.3 Decomposing the Real Consumption Effects of a Hard Brexit 84

5.1 Shares in World GDP, current USD (1970-2015) and Evolution of real GDP per capita in Purchasing Power Parities, 1990=100, 1990-2015 120

5.2 Bilateral Tariffs between EU28 and Japan, % 123

5.3 Bilateral Imports and Exports of EU28 with Japan, Korea and Rest of the World, 2011=100, 2000-2020 130

5.4 Welfare Decomposition: Real Income Changes, in bn USD 141

5.5 Counterfactual Change of Sectoral Value Added in EU28 and Japan, in bn US-Dollars 143

A1 Restrictiveness Index Across Countries 149

A2 Employment Shares Across Chinese Regions 150

A3 Size of Shock Across All Countries 152
A4 Size of the Shock for EU28 Member States 152
A5 Real Income Changes with Different Openness Degrees of the Economy . 154

B1 Interpolation Exercise WIOD - Eurostat: French Value Added 158
B2 Data Fit of Wiod and Interpolated Eurostat across EU28 159
B3 Data Fit of Wiod and Eurostat across sectors of selected countries 160

C.1 Average MFN Tariffs on Intra-EU Trade, 2014 171

List of Tables

1.1 Change of Real Income Across Countries (in %) - Open Economy 22
1.2 Change in Value Added in bn USD - Open Economy 23
1.3 Change of Sectoral Trade, in bn USD - Open Economy 29
1.4 Decomposition of Real Income Changes - Open Economy 30
1.5 Openness, Trade Diversification and Specialization in Production 31
1.6 Real Income Changes (in %) - Less Integrated vs. Open Economy 32

2.1 Change of Value Added - Top 10 and Bottom 10 Regions in EU28 in mn Euro 52
2.2 Normalized Change of Value Added over Income - Top 10 and Bottom 10 Regions in % 53
2.3 Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Regions in mn Euro 56
2.4 Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Regions in % 57
2.5 Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Countries in mn Euro 58
2.6 Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Countries in % 59

3.1 The Impact of EU Integration Steps on Bilateral Imports (2000 - 2014) . 76
3.2 EU Integration Steps and Bilateral Imports (2000 - 2014) 91

3.3 Average Real Wage Changes in a Hard Brexit Scenario (S1), in %, Based on Various NTB Estimations 92
3.4 Counterfactual Change in Real Consumption, in % 93
3.5 Counterfactual Changes of Bilateral Exports of EU27, UK and RoW, in % 94
3.6 Counterfactual Changes of Overall Trade, in % 95
3.7 Counterfactual Changes of Sectoral Value Added, in % 96

4.1 The Impact of EMU on sectoral Bilateral Imports 107
4.2 The Impact of EMU on German Bilateral Imports from Old and New EMU Members 108
4.3 The Impact of EMU on sectoral Bilateral Imports of Goods 110
4.4 The Impact of EMU on sectoral Bilateral Imports of Services 111
4.5 Real Income Changes, in % 112
4.6 Change in Aggregate Trade, in % 113
4.7 Counterfactual Change of Bilateral Trade, in % 114
4.8 German Sectoral Value Added Changes, in % 115

5.1 Initial Bilateral Trade between EU and Japan, in bn USD & % 122
5.2 Gravity Estimates of the Aggregate Trade Effects of the EU-Korea FTA . 134
5.3 Aggregated Sectoral Trade Creation Effects (%) of the EU-Korea FTA . 135
5.4 Counterfactual Real Income Changes, in % 140
5.5 Change of Japanese bilateral Exports, in bn USD 145
5.6 Change of Japanese bilateral Imports, in % and mn USD 145

A1 Teleworkability by Sector 151
A2 Change in Value Added (in %) - Open Economy 153
A3 WIOD Sector Aggregation 155
A4 Concordance WIOD Sectors - ISIC Rev. 4 156

B1 Concordance WIOD- Isic4 and NACE 166

C.1 List of WIOD Manufacturing Sectors 172
C.2 Gross National Income and Transfer Redistribution 173
C.3 EU Integration Steps and Bilateral Imports, Goods (2000 - 2014) 174
C.4 EU Integration Steps and Bilateral Imports, Services (2000 - 2014) 175
C.5 Counterfactual Change in Real Consumption of Welfare Decomposition in Scenario 1, in % 176
C.6 Counterfactual Change in Real Consumption of Welfare Decomposition in scenario 1, in %, continued 177
C.7 Counterfactual Changes of Bilateral Exports of EU27, in % 178
C.8 Counterfactual Changes of Bilateral Exports of UK, in % 179
C.9 Counterfactual Changes of Bilateral Exports of RoW, in % 180
C.10 Counterfactual Changes of Gross Trade Flows, in % 181
C.11 Counterfactual Changes of Real Wages, in % 182
C.12 Counterfactual Changes of Sectoral Value Added of Agricultural and Manufacturing Goods in UK, in % 183
C.13 Changes of UK's Sectoral Value Added of Services, in % 184
C.14 Changes of EU27's Sectoral Value Added of Agricultural and Manufacturing Goods, in % 185
C.15 Changes of EU27's Sectoral Value Added of Services, in % 186
C.16 Sectoral Trade Cost Elasticities from Caliendo & Parro (2015) 187
C.17 Change in Real Consumption, in % 188

D.1 The Impact of EMU on Sectoral Bilateral Imports of Goods 192
D.2 The Impact of EMU on Sectoral Bilateral Imports of Services 193
D.3 The Impact of EMU on sectoral Bilateral Imports of Goods 194
D.4 The Impact of EMU on German Sectoral Bilateral Trade of Services with Old and New EMU member states 195

E.1 Sectoral Trade Creation Effects (%) of the EU-Korea FTA 197

E.2 Trade Cost Elasticities 198
E.3 List of GTAP Sectors 199
E.4 List of GTAP Regions and Countries 200
E.5 Change in Sectoral Value added, EU28 and Japan 201
E.6 Change of Sectoral Value Added of Agri-Food in EU28 and Japan, in bn USD & % 202

Preface

Since the end of World War II, leaders across the globe tried to reduce barriers to live in peace and to increase welfare in their countries. International institutions, such as NATO, the European Union and the World Trade Organization were founded to promote democratic ideals, promote multilateralism, increase international trade and build coalitions to deconstruct nationalism. However, in the last decade surges of rising protectionism increased, questioning the existence of these institutions. Moreover, the uprising of the largest pandemic ever experienced by the modern world posits additional challenges to the existing globalized world (Antras et al., 2020). Globalization has a significant impact on growth across and within countries. It fosters fast-paced changes in technology and increases mobility of goods, services, capital and labor. It facilitated vast opportunities of growth and contributed to a dramatic increase in the world's GDP (Grossman and Helpman (2015), Antràs and Chor (2018), Caliendo and Parro (2015), David et al. (2013),). Yet, these trends were accompanied with uncertainty and sometimes presented an uneven distribution of the costs and benefits (Acemoglu and Yared (2010)). People and nations started to question whether they were among the winners or the losers from globalization. *"To ensure that globalization can be leveraged to support inclusive economic growth and sustainable development, it is essential to analyze the current system as well as emerging trends to devise policy solutions addressing them,"* said Liu Zhenmin, UN DESA's Under-Secretary-General. It is crucial to understand the economic implications of integrating or disintegrating nations. This thesis provides answers how recent trends affect economies in a globalized world.

The first two chapters analyze how the COVID-19 pandemic affects welfare and inequality across the globe and specifically across European regions. The third chapter discusses the economic consequences of Brexit, the predominant example of rising nationalism. The last two chapters scrutinize the effects of increased multilateralism on two examples: The formation of the European Monetary Union and the implementation of the EU-Japan Economic Partnership Agreement.

Chapter 1. The first chapter studies the role of global production linkages in the transmission of the COVID-19 pandemic shock across countries. *"The seismic shock of the coronavirus pandemic has revealed the fragility of an interconnected world"* (The Economist, 2020). The first half of the year 2020 was filled with headlines and discussions about the role of globalization in the diffusion of the negative effects of COVID-19. The COVID-19 pandemic is possibly the biggest production disruption in the recent world history. With 11.648.268 cases, 538.828 deaths and millions of people in quarantine around the world as of 7th of July 2020, the spread of COVID-19 disease is the largest pandemic ever experienced in the globalized world. Globalization allows firms to source intermediate inputs and sell final goods in many different countries, so the economic effects of a global pandemic crucially depend on the extent to which countries are connected in global production networks.

This chapter studies the effects of the COVID-19 induced lockdowns on economies and the role of the diffusion of the shock through global value chains. To perform a counterfactual simulation, this chapter extends a multi-country, multi-sector type Ricardian trade model. The derived general equilibrium effects are decomposed into a direct effect from the production shock induced by the COVID-19 shock and an indirect effect coming from the global shock affecting other countries. Both exercises are performed in an open economy with the actual tariff and trade cost levels and in a closer economy, where trade costs are increased by 100 percentage points in each sector-country. The COVID-19 shock has a considerable impact on most economies in the world. Most of the countries experience a drop in real income up to 18%, with the highest drops for Slovenia and Poland. The observed heterogeneity in the sectoral drop in value-added is partially driven by the geography of production in each country combined with the regional diffusion of the shock - regional variation in lockdown policies - and by the inter-sectoral linkages across countries, but also by the heterogeneity in the degree of *teleworkability* across sectors. The decomposition of the results into a direct effect of production and an indirect effect through global value chains substantiates the role of the global production linkages in magnifying the effect of the production. The trade linkages between countries account for a substantial share of the total income drop observed. The degree of trade openness of a country is a key element in explaining the observed heterogeneity. The findings highlight the importance of inter-sectoral linkages in the transmission of the shock: a higher degree of integration in the global production network implies that a shock in one country directly diffuses though the trade linkages to other countries. Trade smooths the effect of the shock by allowing consumers to purchase and consume goods they wouldn't otherwise be able to consume in a world with production barriers in lockdown. Yet, the COVID-19 shock increases production costs of intermediate inputs that are used at home and abroad. This Chapter is currently published as a working paper and contributed to political debates in Germany and the EU (see Sforza and Steininger (2020)).

Chapter 2. The European Union was faced with various challenges threatening its integrity over the last decades. The diffusion of the COVID-19 virus disease posits an additional severe threat to the resilience of the European Union. Alongside populism, one of the main issues is the increase in inequality. *"Regional inequality is proving too politically dangerous to ignore."* (The Economist, 2016). Chapter 2 studies the diffusion of the economic shock induced by the COVID-19 pandemic to understand how inequality is distributed across European regions. Understanding these patterns is crucial for precise policy measures in the EU.

We propose a methodology to redistribute the general equilibrium changes in value-added by country-sector across European regions. We find that the distributional effects of the COVID-19 pandemic disease are extremely heterogeneous across European regions, exacerbating the "core-periphery" divide and the inequality across the European area. Chapter 2 provides evidence that the COVID-19 shock has a stronger impact on the peripheral regions of Eastern and Southern Europe, together with most of the Mediterranean regions. On the contrary, the central European regions experience a much milder effect of the pandemic on their economic structure. The enormous difference in the size of the economic effect of the COVID-19 shock across European regions emphasizes the importance of policy responses that target the reduction of inequality across regions as a primary goal. The observed heterogeneity is driven by two major components. First, the COVID-19 shock had a heterogeneous impact across countries, and the policy response of lock-down varied substantially across countries, regions and sectors. Second, the geographical distribution of economic activity is extremely polarized, with very concentrated cities and core regions, and poor peripheries. A shock to production that hits disproportionately more labor-intensive sectors that rely on external inputs, happens to have a stronger impact in the peripheral areas of Europe.

Chapter 3. The third chapter analyzes the effects of one of the most predominant examples of protectionism of the last decade, namely Brexit. Only a few years prior to the uprising of the largest pandemic in the recent world history, the United Kingdom voted to leave the European Union in June 2016. 51.9 percent of voters made the momentous choice to leave the EU in the referendum. On the 1st of February 2020, the two parties, UK and EU, agreed upon a Withdrawal Agreement, which ends on the 31st of December 2020.

The UK will no longer be part of the single market and customs union from the 1st of January 2021. The chapter quantifies the general equilibrium trade, welfare and value-added effects of a counterfactual world in which the United Kingdom is no longer part of the European Union. In the first part, trade cost changes of the integration processes of joining the European Union single market and the customs union are estimated. Since Brexit is not observable in the data yet, the estimated trade cost reductions of the EU integration process are inverted and used as proxy for the negative consequences of Brexit. Several counterfactual scenarios analyzing the consequences of different Brexit types are simulated in a multi-country, multi-sector Ricardian trade model.

The ex-post evaluation of EU integration steps shows a successful decrease in trade costs between the EU member states. The EU integration boosted goods exports of the UK to the other EU countries by 24% and increased other EU members' exports to the UK by as much as 76%. The EU membership increased UK's services exports to EU27 by 64%, while bilateral services exports of other EU27 countries to the UK almost doubled. The general equilibrium effects are heterogeneous across the EU27 members. A hard Brexit reduces real consumption in Ireland, Luxembourg and Malta more than in the UK. The core EU economies France, Germany, and Italy face slightly smaller losses. A soft Brexit, namely concluding on a EU27-UK free trade agreement such as the EU-Korea FTA, would avoid three quarters of the losses from Brexit in the EU27 countries and two thirds in the UK compared to the hard Brexit scenario. Yet, instead of staying in the single market and customs union, UK could also try to sign free trade agreements with the non-EU countries (i.e. Korea, Japan, Canada, USA). However, this strategy yields less advantages for UK than staying in the customs union with the EU27. Chapter 3 is published as a working paper and substantially contributed to the public debates in UK and EU27 member states (see Felbermayr et al. (2018c)).

Chapter 4. About twenty years ago, the European Monetary Union was created; a time in which the European Union was in the middle of the process to lower barriers instead of building walls between each other. The objective was to foster intra-European economic exchange, in particular trade, by eliminating currency related transaction costs, such as insurances for exchange rate fluctuations, or reduced-price transparency. Chapter 4 revisits the trade cost effects of the introduction of the Euro. It quantifies the general equilibrium effects for EU member states and specifically Germany if the European Monetary Union was dissolved. The exercise informs the reader about the trade and welfare effects of having a common currency in the EU. A deeper understanding about these patterns is crucial for anti-Euro and in general anti-Europe movements because it provides a deeper understanding of the general equilibrium welfare effects. Using sectoral trade data from 1995 to 2014 and applying structural gravity modelling, the chapter conducts an ex post evaluation of the European Monetary Union.

The Euro led to a significant average trade effect for goods of almost 8 percent, but a much smaller effect for services trade. The Euro had heterogeneous effects across sectors and member states. Singling out Germany, and embedding the estimation results into a quantitative general equilibrium model of world trade, the chapter shows that EMU has increased real incomes in all member states. The German real GDP would have been 0.6% lower if the Euro had not existed in 2014. Among the large EMU members, this is the largest effect. Only the service intensive members, Belgium and Luxembourg, benefited more (1.4% and 2.1%, respectively). German gross trade is by about 1.1% to 1.5% higher with the Euro; within the other EMU members, the effect is even more pronounced. The chapter is published as a research paper (Felbermayr and Steininger (2019)).

Chapter 5. The last chapter concludes the thesis by structurally analyzing the effects of trade liberalization on welfare and trade across countries and sectors. More specifically, it provides a quantitative analysis of the new EU-Japan Economic Partnership Agreement (EPA), the biggest bilateral deal that both the EU and Japan have concluded so far. On 1 February 2019, the Economic Partnership Agreement (EPA) between the EU and Japan entered into force. As of today, it is the largest free trade area in the world. In the times of growing protectionism and unilateralism, it is of strategic importance for both the EU and Japan.

The chapter first employs a state-of-the-art sector level gravity model to ex-post estimate the trade cost changes of a free trade agreement, which is similar in the scope, namely the EU-Korea FTA. The estimated trade cost changes are used as a proxy for the potential trade cost shocks between EU and Japan. Together with observable tariff reductions, these trade cost changes are included as trade cost shocks to inform the CGE model, which provides a data-driven ex-ante analysis of the potential effects of the EU-Japan EPA. The counterfactual scenario of the EPA is simulated on three different baselines. The first baseline is similar to the world as of today, without Brexit, TPP and other future FTAs, such as CETA. The second baseline assumes an economy with Brexit, hence UK left the European Union. The EU-Japan EPA is only implemented between the EU27 and Japan and excludes UK as an EPA partner. The third baseline includes Transpacific Partnership (TPP) agreement in the baseline. This first scenario yields long-run welfare effects for Japan of about 18 bn USD per year (0.31% of GDP) and of about 15 bn USD (0.10%) for the EU. A welfare decomposition shows that 14% of the welfare gains inside the EPA stem from tariffs, the remaining 86% from NTB reforms. The services sectors account for more than half of the non-tariff barrier reductions. In the EU, value-added in the agri-food sector increases the most, while in Japan the manufacturing and services sectors gain the most. Japan and the EU experience very similar welfare gains in absolute terms. In relative terms, Japan's gains are three times as large as the EU's. The EPA leads to trade diversion in Japan towards Europe, especially Eastern Europe and away from former ASEAN countries. The welfare gains are substantially smaller for Japan if UK is not a member of the EU anymore. The third counterfactual scenario includes the Transpacific Partnership (TPP) agreement in the baseline. It has little importance for the effects of the EU-Japan EPA. The chapter is published as a research paper (see Felbermayr et al. (2019)).

Chapter 1

Globalization in The Time of COVID-19

The economic effects of a pandemic crucially depend on the extent to which countries are connected in global production networks. In this paper we incorporate production barriers induced by COVID-19 shock into a Ricardian model with sectoral linkages, trade in intermediate goods and sectoral heterogeneity in production. We use the model to quantify the welfare effect of the disruption in production that started in China and quickly spread across the world. We find that the COVID-19 shock has a considerable impact on most economies in the world, especially when a share of the labor force is quarantined. Moreover, we show that global production linkages have a clear role in magnifying the effect of the production shock. Finally, we show that the economic effects of the COVID-19 shock are heterogeneous across sectors, regions and countries, depending on the geographic distribution of industries in each region and country and their degree of integration in the global production network.

1.1 Introduction

Globalization allows firms to source intermediate inputs and sell final goods in many different countries. The diffusion of a local shock through input-output linkages and global value chains has been extensively studied (see for example Carvalho et al. (2016)) but little is known on how a pandemic affects global production along with its diffusion.[1]

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[1] Huang (2019) studies how diversification in global sourcing improves firm resilience to supply chain disruptions during the SARS epidemics in China. We complement his analysis by studying the effect of an epidemic shock that is not geographically confined to a specific region, but it spreads fast in the entire world

In this paper we study the role of global production linkages in the transmission of a pandemic shock across countries. We exploit an unprecedented disruption in production in the recent world history, namely the global spread of COVID-19 virus disease, to instruct a multi-country, multi-sector Ricardian model with interactions across tradable and non-tradable sectors observed in the input-output tables. We use the model to quantify the trade and welfare effects of a disruption in production that started in China and then quickly spread across the world. The spread of COVID-19 disease provides a unique set-up to understand and study the diffusion of a global production shock along the global value chains for three main reasons. First, it is possibly the biggest production disruption in the recent world history. With around 11.648.268 cases, 538.828 deaths and millions of people in quarantine around the world to date[2], the spread of COVID-19 disease is the largest pandemic ever experienced in the globalized world.[3] Second, the COVID-19 shock is not an economic shock in its nature, hence its origin and diffusion is independent from the fundamentals of the economy. Third, differently from any other non-economic shock experienced before, it is a global shock. Indeed, while the majority of natural disasters or epidemics have a local dimension, the spread of the COVID-19 disease has been confined to the Chinese province of Hubei only for a few weeks, to then spread across the entire world.

Understanding the effects of a global production disruption induced by a pandemic is complex. We build on the work by Caliendo and Parro (2015) who develop a tractable and simple model that allows to decompose and quantify the role that intermediate goods and sectoral linkages have in amplifying or reducing the impact of a change in tariffs.[4] We extend their framework and introduce a role for policy intervention in deterring production. In our set-up, the policy maker can use the instrument of lockdown as a policy response to deter the COVID-19 virus diffusion; moreover, we account for the geographic distribution of industries in each region and country and for the labor intensity of each sector of production to have a complete picture of the distribution of the shock across regions and sectors. The policy intervention of lockdown translates into a production barrier that increases the production costs for intermediates and final goods produced for the internal market as well as for the exporting market. We construct a measure of lockdown using three different pillars: first, we use a country level measure for the stringency of the policy intervention of lockdown from Hale et al. (2020). Second, we allow the lockdown to heterogeneously affect each sector in each country using the share

[2] as of 7th of July 2020

[3] See Maffioli (2020) for a comparison of COVID-19 with other pandemics in the recent history.

[4] Other papers that have used the framework of Caliendo and Parro (2015) include papers, such as Aichele et al. (2016).

of work in a sector that can be performed at home (henceforth *teleworkability*) from Dingel and Neiman (2020).[5] Third, we account for the average duration of lockdown in each region and sector using the information in the CoronaNet database. Crucially, in a model with interrelated sectors the cost of the input bundle depends on wages and on the price of all the composite intermediate goods in the economy, both non-tradable and tradable. In our framework, the policy intervention has a direct effect on the cost of each input as well as an indirect effect via the sectoral linkages.[6] Moreover, our modeling choice for the shock allows the spread of COVID-19 disease to also have a direct effect on the cost of non-tradable goods in each economy, hence on domestic trade.

We follow Dekle et al. (2008a) and Caliendo and Parro (2015) and solve the model in relative changes to identify the welfare effect of the COVID-19 shock. We perform two different exercises: (i) we include the COVID-19 shock in the model and we estimate a scenario based on the lockdown policies implemented in each country-region, (ii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 shock and an indirect effect coming from the global shock affecting other countries. We perform the two exercises both in an open economy with the actual tariff and trade cost levels and in a closer economy, where we increase the trade costs by 100 percentage points in each sector-country. The quantitative exercise requires data on bilateral trade flows, production, tariffs, sectoral trade elasticities, employment shares by sector and region and the number of COVID-19 cases in each region or country. We calibrate a 40 countries 50 sectors economy and incorporate the COVID-19 shock to evaluate the welfare effects for each country both in aggregate and at the sectoral level.

We find that the COVID-19 shock has a considerable impact on most economies in the world. With lockdown, most of the countries experience a drop in real income up to

[5] It is crucial to note that the sectoral heterogeneity in labor intensity as well as teleworkability are time invariant in our set-up, while the number of COVID-19 cases as well as the restrictiveness and duration of the implemented policy measures are in continuous evolution, hence the point estimates of the counterfactual scenarios might change as the spread of the COVID-19 disease affects more countries and more people. Even if the size of the shock changes, the sensitivity and the comparisons across sectors and countries as well as the decomposition of the effects will remain similar. The focus of this paper is to highlight the importance of global production networks in the diffusion of a global shock and on how to use a simple theoretical framework to provide insights on the heterogeneous effects of the COVID-19 shock across countries and across sector under different scenarios, rather than providing the absolute numbers of the drop in real income due to the COVID-19 shock. We will constantly update the results of the paper to account for the new cases as well as for the number of countries in lockdown. The results presented in this version are supposed to provide a first *snap-shot* of the economic effect of the COVID-19 shock. A more complete picture will be available when the full information of COVID-19 cases, lockdown-countries and share of people in lockdown is available.

[6] This feature of the model is a key difference compared to one-sector models or multi-sector models without interrelated sectors, as highlighted by Caliendo and Parro (2015).

18%, with the most pronounced drops for Slovenia and Poland. Accounting for regional variation in the duration of the restrictions as well as for the geographic location of sectors across regions in a country is key to obtain a realistic picture of the impact of the COVID-19 shock. We further decompose the economic impact of the COVID-19 shock by sectors and find that the income drop is widespread across all sectors. Indeed, contrary to drops in tariffs that affect only a subset of sectors, the COVID-19 shock is a production barrier that affects both home and export production in all sectors of the economy. The observed heterogeneity in the sectoral drop in value added is partially driven by the geography of production in each country combined with the regional diffusion of the shock–regional variation in lockdown policies– and by the inter-sectoral linkages across countries, but also by the heterogeneity in the degree of *teleworkability* across sectors.

The role of the global production linkages in magnifying the effect of the production shock is clear when we decompose the total income change into a *direct* component due to a domestic production shock and an *indirect* component due to global linkages. We show that linkages between countries account for a substantial share of the total income drop observed. Moreover, we estimate a simple econometric model to better understand the determinants of the observed heterogeneity in the income drop accounted for by the *direct* and the *indirect* effect. We find that the degree of trade openness of a country is a key element in explaining the observed heterogeneity.

Finally, to deeper understand the importance of global production networks in the diffusion of the shock, we investigate what would have been the impact of the COVID-19 shock in a less integrated world. To answer this question, we quantify the real income effect of the COVID-19 shock in a less integrated world scenario, where we increase the current trade barriers in each country and sector by 100 percentage points. First and unsurprisingly, a less integrated world itself implies enormous income losses for the great majority of countries in our sample. Focusing on the economic impact of the COVID-19 shock in a less integrated world compared to a world as of today, we find some interesting results. Indeed, when raising trade costs in all countries, the *indirect* component is lower than in an open economy, but it still accounts for a relevant share of the drop in the income due to the COVID-19 shock. In our counterfactual exercise, the increase in trade cost mimics a world with higher trade barriers, but not a complete autarky scenario; countries would still trade, use intermediates from abroad and sell final goods in foreign countries. This finding highlights the importance of inter-sectoral linkages in the transmission of the shock: a higher degree of integration in the global production network implies that a shock in one country directly diffuses though the trade linkages to other countries. Trade has two different effects in our model: on the one hand, it smooths the effect of the shock by allowing consumers to purchase and consume goods they wouldn't otherwise be able to consume in a world with production barriers in lockdown. On the other hand, the COVID-19 shock increases production costs of intermediate inputs that are used at home and abroad. Our counterfactual exercise clearly shows that an increase in trade costs would not significantly decrease the impact of the COVID-19 shock across countries. However, increasing trade barriers would imply an additional drop in real income between 14% and 33% across countries.

Our paper is closely related to a growing literature that study the importance of trade in intermediate inputs and global value chains. For example, Altomonte and Vicard (2012), Antràs and Chor (2013), Antràs and Chor (2018), Antràs and de Gortari (Forthcoming), Alfaro et al. (2019), Antràs (Forthcoming), Bénassy-Quéré and Khoudour-Casteras (2009), Gortari (2019), Eaton and Romalis (2016), Hummels and Yi (2001), Goldberg and Topalova (2010), Gopinath and Neiman (2013), Halpern et al. (2015)). Our paper is especially close to a branch of this literature that extends the Ricardian trade model of Eaton and Kortum (2002) to multiple sectors, allowing for linkages between tradable sectors and between tradable and non-tradable.[7] Indeed, our paper is based on the work of Caliendo and Parro (2015) and adds an additional channel through which a policy intervention could affect welfare at home and in other countries, namely a production barrier induced by the spread of the virus. We use an unprecedented shock affecting simultaneously most of the countries across the world to understand the response of the economy under different production barrier scenarios in free trade and a less integrated world. Moreover, we use the rich structure of the model to show the distribution of the effects of the shock across regions and sectors.

Finally, our paper contributes to the literature evaluating the impact of natural disasters or epidemics on economic activities (see for example the papers by Barrot and Sauvagnat (2016), Boehm et al. (2019), Carvalho et al. (2016), Young (2005) and Huang (2019)). Similar to Boehm et al. (2019), Barrot and Sauvagnat (2016) and Carvalho et al. (2016) and Huang (2019) we also study how a natural disaster or an epidemic affects the economy through the input channels. We add to their work by using a shock that is unprecedented both in its nature and in its effect. Indeed, while a natural disaster is a geographically localized shock that can destroy production plants and affects the rest of the economy and other countries only through input linkages, in our set-up the shock induced by COVID-19 is modelled as a policy intervention that constraints production simultaneously in almost all countries in the world. Indeed, in our paper each country is hit by a local

[7] See for example Dekle et al. (2008a), Arkolakis et al. (2012)

shock induced by the spread of the virus at home, and by a foreign shock through the input linkages induced by the spread of corona abroad.[8]

The paper is structured as follows. In section 1.2 we describe the COVID-19 shock and motivate the rationale of our modeling choice. In section 2.2.2 we present the model used for the quantitative exercise. In section 1.4 we describe the data used for the quantitative exercise and we present the results. In section 1.5 we conclude.

1.2 COVID-19 - A Production Barrier Shock

The new coronavirus (the 2019 novel coronavirus disease COVID-19) was first identified in Wuhan city, Hubei Province, China, on December 8, 2019 and then reported to the public on December 31, 2019 (Maffioli (2020)). As of July 7, 2020, the virus has affected 11.648.268 people in the world, causing 538.828 deaths and forcing millions of people in lockdown for several weeks around the world. The exponential contagion rate of the COVID-19 virus has led many governments to implement a drastic lockdown policy, forcing large shares of the population into quarantine. Because of forced quarantine, there is wide consensus that the economic costs of the pandemic will be considerable, as factories, businesses, schools and country boarders have been closed and are going to be closed for several weeks. Moreover, the spread of the COVID-19 disease has followed unpredictable paths, with a marked heterogeneity in the contagion rates across countries and across regions within the same country.

We propose a simple measure that quantifies the intensity of the economic shock, leveraging on the diffusion of COVID-19 across space, the geographical distribution of sectors in each country and the sectoral labor intensity. The shock v_i^j can be expressed as

$$v_i^j = 1 + \sum_{r=1}^{R} \left(\psi_{ir}^j * \frac{l_{ir}^j}{\sum_{r=1}^{R} l_{ir}^j} \right) \tag{1.1}$$

and

$$\psi_{ir}^j = IndexClosure_i * (1 - TW^j) * Duration_{ir}^j \tag{1.2}$$

[8] A growing literature in economics extends the SIER model to study the economic consequences of the diffusion of the pandemic under different policy scenarios (see for example Atkeson (2020), Berger et al. (2020), Eichenbaum et al. (2020))

where l_{ir}^{j} is the total employment of sector j in region r of country i, $\sum_{r=1}^{R} l_{ir}j$ is the sum of employed individuals in a sector j across all regions r of country i and ψ_i^j is a measure of the restrictiveness of the lockdown, comprising three different elements.
$IndexClosure_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (see Hale et al. (2020) for a detailed description of the index), where 100 indicates full restrictions. The index is meant to capture the extent of work, school, transportation and public event restrictions in each country. The second term of equation 2.2, $(1-TW^j)$ contains a key parameter, namely the degree of *teleworkability* of each occupation. Following Dingel and Neiman (2020) we use the information contained in the Occupational Information Network (O*NET) surveys to construct a measure of feasibility of working from home for each sector. Moreover, we allow essential sectors to have a higher degree of *teleworkability*. Finally, to account for the average duration of lockdown in each region and sector, we use the information in the CoronaNet database. We use detailed information on the duration of lockdown in each country, region and sector contained in the CoronaNet database and map the lockdown policies implemented in all regions and sectors of our sample. [9]

The first part of the formula ψ_{ir}^j, returns a measure of lockdown for each country, region and sector in our dataset. In fact, it takes into account the extent of the policy restrictions in each country as well as the possibility to work remotely in presence of restrictions for each sector of the economy. Crucially, we exploit the richness of information in the CoronaNet dataset (see Cheng and Messerschmidt (2020)) to construct a measure of the duration of the restrictions for each country, region and sector. The second term of the formula, $\frac{l_{ir}^j}{\sum_{r=1}^{R} l_{ir}j}$ is a measure of the geographic distribution of production across regions in the country, measuring how much each sector is concentrated in a region compared to the rest of the country. The regional dimension in the duration of the restrictions and in the distribution of production in each country allow us to have a complete and precise picture of the impact of the lockdown measures in each country across space.

It is important to highlight that the COVID-19 shock substantially differs from a natural disaster. A natural disaster is a geographically localized shock that can lead to the destruction of production plants, to the loss of human lives and to a lockdown of many economic activities in a country or region. These types of shocks affect the rest of the economy and foreign countries through input linkages (see Carvalho et al. (2016)). In our set-up, the shock induced by COVID-19 virus is modelled as a shock to the production cost of both domestic goods and goods for foreign markets. Moreover, the global nature of the

[9] A detailed description of the dataset can be found in Cheng and Messerschmidt (2020). In section 1.4 we provide details on the construction of each dataset used to create the variable ψ_{ir}^j

shock implies that most countries are simultaneously affected by the shock both directly – through an increase in the production cost of the goods for domestic consumption – and indirectly – through an increase in the cost of intermediates from abroad and through a decrease in demand of goods produced for the foreign markets. Our set-up crucially allows us to quantify both channels and highlights the importance of the direct effect of the shock on domestic production vis a vis the indirect effect coming from the global production linkages.

To conclude, an economic assessment of the COVID-19 shock should take into account the lockdown policies implemented in each country, the degree of integration among countries through trade in intermediate goods and the heterogeneity in countries' production structure. In the next section we describe the framework used for the analysis and the mechanisms at work.

1.3 Theoretical Framework

The quantitative model presented in this section follows the theoretical framework of Caliendo and Parro (2015) and we refer to their paper for a more detailed description of the framework and the model solution. We modify the model allowing for the role of a policy intervention that leads to a production barrier of the form described in section 1.2. There are N countries, indexed by i and n, and J sectors, indexed by j and k. Sectors are either tradable or non-tradable and labor is the only factor of production. Labor is mobile across sectors and not mobile across countries and all markets are perfectly competitive.

Households. In each country the representative households maximize utility over final goods consumption C_n, which gives rise to the Cobb-Douglas utility function $u(C_n)$ of sectoral final goods with expenditure shares $\alpha_n^j \in (0,1)$ and $\sum_j \alpha_n^j = 1$.

$$u(C_n) = \prod_{j=1}^{J} C_n^{j\,\alpha_n^j} \tag{1.3}$$

Income I_n is generated through wages w_n and lump-sum transfers (i.e. tariffs).

Intermediate Goods. A continuum of intermediates can be used for production of each ω^j and producers differ in the efficiency $z_n^j(\omega^j)$ to produce output. The production technology of a good ω^j is

$$q_n^j\left(\omega^j\right) = z_n^j\left(\omega^j\right)\left[l_n^j\left(\omega^j\right)\right]^{\gamma_n^j}\prod_{k=1}^{J}\left[m_n^{k,j}\left(\omega^j\right)\right]^{\gamma_n^{k,j}}$$

with labor $l_n^j\left(\omega^j\right)$ and composite intermediate goods $m_n^{k,j}\left(\omega^j\right)$ from sector k used in the production of the intermediate good ω^j. $\gamma_n^{k,j} \geq 0$ are the share of materials form sector k used in the production of the intermediate good ω^j. The intermediate goods shares $\sum_{k=1}^{J}\gamma_n^{k,j} = 1 - \gamma_n^j$ and $\gamma_n^j \geq 0$, which is the share of value added vary across sectors and countries.

Due to constant returns to scale and perfect competition, firms price at unit costs,

$$c_n^j = \Upsilon_j^j w_n^{\gamma_n^j}\prod_{k=1}^{J} P_n^{k\gamma_n^{k,j}} \tag{1.4}$$

with the constant Υ_j, and the price of a composite intermediate good from sector k, $P_n^{k\gamma_n^{k,j}}$.

Production Barriers and Trade Costs. Trade can be costly due to tariffs $\tilde{\tau}_{in}^j$ and non-tariff barriers d_{ni}^j (i.e. FTA, bureaucratic hurdles, requirements for standards, or other discriminatory measures). Combined, they can be represented as trade costs κ_{ni}^j when selling a product of sector j from country i to n

$$\kappa_{in}^j = \underbrace{\left(1 + t_{in}^j\right)}_{\tilde{\tau}_{in}^j}\underbrace{D_{in}^{\rho^j} e^{\delta^j \mathbf{Z}_{in}}}_{d_{ni}^j} \tag{1.5}$$

where $t_{in}^j \geq 0$ denotes ad-valorem tariffs, D_{in} is bilateral distance, and $\mathbf{Z}_{in}$ is a vector collecting trade cost shifters.[10]

Additionally, intermediate and final goods are now subject to barriers arising from domestic policy interventions, v_i^j that can potentially deter production. As described in section 1.2, COVID-19 is modeled as a barrier to production in the affected areas. The key difference when compared to trade costs is that the latter one only directly affects tradable goods, while production barriers can also directly affect non-tradable goods.

Under perfect competition and constant returns to scale, an intermediate or final product (trade and non-tradable) is provided at unit prices, which are subject to v_i^j, κ_{ni}^j and depend on the efficiency parameter $z_i^j\left(\omega^j\right)$.

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[10] Iceberg type trade cost in the formulation of Samuelson (1954) are captured by the term $\mathbf{Z}_{in}$

Producers of sectoral composites in country n search for the supplier with the lowest cost such that

$$p_n^j\left(\omega^j\right) = \min_i \left\{ \frac{c_i^j \kappa_{ni}^j \upsilon_i^j}{z_i^j\left(\omega^j\right)} \right\}. \tag{1.6}$$

Note that υ_i is independent of the destination country and thus will also have effects on non-tradeable and domestic sales. In the non-tradable sector, with $k_{in}^j = \infty$, the price of an intermediate good is $p_n^j\left(\omega^j\right) = c_n^j \upsilon_n^j / z_i^j\left(\omega^j\right)$.

Composite intermediate product price. The price for a composite intermediate good is given by

$$P_n^j = A^j \left(\sum_{i=1}^{N} \lambda_i^j \left(c_i^j \kappa_{in}^j \upsilon_i^j \right)^{\frac{-1}{\theta^j}} \right)^{-\theta^j} \tag{1.7}$$

where $A^j = \Gamma\left[1 + \theta^j(1-\eta^j)\right]^{\frac{1}{1-\eta^j}}$ is a constant. Following Eaton and Kortum (2002), Ricardian motives to trade are introduced in the model and allow productivity to differ by country and sector.[11] Productivity of intermediate goods producers follows a Fréchet distribution with a location parameter $\lambda_n^j \geq 0$ that varies by country and sector (a measure of absolute advantage) and shape parameter θ^j that varies by sector and captures comparative advantage.[12]. Equation B.4 also provides the price index of non-tradable goods and goods confronted with production barriers, which can affect tradable and non-tradable goods. For non-tradable goods the price index is given by $P_n^j = A^j \lambda_n^{j-1/\theta^j} c_n^j \upsilon_n^j$.

Firm's output price. Due to the interrelation of the sectors across countries, the existence of production barriers υ_i^j has also an indirect effect on the other sectors across countries. A firm in country i can supply its output at price,[13]

$$p_{in}^j(\omega^j) = \upsilon_i^j \kappa_{in}^j \frac{c_i^j}{z_i^j\left(\omega^j\right)} \tag{1.8}$$

[11] see Caliendo and Parro (2015) for more details.

[12] Convergence requires $1 + \theta^j > \eta^j$.

[13] c_i^j is the minimum cost of an input bundle (see equation 1.5), where Υ_i^j is a constant, w_i is the wage rate in country i, p_i^k is the price of a composite intermediate good from sector k, which can be affected by production barriers. $\gamma_i^j \geq 0$ is the value added share in sector j in country i, the same parameter we use in equation 2.1 when defining the shock υ_i^j. $\gamma_i^{k,j}$ denotes the cost share of source sector k in sector j's intermediate costs, with $\sum_{k=1}^{J} \gamma_i^{k,j} = 1$.

Consumption prices. Under Cobb-Douglas preferences, the consumers can purchase goods at the consumption prices P_n, which are also dependent on production barriers υ_i^j. In fact, with perfect competition and constant-returns to scale, an increase in the costs of production of final goods will directly translate into an increase in consumption prices.

$$P_n = \prod_{j=1}^{J} \left(P_n^j / a_n^j\right)^{a_n^j} \tag{1.9}$$

Expenditure Shares. The total expenditure on goods of sector j from country n is given by $X_n^j = P_n^j Q_n^j$. Country n's share of expenditure on goods from i is given by $\pi_{ni}^j = X_{ni}^j / X_n^j$, which gives rise to the structural gravity equation.

$$\pi_{in}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{in}^j \upsilon_i^j\right]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^{N} \lambda_i^j \left[c_i^j \kappa_{in}^j \upsilon_i^j\right]^{\frac{-1}{\theta^j}}} \tag{1.10}$$

The bilateral trade shares are affected by the production barriers υ_i^j both directly and indirectly through the input bundle c_i^j from equation B.2, which contains all information from the IO-tables.

Total expenditure and Trade Balance. Total expenditure on a good j in country n, X_n^j, has to equal the total expenditures on the composite intermediate goods of firms and households.[14]

$$X_n^j = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^k \frac{\pi_{in}^k}{(1+\tau_{in}^k)} + \alpha_i^j I_i \tag{1.11}$$

To close the model, the value of total imports, trade surplus and domestic demand need to be equal to the value of domestic sales and exports,

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_n^j + D_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{in}^j}{(1+\tau_{in}^j)} X_i^j \tag{1.12}$$

[14] The national income is a function of labor income, tariff rebates R_i and the trade surplus D_i, hence $I_i = w_i L_i + R_i - S_i$. X_i^j is a country i's expenditure on sector j goods and services, $M_n^j = \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_i^j$ a imports of country n in sector j good from a country i. More details can be found in Caliendo and Parro (2015).

Given the trade surplus D_n, labor l_n, the measure of absolute advantage λ_n^j and the trade costs d_{ni}^j, the equilibirum under the domestic production barriers is a wage vector, as in Caliendo and Parro (2015).

Equilibrium in relative changes. We follow Caliendo and Parro (2015) and Dekle et al. (2008a) and define the equilibrium in relative changes, which has the advantage of an exact mapping of the model to the data, and allows to identify the outcomes from the change in the above defined policy intervention, the production barrier $\hat{v}_i^j$. [15]

This provides an equilibrium under the change of policy interventions as inCaliendo and Parro (2015). $\hat{c}_n^j$ are the cost changes, which are dependent on the wage changes, $\hat{w}_n$ and the prices changes $\hat{P}_n^{k\gamma_n^{k,j}}$. These changes directly affect the sectoral price index P_n^j, and translate into changes of the unit costs (see equation B.12). X_n^j are the sectoral expenditure levels, the prime income is given as $I_n' = \hat{w}_n w_n L_n + \sum_{j=1}^J X_n^{j\prime}(1 - F_n^{j\prime}) - S_n$, with $F_n^j \equiv \sum_{i=1}^N \frac{\pi_j^{in}}{(1+t_{in}^j)}$. L_n is a country n's labor force, and D_n depicts the trade surplus. The trade shares (see equation B.13) then respond to changes in the production costs, unit costs, and prices. The productivity dispersion parameter θ^j determines the intensity of the reaction. Equation B.14 ensures that the goods' market is clear and trade is balanced (see equation B.15).

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \prod_{k=1}^J \hat{P}_n^{k\gamma_n^{k,j}} \tag{1.13}$$

$$\hat{P}_n^j = \left[\sum_{i=1}^N \pi_{in}^j [\hat{\kappa}_{in}^j \hat{v}_i^j \hat{c}_i^j]^{-1/\theta^j} \right]^{-\theta^j} \tag{1.14}$$

$$\hat{\pi}_{in}^j = \left[\frac{\hat{c}_i^j}{\hat{p}_n^j} \hat{\kappa}_{in}^j \hat{v}_i^j \right]^{-1/\theta^j} \tag{1.15}$$

$$X_n^{j\prime} = \sum_{k=1}^J \gamma_n^{j,k} \sum_{i=1}^N X_i^k \frac{\pi_{in}^{k\prime}}{(1+\tau_{in}^{k\prime})} + \alpha_i^j I_i' \tag{1.16}$$

$$\sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{ni}^{k\prime}}{(1+\tau_{ni}^{k\prime})} X_n^{j\prime} - D_n = \sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{in}^{k\prime}}{(1+\tau_{in}^{k\prime})} X_i^{j\prime} \tag{1.17}$$

$$\tag{1.18}$$

[15] The interested reader can go to the work of Caliendo and Parro (2015), which provide a complete explanation of the hat algebra.

1.4 Quantifying the Effects of COVID-19

In this section we evaluate the welfare effects from the increase in the production barrier caused by the spread of COVID-19. We use data from different sources to calibrate the model to our base year. To provide a realistic picture of the effect of COVID-19, we maximize the number of countries covered in our sample conditional on having reliable information on tariffs, production and trade flows. Our quantification exercise requires a large number of data, which we gather combining different sources.[16]

First, we use the World Input-Output Database (WIOD). It contains information on sectoral production, value added, bilateral trade in final and intermediate goods by sector for 43 countries and a constructed rest of the world (ROW). WIOD allows us to extract bilateral input-output tables and expenditure levels for 56 sectors, which we aggregate into 50 industries. This aggregation concerns mostly services; we keep the sectoral detail in the manufacturing and agricultural industries. Data on bilateral preferential and MFN tariffs stem from the World Integrated Trade Solutions (WITS-TRAINS) and the WTO's Integrated Database (IDB).

Second, a crucial element for the quantification exercise is to measure the intensity of the COVID-19 shock across countries, regions and sectors. Indeed, our measure of the shock as detailed in equation and 2.1 requires information on employment by country-region and sector. This data is crucial to account for the geographical distribution of sectors across each country and region. We combine different sources: for all countries in the EU we use the information contained in Eurostat, for the US we use IPUMScps to construct employment by state(region) and sector of activity, while for Canada we use official data from the statistical office.[17] The construction of employment by sector and province in China required two different data sources: first, we use the information from the National Bureau of Statistic of China for the year 2018 on employment by region and sector[18]. However, the information for manufacturing and services provided by the National Bureau of Statistic of China is not disaggregated into sub-sectors. We complement this information with the employment shares by region and sector from the 2000 census to retrieve the employment level of manufacturing and services[19]. This

[16] A more detailed description of the different data sources can be found in Appendix A.1.

[17] More information on the construction of the employment matrices is detailed in the appendix.

[18] See http://www.stats.gov.cn/english/ for a general overview of the data collected by the NBSC, and http://data.stats.gov.cn/english/ for employment data at regional level.

[19] We thank Matilde Bombardini for kindly providing us the employment shares by region and industry from the 2000 Chinese Census used in the paper Bombardini and Li (2016). More details on the construction of the region-sector employment shares for China is provided in the appendix.

procedure returns employment shares by region and sector for 50 sectors and each province in China in 2018.[20].

Third, constructing the lockdown index ψ_i^j requires information on the degree of restriction for each country ($IndexClosure_i$), on the degree of *teleworkability* of each occupation and on the duration of the lockdown in each region. We use the index on government responses to the COVID-19 diffusion of the University of Oxford (https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker), where *IndexClosure*$_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (see Hale et al. (2020) for a detailed description of the index), where 100 indicates full restrictions. The index is meant to capture the extent of work, school, transportation and public event restrictions in each country. Moreover, we follow Dingel and Neiman (2020) and construct a measure of the degree of *teleworkability* of each occupation. We use the information contained in the Occupational Information Network (O*NET) surveys to construct a measure of feasibility of working from home for each sector.[21] Finally, we account for the duration of lockdown in each region and sector using the information in the CoronaNet database. We use detailed information on the duration of lockdown in each country, region and sector contained in the CoronaNet database and map the lockdown policies implemented in all regions and sectors in the sample. [22]

We use this extensive set of data to construct a measure for the COVID-19 shock as detailed in equation 2.1 that accounts for the regional variation in the duration as well as the restrictiveness of the lockdown policies implemented, for the degree of *teleworkability* of each occupation and for the geographic distribution of production across regions in the country. Intuitively, the COVID-19 shock described in equation 2.1 has a similar interpretation of an iceberg type trade cost. In fact, the shock v_i^j equals 1 when there is no restriction in place, hence it does not increase the cost of producing a good. On the contrary, v_i^j increases in the degree of the restriction and the duration of the lockdown, while it decreases in the degree of *teleworkability* of each occupation.

[20] Data on employment at sector-region level are not available for some countries in our sample. In this case, the formula does not capture the geographical distribution of sectors in the country, but accounts for the sectoral distribution of employment and for their labor intensity. This is the case for Australia, Brazil, Canada, India, Indonesia, Japan, Korea, Mexico, Russia, Taiwan, RoW.

[21] Some *sensitive* sectors of the economy are excluded by each government from the restrictive measures. We account for *sensitive* sectors by increasing the share of employment that can be teleworkable to 0.8 in each of the *sensitive* sectors. The list of sensitive sectors includes (ISIC rev 3 sectoral classification): Agriculture (sector 1), Fishing (sector 3), Electricity and gas (sector 23), Water supply (sector 24), Sewage and Waste (sector 25), Postal and courier (sector 34), Human health and social work (sector 49).

[22] A detailed description of the dataset can be found in Cheng and Messerschmidt (2020).

The constructed shock v_i^j and the extensive set of data are used to instruct the model to perform counterfactual analysis. As described in section 2.2.2, we follow Dekle et al. (2008a) and Caliendo and Parro (2015) and solve the model in relative changes to identify the welfare effect of the COVID-19 shock. We perform two different exercises: (i) we include the COVID-19 shock in the model and we estimate a scenario based on the lockdown policies implemented in each country-region, (ii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 shock v_i^j and an indirect effect coming from the global shock affecting other countries. We perform the two exercises both in an open economy with the actual tariff and trade cost levels and in a closer economy, where we increase the trade costs by 100 percentage points in each sector-country.

1.4.1 Open Economy

In this section, we present the results of the change in welfare, sectoral value added and trade for each country in our sample. The formula for the welfare change is

$$\hat{W}_n = \frac{\hat{I}_n}{\prod_{j=1}^{J} (\hat{p}_n^j)^{\alpha_n^j}}$$

where $\hat{W}_n$ is the change in welfare of country n, $\hat{I}_n$ is the change in nominal income of country n and $\prod_{j=1}^{J} (\hat{p}_n^j)^{\alpha_n^j}$ is the change in the price index for country n in each sector j. The aggregated welfare results are presented in table 1.1. Countries have heterogeneous *treatments* depending on the restrictiveness of the policy measures, on the share of workforce employed in each sector of the economy and on the degree of *teleworkability* of each sector. Results in table 1.1 show that most countries experience a drop in real income above 10%, with few exceptions, among which Sweden. Indeed, Sweden it's the only European country that did not implement any coercive and generalized restriction to the workforce.

In tables 1.2, we further investigate the sectoral distribution of the economic impact of the COVID-19 shock. We find that the drop in the value added (in billion US dollars) is widespread across all sectors, but it is especially pronounced for services, intermediate resource manufacturing and wholesale and retail trade across all countries. In absolute

Table 1.1: Change of Real Income Across Countries (in %) - Open Economy

Country	Δ in %	Country	Δ in %
Australia	-12.76	Ireland	-9.27
Austria	-18.11	Italy	-17.15
Belgium	-13.20	Japan	-10.64
Bulgaria	-6.96	Korea	-14.34
Brazil	-13.23	Latvia	-7.84
Canada	-11.04	Lithuania	-14.10
Switzerland	-18.05	Luxembourg	-12.01
China	-3.95	Malta	-14.59
Cyprus	-13.56	Mexico	-13.76
Czech R.	-17.27	Netherlands	-7.16
Germany	-9.11	Norway	-11.77
Denmark	-10.84	Poland	-18.40
Spain	-17.76	Portugal	-16.86
Estonia	-7.28	ROW	-15.27
Finland	-14.67	Romania	-17.27
France	-13.93	Russia	-15.25
UK	-11.43	Slovakia	-16.24
Greece	-9.61	Slovenia	-18.45
Croatia	-16.72	Sweden	-3.61
Hungary	-15.73	Taiwan	-9.17
Indonesia	-15.32	Turkey	-8.54
India	-15.95	USA	-11.05

Note: The table presents the aggregated real income changes in % for every country.

terms, the strongest drops in value added are experienced in the services sectors, which include services, such as accommodation and food, real estate, and also public services.[23]

The impact of the COVID-19 shock on countries' trade is presented in tables 1.3. For the case of Italy, we observe a severe decline in exports in billion US Dollars in intermediate resource manufacturing, machinery equipment and textiles. Germany faces a decrease in exports especially pronounced in the motor vehicle industry, as well as in the intermediate

[23] Table 1.2 provides the results for aggregated sectors. See table A3 for the aggregation of the 50 WIOD-sectors. All results for the sectoral value added changes for each of the sectors in all countries can be retrieved from the authors.

Table 1.2: Change in Value Added in bn USD - Open Economy

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-7.47	-2.23	-23.86	-33.42	-38.69	-267.85
Food, Beverages, Tabacco	-5.80	-5.44	-26.78	-15.46	-46.74	-91.30
Mining, Quarrying	-1.51	-0.43	-50.23	-19.60	-14.33	-327.96
Textiles	-5.89	-0.62	-3.00	-5.20	-14.18	-36.99
Electrical Equipment	-4.89	-7.72	-36.26	-6.73	-32.21	-86.12
Machinery, Equipment	-9.11	-14.77	-19.33	-13.10	-51.03	-43.49
Motor Vehicles	-2.30	-15.66	-15.66	-11.67	-32.49	-49.60
Intm. Resources Manufacturing	-17.69	-18.61	-69.89	-36.82	-103.38	-212.13
Manufacturing, nec.	-3.77	-4.99	-26.54	-8.65	-25.64	-37.65
Pharmaceuticals	-1.97	-3.60	-10.76	-3.65	-18.60	-19.77
Chemicals	-3.10	-3.82	-29.48	-6.56	-22.27	-46.55
Electricity, Water, Gas	-8.98	-9.34	-35.91	-8.36	-64.36	-136.60
Construction	-16.82	-14.86	-73.54	-27.57	-120.10	-265.33
Wholesale, Retail Trade	-37.97	-28.92	-233.13	-29.84	-241.07	-542.96
Transport	-19.14	-13.20	-49.80	-15.02	-105.96	-219.82
Accommodation and Food	-12.24	-4.87	-53.85	-7.52	-68.51	-86.96
Real Estate	-47.06	-35.52	-227.43	-21.90	-242.61	-296.87
Public Services	-33.75	-35.89	-325.71	-18.09	-232.70	-381.68
Social Services	-21.73	-25.12	-135.61	-7.38	-158.88	-147.36
Services, nec.	-84.19	-77.39	-473.31	-67.34	-561.44	-803.48

Note: The table presents the sectoral value added changes, in bn USD for selected countries, Italy, Germany, USA, and China. Column 6 reports the value added results for EU28, which are weighted by the initial value added by country. Column 7 shows the value added weighted results for all remaining countries. Further, sectors are aggregated into broader categories (see table A3 in the Appendix).

resource manufacturing sector and machinery and equipment. The US has a severe drop in exports in the service sector, followed by the intermediate resource manufacturing and wholesale trade while China experiences the biggest drop in exports in the sectors of electrical equipment, intermediate resource manufacturing and textiles.

All results in tables 1.2 and 1.3 present a clear picture of the structure of comparative advantages of each economy, highlighting the importance of accounting for sectoral production linkages and inter-sectoral trade when studying the economic impact of a global shock. Moreover, these results suggest that the production structure of each economy, as well as their centrality in the global value chains might have heterogeneous roles in explaining the size of the observed income drops across the countries.

Decomposition of the Effects

What is the share of the real income drop due to COVID-19 shock that comes from the disruption of production in each country? What is the share that comes from a decrease in trade through global production networks? To decompose the real income changes observed in table 1.1 we use the structural model and perform two counterfactual exercises: one in which we shock each country individually and one in which we shock all countries but one. This allows us to isolate the direct production effect of the COVID-19 shock on each country from the indirect effect that each other country experience through the shock to the global production network. We perform the following decomposition:

$$\forall i \neq j : \hat{W}_i = \Bigg(\underbrace{\hat{W}_i^D(v_i)}_{\text{Direct}} + \underbrace{\sum_{j=1}^{J} \hat{W}_i^I(v_j)}_{\text{Indirect}} \Bigg) \times \underbrace{\Bigg(1 - \hat{W}_i(v_{ALL}) \Bigg)}_{\text{Global}} \tag{1.19}$$

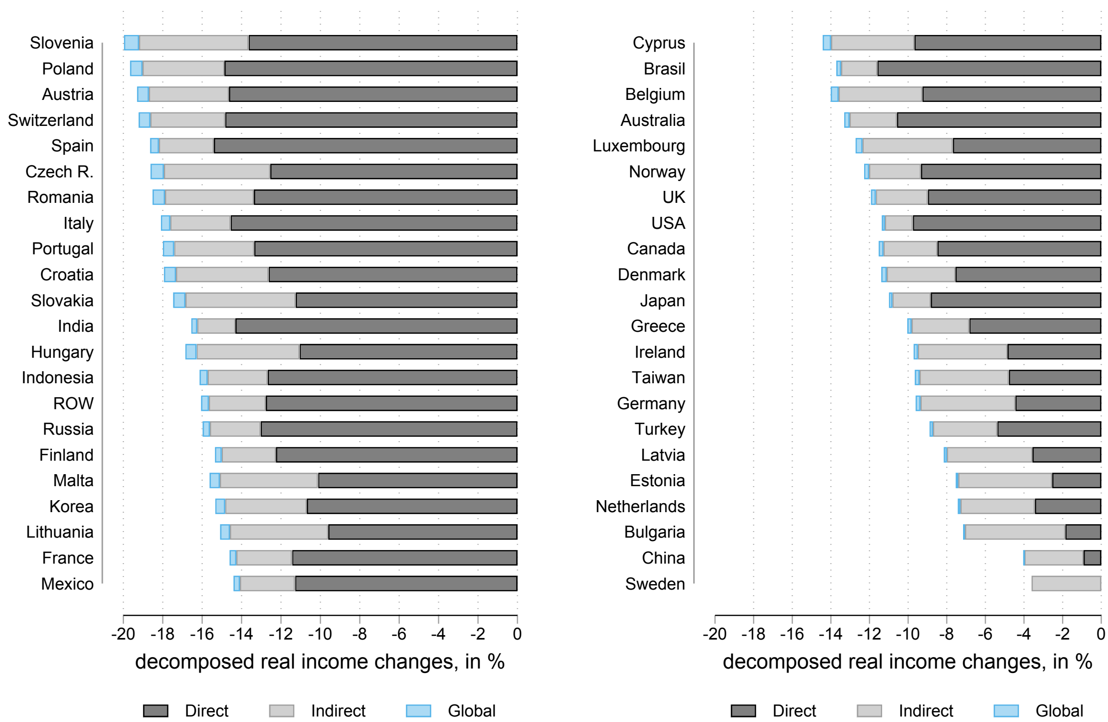
where $\hat{W}_i^D(v_i)$ is the direct (D) change in real income of country i when only country i is hit by the COVID-19 shock (v_i), $\sum_{j=1}^{J} \hat{W}_i^I(v_j)$ is the sum of the indirect (I) real income changes in country i when any other country j is treated with the COVID-19 shocks (v_j) but not country i, $\hat{W}_i(v_{ALL})$ is the total change in real income of country i when all countries are affected by the COVID-19 shock (v_{ALL}), and $\hat{W}_i$ is the sum of the three different components from the decomposition.

Suppose, for example, that Germany is the only country hit by the COVID-19 virus disease; in this case, the real income of Germany would drop because of the disruption in production that the COVID-19 shock provokes to the German economy, what we call the *direct* effect in our decomposition. Suppose now that Italy is the only country affected by the COVID-19 shock. In this case, we would observe a drop in real income for Germany as well, which is driven by the decrease in trade between Germany and Italy, as well as by the increase in the cost of intermediates that Germany buys from Italy. This is what we call the *indirect* effect. Summing over the *indirect* effects for Germany will provide us the total *indirect* effect, namely the drop in real income that Germany faces when all other countries but Germany are shocked.

The third term of our decomposition is the difference between the sum of the direct and the indirect effects for Germany from the decomposition and the drop in real income observed for Germany in the counterfactual exercise in which we shock all the countries at same time. We call this component the *global* adjustment. Indeed, when we shock all the countries at the same time, the observed income drop differs from the sum of the direct and the indirect effect from the decomposition. This points to the importance of using a GE framework with input-output linkages and trade when studying the effect of a global shock to local economies. In fact, when shocked all together, each country keeps the relative importance in the world trade networks, hence the structure of comparative advantages remains the same and the total effect of the shock is smaller for each of them. On the contrary, when only one country is hit by the COVID-19 shock, that country faces an increase in the production costs of the goods produced for the domestic and for the foreign markets and loses its role in the global production networks, thus experiencing an additional drop in income.

Figure 1.1 and table 1.4 show the results of the decomposition in open economy. In this case, each country is hit by a shock that accounts for the restrictiveness of the policy implemented as explained in section 1.2. It is straightforward to notice the heterogeneity in the relative importance of the *direct* as well as the *indirect* components of the shock across countries. Moreover, the share of the total drop in real income accounted for by the *indirect* effect is systematically higher for European countries than for the other countries in our sample, with the exceptions of Korea and Taiwan.

Figure 1.1: Decomposition of Real Income changes - Open Economy



Note: The figures shows the decomposition of the real income changes in percent for all countries of the sample. The dark gray bars illustrate the real income changes that stem from the direct effect, the light gray bars the real income changes from the indirect effect, the blue bars show the additional GE feedback effects. All effects are described in more detail in the main body of the text.

To better understand the heterogeneities observed in figure 1.1 and table 1.4, we construct a simple measure of trade openness as the sum of imports and exports over total income of the country ($\frac{X_i+M_i}{I_i}$). Using the data from the baseline economy and the results of counterfactual economy, we investigate if our measure of openness is correlated with a higher *indirect* effect. We estimate the following model:

$$\sum_{j=1}^{J} \hat{W}_i^I(v_j) = \beta_0 + \beta_1 \frac{X_i + M_i}{I_i} + \beta_2 \hat{W}_i + \beta_3 HHI\_M + \beta_4 HHI\_output + I_i + \epsilon_i \quad (1.20)$$

where $HHI\_M = \sum_{n=1}^{N} \left(\frac{M_{ni}}{\sum_{n=1}^{N} M_{ni}} \right)^2 \forall i \neq n$ is an Herfindahl index of diversification in trade partners. The fraction shows the imports of country i, M_{ni} from origin country n, over the sum of all Imports of country i; the higher the number of trading partners and the more diversified its importing sources are, the lower is the HHI of diversification. $HHI\_output = \sum_{j=1}^{J} \left(\frac{output_i^j}{\sum_{j=1}^{J} output_i^j} \right)^2 \forall i \neq n$ is an index of specialization in production. The fraction within the brackets presents the output in sector j, in country i, over the total output of country i. The higher the HHI of specialization, the lower is the degree of specialization in the country.[24]

Table 1.5 presents the results of this exercise. Indeed, countries with a higher degree of trade openness experience a bigger *indirect* effect (columns 1 to 3 in table 1.5). This simple exercise confirms that openness is correlated with a higher global production network shock. In fact, countries that rely more on international partners both for intermediate supplies as well as for exporting their goods, experience a higher *indirect* shock. Looking at the degree of specialization in production ($log(specialization)$), we find that a higher degree of specialization is correlated with a bigger indirect effect of the shock.[25] Countries that specialize their production leverage more on their comparative advantages. At the same time, a higher degree of specialization implies a higher dependence on other countries both for the intermediaries as well as for exporting the final goods, but crucially it also implies a higher dependence on trading partners to buy all other goods that are not produced at home.

[24] Similarly, we construct an index of diversification of exports. Results using the index of diversification of exports are similar to the ones using the diversification in imports.

[25] Note the dependent variable in the regression is $log(\mid indirect \mid)$ and the HHI index for specialization in production is higher for less specialized countries, while it is lower for more specialized countries. The same applies for the HHI index of diversification in trade partners.

In columns 4 to 6 of table 1.5, we show the regressions where the dependent variable is the $log(\mid direct \mid)$. First, both the degree of openness as well as the degree of specialization in production play a smaller role. The direct effect is mainly driven by the direct production shock that each country experiences due to the policy intervention of the lockdown. In this case, openness smooths the direct effect of the COVID-19 shock, allowing countries to source intermediates or consumption goods when home production is disrupted. On the other hand, a higher degree of specialization in production is correlated with a smaller direct effect. In this case, a higher degree of specialization implies that countries have a higher comparative advantage in a specific sector, hence a lower price compared to their competitors. In our model, the COVID-19 shock is a production barrier that imposes lockdown to a share of the labor force and increases the production cost of the goods produced in each country, proportionally to the share of employment in each sector of activity. An increase in the production cost in a sector will prove to be less severe in a country that has a higher comparative advantage in that specific sector.

It is important to clarify that this exercise compares countries with different degrees of openness conditional on receiving the same drop in real income. However, it does not allow us to answer the following counterfactual question: "What would have happened if the world was less integrated? Would the total drop in real income due to the COVID-19 be smaller in a less integrated world? In the next section, we leverage on our model to answer these questions.

1.4.2 Less Integrated World

In this section we quantify the real income effect of the COVID-19 shock in a less integrated world scenario, where we increase the trade costs in each country and sector by a 100 percentage points. First and unsurprisingly, a less integrated world itself implies enormous income losses for all countries in our sample. Table 1.6 shows the real income changes for all countries in the sample in a less integrated world. In both tables, column 2 and 7 present the real income losses stemming from the increase in trade costs by a 100 percentage points. Column 3 and 8 show the real income changes stemming from the COVID-19 shocks in a less integrated economy, while columns 4 and 9 present the welfare effects due to the COVID-19 shocks in the open economy (as in table 1.1). Finally, columns 5 and 10 (Δ) present the difference between the real income drop due to the COVID-19 shocks in a less integrated vs. open economy.

The COVID-19 shock is smaller for all countries in the less integrated economy than in the open economy under both shocks. Indeed, in a less integrated world countries experience an enormous reduction in real income due to the increase in trade costs, hence the additional effect of the global pandemic shock plays a relatively smaller role. In our counterfactual exercise, the increase in trade cost mimics a world with higher trade barriers, but not a complete autarky scenario; countries would still trade, use intermediates from abroad and sell final goods in foreign countries.

This finding highlights the importance of inter-sectoral linkages in the transmission of the shock: a higher degree of integration in the global production network implies that a shock in one country directly diffuses though the trade linkages to other countries. Trade has two different effects in our model: on the one hand, it smooths the effect of the shock by allowing consumers to purchase and consume goods they wouldn't otherwise be able to consume in a world with production barriers in lockdown. On the other hand, the COVID-19 shock increases production costs of intermediate inputs that are used at home and abroad. Our counterfactual exercise clearly shows that an increase in trade costs would not significantly decrease the impact of the COVID-19 shock across countries. However, increasing trade barriers implies an additional drop in real income between 14% and 33% across countries.

Table 1.3: Change of Sectoral Trade, in bn USD - Open Economy

Panel A: Changes of Exports - Open Economy

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-0.90	-1.94	-5.83	-2.07	-16.04	-29.47
Food, Beverages, Tobacco	-2.82	-11.98	-8.76	-9.55	-50.14	-40.87
Mining, Quarrying	-0.18	-1.70	-5.46	-1.85	-12.68	-186.58
Textiles	-6.26	-4.21	-1.60	-45.14	-22.51	-41.80
Electrical Equipment	-4.68	-23.13	-18.02	-107.89	-65.86	-101.04
Machinery, Equipment	-4.72	-31.94	-13.32	-38.41	-66.04	-26.71
Motor Vehicles	-2.29	-43.87	-11.58	-13.42	-77.53	-54.45
Intm. Resources Manufacturing	-12.34	-38.80	-35.69	-56.59	-140.21	-160.39
Manufacturing, nec.	-2.12	-13.74	-20.44	-30.22	-40.64	-33.67
Pharmaceuticals	-1.83	-7.72	-5.94	-4.10	-30.65	-9.64
Chemicals	-3.76	-19.07	-14.30	-13.01	-58.36	-52.01
Electricity, Water, Gas	-0.47	-3.85	-2.59	-0.76	-14.04	-6.83
Construction	-0.29	-0.42	-0.02	-2.53	-7.65	-3.48
Wholesale, Retail Trade	-3.19	-12.43	-29.68	-30.95	-76.02	-58.54
Transport	-2.17	-7.80	-15.25	-13.87	-57.80	-53.49
Accommodation and Food	-0.01	-1.62	-0.22	-1.54	-6.20	-18.33
Real Estate	-0.32	-0.36	-0.41	0.00	-1.90	-1.16
Public Services	-1.44	-2.04	-8.69	-0.59	-27.38	-25.43
Social Services	-0.18	-0.12	-0.27	-0.12	-1.71	-1.99
Services, nec.	-4.04	-19.98	-45.63	-14.03	-132.57	-73.05

Panel B: Changes of Imports - Open Economy

Sector	Italy bn USD	Germany bn USD	USA bn USD	China bn USD	EU28 bn USD	Rest of World bn USD
Agriculture	-3.01	-3.08	-6.12	-2.04	-20.77	-27.28
Food, Beverages, Tobacco	-7.03	-4.54	-9.15	1.00	-48.09	-60.87
Mining, Quarrying	-7.26	-4.23	-26.56	-8.68	-50.28	-123.62
Textiles	-6.33	-4.29	-18.34	0.01	-35.45	-64.53
Electrical Equipment	-7.54	-12.58	-40.30	-6.48	-76.98	-175.68
Machinery, Equipment	-6.39	-4.83	-15.47	4.21	-45.69	-90.43
Motor Vehicles	-6.55	-6.16	-29.83	3.75	-57.37	-79.19
Intm. Resources Manufacturing	-16.72	-17.81	-40.65	-2.68	-131.66	-228.40
Manufacturing, nec.	-3.81	-4.85	-14.62	2.58	-36.45	-79.98
Pharmaceuticals	-3.93	-1.90	-5.42	0.77	-24.29	-21.85
Chemicals	-7.26	-7.89	-15.92	-4.10	-52.41	-68.99
Electricity, Water, Gas	-1.95	-1.63	-1.76	-0.07	-13.44	-8.95
Construction	-0.59	-0.91	-0.33	-0.06	-5.14	-8.16
Wholesale, Retail Trade	-6.47	-6.77	-7.22	-0.99	-49.89	-137.10
Transport	-4.30	-4.24	-5.28	-1.31	-37.32	-96.49
Accommodation and Food	-0.76	-0.71	-0.75	-0.37	-6.91	-18.27
Real Estate	-0.20	-0.05	-0.04	-0.00	-1.32	-2.11
Public Services	-2.55	-1.50	-12.79	-0.26	-28.43	-20.60
Social Services	-0.07	-0.07	-0.55	-0.04	-1.21	-2.30
Services, nec.	-7.58	-12.51	-18.32	-2.31	-87.96	-156.70

Note: The table presents the sectoral export and import changes under shock 1 in an open economy. The upper part of the table shows the changes in exports in bn USD for the selected countries and regions, while the lower part of the table shows the sectoral import changes for the same countries and regions in the open economy.

Table 1.4: Decomposition of Real Income Changes - Open Economy

Country	Direct Effect in %	GVC Effect in %	GE Effect in %	Country	Direct Effect in %	GVC Effect in %	GE Effect in %
Australia	-10.58	-2.45	-0.28	Korea	-10.69	-4.15	-0.50
Austria	-14.64	-4.07	-0.59	Latvia	-3.56	-4.43	-0.16
Belgium	-9.26	-4.34	-0.40	Lithuania	-9.60	-4.99	-0.49
Brasil	-11.60	-1.88	-0.24	Luxembourg	-7.68	-4.68	-0.35
Bulgaria	-1.86	-5.19	-0.10	Malta	-10.12	-4.98	-0.51
Canada	-8.49	-2.79	-0.24	Mexico	-11.29	-2.80	-0.32
China	-0.91	-3.07	-0.03	Netherlands	-3.44	-3.85	-0.13
Croatia	-12.63	-4.70	-0.61	Norway	-9.34	-2.69	-0.26
Cyprus	-9.68	-4.32	-0.43	Poland	-14.87	-4.16	-0.63
Czech R.	-12.55	-5.40	-0.67	Portugal	-13.36	-4.07	-0.57
Denmark	-7.55	-3.56	-0.28	ROW	-12.77	-2.90	-0.39
Estonia	-2.54	-4.86	-0.13	Romania	-13.38	-4.51	-0.62
Finland	-12.25	-2.76	-0.34	Russia	-13.03	-2.58	-0.36
France	-11.44	-2.83	-0.34	Slovakia	-11.25	-5.60	-0.61
Germany	-4.45	-4.91	-0.25	Slovenia	-13.65	-5.56	-0.76
Greece	-6.84	-2.99	-0.22	Spain	-15.41	-2.79	-0.44
Hungary	-11.06	-5.23	-0.56	Sweden	0.00	-3.61	0.00
India	-14.31	-1.94	-0.30	Switzerland	-14.83	-3.80	-0.59
Indonesia	-12.67	-3.05	-0.40	Taiwan	-4.79	-4.62	-0.24
Ireland	-4.86	-4.64	-0.22	Turkey	-5.39	-3.33	-0.18
Italy	-14.56	-3.06	-0.47	UK	-8.98	-2.69	-0.25
Japan	-8.83	-1.99	-0.18	USA	-9.76	-1.44	-0.16

Note: The table reports the real income changes decomposed into the direct production effect (columns 2 and 6), the indirect global value chains effect (columns 3 and 7)and into the additional GE effect that occurs due to the global nature of the shock and its feedback general equilibirum effects (columns 4 and 8).

Table 1.5: Openness, Trade Diversification and Specialization in Production

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	log(indirect)	log(indirect)	log(indirect)	log(direct)	log(direct)	log(direct)
log(Openness)	0.639^a	0.921^a	0.902^a	-0.299^a	-0.383^a	-0.386^a
	(0.185)	(0.118)	(0.109)	(0.070)	(0.032)	(0.031)
log(Specialization)		-8.380^a	-7.903^a		2.661^a	2.733^a
		(1.220)	(1.157)		(0.429)	(0.384)
log(Diversification)			-0.446			-0.070
			(0.434)			(0.136)
Constant	1.155^b	1.192^a	1.140^a	-0.913^a	-1.036^a	-1.038^a
	(0.561)	(0.377)	(0.368)	(0.275)	(0.229)	(0.228)
Controls	x	x	x	x	x	x
Observations	44	44	44	43	43	43
Adjusted R^2	0.697	0.839	0.841	0.924	0.958	0.957

Notes: The table reports the regression of the $log(\mid direct \mid)$ and the $log(\mid indirect \mid)$ change in real income for all the 44 countries in our sample. In columns from 4 to 6, the number of observation is 43 because Sweden did not implement any policy restriction that imposed quarantine to the population, so it is not included in the regression. The explanatory variables are $log(openness) = log(\frac{X_i+M_i}{I_i})$, $log(diversification) = log(HHI\_M)$, $log(specialization) = HHI\_output$. Note that an increase in the HHI indexes implies a reduction in diversification(specialization). Controls include $log(initial - income)$ and $log(total - income - change)$ Robust standard errors in parenthesis, ^{a}<0.01, ^{b}<0.05, ^{c}<0.10.

Table 1.6: Real Income Changes (in %) - Less Integrated vs. Open Economy

Country	Change of real income in % Less integrated Economy		Open Economy	Δ	Country	Change of real income in % Less integrated Economy		Open Economy	Δ
	Trade Costs	Shock	Shock			Trade Costs	Shock	Shock	
Australia	-18.36	-10.45	-12.76	2.31	Korea	-21.77	-11.12	-14.34	3.22
Austria	-22.59	-14.03	-18.11	4.08	Latvia	-30.80	-5.54	-7.84	2.30
Belgium	-27.05	-9.66	-13.20	3.54	Lithuania	-30.00	-9.96	-14.10	4.14
Brasil	-13.98	-11.41	-13.23	1.82	Luxembourg	-29.65	-8.76	-12.01	3.25
Bulgaria	-33.50	-4.78	-6.96	2.18	Malta	-34.43	-9.56	-14.59	5.03
Canada	-20.02	-8.85	-11.04	2.18	Mexico	-17.38	-11.39	-13.76	2.37
China	-17.12	-3.72	-3.95	0.23	Netherlands	-19.99	-5.87	-7.16	1.29
Croatia	-27.89	-12.05	-16.72	4.67	Norway	-19.55	-9.56	-11.77	2.21
Cyprus	-31.14	-9.35	-13.56	4.21	Poland	-23.09	-14.13	-18.40	4.27
Czech R.	-21.68	-13.70	-17.27	3.57	Portugal	-24.12	-12.73	-16.86	4.13
Denmark	-19.91	-8.80	-10.84	2.04	ROW	-29.33	-10.72	-15.27	4.55
Estonia	-31.87	-5.11	-7.28	2.17	Romania	-27.35	-12.53	-17.27	4.74
Finland	-22.12	-11.40	-14.67	3.27	Russia	-20.91	-12.05	-15.25	3.20
France	-18.87	-11.29	-13.93	2.64	Slovakia	-25.90	-12.06	-16.24	4.18
Germany	-19.44	-7.48	-9.11	1.63	Slovenia	-26.58	-13.56	-18.45	4.89
Greece	-24.02	-7.40	-9.61	2.20	Spain	-18.31	-14.40	-17.76	3.35
Hungary	-22.13	-12.40	-15.73	3.32	Sweden	-22.61	-2.99	-3.61	0.62
India	-13.84	-13.66	-15.95	2.29	Switzerland	-19.72	-14.62	-18.05	3.42
Indonesia	-18.60	-12.53	-15.32	2.79	Taiwan	-24.39	-6.97	-9.17	2.20
Ireland	-21.57	-7.46	-9.27	1.81	Turkey	-18.55	-7.06	-8.54	1.48
Italy	-16.61	-14.24	-17.15	2.91	UK	-20.38	-9.14	-11.43	2.28
Japan	-14.63	-9.12	-10.64	1.52	USA	-13.06	-9.63	-11.05	1.41

Note: The table presents the aggregated real income changes in % for every country. Column 2 and 6 show the real income changes solely driven by the increase in trade costs by 100 percentage points. Column 3 and 7 present the real income changes in % driven by the COVID-19 shock under a Less integrated economy. Column 4 and 8 present the shock i under an open economy (similar to table 1.1). Column 5 and 9 present the difference between the shock under an open vs. a Less integrated economy.

1.5 Conclusion

This study uses a general equilibrium framework to evaluate the economic impact of the COVID-19 shock. We model the COVID-19 shock as a production barrier that deters production for home consumption and for exports through a temporary drop in the labor units available in each country. The spread of COVID-19 disease provides a unique set-up to understand and study the diffusion of a global production shock along the global value chains. However, understanding the effects of a global production disruption induced by a pandemic is complex. In this paper, the modeling choice of the shock accounts for the geography of the diffusion of the COVID-19 shock across regions and countries, the geographical distribution of sectors in each country and the labor intensity of each sector of production to return a reliable measure of the impact of the COVID-19 disease as a production barrier. Crucially, in a model with interrelated sectors the cost of the input bundle depends on wages and on the price of all the composite intermediate goods in the economy, both non-tradable and tradable. In our framework, the COVID-19 shock has a direct effect on the cost of each input as well as an indirect effect via the sectoral linkages.

We perform three different exercises: (i) we include the COVID-19 shock in the model and we estimate a scenario based on the lockdown policies implemented in each country-region, (ii) we decompose the effect into a direct effect from the production shock induced by the COVID-19 shock v_i^j and an indirect effect coming from the global shock affecting other countries. We perform the two exercises both in an open economy with the actual tariff and trade cost levels and in a closer economy, where we increase the trade costs by 100 percentage points in each sector-country. The quantitative exercise requires data on bilateral trade flows, production, tariffs, sectoral trade elasticities, employment shares by sector and region and the number of COVID-19 cases in each region or country. We calibrate a 44 countries 50 sector economy and incorporate the COVID-19 shock to evaluate the welfare effects for each country both in aggregate and at the sectoral level.

We show that the shock dramatically reduces real income for all countries in all counterfactual scenarios and that sectoral interrelations and global trade linkages have a crucial role in explaining the transmission of the shock across countries. COVID-19 shock is a pandemic shock; hence it has a contemporaneous effect in many countries and to all sectors of production. We use the model to perform a model-based identification of the effect of COVID-19 shock and provide evidence on the importance of global trade linkages and inter-sectoral trade when studying the effect of a global shock to production on the welfare of each country. We decompose the COVID-19 total income change into a *direct* component due to the domestic production shock and an *indirect* component due to global linkages. We show that linkages between countries account for a substantial share of the total income drop observed.

Certainly, this model abstracts from many other aspects related to the diffusion of the COVID-19 disease which are the topic of study of epidemiologist, medical doctors and statisticians. Moreover, we do not account for the health consequences of the pandemic itself. We believe that understanding how the COVID-19 virus disease spreads across regions is outside the scope of this paper. In our framework, the spread of COVID-19 disease is modelled an exogenous shock that allows us to study the diffusion of the production disruption along the global value chains and to highlight the importance of modelling and including sectoral interrelations to quantify the economic impact of the COVID-19 shock.

Chapter 2

Covid-19 Pandemic, Trade and Inequality

The European Union was faced with various challenges threatening its integrity over the last decades. The diffusion of the COVID-19 virus disease posits an additional severe threat to the resilience of the European Union. In this paper we study the diffusion of the economic shock induced by the COVID-19 pandemic to understand how inequality across European regions is distributed. We use a multi-country, multi-sector Ricardian trade model to quantify the value-added effect of the disruption in production that spread across the world. We propose a methodology to redistribute the counterfactual changes in value-added by country-sector across European regions. The distributional effects of the COVID-19 pandemic disease are heterogeneous across European regions, exacerbating the "core-periphery" divide and the inequality across the European area. We find evidence that the COVID pandemic-19 shock has a stronger impact on the peripheral regions of Eastern and Southern Europe, together with most of the Mediterranean regions and the Atlantic regions of Portugal and Spain. On the contrary, the central European regions of the Netherlands and Germany, together with most Swedish regions experience a much milder effect of the pandemic on their economic structure.

2.1 Introduction

In the European Union (EU), inequality among regions has turned sharply up in the last two decades.[1] In the words of *The Economist* of the 17^{th} of December 2016 "Regional inequality is proving too politically dangerous to ignore." The European Union is now faced with an additional and unprecedented challenge, the diffusion of the COVID-19

[1] See the report of the European commission on the topic, Widuto (2019).

virus disease. Besides the enormous cost in terms of human lives, the economic crisis induced by the COVID-19 pandemic posits a severe threat to the resilience of the European Union.

In this paper we study how the diffusion of the economic shock induced by the COVID-19 pandemic affects inequality across European regions. We exploit the heterogeneous disruption in production across European regions induced by the COVID-19 pandemic to instruct a multi-country, multi-sector Ricardian model with interactions across tradable and non-tradable sectors observed in the input-output tables. We use the structural model to retrieve the primitive for our exercise, namely the changes in value-added by country-sector; we then use a *back of the envelope calibration* methodology to parsimoniously redistribute the changes in value-added across European regions.

Economic activity is unevenly distributed across space (see Ellison and Glaeser (1997), Ellison et al. (2010), Greenstone et al. (2010) or Oberfield et al. (2020)). Initial differences in the allocation of resources and of sectors to space can be exacerbated or mitigated by a negative global shock. However, understanding the effect of a global production shock induced by the COVID-19 pandemic across regions is crucial to target effective policies to mitigate the unequal impact of the shock across European areas. This exercise is however extremely complex. Calibrating a structural general equilibrium model that accounts for inter-sectoral linkages, domestic and foreign trade both in intermediates and final goods at regional level requires information on input-output tables, bilateral trade in intermediate and final goods, sectoral output and value-added, consumer and producer prices for all regions and sectors in the economy. Moreover, one would need information on productivity dispersion–the trade cost elasticity–at regional level. Having all this data at hand, one could calibrate the model accounting for sector-region specific specialization, productivity differences, trade openness, and value-added and solve it with the methodology developed by Dekle et al. (2008a) to study counterfactual scenarios.

We propose a methodology to approximate the sector-region specific effects of the COVID-19 pandemic for European regions, what we call *back of the envelope calibration*. We leverage on a rich set of data that includes regional economic accounts from Eurostat, which provides key information on employment and gross value-added for up to NUTS-3 regions in Europe from 1995 to 2018. The object of our analysis are regions, defined as political entities with similar geographical and economical size.[2] Using our methodology

[2] Eurostat provides a disaggregation of the countries in Europe at NUTS-2 or NUTS-3 level. However, a German state (say Bavaria) is defined as a NUTS-2 entity and it is comparable with an Italian region, say Lombardy, which is however a NUTS-3 entity. We systematically check every country in our sample to use the appropriate definition to have homogeneous objects (regions) in our exercise.

we parsimoniously redistribute the country-sector specific general equilibrium changes in value-added across regions within a country according to the composition and importance of the sectoral activity of each region.[3]

We find that the distributional effects of the COVID-19 pandemic disease are extremely heterogeneous across European regions even within a country, exacerbating the "core-periphery" divide and the inequality across the European area. In fact, we present evidence that the COVID-19 shock has a stronger impact on the peripheral regions in Eastern and Southern Europe, together with most of the Mediterranean regions and the Atlantic regions in Portugal and Spain. On the contrary, the central European regions in the Netherlands and Germany, together with most Swedish regions experience a much milder effect of the pandemic on their economic structure. The enormous difference in the size of the economic effect of the COVID-19 shock – the economic effect is up to eight time higher in east and south of Europe compared to the least affected regions in Sweden – across European regions strongly emphasize the importance of policy responses that target the reduction of inequality across regions as a primary goal. The observed heterogeneity is driven by two major components. First, the COVID-19 shock had a heterogeneous impact across countries, and the policy response of lock-down have been extremely varied across countries, regions and sectors. Second, the geographical distribution of economic activity is extremely polarized, with very concentrated cities and core regions, and very poor peripheries. A shock to production that hits disproportionately more labor-intensive sectors that rely on external inputs, happens to have a stronger impact in the peripheral regions and areas in Europe in our set-up.

This paper contributes to several strands of literature. First, we contribute to the literature on the economic impact of the COVID-19 shock by crucially adding the regional dimension into the picture. Sforza and Steininger (2020) develop a general equilibrium framework that allows the introduction of the COVID-19 shock in the form of a policy response – lock-down – while Bonadio et al. (2020) builds the COVID-19 shock as a labor shock into a network model of trade. Moreover, Dingel and Neiman (2020) allow the lockdown to heterogeneously affect each sector in each country using the share of work in a sector that can be performed at home. We complement this literature by providing the first regional analysis of the impact of the COVID-19 pandemic disease. We allow each country to have heterogeneous effects across regions depending on the geographical distribution of economic activity in the country. Moreover, a growing literature in eco-

[3] Sectoral activity can be measured in terms of regional value-added, employment, or income, depending on the type of general equilibrium effect being analyzed. Through the paper, we use regional employment to distribute the effects across regions. We test the sensitivity of our estimation using all the available measures to redistribute the shock across sectors and regions.

nomics extends the SIER model to study the economic consequences of the diffusion of the pandemic under different policy scenarios, also in the context of a general equilibrium framework with trade across countries and sectors (see, for example, the recent work of Antras et al. (2020).[4] We depart from considerations on the endogenous diffusion of the pandemic and focus on a different but equally crucial aspect: the (unequal) impact of a global production shock across regions.

Second, we contribute to the literature that studies regional inequality across European regions. Since the work of John Friedman (Friedmann (1966)) and later by Paul Krugman (Krugman (1991)), economists have given increasing attention to spatial inequality.[5] The topic has been studied also more qualitatively by scholars in human and economic geography. Iammarino et al. (2018) provide an insightful picture of the distribution of income across European regions and propose some policy response to progressively reduce the gap between core and periphery.[6] We add to this literature by studying this topic in a multi-country, multi-sector Ricardian model with interactions across tradable and non-tradable sectors observed in the input-output tables. Moreover, we leverage on an unprecedented shock – the COVID-19 pandemic – to have a clear picture of the impact on inequality across regions in Europe.

Finally, our paper is closely related to a growing literature that study the importance of trade in intermediate inputs and global value chains. For example, Altomonte and Vicard (2012), Antràs and Chor (2013), Antràs and Chor (2018), Antràs and de Gortari (Forthcoming), Alfaro et al. (2019), Antràs (Forthcoming), Bénassy-Quéré and Khoudour-Casteras (2009), Gortari (2019), Eaton and Romalis (2016), Hummels and Yi (2001), Goldberg and Topalova (2010), Gopinath and Neiman (2013), Halpern et al. (2015)). Our paper is especially close to a branch of this literature that extends the Ricardian trade model of Eaton and Kortum (2002) to multiple sectors, allowing for linkages between tradable sectors and between tradable and non-tradable.[7] Indeed, our paper is based on the work of Caliendo and Parro (2015) and adds an additional channel through which a policy intervention could affect value-added at home and in other countries, namely a production barrier induced by the spread of the virus. We use an unprecedented shock affecting simultaneously most of the countries across the world to understand the response of the economy under different production barrier scenarios in free trade and a less inte-

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[4] Other studies include Atkeson (2020), Berger et al. (2020), Eichenbaum et al. (2020).

[5] See, for example, Puga (1999), Ottaviano and Puga (1998), Puga and Venables (2001), Puga (2002), Overman and Puga (2014) for additional evidence.

[6] See also Charron (2016), Crescenzi and Rodríguez-Pose (2012) and Crescenzi and Iammarino (2017) for additional evidence on the topic

[7] See for example Dekle et al. (2008a), Arkolakis et al. (2012)

grated world. Moreover, we use the rich structure of the model to show the distribution of the effects of the shock across regions and sectors.

The reminder of the paper is the following. In section 2 we describe the methodology used to include the COVID-19 shock into the model and to retrieve the regional effects across regions. In section 3 we present the data and descriptive evidence. Section 4 presents the results and section 5 concludes.

2.2 Methodology

In this section we present the methodology we use to include the COVID-19 shock into the general equilibrium framework *a la* Caliendo and Parro (2015), a sketch of the model we use to perform the counterfactual exercise and the methodology used to compute the regional effects of the COVID-19 shock across European regions.

2.2.1 The COVID-19 Shock

The COVID-19 virus forced vast majorities of people across the globe into quarantine and businesses were closed for several weeks. It lead to major sector-region specific policy interventions across the globe. An economic assessment of such a shock should therefore account for the lockdown policies implemented in each country, the interconnections of countries through trade and the heterogeneity in countries' sectors specific productivities, specialization, competitiveness and production structures. This paper uses recent work of Sforza and Steininger (2020) to construct a COVID-19 shock. The shock is a measure to quantify the intensity of the economic shock across regions, countries and sectors. The shock v_i^j is given as

$$v_i^j = 1 + \sum_{r=1}^{R} \left(\psi_{ir}^j * \frac{l_{ir}^j}{\sum_{r=1}^{R} l_{ir}^j} \right) \tag{2.1}$$

and

$$\psi_{ir}^j = IndexClosure_i * (1 - TW^j) * Duration_{ir}^j \tag{2.2}$$

As described in detail in Sforza and Steininger (2020), $l_{ir}^j$is the total employment of sector j in region r of country i, $\sum_{r=1}^{R} l_{ir}^j$ is the sum of employed individuals in a sector j across all regions r of country i.

ψ_i^j is a sector-region and country specific measure of the restrictiveness of the lockdown, which takes into account the extent of the policy restrictions in each country and the possibility to work remotely. The $IndexClosure_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (100 indicates full restrictions). The second term of equation 2.2, $(1 - TW^j)$ represents the degree of *teleworkability* of each occupation.[8] The average duration of lockdown in each region and sector is constructed with the CoronaNet database, which provides sector-region and country specific information on the duration of lockdown (see Cheng and Messerschmidt (2020)). The second term of the formula, $\frac{l_{ir}^j}{\sum_{r=1}^R l_{ir}^j}$ measures the geographic distribution of production across regions in the country. The regional dimension in the duration of the restrictions and in the distribution of production in each country allows a precise picture of the impact of the lockdown measures in each country across the regions.

2.2.2 The Theoretical Framework

This section provides a brief summary of the theoretical framework of the general equilibrium model underlying the counterfactual simulation of the Covid-19 triggered partial shutdown of economic activities across countries and sectors. The quantitative model follows the theoretical framework of Caliendo and Parro (2015) and shows the modifications of Sforza and Steininger (2020).

The production of an output uses two inputs, labor and intermediate goods in a Cobb-Douglas type production setup. Labor is mobile across sectors, but immobile across countries and all markets are perfectly competitive. While labor can only be sourced domestically, intermediate products can be acquired from the domestic or foreign markets across all sectors.

Due to perfect competition and constant returns to scale, firms price final and intermediate products at unit costs. Hence, the more efficiently a product can be produced, the lower will be the price. Producers of a composite product in country n search for the lowest cost supplier. But sourcing products from abroad is not only subject to the unit costs of production. Trade can be costly in the form of trade costs (i.e. tariffs or non-tariff barriers). So, the decision to buy an intermediate or final product from abroad or domestically does not only consist of the production price (unit costs) of a product, but also of the additional costs of trading.

8 This approach follows Dingel and Neiman (2020), which use information contained in the Occupational Information Network (O*NET) surveys. More details about the construction of the teleworkability index can be found in Sforza and Steininger (2020).

The production barrier (the policy intervention due to COVID-19 pandemic), introduced by Sforza and Steininger (2020) additionally influences the costs of production and hence the price to sell the products. Different from trade costs, the production barriers also affect the domestic market of within country tradeable and non-tradeable goods.[9] If the production barrier hits the domestic market in country n, it will increase the costs and hence the price of production. It translates into higher prices for both the domestic and the foreign market. Either, the quantity demanded decreases because the product becomes too expensive, or the supply decreased due to higher production costs. This potentially leads to trade diversion and change in global value chains patterns. The bilateral trade shares are affected by the production barriers directly and indirectly through the input bundle from equation B.2, which contains all information from the IO-tables (see B.8).

Households consume at consumption prices, which are affected by a change in their income sources, the wages and the prices. Wages decrease if the output in the respective sector decreases, or less value-added is generated. The prices increase for goods and services, which are directly and indirectly affected by the increase in production barriers. To close the model, the demand for all goods and services is set equal to the supply of production and trade is balanced by setting all imports, trade surplus and domestic demand equal to the value of domestic sales and all exports see equations D.1 and D.2.

The model is solved with hat algera, thus the equilbirium is defined in relative changes (Caliendo and Parro (2015) and Dekle et al. (2008a)). A change in the production barrier translates into cost changes, which affect prices and wages. This will deter the expenditure shares across countries and will affect each sectoral value-added, wages, and income directly and indirectly.

To sum up, the introduced COVID-19 related shock translates into the model as a shock to the production cost of both goods and services for domestic and foreign markets. It is directly transmitted through an increase in the production cost of the goods for domestic consumption and indirectly through an increase in the cost of intermediates from abroad and through a decrease in demand of goods produced for the foreign markets. The set-up allows to capture both of these channels.

The constructed policy intervention shock v_i^j is then used to perform a counterfactual analysis. As described in above and in the technical appendix 2.2.2, we follow Dekle et al. (2008a) and Caliendo and Parro (2015) and solve the model in relative changes to identify the value-added effect of the COVID-19 shock.

[9] See Appendix B.2 for a more technical explanation. For more details, see Sforza and Steininger (2020).

2.2.3 The Regional Effects of COVID-19

Understanding the effect of a global production shock induced by the COVID-19 pandemic across regions is crucial to target effective policies to mitigate the increase in inequality across European areas. This exercise is however extremely complex. Calibrating a structural general equilibrium model that accounts for inter-sectoral linkages, domestic and foreign trade both in intermediates and final goods at regional level requires information on input-output tables, bilateral trade in intermediate and final goods, sectoral output and value-added, consumer and producer prices for all regions and sectors in the economy. Moreover, one would need information on productivity dispersion–the trade cost elasticity–at regional level. Having all this data at hand, one could calibrate the model accounting for sector-region specific specialization, productivity differences, trade openness, and value-added and solve it with the methodology developed by Dekle et al. (2008a) to study counterfactual scenarios.

Several authors extensively worked to create regional input output tables for selected regions. Kronenberg (2009) constructs regional input-output tables for North Rhine–Westphalia to study the problem of cross-hauling (the simultaneous exporting and importing of one and the same type of product), Kronenberg (2010) constructs input-output tables at regional level for Mecklenburg-Vorpommern, while Schröder and Zimmermann (2014) performs the same exercise for the baltic sea region of Germany. However, none of these studies accout for inter-regional trade across and within countries. Krebs (2020) goes one step further and constructs an inter-regional input-output table for Germany, which includes trade linkages between German counties. In his work, he builds a dataset that accounts for spatial and sectoral production networks within Germany. Moreover, Krebs and Pflüger (2018) use an earlier version of the dataset of Krebs (2020) to study sector-region specific spillover effects of productivity shocks in Germany.[10]. However, all the above cited papers construct input-output tables for one region or at most, one country. Understanding the impact of a global shock to production that diffused through global value chains requires the contemporaneous study of multiple counties within a general equilibrium framework, even if one is interested in the regional dimension. Not accounting for inter-country trade would indeed lead to misleading partial equilibrium estimates of the effect of the policy.[11]

[10] There are several other papers that use German RIOT data, such as Becker and Henkel (2020) and Krebs and Pflüger (2019).

[11] We are currently working on developing input-output tables at regional level for all regions (NUTS2) in Europe, as well as intra and inter-regional trade to calibrate the framework with regional information.

Due to the lack of data for multiple countries in Europe, we rely on a second-best strategy to approximate the sector-region specific effects of the COVID-19 pandemic for European regions. For this purpose, we developed a methodology that parsimoniously redistributes the country-sector specific general equilibrium changes (i.e. sectoral value-added, trade, real income, and real wages) across regions within a country according to the composition and importance of the sectoral activity of each region. Sectoral activity can be measured in terms of regional sectoral value-added, employment, or income, depending on the type of general equilibrium effect being analyzed. Thorough the paper, we use regional employment to distribute the effects across regions. We accurately test the sensitivity of our estimation using all the available measures to redistribute the shock across sectors and regions.

In the next section, we present our methodology and discuss the key assumptions.

2.2.3.1 Back of the Envelope Calibration

We assess the regional impact of the COVID-19 shock in Europe by proportionally redistributing the country level effects coming from the structural general equilibrium framework using the following formula:

$$\hat{\varphi}_r = \sum_{1=j}^{J} \left(\frac{l_{ir}^j}{l_{ir}} \hat{\phi}_i^j \right) \tag{2.3}$$

where $\hat{\phi}_i^j$ is the change in value-added in a country i and sector j, l_{ir}^j is the employment level in country n, sector j and region r and l_{ir} is the employment level in country n, region r. Intuitively, we apply the same criteria used in equation 2.2 and redistribute the change in value-added obtained from the model $\hat{\phi}_i^j$ proportionally according to the employment shares in each sector-region. Indeed, we model the COVID-19 shock as a production shock that induces countries to implement a lock-down policy and hits sector-region pairs proportionally to their degree of labor intensiveness. The rationale for the modelling choice for both the formulation of the shock in equation 2.2 and for the redistribution of the effects across regions in equation 2.3 mainly stems from the evidence presented by Sforza and Steininger (2020), as well as from the evidence on the importance of accounting for the *teleworkability* of each sector presented in the paper by Dingel and Neiman (2020): it is crucial to account for the geographic distribution of sectoral production across regions as well as for the degree of teleworkability and for the labor intensiveness of each sector if one wants to correctly estimate the economic impact of the COVID-19 shock in a structural general equilibrium framework.[12]

Redistributing the country-sector effects of COVID-19 across regions using equation 2.3 returns reliable estimates under two key assumptions: (i) the distribution of sectoral productivity across sectors does not substantially vary across regions within a country and (ii) the exposure to trade of each sector does not substantially vary across regions within a country.

We directly test assumption (i) by constructing the distribution of sectoral productivity for each region. We use a simple measure of productivity – value-added per worker – and investigate if sectoral productivity varies substantially across regions within the same country. Figure 2.1 plots the sectoral productivity differences across a group of European countries. It is striking to notice that the dispersion of productivity across regions is almost null for the great majority of sectors and countries. The real-estate sector and the constructions sector systematically present a higher dispersion in productivity across regions, mostly driven by the presence of big cities in some specific regions. [13] It is also key to highlight that the set of countries in figure 2.1 presents the higher dispersion in productivity across regions in our sample, as it is clear from figure 2.2 where we plot the dispersion of sectoral productivity across regions for each country in our sample. Strikingly, there are minimal differences thorough the countries in our sample which makes us confident in the robustness of assumption (i).

Second, another key assumption is that the exposure to trade of each sector does not substantially vary across regions within a country. We cannot directly test assumption (ii) because that would require trade data at regional-sectoral level for each country in our sample. However, this is a standard assumption in international trade: in fact, studies that investigate the labor market effects of exposure to trade across regions, implicitly assume that the exposure to trade varies at sector (or sector-firm) level, hence the labor market effect of the exposure to trade crucially depend on the geographic distribution

[12] Bonadio et al. (2020) use a structural model to estimate the effect of the COVID-19 shock in a general equilibrium framework that accounts for the global networks of production across countries. We depart from their study by accounting for the geographical distribution of the economic activity across countries and crucially, across sectors. In fact, accounting for the granularity of production at sector-region level allows to have a more precise picture of the economic effect of the pandemic.

[13] Results holds if we exclude the real estate sector from our analysis.

of sectors across regions. [14] In the next section we describe the data needed for this exercise.

2.3 Data and Descriptive Evidence

In this section we present the data used to calibrate the model, to construct the COVID-19 shock as well as to account for the regional distribution of the economic effects of the shock.

2.3.1 Data

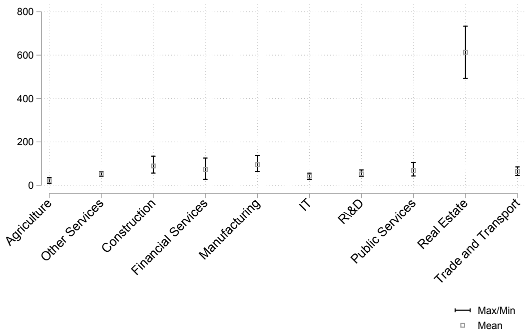
Our main source of data for the calibration of the model is the World Input-Output database (WIOD). It contains information on bilateral intermediate and final trade, sectoral output and value-added information, consumer and producer prices (Timmer et al., 2015). The most recent data is from 2014 and provides information for 43 countries, one rest of the world aggregate and 56 sectors. Bilateral preferential and MFN tariffs stem from the World Integrated Trade Solutions (WITS-TRAINS) and the WTO's Integrated Database (IDB). Productivity dispersion, the trade cost elasticity is taken from Caliendo and Parro (2015). This paper uses a modelling version of the COVID-19 shock described in Sforza and Steininger (2020) at regional level. The authors construct a rich dataset that includes regional and sectoral information of COVID-19 specific policy interventions, teleworkability across sectors, and duration of the shock. Cheng et al. (2020) is the main data source for the information on over 15 thousand policy interventions in 195 countries. Furthermore, an index on government responses to the COVID-19 diffusion of the University of Oxford is taken to proxy the severity of the government shutdowns, where $IndexClosure_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (see Hale et al. (2020) for a detailed description of the index), where 100 indicates full restrictions. Sector-region-country specific employment data is used to account for the geographical distribution of sectors across each country.[15]

[14] See for instance the seminal paper by Autor et al. (2013a): they exploit the cross-market variation in import exposure stemming from initial differences in industry specialisation and instrumenting for US imports using changes in Chinese imports by other high-income countries. Intuitively, they leverage on the geographic distribution of sectors in space and assume that the exposure of a sector to Chinese competition is the same across space. See, for instance Autor et al. (2013b), Autor et al. (2014), Dvorkin et al. (2015) as examples of research papers that rely on this assumption.

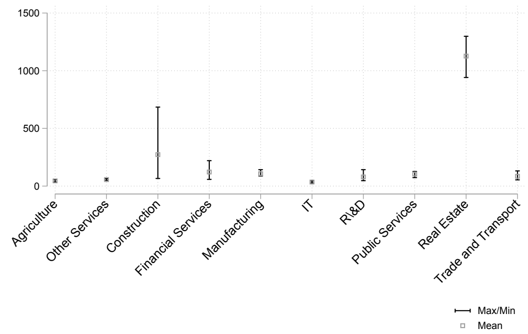
[15] see Sforza and Steininger (2020) for more details about the data used to construct the COVID-19 shock.

Figure 2.1: Sectoral Productivity Differences across Selected Countries

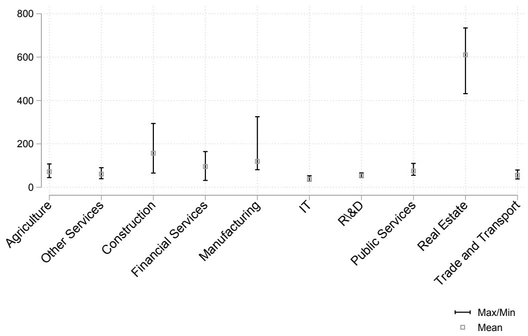
(a) Austria



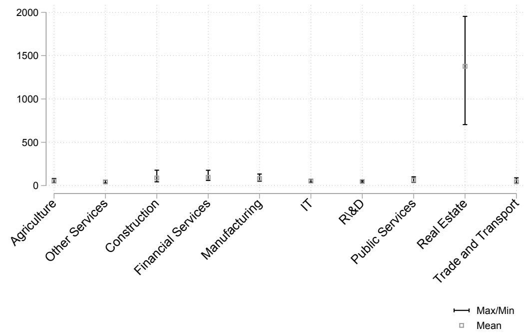
(b) Belgium



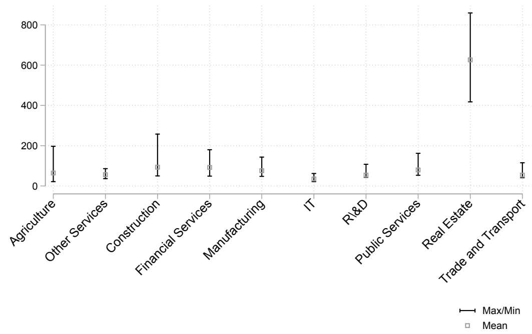
(c) Netherlands



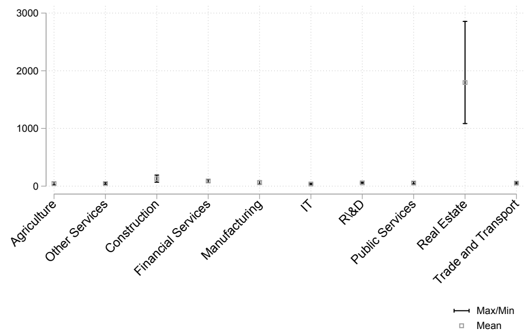
(d) Germany



(e) France

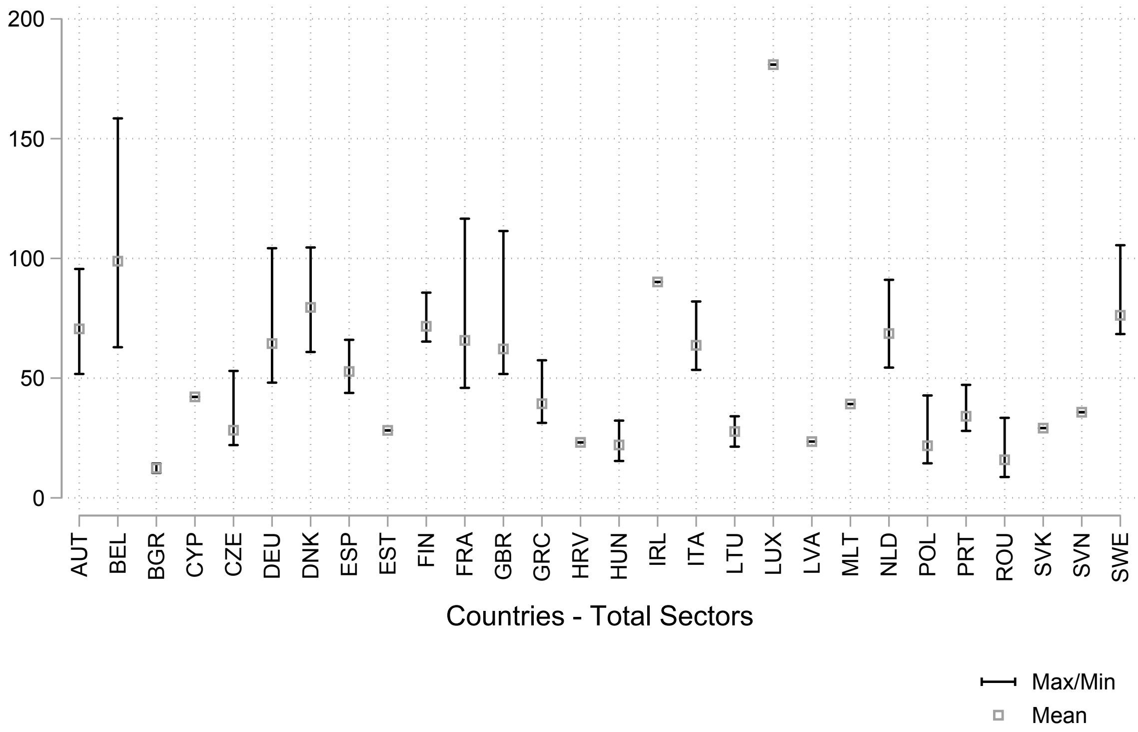


(f) Italy



Note: The figures show the value-added (in mn. Euro) over the number of employees (in thousands) across regions of all sectors. The figures highlight the region with the highest ratio (max), the region with lowest ratio (min) and the average. The ratio, value-added over employment is a simple measure of productivity.

Figure 2.2: Productivity Differences across Regions within EU28 Countries



Note: The figure shows the how total productivity is dispersed across regions within each countries. The max/min ratio indicates the highest and lowest region within each country and the simple productivity mean within each country.

To perform the back of the envelope calculations one needs sector-region specific data to distribute the country sector level shares across the regions. We use regional economic accounts from Eurostat, which provides data on employment and gross value-added for regions of the Nuts 0 to 3 classification in Europe from 1995 to 2018. The classification of economic activities within the regions is based on the NACE Revision 2 classification. As mentioned before, the counterfactual COVID-19 scenario is based on the World input output database (WIOD), with the base year 2014. Therefore, the back of the envelope calculations is based on the same year.

Missing data in both the employment dataset and the gross value-added dataset is interpolated, based on the average growth trend within a sector and region. This exercise retrieves accurate results for the year 2014. A cross validation exercise shows that the correlation of the regional gross value-added Eurostat dataset and the WIOD data is 0.998. Interestingly, the deviations are mainly driven by the public services sectors. For example, in Germany, the largest differences of the datasets in absolute terms are found in the manufacturing and the public services sectors. In WIOD the value-added in the manufacturing sector is equal to 623 mn. Euro, while in Eurostat the value-added in manufacturing for 2014 is equal to 592 mn. Euro, which makes a difference of less than 5%.

In the next section we present descriptive evidence on the distribution of economic activity across European regions and we present the results of our analysis.

2.3.2 Descriptive Evidence

Since the work of John Friedman (Friedmann (1966)) and later by Paul Krugman (Krugman (1991)), economists have given increasing attention to spatial inequality.[16] The core-periphery model has become a tool to analyze the evolution of inequality across geographical areas, allowing a country – or a broader geographic area, like the European Union – to endogenously become differentiated into an industrialized "core" and an agricultural "periphery". Due to the existence of transportation costs, manufacturing firms tend to locate in the region with larger demand, but the location of demand itself depends on the distribution of manufacturing. Emergence of a core-periphery pattern then depends on transportation costs, economies of scale, and the share of manufacturing in national income.

Since the very first days of its creation, the European Union has strategized to reduce the income inequality across regions within the union. However, despite the enormous efforts, the European Union is still challenged with this problem. Figure 2.3 presents a visual representation of the distribution of value-added across European regions in 2014, the baseline year for our quantitative exercise. It is straightforward to notice the existence of a richer "core", including most of the areas of Germany, northern Italy, part of France and the UK, and a lagging behind "periphery", which includes the Eastern European countries as well as most of the Mediterranean regions of Europe.

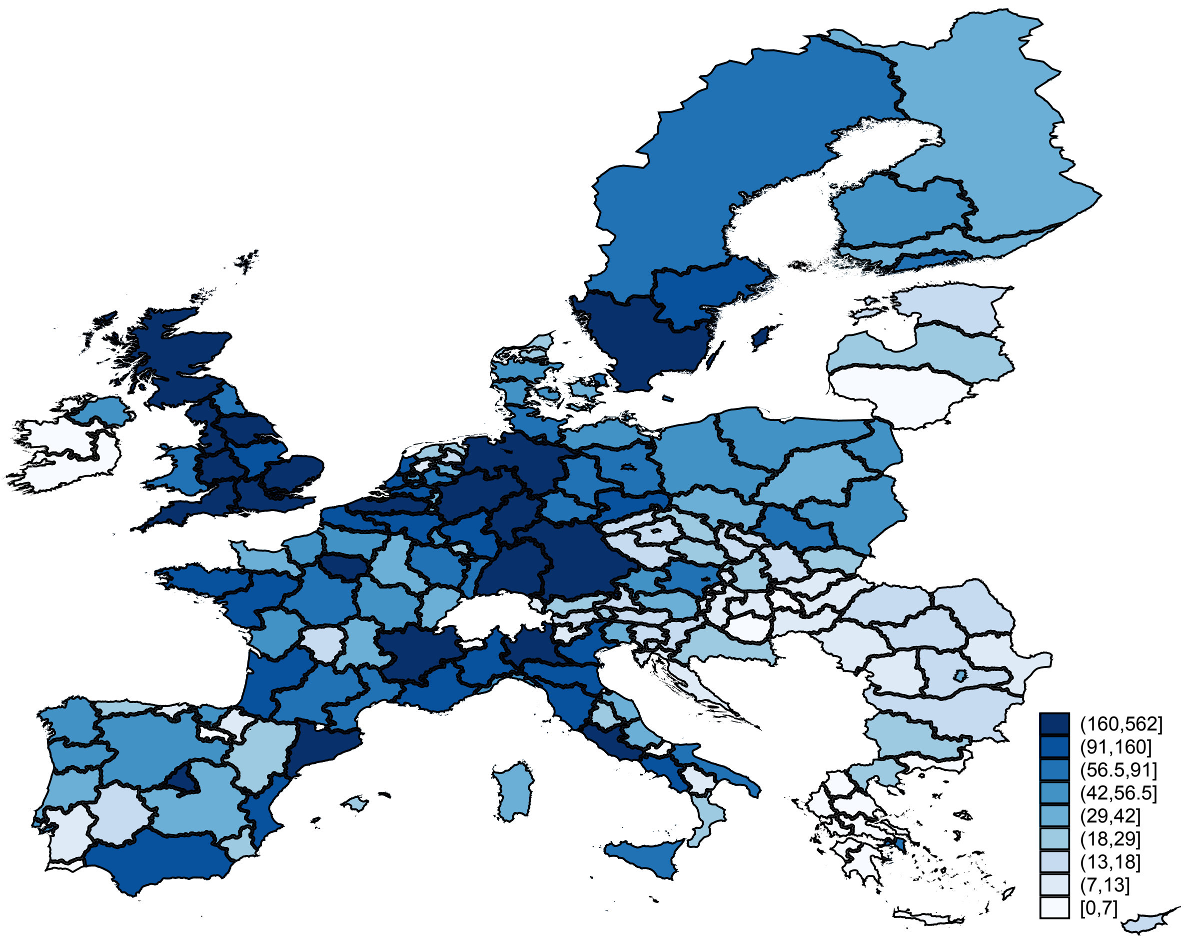
The existence of the pattern shown in figure 2.3 is well documented and studied.[17] The economic activity is enormously dispersed across countries and regions, with sectoral specialization arising in some specific areas in each country. A key question is whether a global production shock induced by the COVID-19 pandemic would increase or decrease the inequality across regions in the European Union. In the next section we present the results of our analysis and we try to investigate whether the global production shock

[16] See, for example, Puga (1999), Ottaviano and Puga (1998), Puga and Venables (2001), Puga (2002), Overman and Puga (2014) for additional evidence.

[17] See for instance the recent paper by Iammarino et al. (2018) for an extensive picture of the literature on regional inequality across European regions.

induced by the COVID-19 pandemic have a differential impact on "core" and "peripheral" regions.

Figure 2.3: Initial Value Added in bn. Euro across Europe's Regions



Note: The map shows the initial value-added in bn Euro for all European regions. The darker the shaded area, the higher the is the value-added of the respective region. The scale indicates the size of the value-added.

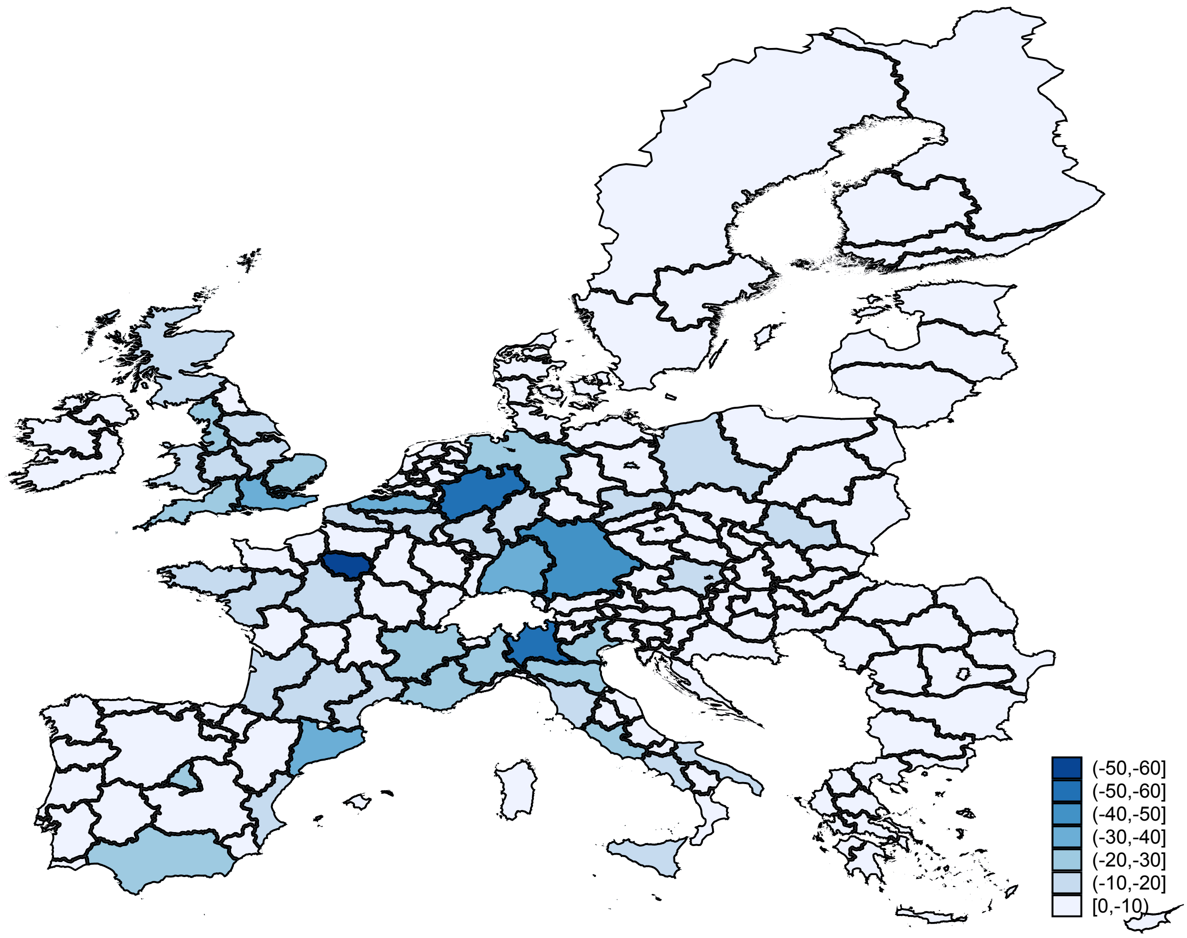
2.4 Results

In this section we present three sets of results. First, we focus on the regional distribution of the COVID-19 shock in Europe, providing evidence on the geographical heterogeneity across countries. Second, we zoom in the sectoral composition of each region and we provide a complete picture of the most and the least affected sectors across European regions. Finally, we provide aggregate results at sector-country level to have a macroeconomic picture of the effect of the COVID-19 shock across the entire Europe.

The regional distribution of the COVID-19 shock in Europe Figure 2.4 plots the change in value-added in billions of Euro across European regions. In order to compute the value-added changes at regional level, we follow a two-step procedure: (i) we perform a counterfactual exercise in which we include the COVID-19 shock in the model (as in Sforza and Steininger (2020) and we estimate a scenario based on the lockdown policies implemented in each country-region, and (ii) we redistribute the changes in value-added $\hat{\phi}_n^j$ from the counterfactual exercise according to equation 2.3. This procedure returns changes in value-added due to the COVID-19 shock for each region in Europe, as pictured in figure 2.4.

Strikingly, figure 2.4 presents a clear picture of the impact of the COVID-19. Looking at absolute changes in value-added as in figure 2.4 highlights an inverted "core-periphery" pattern: regions at the core of Europe experience the higher absolute drops in value-added, while peripheral regions – both eastern European countries as well as Mediterranean areas – experience lower absolute drops in value-added in bn. Euros.

Figure 2.4: Value Added Change in bn Euro across Europe's Regions



Note: The maps shows the value-added change (in bn. Euro) across Europe's regions. The darker the shaded region, the more it is affected by the COVID-19 shock.

In table 2.1 we present the absolute contractions in value-added for the regions that are hit the most (Top-10 affected Regions) and for the regions that are hit the least (Bottom-10 affected regions). The regions Ile de France, Lombardy (Italy), North Rhine-Westphalia, Bavaria (Germany), London (UK), South East UK (UK), Baden-Wuerttemberg (Germany), Cataluna (Spain), Vlaams Gewest (Belgium), and Lazio (Italy) experience the highest overall losses, while mainly southern European regions populate the list of the Bottom-10 affected regions.

The picture presented in figure 2.4 and table 2.1 would let the reader conclude that the negative shock induced by the COVID-19 pandemic disease has a stronger negative effect on richer regions, and a milder effect on peripheral poorer areas, hence leading to a reduction of across-region income inequality in Europe.

However, to have a complete picture on the actual distribution of the economic impact of the shock induced by the COVID-19 pandemic disease across regions, it is crucial to analyze the drop of value-added relative to the regional income. In figure 2.4 we present a map of the distribution of value-added change over regional income for the European Union.[18]

It is immediate to notice a clear "core-periphery" pattern, with the central and northern European regions experiencing relative drops in value-added up to 8 times smaller than southern and eastern European areas. In fact, the highest drop in value-added relative to a region's income is observed in regions of Romania, Czech Republic and Slovakia, followed by Poland, the Mediterranean regions of Italy and Spain and Portugal. On the contrary, most regions in Germany, the Netherlands and Sweden are the least affected in relative terms. In table 2.2 we present the Top-10 and Bottom-10 affected regions when accounting for the change in value-added relative to the real income. Two patterns clearly emerge from figure 2.4 and table 2.2: First, within a country, peripheral regions experience the most severe drops in value-added compared to core regions. Second, across Europe, the shock seems to amplify the inequality in the distribution of income, affecting the peripheral regions of the east, the west and the south substantially more compared to the core central and northern European areas.[19]

[18] To better compare the ratios across all European regions, the ratios are normalized by using the following procedure: The minimum ratio, of the value-added over the income across all sectors within a region, (Oestra Sverige area, Sweden) is set equal to one. All other values are normalized relative to the minimum ratio.

[19] Focusing on Germany, the region hit the least in terms of value-added change over income in Germany is Bremen, Hamburg, and Baden-Wuerttemberg. The regions hit the most are Saxony, Mecklenburg-Vorpommern and Berlin. In Italy, the regions hit the most in terms of value-added change over income are Abruzzo, Lazio and Umbria. The least affected are the Northern regions Bolzano, Alto Adige, and Trentino.

Table 2.1: Change of Value Added - Top 10 and Bottom 10 Regions in EU28 in mn Euro

Country iso-code	Region	Change of Value Added in mn. Euro
Top-10 affected EU28 Regions		
FRA	Ile de France	-60556
ITA	Lombardia	-53809
DEU	NordrheinWestfalen	-50264
DEU	Bayern	-40914
GBR	London	-35168
GBR	South East (UK)	-34848
DEU	BadenWuerttemberg	-34331
ESP	Cataluna	-32183
BEL	Vlaams Gewest	-30622
ITA	Lazio	-29367
Bottom-10 affected EU28 Regions		
GRC	Peloponnisos	-577
FRA	Guyane	-509
ITA	Valle d'Aosta/Vallee d'Aoste	-495
GRC	Notio Aigaio	-439
GRC	Ipeiros	-345
GRC	Dytiki Makedonia	-289
GRC	Ionia Nisia	-235
ESP	Ciudad Autonoma de Ceuta (ES)	-202
GRC	Voreio Aigaio	-202
FRA	Mayotte	-180

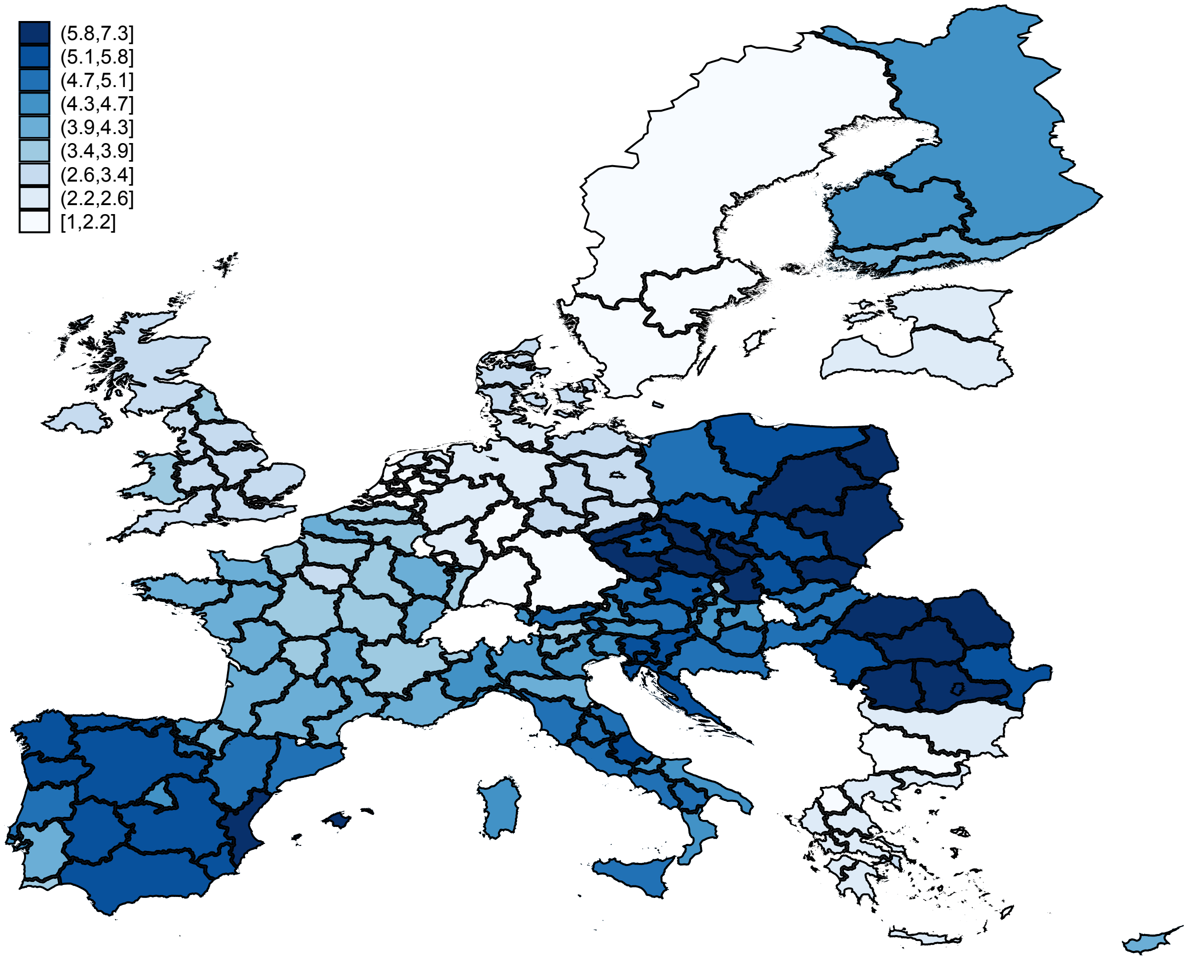
Note: The table shows the top 10 and bottom 10 regions that experience the highest and respectively lowest change in value added in million Euro.

Table 2.2: Normalized Change of Value Added over Income - Top 10 and Bottom 10 Regions in %

Country	Region	Normalized relative VA to Income
Top-10 affected EU28 Regions		
ROU	NordEst	7.31
ROU	Sud Muntenia	7.20
POL	Makroregion Centralny	6.86
CZE	Severozápad	6.82
ROU	NordVest	6.55
ROU	SudVest Oltenia	6.43
SVK	Vychodne Slovensko	6.34
CZE	Moravskoslezsko	6.29
SVK	Západne Slovensko	6.26
POL	Makroregion Wschodni	6.22
Bottom-10 affected EU28 Regions		
GRC	Ionia Nisia	2.03
NLD	ZuidHolland	2.01
NLD	Flevoland	1.99
NLD	NoordHolland	1.99
FIN	Aland	1.98
GRC	Notio Aigaio	1.98
NLD	Utrecht	1.91
BGR	Yugozapadna	1.88
FRA	Corse	1.83
SWE	Norra Sverige	1.17

Note: The table shows the top 10 and bottom 10 regions with the highest and respectively lowest normalized relative change in value added to regional income.

Figure 2.5: Value Added Change Over Income in bn Euro across Europe's Regions



Note: The map shows the value-added change over the income of the respective EU regions. The darker the shaded region, the more it is affected by the COVID-19 shock. To better compare the ratios across all European regions, the ratios are normalized by using the following procedure: The minimum ratio, of the value-added over the income across all sectors within a region, (Stockholm area, Sweden) is set equal to one. All other values are normalized relative to the minimum ratio.

The sectoral-regional dimension of the COVID-19 shock An important dimension in the understanding of the impact of the COVID-19 shock is the sectoral dimension across regions. We leverage on the richness of the general equilibrium framework that allows to account for inter-sectoral linkages within and across countries to compute the counterfactual change in sectoral value-added for each country and we account for the geographic distribution of sectors across regions and proportionally redistribute the change in sectoral value-added across regions using equation 2.3.

Table 2.3 presents the Top-10 and Bottom-10 sectoral change in value-added across European regions in absolute terms, while table 2.4 presents the same results in relative changes to initial sectoral value-added in a region. Not surprisingly, focusing on table 2.3 the Italian region of Lombardy together with the Paris region of Ile de France lead the Top-10 drop in value-added in absolute terms, with the sectors of manufacturing, public services, real estate and trade and transport. On the other hand, the sectors of IT, agriculture and other services in southern and eastern European countries are the least affected in absolute terms. However, looking at table 2.4, the sectors of trade and transport and IT in Slovenian and Polish regions lead the group of the Top-10 drop in relative value-added, while agriculture in the Swedish regions of Soedra Sverige, Oestra Sverige and Norra Sverige are the least affected sectors in relative terms.

These results are partially driven by the nature of the COVID-19 shock, affecting in a more severe way labor intensive sectors that cannot leverage on the *teleworking*, like for example trade and transport or manufacturing, while hitting only marginally essential sectors that did not experience restrictive lock-down policies, like for instance agriculture. At the same time, the shock hits stronger regions and sectors that substantially rely on across-country linkages, external inputs of production or foreign markets. That is because the COVID-19 shock is a global shock that affects all countries at the same time; our general equilibrium framework captures the importance of the inter-sectoral linkages both within a country and across countries and allows us to have a complete picture of the magnitude of the shock across sectors and regions.

Country-Sector Dimension After studying the regional and sectoral dimension of the distribution of the COVID-19 shock, we provide aggregate results at sector-country level to have a macroeconomic picture of the effect of the COVID-19 shock across the entire Europe.

In aggregate and absolute terms (see table 2.5), the sectors of manufacturing, trade and transport and public services across Germany, Italy and the UK suffer the biggest drop in value-added, while agriculture and some residual services (other services) in eastern European regions suffer the smallest drop in value-added.[20]

In table 2.6 we present the relative changes in value-added at country-sector level. Similar to the results in table 2.4, the sectors of trade and transport, research development and IT in eastern European countries (Slovenia and Poland) suffer the strongest decline in value-added, while the sector of agriculture in Sweden experiences the smallest drop in relative terms.

[20] Notice that "other services" is one of the smallest sector in each country, hence it is not surprising that it always appear in the list of bottom-10 sectors.

Table 2.3: Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Regions in mn Euro

Country iso-code	Region	Sector	Change of Value Added in mn. Euro
Top-10 affected Sector of EU28 Regions			
ITA	Lombardia	Manufacturing	-12092
FRA	Ile de France	Public Services	-11405
FRA	Ile de France	Real Estate	-10116
FRA	Ile de France	Trade and Transport	-9997
FRA	Ile de France	R&D	-9737
ITA	Lombardia	Real Estate	-9535
ITA	Lombardia	Trade and Transport	-9089
ESP	Cataluna	Manufacturing	-7000
ESP	Cataluna	Trade and Transport	-6994
ESP	Andalucia	Trade and Transport	-6797
Bottom-10 affected Sectors of EU28 Regions			
GRC	Thessalia	IT	-10
HUN	Budapest	Agriculture	-10
GRC	Voreio Aigaio	Construction	-9
GRC	Dytiki Makedonia	Other Services	-8
CZE	Praha	Agriculture	-8
ESP	Ciudad Autonoma de Melilla (ES)	Other Services	-7
GRC	Voreio Aigaio	Other Services	-7
ESP	Ciudad Autonoma de Ceuta (ES)	Other Services	-6
ROU	Bucuresti Ilfov	Agriculture	-5
FRA	Corse	Agriculture	-3

Note: The table shows the top 10 and bottom 10 regions that experience the highest and respectively lowest change in value added in million Euro.

2.5 Conclusion

This paper studies the distributional effects of the COVID-19 shock across European regions. We exploit the heterogeneous disruption in production across European regions induced by the COVID-19 pandemic to instruct a multi-country, multi-sector Ricardian model with interactions across tradable and non-tradable sectors observed in the input-

Table 2.4: Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Regions in %

Country iso-code	Region	Sector	Change of Value Added in %
Top-10 affected Sectors of EU28 Regions			
POL	Makroregion Poludniowy	Construction	-18.571
SVN	Zahodna Slovenija	Real Estate	-18.623
POL	Makroregion PoludniowoZachodni	R&D	-18.701
SVN	Zahodna Slovenija	Construction	-18.721
SVN	Zahodna Slovenija	Financial Services	-18.726
POL	Makroregion Poludniowy	IT	-18.735
SVN	Vzhodna Slovenija	R&D	-18.743
POL	Makroregion Polnocny	Trade and Transport	-18.898
SVN	Zahodna Slovenija	IT	-18.978
SVN	Vzhodna Slovenija	Trade and Transport	-19.356
Bottom-10 affected Sectors of EU28 Regions			
SWE	Norra Sverige	Agriculture	-2.568
SWE	Soedra Sverige	IT	-2.834
SWE	Norra Sverige	R&D	-3.095
SWE	Norra Sverige	Trade and Transport	-3.144
SWE	Oestra Sverige	Financial Services	-3.353
SWE	Soedra Sverige	Real Estate	-3.516
SWE	Norra Sverige	Construction	-3.563
SWE	Oestra Sverige	Other Services	-3.567
SWE	Norra Sverige	Public Services	-3.585
SWE	Oestra Sverige	Manufacturing	-3.786

Note: The table shows the top 10 and bottom 10 regions that experience the highest and respectively lowest change in value added in Percent.

output tables. We use the structural model to retrieve the primitive for our exercise, namely the changes in value-added by country-sector; we then use a *back of the envelope calibration* methodology to parsimoniously redistribute the changes in value-added across European regions.

Understanding the effect of a global production shock induced by the COVID-19 pandemic across regions is crucial to target effective policies to mitigate the unequal impact of the shock across European areas. This exercise is however extremely complex. Calibrating a structural general equilibrium model that accounts for inter-sectoral linkages,

Table 2.5: Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Countries in mn Euro

Country iso-code	Sector	Change of Value Added in mn Euro
Top-10 affected Regions		
Germany	Manufacturing	-63919
Italy	Trade and Transport	-52886
Italy	Manufacturing	-48874
Germany	Public Services	-45641
United Kingdom	Public Services	-45130
Italy	Public Services	-44927
United Kingdom	Trade and Transport	-43353
Spain	Trade and Transport	-41921
Germany	Trade and Transport	-36610
United Kingdom	Manufacturing	-36388
Bottom-10 affected Sectors in Regions		
Latvia	Agriculture	-58
Malta	Real Estate	-55
Cyprus	Agriculture	-53
Latvia	Other Services	-53
Estonia	Financial Services	-48
Estonia	Agriculture	-47
Malta	Construction	-46
Estonia	Other Services	-33
Luxembourg	Agriculture	-21
Malta	Agriculture	-15

Note: The table shows the top 10 and bottom 10 sector country combinations that experience the highest and respectively lowest change in value added in mn Euro.

domestic and foreign trade both in intermediates and final goods at regional level requires information on input-output tables, bilateral trade in intermediate and final goods, sectoral output and value-added, consumer and producer prices for all regions and sectors in the economy. Moreover, one would need information on productivity dispersion - the trade cost elasticity - at regional level. Having all this data at hand, one could calibrate the model accounting for sector-region specific specialization, productivity differences, trade openness, and value-added and solve it to perform counterfactual simulations.

Table 2.6: Change of Value Added - Top 10 and Bottom 10 Sectors of EU28 Countries in %

Country	Sector	Change of Value Added in %
Top-10 affected Regions		
Slovenia	Trade and Transport	-19.356
Slovenia	IT	-18.978
Poland	Trade and Transport	-18.898
Slovenia	R&D	-18.743
Poland	IT	-18.735
Slovenia	Financial Services	-18.726
Slovenia	Construction	-18.721
Poland	R&D	-18.701
Slovenia	Real Estate	-18.623
Poland	Construction	-18.571
Bottom-10 affected Sectors in Countries		
Sweden	Manufacturing	-3.786
Sweden	Public Services	-3.585
Sweden	Other Services	-3.567
Sweden	Construction	-3.563
Sweden	Real Estate	-3.516
Sweden	Financial Services	-3.353
Sweden	Trade and Transport	-3.144
Sweden	R&D	-3.095
Sweden	IT	-2.834
Sweden	Agriculture	-2.568

Note: The table shows the top 10 and bottom 10 regions that experience the highest and respectively lowest change in value added in percent.

We propose a methodology to approximate the sector-region specific effects of the COVID-19 pandemic for European regions, what we call *back of the envelope calibration*. We leverage on a rich set of data that includes regional economic accounts from Eurostat, which provides key information on employment and gross value-added for up to NUTS-3 regions in Europe from 1995 to 2018. Using our methodology, we parsimoniously redistribute the country-sector specific general equilibrium changes in value-added across regions within a country according to the composition and importance of the sectoral activity of each region.

We find that the distributional effects of the COVID-19 pandemic disease are extremely heterogeneous across European regions, exacerbating the "core-periphery" divide and the inequality across the European area. In fact, we present evidence that the COVID-19 shock has a stronger impact on the peripheral regions of Eastern and Southern Europe, together with most of the Mediterranean regions and the Atlantic regions of Portugal and Spain. On the contrary, the central European regions of the Netherlands and Germany, together with most Swedish regions experience a much milder effect of the pandemic on their economic structure.

The enormous difference in the size of the economic effect of the COVID-19 shock - the economic effect is up to eight time higher in east and south of Europe compared to the least affected regions in Sweden - across European regions strongly emphasize the importance of policy responses that target the reduction of inequality across regions as a primary goal.

Chapter 3

Quantifying Brexit: From Ex Post to Ex Ante Using Structural Gravity

Exploiting changes in the geography of economic integration in Europe, this paper quantifies the effects of Brexit from ex post to ex ante using structural gravity. By isolating the directional treatment effects of EU agreements for the UK, the analysis reveals important heterogeneity across agreements, sectors, and within pairs. We find that these directional effects matter for the size and distribution of the welfare effects of Brexit – the withdrawal of the UK from EU agreements resulting into a return of trade costs to the situation quo ante. We make this point with the help of a modern multi-sector trade model that is able to capture inter- and intranational production networks. In line with other papers, the welfare costs of Brexit are higher in the UK than in most other EU countries. However, heterogeneity tends to attenuate overall costs while giving rise to substantial heterogeneity between EU27 members and sectors. A scenario that could shift bargaining power eliminates asymmetries in the costs of Brexit as soon as the UK fully liberalizes its market.

3.1 Introduction

The relationship between the European Union (EU) and the United Kingdom (UK) has always been fraught with complexity for reasons related to history, culture and geography. Differences over the long term goal of the EU integration process – whether the objective is a political union or just the establishment of a common market – date back at least to 1983 when the term "ever closer union" was coined.[1] The creation of the European Monetary Union – from which the UK opted out – and even more so the emergence of deficiencies in the construction of the Eurozone made the necessity of further political integration apparent, and widened the gap between the UK and the continent. At the same time, the relative importance of Europe as a trade partner for the UK fell from about 65% in the early 1990s to less than 45% in 2016, presumably because trade costs with third countries dropped more than costs of intra-EU trade.[2] This fact, together with rising net budgetary contribution to the EU, seems to imply that the relative costs of a withdrawal from the EU are lower today than what they would have been 25 years ago.

In this paper, we ask: If, in 2014, the UK had not been part of the EU? What would counterfactual real consumption, trade volumes, and sectoral value added have looked like? This provides us with an estimate of UK benefits from EU membership, which – in turn – we take as a proxy of what the costs of leaving the EU would be. To answer this question, we first conduct an ex post evaluation to back out trade cost changes. These can be used as proxies for non-tariff barriers in different counterfactual Brexit scenarios. More specifically, we exploit different integration steps of the UK and the EU members (i.e. becoming a member of the European Union Single Market, or joining a free trade agreement) on the sector-level. To correctly estimate trade cost shocks, we consider directionality in the treatment effects of UK-EU relations. Second, we run ex ante simulations of the effects from reversing those trade cost savings in a quantitative Ricardian trade model. We focus on the trade effects and do so in great detail, distinguishing 22 goods and 28 services industries and 43 countries and a rest of the world component representing more than 90% of world GDP.

We are not the first to study the potential economic consequences of UK's withdrawal from the EU, but we believe we offer the most detailed and most data-driven analysis of the trade-related effects of Brexit. We contribute by embedding a careful ex post evaluation of British EU membership into an ex ante analysis of its dissociation from the EU.

First, we estimate directional trade effects of the British EU membership or of EU trade agreements with third countries (such as with Korea) and allow these to differ across

[1] The term first appeared in European Council (1983), "A Solemn Declaration on European Union" at the Council Meeting in Stuttgart, Germany. The document prepared the creation of the Single Market, a central request of Margaret Thatcher, but also led to the granting of annual budget rebates to the UK in 1984.

[2] Exports of goods and services; see Ward (2017).

industries.[3] Separating tariff and non-tariff barrier (NTB) trade effects in EU membership, we use the estimated trade cost shocks to carry out our comparative statics exercise in the year 2014, for which we have real data.[4] This allows us to put special emphasis on sectoral heterogeneity. In contrast, Dhingra et al. (2017) use estimates of NTBs by Berden et al. (2013) for the US-EU relationship dating from the year 2007 and assume a uniform increase by 25% across all sectors. Moreover, they also assume that the UK would not be able to participate in future reductions in NTBs. Further, we estimate the changes of non-tariff barriers and not the levels, which makes the results independent of other policy components.[5] Second, we estimate the crucial trade elasticities on exactly the same data that we calibrate our model with and which also defines the baseline that we compare our counterfactual equilibrium with. This is in the spirit of structural gravity modeling and allows for a tight connection between theory, estimation and calibration.[6] Moreover, the econometric exercise supplies us with the necessary information to simulate confidence intervals for all of our endogenous variables. By quantifying uncertainty, we also go beyond Dhingra et al. (2017) and Steinberg (2019). Third, when evaluating the possible effects of new bilateral trade agreements of the UK with third parties, we do not make educated guesses about the size and distribution of sectoral changes in NTBs. Rather, we estimate the potentially asymmetric sectoral trade effects of the EU-Korea trade agreement for the UK and assume that new agreements could implement what has proven feasible in that agreement. The EU-Korea deal has been in force since 2011 and is one of the most ambitious (and successful) FTAs of the EU (Lakatos and Larsson, 2017). Further, next to tariffs and NTBs, we consider fiscal transfers within the EU as an important component of EU membership. Hence, we evaluate their impact on disintegration by decomposing welfare effects into tariff, NTB, and fiscal transfer components in the context of Brexit.

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[3] Baier et al. (2016) show that asymmetries in trade agreements occur particularly within pairs and play an important role for their exports and imports. Graziano et al. (2018) estimate uncertainty effects surrounding the probability of Brexit considering such asymmetries.

[4] Steinberg (2019) uses a dynamic general equilibrium model with firm heterogeneity, but relies on the calibration of parameters from different sources of data and on several specific assumptions surrounding e.g. future technology adoption. Our focus lies on the identification of the trade cost shocks surrounding Brexit by separating tariffs and NTBs, considering the directionality of treatment effects, and the consideration of fiscal transfer systems within the EU. Relying on a single source of data has the advantage to rely on fewer assumptions, but obviously limits us with respect dynamic adaptions in case of Brexit.

[5] Sampson (2017) provides an excellent overview of trade and other issues related to Brexit.

[6] see Yotov et al. (2016) for an excellent survey and Mayer et al. (2019) for an application to the costs of non-Europe

We use a computable general equilibrium framework (see e.g, Costinot and Rodriguez-Clare, 2014). A common feature of these models is that they give rise to a theoretical foundation of the gravity equation of international trade and that they can be solved in changes, a feature referred to as "exact hat algebra" in the literature (Dekle et al., 2008b). This has obvious computational advantages but also helps with calibration as unknown constants drop out. More specifically, our modeling framework is based on Caliendo and Parro (2015)'s multi-sector input-output version of the Ricardian trade model by Eaton and Kortum (2002). We extend this setup to include services trade, non-tariff barriers and the directional treatment heterogeneity of trade agreements. Our parameter estimation and the calibration of the model are based on data provided by the World Input-Output Database (WIOD) as described by Timmer et al. (2015). Importantly, the model features a detailed account of international input-output linkages.[7]

We consider four scenarios: (i) a WTO scenario (hard Brexit) in which the UK loses preferential access to EU27 countries and to third countries with which the EU currently maintains free trade agreements; most favored nations (MFN) tariffs apply and non-tariff barriers (NTBs) are reintroduced; (ii) a scenario with a modern and ambitious trade agreement between the EU27 and the UK, comprising tariffs and NTBs, and modeled after the EU-Korea FTA; (iii) a global Britain scenario, with tariffs and NTBs as defined in the WTO scenario, but bilateral FTAs between the UK with USMCA countries, Asian countries and non-European members of the Commonwealth; and (iv) a hard but smart Brexit scenario in which the UK decreases its tariffs to zero for all trading partners and does not impose additional non-tariff barriers against the European Union, while the EU27 increase tariffs against the UK to MFN levels and impose non-tariff barriers against the UK.

The main results of our ex post evaluation of EU integration steps are that the EU has been very successful in reducing trade costs between its members. While, in the partial equilibrium, EU integration has boosted goods exports of the UK to the other EU countries by about 24%, it has increased other EU members' exports to the UK by as much as 76%. In services trade, we find that UK exports to EU27 countries are 64% higher due to EU membership, while bilateral services exports of other EU27 countries to the UK have almost doubled. Ignoring this important directional heterogeneity, one could easily overestimate the costs of Brexit to the UK and underestimate it for the rest of the EU. At the finer sectoral level, a lot of heterogeneity exists, but the general picture remains. For example, EU membership has increased exports of the UK to the EU in

[7] Recent work by Vandenbussche et al. (2017) highlights the importance of such networks in the context of Brexit.

the air transport sector substantially, while it has not affected exports in its postal and courier sector. The opposite pattern holds for the UK's imports in these sectors. Also, the results suggest that the EU-Korea FTA from 2011 has not had any positive effects on UK overall exports of goods, but on services trade.

We use these partial equilibrium estimates to define directional trade cost shocks for the counterfactual general equilibrium analysis. It turns out that effects depend on treatment heterogeneity. We show that sectoral heterogeneity and asymmetries in trade cost changes matters for the size of macroeconomic outcomes. Ignoring heterogeneity, the costs of Brexit could be inflated by as much as 25% for the UK. Next, we fully account for the directionality of effects and simulate four Brexit scenarios to assess the general equilibrium effects on real consumption, trade, and sectoral value added for 43 countries and a rest of the world component. We find substantial heterogeneity among EU27 members. A hard Brexit reduces real consumption more in Ireland, Luxembourg and Malta than in the UK, where the 90% confidence interval is [-3.32%,-2.19%]. The core EU economies France, Germany, and Italy face losses in the intervals [-0.66%,-0.38%],[-0.84%,-0.59%], and [-0.50%,-0.31%], respectively. The conclusion of a modern FTA, drafted after the existing EU-Korea FTA, allows avoiding three quarters of the loss from Brexit in the EU27 countries and two thirds in the UK compared to the hard Brexit scenario. If the UK concludes FTAs with many countries outside of the EU27, the change in real consumption is contained in the 90% interval [-2.10%,-0.76%] for the UK. Due to trade diversion effects, losses in EU countries would be higher than under the hard Brexit scenario. For third countries, real consumption changes are mostly not statistically different from zero. An exception is Switzerland, who could slightly benefit from a hard Brexit and a subsequent relocation of financial services. With a hard but smart Brexit strategy, the UK decreases tariffs across all goods sectors to zero for all trade partners and does not impose additional controls on imports from the EU27, while the EU imposes tariffs and additional non-tariff barriers against the UK. With this strategy, the UK could lower its economic damage to half a percent. The existing asymmetry between Britain and the EU27 would vanish and the bargaining power would shift from Brussels to London.

The remainder of this paper is organized as follows. Section 5.3 presents the methodological framework. Section 4.3.1 discusses the main data sources, explains the empirical estimation method, and discusses gravity results. Based on the defined Brexit scenarios, we examine general equilibrium consistent results on trade and welfare in section 3.4. The final chapter concludes.

3.2 Model

The model follows Caliendo and Parro (2015), who provide a multi-sector version of the Eaton and Kortum (2002) gravity model with input-output linkages.

3.2.1 Setup

There are N countries indexed by i and n, as well as J sectors indexed by j and k. Sectoral goods are either used as inputs in production or consumed, with the representative consumer having Cobb-Douglas preferences over consumption C_n^j of sectoral final goods with expenditure shares $\alpha_n^j \in (0,1)$ and $\sum_j \alpha_n^j = 1$.

Labor is the only production factor and labor markets clear. The labor force L_n is mobile across sectors such that $L_n = \sum_{j=1}^{J} L_n^j$, but not between countries. In each sector j, there is a continuum of intermediate goods producers indexed $\omega^j \in [0,1]$ who combine labor and composite intermediate input and who differ with respect to their productivity $z_i^j\left(\omega^j\right)$. Intermediate goods are aggregated into sectoral composites using CES production functions with elasticity η^j. On all markets, there is perfect competition.

A firm in country i can supply its output at price

$$p_{in}^j(\omega^j) = \kappa_{in}^j \frac{c_i^j}{z_i^j\left(\omega^j\right)} \text{ with } c_i^j = \Upsilon_i^j \, w_i^{\beta_i^j} \left[\prod_{k=1}^{J} p_i^{k\,\gamma_i^{k,j}}\right]^{(1-\beta_i^j)}. \tag{3.1}$$

The minimum cost of an input bundle is c_i^j, where Υ_i^j is a constant, w_i is the wage rate in country i, p_i^k is the price of a composite intermediate good from sector k, $\beta_i^j \geq 0$ is the value added share in sector j in country i and $\gamma_i^{k,j}$ denotes the cost share of source sector k in sector j's intermediate costs, with $\sum_{k=1}^{J} \gamma_i^{k,j} = 1$. κ_{in}^j denotes trade costs of delivering sector j goods from country i to country n such that

$$\kappa_{in}^j = (1 + t_{in}^j) D_{in}^{\rho^j} e^{\mathbf{ffi}^j \mathbf{Z}_{in}}, \tag{3.2}$$

where $t_{in}^j \geq 0$ denotes ad-valorem tariffs, D_{in} is bilateral distance, and $\mathbf{Z}_{in}$ is a vector collecting trade cost shifters (such as FTAs or other trade policies).

Productivity of intermediate goods producers follows a Fréchet distribution with a location parameter $\lambda_n^j \geq 0$ that varies by country and sector (a measure of absolute advantage) and shape parameter θ^j that varies by sector (and captures comparative advantage).[8]

Producers of sectoral composites in country n search for the supplier with the lowest cost such that

$$p_n^j = \min_i \left\{ p_{in}^j(\omega^j); i = 1, \ldots, N \right\}. \tag{3.3}$$

Caliendo and Parro (2015) show that it is possible to derive a closed form solution of composite intermediate goods price

$$p_n^j = A^j \left(\sum_{i=1}^{N} \lambda_i^j \left(c_i^j \kappa_{in}^j \right)^{\frac{-1}{\theta^j}} \right)^{-\theta^j}, \tag{3.4}$$

where $A^j = \Gamma\left[1 + \theta^j(1 - \eta^j)\right]^{\frac{1}{1-\eta^j}}$ is a constant.

Similarly, a country n's expenditure share π_{in}^j for source country i's goods in sector j is

$$\pi_{in}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{in}^j \right]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^{N} \lambda_i^j \left[c_i^j \kappa_{in}^j \right]^{\frac{-1}{\theta^j}}}, \tag{3.5}$$

which forms the core of a gravity equation.

3.2.2 General Equilibrium

Let Y_n^j denote the value of gross production of varieties in sector j. For each country n and sector j, Y_n^j has to equal the value of demand for sectoral varieties from all countries $i = 1, \ldots, N$.[9] The goods market clearing condition is given by

$$Y_n^j = \sum_{i=1}^{N} \frac{\pi_{ni}^j}{(1 + t_{ni}^j)} X_i^j \qquad \text{with} \qquad X_i^j = \sum_{k=1}^{J} \gamma_i^{j,k} (1 - \beta_i^k) Y_i^k + \alpha_i^j I_i, \tag{3.6}$$

where national income consists of labor income, tariff rebates R_i and the (exogenous) trade surplus S_i, i.e. $I_i = w_i L_i + R_i - S_i$ and X_i^j is country i's expenditure on sector j goods.We keep the trade surplus relative to GDP constant. Quite mechanically, this

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[8] Convergence requires $1 + \theta^j > \eta^j$.

[9] Our exposition differs from Caliendo and Parro (2015) in that they use total expenditure on composite goods instead of total production of varieties as endogenous variable. So, in Caliendo and Parro (2015) the value of gross production comprises all foreign varieties that are bundled into the composite good without generation of value added.

forces additional asymmetry on the change in trade flows even if trade cost shocks are rather similar. We do not eliminate the trade surplus through reparameterization as in Caliendo and Parro (2015). We assume that $s_n \equiv S_n/B$, where $B \equiv \sum_n w_n L_n$ is global labor income, to make sure that the system is homogeneous of degree zero in prices. In the Brexit scenarios, we will redistribute the fiscal transfers of the EU budget by adjusting the trade surplus S_n.

The first term on the right-hand side gives demand of sectors k in all countries i for intermediate usage of sector j varieties produced in country n, the second term denotes final demand. Tariff rebates are $R_i = \sum_{j=1}^{J} X_i^j \left(1 - \sum_{n=1}^{N} \frac{\pi_{ni}^j}{(1+t_{ni}^j)}\right)$.[10]

The second equilibrium condition requires that, for each country n, the value of total imports, domestic demand and the trade surplus has to equal the value of total exports including domestic sales, which is equivalent to total output Y_n:

$$\sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{in}^j}{(1+t_{in}^j)}X_n^j + S_n = \sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{ni}^j}{(1+t_{ni}^j)}X_i^j = \sum_{j=1}^{J} Y_n^j \equiv Y_n \tag{3.7}$$

Conditions (D.1) and (D.2) close the model.

3.2.3 Comparative Statics in General Equilibrium

We are interested in the effects of different Brexit scenarios on trade flows, wages, sectoral value added, and real consumption (as our measure of welfare). Hence, we need to quantify the comparative static effects of changes in trade costs (tariffs and non-tariff barriers) κ_{in}^j on endogenous quantities such as trade flows, wages, sectoral value added, production and tariff income. As shown by Dekle et al. (2008b), we solve the model in changes. Let z denote the initial level of a variable and z' its counterfactual level. Then, trade cost shocks are given by $\hat{\kappa}_{in}^j = \frac{1+t_{in}^{j'}}{1+t_{in}^j} e^{\delta^j (Z'_{in} - Z_{in})}$ and the change in real consumption is

$$\hat{W}_n = \frac{\hat{X}_n}{\prod_{j=1}^{J} \left(\hat{p}_n^j\right)^{\alpha_n^j}}. \tag{3.8}$$

In Appendix C.1, we present the system of equations in changes required to solve the model. An important advantage of solving the model in changes is that certain constant parameters such as the absolute advantage or the elasticity of substitution between input

[10] Instead of the goods market clearing condition, one can also use the expenditure equation $X_i^j = \left(\sum_{k=1}^{J} \gamma_i^{j,k} (1-\beta_i^k)(F_i^k X_i^k + S_i^k) + \alpha_i^j I_i\right)$ as in Caliendo and Parro (2015).

varieties ω drop out and need not be estimated. This reduces the data needs and lowers the scope for measurement error – of course, at the price of functional assumptions.

Our comparative statics exercise refers to the long-run, i.e., to a new equilibrium in which all relevant general equilibrium interactions have already fully taken place. Short-run effects can differ from those long-run predictions. Moreover, we hold technology fixed and abstract from endogenous innovation or technology adoption. The latter would require leaving the bedrock of a standard and widely accepted modeling framework.

3.3 Empirical Model, Data, and Parameter Estimates

3.3.1 Empirical Model

From equations (4.2) and (B.8) we derive the following sector-level gravity equations which we use to estimate the parameters θ and δ:

$$M^j_{in,t} = \exp\Bigg[-\frac{1}{\theta^j}\ln(1+t^j_{in,t}) + \frac{\delta^j_1}{\theta^j}EU27^j_{in,t} + \frac{\delta^j_2}{\theta^j}EU^j_{UKn,t} + \frac{\delta^j_3}{\theta^j}EU^j_{iUK,t} + \frac{\delta^j_4}{\theta^j}Euro^j_{in,t} + \frac{\delta^j_5}{\theta^j}Schengen^j_{in,t} + \frac{\delta^j_6}{\theta^j}EU27KOR^j_{in,t} + \frac{\delta^j_7}{\theta^j}UKKOR^j_{in,t} + \frac{\delta^j_8}{\theta^j}FTA^j_{in,t} + \nu^j_{in} + \nu^j_{i,t} + \nu^j_{n,t}\Bigg] + \varepsilon^j_{in,t}. \quad (3.9)$$

$M^j_{in,t}$ denotes the value of imports of country i to country n in sector j at time t, the ad valorem tariff factor is given by $1 + t^j_{in,t}$, and the trade elasticity is $1/\theta^j > 0$. $\nu^j_{i,t}$ and $\nu^j_{n,t}$ denote importer- and exporter-specific year fixed effects, respectively. ν^j_{in} denotes bilateral country-pair fixed effects which account for all time-invariant determinants of trade, such as geographical distance, or initial conditions. The time-varying importer and exporter effects control for multilateral resistance. By triangulation, they also account for the effects of exchange rate variation. $\varepsilon^j_{in,t}$ is a random error term.

For the simulation, we require estimates of δ^j_k/θ^j. Whenever an agreement affects the UK, we allow for treatment heterogeneity, hence, its effect to differ for the UK and the other 27 EU members (EU27). For example, we impose symmetry in the trade cost effect of EU membership amongst the EU27, but allow the EU membership for the UK to differ from that average; moreover, we also allow for directionality (UK exports to be affected differently than imports). We deal similarly with the conclusion of the EU-Korea agreement in 2011. Because the UK is neither a member of the Schengen-zone nor the Eurozone, we do not further differentiate those effects.[11]

All integration measures are defined as binary variables taking the value one in a year if countries i and j are both members of an agreement. $\text{Schengen}^j_{in,t}$ is different; it systematically treats European countries as heterogeneous, as land-borne trade within Europe from i to n may cross one or up to eight Schengen-internal borders. Aside, even if i and/or n are outsiders to the Schengen area, a pair in may experience lower transit costs. We thus use a variable $\text{Schengen}^j_{in,t} = \{1, \ldots, 8\}$ that counts the number of Schengen-internal borders between a pair in (see Felbermayr et al., 2018a).

Econometric identification relies on countries joining the EU, the Euro, the Schengen-zone or FTAs in the period 2000-2014. Thus, the trade cost effect of the Single Market is identified through the various waves of Eastern enlargement (2004, 2007, 2013). The Eurozone was created in 1999 by 11 EU members; until 2014 seven additional countries joined. Similarly, Schengen was gradually expanded. The EU-Korea FTA entered into force in 2011 (the latest trade agreement of the EU available in our data), as did a number of other FTAs amongst non-EU countries.

The selection of country pairs into trade agreements with many members such as the EU is not random; the same is true for the setting of tariffs. To obtain unbiased estimates of θ^j and δ^j_k we require that the covariances between the error term $\varepsilon^j_{in,t}$ and the integration dummy on the one hand and between $\varepsilon^j_{in,t}$ and the sectoral tariff rate on the other are zero conditional on controls. Note that we include bilateral fixed effects ν^j_{in} to account for all time invariant variables that jointly affect policy variables and bilateral trade flows. Next to potential endogeneity, this also addresses omitted variable bias in integration agreements (see, e.g., Baier and Bergstrand, 2007).

As recommended by Santos Silva and Tenreyro (2006) and Fally (2015), we estimate the model using Poisson Pseudo Maximum Likelihood (PPML) methods. We cluster standard errors at bilateral pairs.

3.3.2 Data Sources

To calibrate the model and to estimate the possible effects of the UK leaving the EU Single Market and Customs Union, we need comprehensive data.

[11] The same approach is taken for FTAs other than the EU-Korea agreement.

The World Input-Output Database (WIOD) comprises our main data source. It contains information on sectoral production, value added, and bilateral trade in final and intermediate goods in producer and consumer prices detailed by sector. This allows us to extract bilateral input-output tables and expenditure levels. WIOD includes 43 countries and a rest-of-the-world (RoW) aggregate for the years 2000 to 2014. It captures 56 sectors, which we aggregate into 50 industries as some sectors display zero output for some countries (see Table C.1 in the Appendix). This aggregation concerns mostly services; we keep the sectoral detail in the manufacturing and agricultural industries.[12]

Data on bilateral preferential and MFN tariffs stem from the World Integrated Trade Solutions (WITS-TRAINS) and the WTO's Integrated Database (IDB).[13] Data on tariffs and on trade from WIOD are used to estimate trade elasticities for the 22 manufacturing sectors – jointly with the ad valorem equivalent changes in NTBs associated with the different steps of European and trade integration in general.[14] We use data on FTA membership from the WTO.[15] Data on membership in the EU, the Eurozone and the successive accession of countries to the Schengen agreement stem from the European Commission. We capture membership in the EU, the Euro or in FTAs by indicator variables. To obtain a geographical measure of Schengen, we follow Felbermayr et al. (2018a) and use the count of the number of Schengen borders crossed by truck and ferry when moving from economic centers of i to n in year t.

We use those data to structurally estimate the elasticities θ and coefficients δ. Input-output tables provide us with data on the expenditure shares α, and the cost shares β and γ. Further, data on bilateral trade shares π, countries' total value added $w_n L_n$, and trade surpluses S are calculated from input-output tables.

We take information on net fiscal transfers of EU members to the EU budget from the European Commission. Transfer redistribution is calculated based on the operating budgetary balance for the 2010-2014 UK average, relative to each country's gross national income (see Table C.2 in the Appendix). The year 2014 is the latest year available in the

[12] We use the approach outlined in Aichele and Heiland (2016) to account for the fact that WIOD expenditure shares are valued in "basic" (or "producer") prices (net of tariffs), while expenditure shares in the model are defined in "market" prices (including tariffs). Further, we utilize their approach to account for changes in inventory as part of the accounting system of WIOD but do not feature in our model.

[13] As tariffs are not available for every year and every pair within our time frame, we interpolate tariff levels forward and backward.

[14] For services sectors, we borrow an average estimate of the elasticity of services trade with respect to trade cost from Egger et al. (2012). We adapt their method to obtain a trade elasticity of services and apply it to our estimated goods elasticity from our aggregated gravity estimation.

[15] The RTA gateway is accessible via http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx.

WIOD data and thus serves as our baseline. Our simulation exercise compares the status quo in 2014 with a hypothetical situation in which the UK would leave the European Union in that year.

3.3.3 The UK's Europe Exposure in Comparison

Our analysis is based on one important conjecture, namely that inward and outward market access costs of the UK have benefited differently – possibly by less – from EU membership than other countries, and one key assumption, namely that the analysis of sector-level trade data for the years 2000 to 2014 is informative about the unwinding of integration steps between the UK and continental European countries that happened much earlier. In fact, through Brexit, we assume that trade costs between the EU and the UK go up by the amount that the Eastern enlargement has brought them down. While this is innocuous for trade costs between the UK and the new EU members, it may underestimate the effect of EU membership on trade costs between the UK and old EU member states.

Here, we present very simple facts suggesting that our presumptions are plausible. Consistent with our formal model, we compute a simple index of average inverse trade frictions of the form

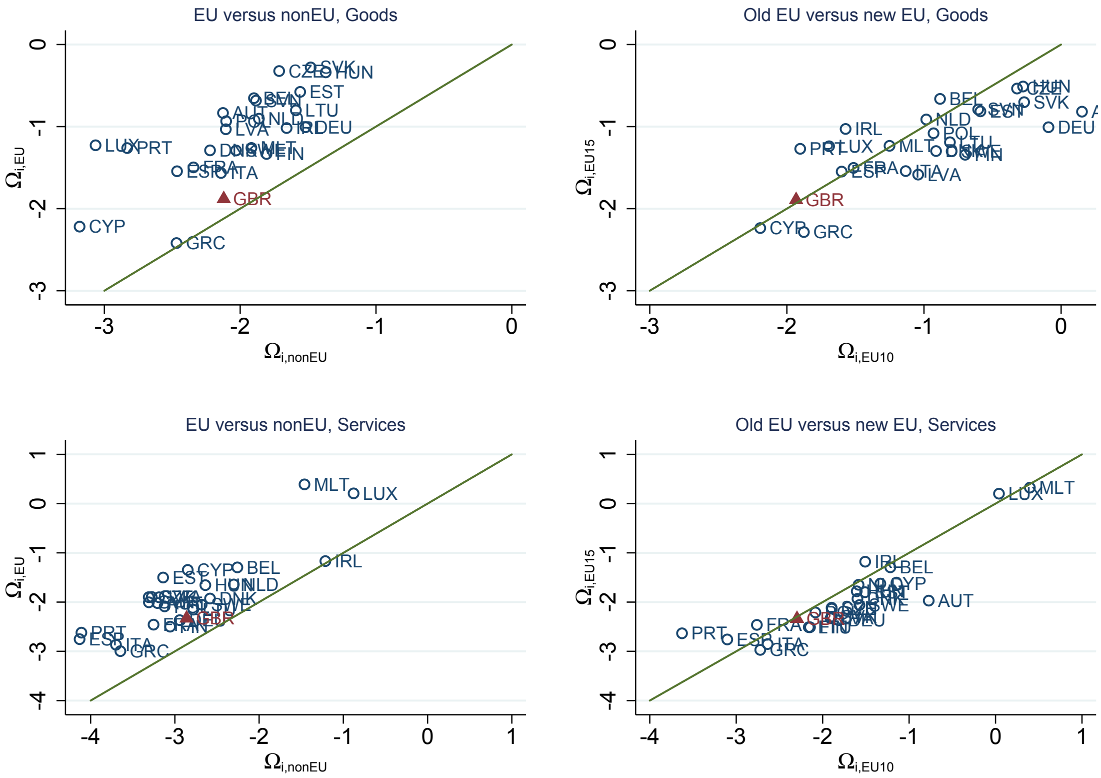
$$\Omega_{in} \equiv \ln[X_{in}^{1/2} X_{ni}^{1/2} Y^w / (Y_i Y_n)], \tag{3.10}$$

where Y_i and Y_n denote country i's and n's GDPs, $Y^w = \sum_i Y_i$ is world GDP and X_{in} are country i's exports to country n.[16]

Figure 3.1 plots countries' inverse trade frictions with other EU members and with trade partners outside of the EU. The upper row looks at goods trade; the lower row at services trade. The left column compares inverse trade frictions of countries with EU members and with non-EU members. The right column compares countries' inverse trade frictions with 'old' EU and with 'new' EU members. The pictures suggest that all 25 countries (the 'old' 15 EU members and the ten countries that joined in 2004) have lower frictions amongst themselves than with the rest of the world. This is no surprise and reflects lower geographical and political trade costs. However, intra-EU goods trade frictions $\Omega_{i,EU}^{-1}$ are

[16] A simple way of writing a model-consistent gravity equation is to posit $X_{in} = (Y_i Y_n / Y^w)\, \tilde{\Omega}_{in}$. Total bilateral trade is characterized by the geometric mean $(X_{in} X_{ni})^{1/2} = (Y_i Y_n / Y^w) \left(\tilde{\Omega}_{in} \tilde{\Omega}_{ni}\right)^{1/2}$. The inverse, non-directional (i.e., average) index of bilateral trade costs $\Omega_{in} \equiv \ln[\left(\tilde{\Omega}_{in} \tilde{\Omega}_{ni}\right)^{1/2}]$ can be calculated by available data. We know that this index is only an approximation; however, we do not calculate the Head-Ries-Index, as this would require trade cost symmetry and our point is that trade costs involving the UK and the EU are indeed asymmetric.

Figure 3.1: Inverse Trade Frictions with Different Trade Partners, 2014



Note: Data from WIOD 2016. The straight line is the 45-degrees line.

nowhere higher than in Greece, Cyprus and the UK, while the latter occupies a middle ground when looking at trade frictions with third parties. Hence, the UK seems less strongly tied to intra-European goods trade than other countries of similar size such as Italy, France, Spain, or Germany. This also implies that it has less to lose should it exit the union. With services trade, the UK's position is slightly better.

The right-hand diagram in figure 3.1 plots inverse trade frictions of countries relative to 'old' (EU15) and 'new' (EU10) EU members. Again, the UK lies in the bottom-lower corner, signaling relatively high trade costs with both groups of countries. Importantly, it lies on the 45-degrees line, both for goods and services trade. This suggests that UK exporters and importers face similar situations in both new and old member states. This leaves us confident that, even though our strategy identifies the effects of EU membership using accessions within the period 2000-2014, the estimates are, on average, also sensible with regard to the UK's trade relationship with the old EU15 countries.

3.3.4 Gravity Analysis of Aggregate Data

Table 3.1 shows results from regressions on aggregate data. Columns (1) to (6) report the effects on integration arrangements on goods trade; columns (7) to (10) on services trade. It reveals four insights that are of paramount importance for the following quantitative analysis.

First, on average, EU membership is associated with substantial trade creation. Coefficients on goods (column (1)) and on services (column (7)), both statistically significant at the 1% level, imply trade creation of 72% and 95%, respectively. Assuming an elasticity of 3.5 for goods and 1.5 for services, [17] the estimates imply trade cost reductions of 14% and 36%, respectively. FTAs other than the EU create less trade and indicate trade cost reductions of 3.4% and 4.8%, respectively. The Chi2-test clearly rejects equality of EU and FTA effects; for services, FTAs are not even significant.

Second, accounting for other steps of European integration is important to correctly isolate the role of EU membership. Columns (2) and (8) add Eurozone and Schengen membership. It turns out that Schengen matters, both, for goods and services trade; but Eurozone membership is not statistically significant. However, controlling for those, the coefficient for the EU membership falls to 0.470 for goods and 0.594 for services, implying a fall in the trade cost reduction relative to columns (1) and (7).

Third, the effect of EU membership on trade may differ between country pairs involving the UK and those involving only EU27 members (excluding UK). For goods, the coefficient in column (3) is smaller for pairs involving the UK than for non-UK pairs; column (4) indicates that estimated trade cost reductions due to EU membership are 13% for EU27-pairs and 11% for pairs involving the UK. Note that the difference is not statistically significant. For services, trade cost reductions in pairs involving the UK are stronger than for EU27 (column (9)). Again, the difference is not statistically different from zero. Importantly, adding tariffs for goods trade in column (4) yields a very plausible estimate of the trade elasticity (3.5), with a variance of 0.92. Accounting for tariffs reduces trade costs of EU membership from 12.5% to 8.1% for EU27 pairs and from 10.7% to 6.4% for EU27-UK pairs. This is crucial, as tariffs imply very different welfare implications than iceberg trade costs (non-tariff barriers, NTBs); mistaking tariffs with NTBs would lead to an overestimate of the welfare damage of Brexit.

Fourth, allowing exports of the UK to EU27 to be affected differently than imports, i.e., turning to directional FTA effects, columns (5), (6) and (10) provide evidence for

[17] See below for more details.

strong asymmetries. Columns (5) and (6) show that EU27 goods exports to the UK have increased through EU membership of the UK, but UK exports to EU27 countries have benefited only through the elimination of tariffs but not through NTBs. The difference between UK exports and imports is statistically significantly different from zero at the 1%-level. In the area of services, UK exports seem to have benefited more, but here the difference is not statistically different from zero.

Table 3.1: The Impact of EU Integration Steps on Bilateral Imports (2000 - 2014)

Dep. var.:	Bilateral Imports									
	Goods						Services			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Both EU	0.542***	0.470***	0.466***	0.294***	0.468***	0.294***	0.667***	0.594***	0.515***	0.512***
	(0.05)	(0.05)	(0.06)	(0.07)	(0.06)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)
EU27-UK			0.398***	0.232**					0.601***	
			(0.09)	(0.10)					(0.13)	
Exp: EU27, imp: UK					0.564***	0.399***				0.687***
					(0.11)	(0.11)				(0.20)
Exp: UK, imp: EU27					0.213***	0.039				0.497***
					(0.08)	(0.08)				(0.17)
Euro		0.060	0.056	0.058	0.056	0.058		0.152***	0.153***	0.152***
		(0.04)	(0.04)	(0.04)	(0.04)	(0.04)		(0.06)	(0.06)	(0.06)
Schengen		0.093***	0.093***	0.090***	0.094***	0.090***		0.076***	0.077***	0.077***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)		(0.02)	(0.02)	(0.02)
EU-KOR			0.370***	0.253***					0.516***	
			(0.05)	(0.06)					(0.08)	
EU27-KOR					0.203***	0.117*				0.378***
					(0.07)	(0.07)				(0.06)
UK-KOR					0.078	-0.007				0.182***
					(0.24)	(0.23)				(0.06)
Other FTAs	0.122***	0.122***	0.108**	0.029	0.110**	0.029	0.073	0.072	-0.007	-0.009
	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)
Tariff				-3.443***		-3.471***				
				(0.91)		(0.92)				
Chi2-Test										
Prob > chi2	0.000	0.000	0.403	0.451	0.002	0.002	0.000	0.000	0.486	0.470

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use Poisson Pseudo Maximum Likelihood (PPML) methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Specifications (1), (2), (7) and (8) use EU28 and other RTA excluding the EU. All other use EU27, treating the UK separately, and other RTA exclude the EU and the EU - Korea RTA. Number of observations: 27,735. Chi2-Tests compare “Both EU” to “Other RTA” in columns (1), (2), (7) and (8); “Both EU” and “EU-UK, symmetric” in columns (3), (4), and (9); and “EU->UK, asymmetric” with “EU<-UK,asymmetric” in columns (5), (6), and (10).

3.3.5 Gravity Analysis of Sectoral Data

Table 3.2 reports key results from sector-level gravity regressions which are replica of the equations on aggregate data described in columns (6) and (10) of Table 3.1. It documents substantial heterogeneity across the 22 goods and 28 services sectors with respect to the trade elasticity, and regarding effects of EU membership or the EU-Korea FTA.[18]

We find reasonable trade elasticities (estimated coefficients on tariffs) for most goods sectors; in sectors where the estimates violate regularity conditions, we report estimates based on tariff adjusted imports and replace elasticities with estimates obtained for aggregate data; see Table 3.1, column (6). Economic integration arrangements have very different effects on different sectors. Bilateral trade between the EU27 and the UK is shown to increase unambiguously through EU integration in 33 out of 50 sectors (both UK exports and imports go up with at least one effect statistically significant at the 10%-level). In 16 cases (mostly manufacturing), UK imports increase by more than UK exports; in 15 sectors (mostly services) the opposite is true. In the automotive sector (20), UK imports are affected very positively, but UK exports are not. A strong asymmetry exists in the chemicals sector, too, while in basic metals the situation is relatively balanced. In services sectors, postal & courier and financial services stand out, where, against the trend, UK imports have grown by more than UK exports due to EU integration.

3.4 General Equilibrium Results

3.4.1 Counterfactual Scenarios

We have now paved the way to simulate general equilibrium effects of the UK leaving the European Union Single Market and Customs Union. For each sector, the gravity model provides us with estimates of the (inverse) trade elasticity θ and of the NTB effects δ of various integration steps, as well as with estimates of the associated variance-covariance matrices. For services, we have no trade cost shifters such as tariffs. We turn to Egger et al. (2012) to infer a trade elasticity of $\widehat{1/\theta}_{\text{Services}} = 1.446$.[19]

[18] To save space, the table drops other covariates included in the model; see Tables C.3 and C.4 in the Appendix for full detail.

[19] Importantly, Egger et al. (2012) state that services trade reacts more elastically to trade liberalization than goods trade. Hence, assuming an elasticity of 5 as in Caliendo and Parro (2015) seems not to be a reasonable choice in our context. This is supported by recent applications of Hobijn and Nechio (2019) using VAT data for the EU25 and Marquez (2006) using price and income data for the US. Both find a range for services elasticities between 1 and 3. More specifically, Egger et al. (2012) estimate

Assuming that parameters are jointly normally distributed, we draw a value of θ to calibrate the model, and a full set of NTB shifters δ to inform the counterfactual analysis.[20] We repeat this procedure 1,000 times and obtain a distribution of NTB cost shocks and a distribution of changes of endogenous variables. This allows us to construct confidence intervals.[21]

We define the following counterfactual scenarios. Figure 3.2 illustrates trade cost shocks $\hat{\kappa}$ (equation (4.2)) and their distribution for each sector.

S1 **WTO Scenario ("Hard Brexit")**: The UK is no longer part of the European Single Market and Customs Union and there is no new FTA substituting for it. The EU27 and the UK apply MFN tariffs as currently granted under WTO rules on imports of third countries.[22] In addition, directional NTBs are reintroduced between the EU27 and the UK according to the sectoral trade costs calculated from the gravity estimations. Figure 3.2a shows NTB changes for the UK (importer) with EU27 countries; Figure 3.2b shows respective barriers for EU27 members with the UK (exporter). Moreover, the UK loses all existing tariff and non-tariff preferences that it currently enjoys with third countries with whom the EU has an FTA in force. We apply the heterogeneous UK-Korea agreement effect from the gravity model and effects from further pre-EU accession treaties. Additionally, we consider fiscal transfers by correcting the specific trade balances for fiscal transfers between the EU27 and the UK.

S2 **FTA Scenario ("Soft Brexit")**: The UK exits the EU Single Market and Customs Union, but the EU27 and the UK negotiate a modern free trade agreement (FTA), which comprises not only tariffs but also affects NTBs on goods and services. We model the FTA scenario as a replication of the EU-Korea agreement of 2011 – the latest and most comprehensive trade agreement of the EU covered in the data. We

a parameter β in their model (which belongs to a related class of new quantitative trade models), which is given by $\beta = \beta_{\text{Goods}} - \beta_{\text{Services}}$. Given their estimate $\hat{\beta} = 2.026$ and our own estimate $\hat{\beta}_{\text{Goods}} = \widehat{1/\theta}_{\text{Goods}}$, we can infer $\hat{\beta}_{\text{Services}} = \widehat{1/\theta}_{\text{Services}}$, with a variance 0.144.

[20] The choice of normal distribution implies that we will always obtain some draws that violate the model-imposed parameter constraint $1/\theta > 0$. To circumvent this problem we drop the (very few) parameter draws of θ that violate the constraint. This comes at the expense of a small upward bias of the mean parameter estimate and a downward bias of the standard errors.

[21] The underlying normality assumption is not completely innocuous, given that the model outcomes are potentially highly non-linear functions of the parameters. The distribution of model outcomes might be highly asymmetric even if the size of the underlying sample is large enough for the normal approximation to work well for parameter estimation.

[22] Figure C.1 in the Appendix shows sectoral trade-weighted MFN tariffs granted at the product-level by the EU to third countries in 2014. These are used for simulation in the WTO scenario.

utilize the estimated trade cost reductions of the EU-Korea FTA from our gravity model as a proxy for a potential NTB effects between the EU27 and the UK (see figure 3.2c).

S3 **Global Britain Scenario**: We model the same relationship regarding tariffs and NTBs between the EU27 and the UK as under the WTO scenario, but now the UK unilaterally eliminates tariffs and concludes FTAs with various third countries in order to lower NTBs. The scenario is divided into three stages:

(a) The UK concludes an FTA with the USMCA countries the US, Mexico, and Canada. NTBs are reduced as under the EU-Korea FTA.

(b) Further, the UK concludes an FTA with selected non-EU Commonwealth countries, namely Australia and India.

(c) Finally, we assume that the UK also concludes additional FTAs with selected Asian countries (JPN, KOR, CHN).

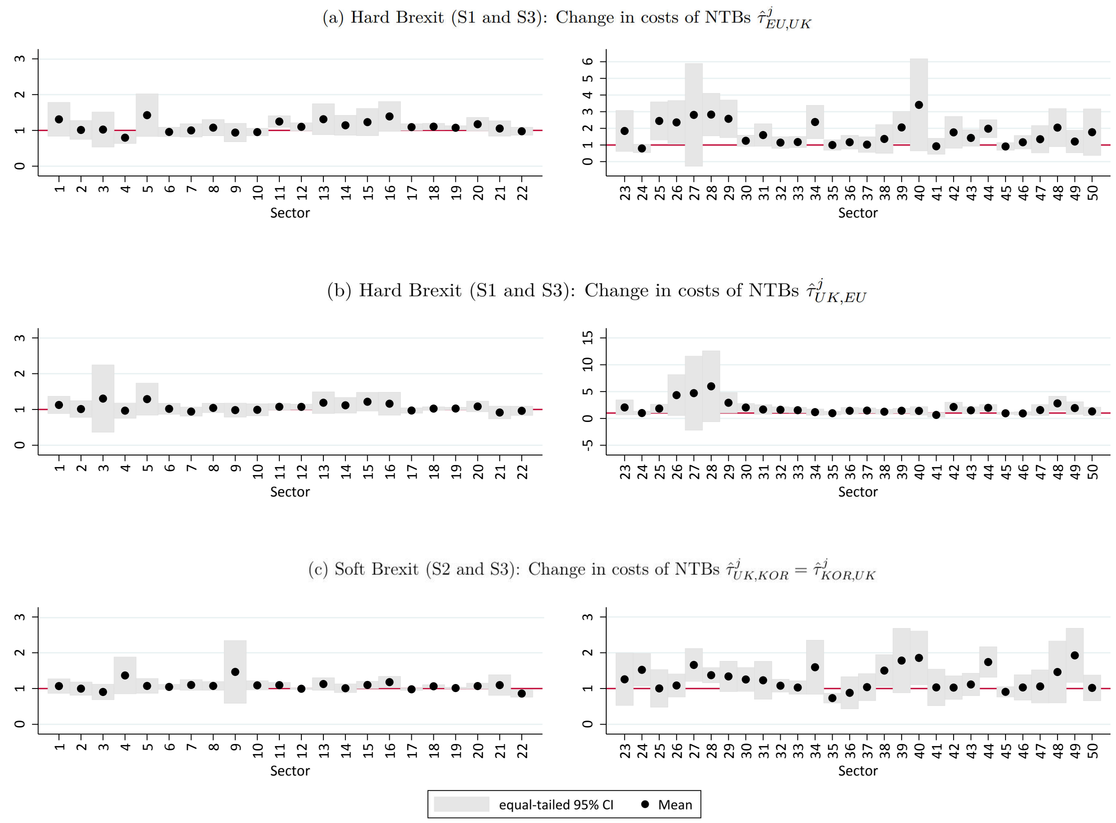
S4 **Hard but Smart Brexit**: Similar to S1, the UK is no longer part of the European Single Market and Customs Union with no new FTA in place. The EU27 apply MFN tariffs to the UK as currently granted under WTO rules on imports to third countries. Directional NTBs are reintroduced in the EU27 for UK's exports according to the sectoral trade costs calculated from the gravity estimations. In contrast to S1, the UK now decreases all existing tariffs for all its trading partners to zero. Additionally, we account for fiscal transfers within the EU by correcting the specific trade balances between the EU27 and the UK.

3.4.2 The Role of Treatment Heterogeneity

Before turning to the detailed general equilibrium analysis, we illustrate the importance of considering heterogeneity in trade cost shocks for quantitative results. Table 3.3 shows the real wage changes for various model specifications under the hard Brexit scenario (S1).[23] While allowing for the heterogeneity of treatment effects, Panel A uses the broad sector specification of Table 3.1, while Panel B allows elasticities to vary across the 50 sectors in our data (cp. Table 3.2).

[23] We focus on real wages which are less strongly affected by whether trade cost shocks are modeled as affecting tariffs or iceberg trade costs, a distinction that is lost when lumping together different steps of European integration.

Figure 3.2: Change in Non-Tariff Barriers, in %



Note: Dots depict percentage changes of non-tariff barriers. Bars show 90%-confidence bounds, which are based on 1,000 replications and approximate normal distribution. Sector 1 to 4 are agricultural and natural resources sectors, 5 to 22 are manufacturing sectors, and 23 to 50 are services sectors.

Panel A reveals that moving from a simple dummy treatment of EU membership (row [1]) to a subtler measurement allowing for variable geometry (row [2]), to asymmetry between the effects on EU27 pairs and pairs involving the UK (row [3]), and to directionality in the EU27-UK effects (row [4]) gradually reduces the real wage losses due to Brexit from 0.57% in row [1] to 0.41% in row [4] for the EU27 and from 3.20% to 2.53% for the UK. Hence, a simple dummy approach overestimates the costs from Brexit by about 40% for the EU27 average and 25% for the UK.

If trade elasticities and treatment effects vary across sectors (rows [5] to [8]), we find higher simulated costs from Brexit relative to estimates based on a two-sector model (goods and services) – but only for the combination of sectoral heterogeneity and directional UK-specific treatments. Consequently, being precise in the econometric identification of NTB effects matters for macroeconomic outcomes, even if the most simplistic treatment (row[1]) and our preferred, more sophisticated specification (row[8]) show rather similar effects.

3.4.3 Effects on Real Consumption

We now turn to the detailed general equilibrium analysis of Brexit by using the trade cost shocks described in the counterfactural scenarios in our general equilibrium trade model. Table 3.4 starts by reporting changes in real consumption, our preferred measure of welfare, for 44 countries and the four Brexit scenarios. The advantage of reporting real consumption compared to real wage changes (see Table C.11 in the Appendix) is that real consumption accounts for the direct effects of tariff income, transfers, and trade imbalances.

A hard Brexit (S1) decreases the UK's real consumption by 2.76% per annum relative to the status quo in the year 2014.[24] This compares to a reduction of 0.93% in the case of a modern FTA (S2). Opening the British market toward non-EU countries (S3) cannot fully compensate for the negative effect of Brexit and causes the UK's real consumption to fall by 1.43%. This indicates that the well-established trade ties between EU27 economies and the UK cannot easily be compensated through trade agreements between the UK and other Commonwealth countries, Japan, Korea, or China, and the USMCA economies. Real consumption effects for the UK and the EU27 average are statistically significant at the 10%-level. The changes in real consumption for the EU27 are on average smaller than those for the UK in the first three scenarios. The reason is that a smaller trade share per EU27 country is affected by Brexit compared to the UK. The EU27 real consumption losses are nearly four times as large under a hard Brexit (-0.78%) compared to a FTA (-0.20%). Global Britain slightly increases the losses (-0.83%) for the EU27 economies, as a hard Brexit with additional FTAs between the UK and non-EU countries would cause trade diversion away from Europe.

EU27 countries are affected very differently; mean losses lie between -8.16% in Ireland and -0.34% in Croatia. This reflects the initial strength of trade ties by taking input-output linkages involving third countries into account.[25] In case of a hard Brexit, Luxembourg and Malta would face higher losses than the UK and the Netherlands, Belgium, and Cyprus would experience drops in real consumption of more than one percent each.

[24] This effect is different from Table 3.3 as it treats changes in tariffs and NTB changes separately. It uses detailed trade costs derived from Table 3.2.

[25] The relatively strong effect on Hungary or Slovakia from Brexit is related to their role in German production networks.

Malta and Cyprus are former colonies; Luxembourg has strong linkages to the UK financial services industry, and the Netherlands and Belgium are geographically very close to the UK. Larger EU countries would experience smaller losses as they are protected by larger home markets and also tend to have more diversified trade ties. In case of a hard Brexit, Germany faces a decrease in real consumption of 0.72%, while France loses 0.52%. A FTA between the EU27 and the UK nearly divides the size of real consumption losses for EU27 by four. With a FTA, Ireland's real consumption decrease is 3.08%, still substantially more than the UK's with 0.93%. Germany would have to face a loss of 0.20%, almost identical to the EU27 average, and statistically different from zero at the 10% level. France, in contrast, would suffer a loss of 0.10% only, which is statistically not distinguishable from a zero effect. Compared to a hard Brexit, losses in real consumption slightly worsen for EU27 countries under a global Britain scenario, as countries are negatively affected by trade diversion caused by the conclusion of trade agreements between the UK and third countries. Germany and France would experience a drop in real consumption of 0.80% and 0.54%, respectively; the EU average goes from -0.78% under S1 to -0.83% under S3.

Turning to non-EU countries, we find small losses for Brazil, Turkey, or the US and slight benefits for China, India, Indonesia, Norway and Taiwan from a hard Brexit. Countries with whom the UK would conclude a new FTA would mostly benefit in real consumption terms; but the relative gains are rather small: India's real consumption would go up by about 0.20% or the real consumption of the US by 0.11%. Canada, with its relatively small home market, would benefit most: its real consumption could increase by 0.26%. All those gains are statistically different from zero.

The EU's dominating power in the Brexit negotiations rests upon the believe that the UK would suffer substantially more in the case of an unsorted, non-cooperative Brexit than the EU27 on average. Our counterfactual scenarios S1 to S3, next to the existing literature that quantifies the outcome of Brexit (see, e.g. Dhingra et al., 2017, Sampson, 2017, Steinberg, 2019) support this believe. While under any previous scenario the UK would lose substantially more than the EU27 on average, the question is whether a hard Brexit that reintroduces MFN tariffs and NTBs is feasible. London could shift the bargaining power with a simple trick: the hard but smart Brexit strategy (S4). Under S4, the UK would no longer suffer fundamentally more than the EU27. The UK's real income would decrease by half a percent (see Table 3.4) – which is more than 5 times less than under a hard Brexit, and about half the loss from a soft Brexit. The effect is mainly driven by two channels: First, the absence of tariffs does not lead to additional price increases for British consumers, in contrast to the hard Brexit scenario (S1). In fact, the complete tariff liberalization even leads to price decreases. A negative nominal income effect still outweighs these positive price effects. As the EU27 increase their barriers (tariffs and non-tariff barriers), exporting British goods and services to the EU27 becomes more expensive and thereby decreases the nominal income. Overall, the reduction in nominal income dominates. Still, no other scenario is more endurable for the UK than this one, even though the EU27 increase their barriers. The effects for the remaining EU members do not substantially differ from the hard Brexit scenario.

In a next step, we decompose the hard Brexit scenario to identify the key components of the overall welfare effects; see figure 3.3a for the UK and figure 3.3b for the EU27.[26] We distinguish between the effects of (a) fiscal transfers, (b) tariffs on agriculture, and (c) tariffs on manufacturing, (d) NTBs on agriculture, (e) NTBs on manufacturing, and (f) NTBs on services.[27]

Ending net fiscal transfers has direct effects on real consumption, but it also affects countries' terms-of-trade; see the famous debate about the German transfer problem between Keynes (1929) and Ohlin (1929). In Keynes's logic, transfers worsen the terms of trade (TOT) since exports would have to increase and imports to decrease so that the price for exported relative to imported goods would have to fall. Transfers, thus, impose an additional burden on the paying countries. As shown in Table C.2, UK net transfers to the EU27 amounted to an average of about 6.5 billion Euro in the 2010-2014 period or slightly more than 0.30% of GDP. figure 3.3a shows that unwinding those transfers would allow UK consumers to increase real consumption by 0.29%, slightly less than the pure transfers themselves. In line with Keynes (1929), the UK benefits from an end to transfers not only from a direct effect but also from an amelioration of its TOT, even though this gain is extremely small. Regarding the remaining EU27 members, we assume that the end of UK transfers is borne by all countries proportionally to their GDP. This amounts to an average reduction of net transfers by 0.06% of GDP. Not surprisingly, the real consumption losses from such a scenario are indeed centered around 0.06%; losses in Ireland or Luxembourg, the Netherlands, or Germany are increased by adverse movements in TOT: these countries seem to benefit from the system of EU transfers as this drives up the relative demand for their exports.

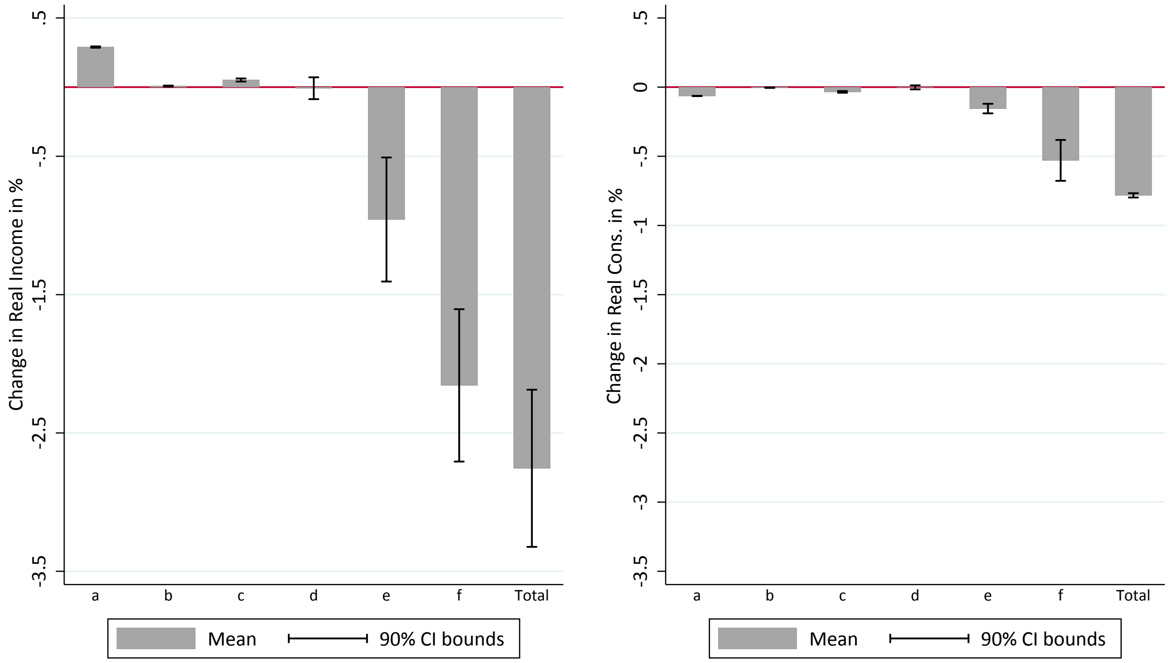
figure 3.3a and 3.3b also show that the reintroduction of agricultural tariffs yields a very small positive consumption effect in the UK; the UK benefits as the negative allocation effects are outweighed by positive TOT effects. Tariffs are at least partly absorbed by the UK's trading partners while agricultural tariff income remains in the country. A similar

[26] Detailed results are provided in Tables C.5 and C.6 in the Appendix.

[27] Note that separate welfare effects of (a) to (f) do not add up to the total effect of all components together, as the different barriers may complement or substitute each other.

picture emerges in manufacturing. However, gains and losses on real consumption from reintroducing tariffs are very minor, as tariff income is rebated and welfare damages are always of a “triangular” form.

Figure 3.3: Decomposing the Real Consumption Effects of a Hard Brexit



(a) United Kingdom **(b)** EU27

Note: a: fiscal transfers; b: tariffs in agriculture; c: tariffs in manufacturing; d: NTBs in agriculture; e: NTBs in manufacturing; f: NTBs in services. The baseline year is 2014. Bars depict real consumption percentage changes; details are shown in Tables C.5 and C.6 in the Appendix. The black solid lines show 90%-confidence bounds, which are based on 1,000 replications.

3.4.4 Effects on Bilateral Trade

Table 4.7 reports changes in bilateral trade flows in our four scenarios for the EU27, the UK and the rest of the world (ROW). Sectors are aggregated into three broad categories: agriculture, manufacturing, and service. Bold face characters denote mean effects that are statistically different from zero.[28] Trade flows are impacted by changes in bilateral trade costs and by general equilibrium forces through changes in total expenditure and revenue, and by multilateral resistance terms. Note that we keep the trade surplus of countries relative to GDP constant; quite mechanically, this forces some additional asymmetry in the rates of change in trade flows even if trade cost shocks are very similar.

[28] Tables C.7 to C.9 in the Appendix provide details.

Our analysis implies that EU27 exports to the UK would fall by 27% in the hard Brexit scenario (S1), with 90% of the probability mass lying in the interval [-30,-25]. Exports would fall by 29% in the global Britain scenario (S3). With a FTA (S2), exports would fall by an expected effect of 4%, but the associated confidence interval is large: [-9,1]. So, if the EU27 and the UK sign an ambitious FTA, it is no longer certain that trade will actually fall. Interestingly, this does not apply to services transactions, where we report a statistically significant expected drop of 8%. In all other scenarios, EU27 exports to the UK would contract in all sectors, with the largest effects expected in manufacturing. In the hard but smart Brexit scenario (S4), the UK offers a liberal market access for exporters from the EU27 and the RoW. Hence, EU27 exports to the UK fall by only 9%, and thereby decrease by less than half compared to a hard Brexit.

Overall, we find that UK exports to the EU27 fall by 25% in S1 and S3, which is 3 to 4 percentage points less than what is expected to happen to EU27 exports to the UK. However, the difference is not statistically distinguishable from zero. UK manufacturing exports suffer most; in agriculture, effects are not significant, reflecting the lack of trade cost reductions in this area. Services exports of the UK fall by about 21% in S1 and S3; with a FTA, they drop by 7% only, but trade effects in other sectors are indistinguishable from zero. With a hard but smart Brexit, it is not surprising that UK's exports towards the EU27 would also decrease by -18%, as the market access to the EU27 is simulated similarly to a hard Brexit, where tariff and non-tariff barriers against the UK exist.

EU27 exports to RoW increase by about 1% in S1 and S3, signaling the presence of some trade diversion. Interestingly, exports from one EU27 member to the other barely change; and if they do, the sign is negative. It appears that the increased trade costs with the UK lead to an overall reduction of intra-EU27 trade flows along the highly-integrated EU production networks. Similarly, the model does not predict that UK exports to the RoW go up from Brexit scenarios S1 and S2, as increased trade costs with Europe reduce the UK's competitiveness with third countries. Of course, in the context of global Britain, UK exports to third countries would go up quite substantially and slightly less with a hard but smart Brexit; in manufacturing, the increase can be expected to be about 15% in S3 and 10% in S4; exports of third countries to the UK are expected to go up by much more with an FTA. Again, this reflects the lack of evidence for strong trade creating effects of FTAs with third countries for the UK.

3.4.5 Effects on Overall Trade

Next, we turn to the effect on overall trade in Table 4.6. We show baseline trade levels for 2014, where the UK features a small deficit in goods and services trade, while the EU27 has a substantial surplus of 780 bn USD. Across all scenarios, overall UK exports and imports drop; compared to the change in GDP, trade falls by more such that the openness of the UK economy (measured as total trade over GDP) drops quite substantially. With a hard Brexit (S1), the reduction in both exports and imports is strongest in manufacturing, but UK services imports drop substantially as well, as domestic output is increasingly absorbed by domestic rather than foreign demand. Total EU27 exports fall by 1.43% and total imports by 1.75%; manufacturing exports fall the most; while the import side is dominated by services. Trade effects for the RoW are relatively low yet statistically significant and typically positive.

With a FTA (S2), trade losses for all parties are strongly reduced, but they remain about five times as large for the UK as compared to the EU27, and the effects are mostly not statistically significant. As expected, UK trade losses fall by about two thirds under global Britain (S3) compared to a hard Brexit, while they increase slightly for the EU27. RoW can expect a small and statistically significant increase in its overall trade, most pronounced in manufacturing. With a hard but smart Brexit, the UK's overall exports still decrease by 4%, but this is almost solely driven by the decrease of exports in services.

3.4.6 Changes in Sectoral Value Added

Changes in bilateral trade depend on the sectoral composition of value added trade flows. The dependence on (imported) intermediate inputs varies greatly across sectors, but it is generally more important for complex manufacturing goods than for raw materials or services. We show the changes in sectoral value added for the UK and the EU27 average in Table 3.7.[29] Sectoral value added is affected by a price and a quantity effect. Brexit changes the wage rate by the same in all sectors (roughly by the same effect as GDP per capita; see Table C.11 in the Appendix), and it reallocates labor between sectors. For the UK, for example, sectors whose value-added falls by less than 3.37% under a hard Brexit (S1) experience an increase in employment, while sectors whose value added falls by more see their employment shrink.

[29] Full results and initial VA per sector in 2014 are provided in Tables C.12, C.13, C.14, and C.15 in the Appendix. Country-sector level results on all remaining economies in the sample can be obtained from the authors on request.

Within manufacturing, the largest sectors for the UK in terms of value added are food, beverages & tobacco, mining & quarrying (includes oil and gas extraction), machinery & equipment, fabricated metals, pharmaceuticals, and motor vehicles, with 47, 43, 32, 28, 22, and 21 bn USD value added, respectively. Amongst these, mining & quarrying and machinery & equipment are expected to lose most with a hard Brexit (-8% and -7%, respectively). The other mentioned sectors feature changes that are not statistically significant; the food sector even is expected to expand as higher trade costs force the UK to move into this comparative disadvantaged sector. The same is true for crops & animals. The largest percentage loss is expected in basic metals (-17%) and fishing & aquaculture (-16%), but initial value added positions in these sectors are relatively small.

Value added changes from a FTA (S2) differ from those in S1 in sign, size and statistical significance, because the structure of trade cost savings available under the FTA may deviate from those obtained in the EU Single Market. Nonetheless, the overall picture remains: Brexit drives the UK into the agri-food sectors and out of manufacturing sectors, such as basic metals. Note, however, that changes are statistically insignificant for many UK sectors in S2. Global Britain (S3) yields sectoral value-added gains where trade cost reductions with third countries are expected. This is the case in transportation, for example, but not in chemicals or pharmaceuticals, where reductions in NTBs are usually harder to realize. The expansion of agri-food remains, as historical experience does not suggest significant trade costs savings from FTAs with third countries in these sectors. UK textiles is expected to shed employment as import competition goes up. Compared to the other three scenarios, a hard but smart Brexit (S4) leads to stronger sectoral divergences. The liberalization of the agrifood sector puts pressure on British farmers, while effects in the manufacturing industry are quite heterogeneous. The value-added increases in sectors that import a large amounts of intermediate products and simultaneously export only few final goods (i.e. pharmaceuticals, chemicals, machinery, and electronics). The explanation is simple: the intermediate product imports are cheaper than before.

Turning to services, the largest losses from a hard Brexit (S1) in the UK are expected in wholesale trade (-8%), a sector that generates value added worth 88 bn USD in 2014; legal & accounting and business services, both quantitatively important sectors, also have to expect sizable losses of 2% and 3%, respectively. Interestingly, financial services are not affected in a statistically significant way. The reason is the combination of two effects: First, the ex post analysis of trade integration does not suggest large trade cost savings in the first place; Second, the UK has a strong comparative advantage over its competitors. This is less true for publishing and media services, two sectors with smaller quantitative importance which would lose about 2% of their value added. With a hard but smart

Brexit (S4), the services sectors lose more compared to manufacturing and agriculture, as potential tariff reductions are not relevant for services.

In the EU27, sectoral value-added effects are generally less pronounced. One sector worth pointing out is motor vehicles, where losses of about 2% are to be expected, as the relatively high EU tariffs of 10% kick in and strongly affect the tight production network between the EU27 and the UK. With global Britain (S3), the loss increases as EU firms face tougher competition from third country suppliers in the UK. In contrast, if the EU and the UK strike a FTA (S2), losses for the EU car industry disappear. With a unilateral reduction of UK tariffs, losses from a hard Brexit in the automotive industry are reduced by half under a hard but smart Brexit (S4).

3.5 Robustness

Finally, we analyze the robustness of our findings with regard to the choice of trade elasticities. We focus on changes in real consumption for the hard Brexit scenario. Results are summarized in Table C.17 in the Appendix.

First, even though our calculated services elasticities are in line with the above discussed literature on services elasticities, we now rely on elasticities of a value of five as assumed in Caliendo and Parro (2015) and Costinot and Rodriguez-Clare (2014). Overall, we find that real consumption losses are slightly smaller due to the down weighting of trade cost changes in services. We need to keep in mind that services sectors are extremely important for the UK, hence, assuming a much higher trade elasticity might strongly affect results. For a hard Brexit, losses are 5.4 times smaller compared to the baseline in Table 3.4 for the most extreme case (Luxembourg) with its very strong reliance on services sectors. Other EU27 countries experience losses that are two to three times smaller compared to the baseline. The UK faces losses of -1.17% of real consumption, which is 2.4 times smaller than in the baseline of -2.76%.

Second, we apply sectoral elasticities estimated by Caliendo and Parro (2015) (see Table C.16 in the Appendix). To be empirically consistent, we re-estimate our sector-level gravity equations constraining θ to equal the external estimate and backing out new NTB changes. We find that countries lose less from a hard Brexit comparing magnitudes to the baseline. In relative terms, EU27 countries real consumption losses are doubled compared to the baseline. On the contrary, the UK loses 0.8 times more (-3.27% compared to -2.76%). Note, that 10% confidence intervals in the baseline are [-3.32, -2.19] and [-

3.95, -2.59] for the UK, such that the slightly higher losses are still close to the range of our baseline estimates.

Further, while the magnitudes of real consumption changes vary slightly with the choice of elasticities, the ranking of countries does not vary much. Countries with the highest losses in the baseline and both robustness checks are Ireland, the UK, Malta, Luxembourg and the Netherlands. EU27 countries with the lowest losses are Greece, Romania, Austria, Croatia. Germany varies between rank 11 and 15, while France switches between rank 17 and 19. Hence, we are confident that our baseline results represent reasonable estimates for the changing trade policy environment with Brexit.

3.6 Conclusion

In this paper, we conduct an ex ante analysis of trade and welfare effects of Brexit based on an econometric ex post assessment of EU integration and other trade agreements. We quantify the economic consequences of Brexit through a quantitative trade theory framework and isolate the role of EU membership for the UK in three distinct ways: first, we allow for directional treatment heterogeneity in the relation between the UK and EU27 economies; second, we distinguish different steps of European integration that affect tariffs and iceberg trade costs separately to model trade cost shocks. Third, we consider fiscal transfers within the EU, which affect the terms-of-trade of countries, and their role in the economic costs of Brexit. The analysis is based on the integration of parameter calibration and scenario definition based on the estimation of sector-level gravity equations. It allows for simulating confidence intervals for all endogenous variables. This makes an important component of uncertainty surrounding our results visible. Interestingly, in most cases, the confidence intervals are rather narrow.

In the partial equilibrium gravity analysis, we find that the EU and trade agreements have been very successful in reducing trade costs and boosting trade between its members, but effects turn out to be directional, in particular, with respect to the UK. We make use of the treatment heterogeneity identified at the finer sectoral level and of the model structure to back out the trade cost effects of European integration steps for the counterfactual general equilibrium analysis. Allowing for treatment heterogeneity in the ex post analysis turns out relevant quantitatively for the overall economic costs of Brexit and its distribution between the UK and the other European countries. Neglecting the asymmetry in EU-UK relations overestimates the costs from Brexit up to 40%.

We simulate real consumption, gross and value-added trade changes for four different scenarios. While we find a lot of heterogeneity across the 43 geographical countries and the RoW component, a general pattern persists. Both, the UK and EU27 countries lose welfare in any of the assumed Brexit scenarios. Some small EU27 countries with very close trade ties to the UK, such as Ireland, Luxembourg, and Malta, lose even more than the UK itself. Overall, conducting new trade agreements outside of the EU cannot fully compensate the losses suffered from Brexit for the UK, while EU27 countries lose even more in this scenario due to trade diversion. A comprehensive trade agreement between the EU and the UK would definitely be preferred. But in the light of the staggering process around such a new and comprehensive trade agreement, we offer an alternative hard but smart Brexit – where besides falling back to WTO rules, the UK eliminates all existing tariffs against the remaining EU27 members and the RoW countries. For the UK, this generates the smallest losses, while the EU27 at least loose less than under a hard Brexit. Still, a lot of potential exists in trade relations between the UK and the remaining EU countries.

Overall, our paper is probably the most ambitious amongst the existing studies on Brexit in mapping out the trade effects. But it does not feature labor or capital mobility. Needless to say, a careful analysis of these facets of European integration would be important but faces both modeling and data-related issues. Brexit underlines the urgency for additional research in these areas.

Table 3.2: EU Integration Steps and Bilateral Imports (2000 - 2014)

Dep. var.:	Bilateral Imports				
Sector Description id-WIOD	exp: EU27 imp: UK	exp: UK imp: EU27	EU27 - KOR	UK - KOR	Tariff
1 Crops & Animals°	1.254***	0.733***	0.327	-0.212	-3.471***
2 Forestry & Logging°	0.194	0.267	0.091	-0.919***	-3.471***
3 Fishing & Aquaculture°	0.003	1.057	-0.174	0.605	-3.471***
4 Mining & Quarrying°	-0.797***	-0.192	1.136***	2.792***	-3.471***
5 Food, Beverages & Tobacco	0.736***	0.555***	0.18	-0.611***	-1.066
6 Textiles, Apparel, Leather°	0.117	0.295	0.345***	-0.414*	-3.471***
7 Wood & Cork°	0.076	-0.109	0.410***	0.479***	-3.471***
8 Paper°	0.369	0.307**	0.341***	-0.167	-3.471***
9 Recorded Media Reproduction	-0.111	-0.011	0.879***	0.174	-1.254
10 Coke, Refined Petroleum	-0.292	-0.029	0.512*	0.372***	-6.020***
11 Chemicals	0.777***	0.253**	0.318***	0.166**	-3.531***
12 Pharmaceuticals	1.098***	0.828***	-0.061	-0.088	-11.390***
13 Rubber & Plastics	0.698***	0.448***	0.307***	0.116*	-2.258**
14 Other non-Metallic Mineral	0.265	0.223*	0.029	0.033	-1.366*
15 Basic Metals	0.681**	0.641***	0.308***	0.075	-3.191***
16 Fabricated Metal	0.551***	0.254	0.275***	0.135	-1.543***
17 Electronics & Optical Products	0.694***	-0.208	-0.15	-0.809***	-7.780***
18 Electrical Equipment	0.601***	0.151	0.370***	-0.003	-6.001***
19 Machinery & Equipment	0.568***	0.214*	0.119*	0.180***	-7.873***
20 Motor Vehicles	0.730***	0.364	0.311***	0.144	-4.611***
21 Other Transport Equipment	0.188	-0.303	0.315	0.169	-2.947
22 Furniture & Other Manufacturing	-0.086	-0.149	-0.571***	-1.110***	-3.727***
23 Electricity & Gas	0.895**	1.068**	0.355	-1.653***	-1.446***
24 Water Supply	-0.334	0.001	0.629***	0.623***	-1.446***
25 Sewerage & Waste	1.314***	0.893***	-0.015	-0.015	-1.446***
26 Construction	1.239***	2.154***	0.137	0.234	-1.446***
27 Trade & Repair of Motor Vehicles	1.503**	2.256***	0.736***	1.097***	-1.446***
28 Wholesale Trade	1.515***	2.611***	0.471***	1.299***	-1.446***
29 Retail Trade	1.374***	1.571***	0.425*	0.847***	-1.446***
30 Land Transport	0.333*	1.047***	0.327*	0.384	-1.446***
31 Water Transport	0.679**	0.759**	0.302	-1.020**	-1.446***
32 Air Transport	0.198	0.700***	0.108	-0.859**	-1.446***
33 Aux. Transportation Services	0.24	0.638***	0.04	-0.025	-1.446***
34 Postal & Courier	1.266***	0.245	0.680**	-0.163	-1.446***
35 Accommodation & Food	0.002	-0.018	-0.456***	-1.576***	-1.446***
36 Publishing	0.23	0.542*	-0.191	-0.096	-1.446***
37 Media Services	0.027	0.565**	0.071	0.063	-1.446***
38 Telecommunications	0.466	0.323	0.604***	-0.06	-1.446***
39 Computer & Information Services	1.067***	0.532**	0.848**	-0.221	-1.446***
40 Financial Services	1.809***	0.484	0.899***	-0.366*	-1.446***
41 Insurance	-0.121	-0.609	0.058	-0.147	-1.446***
42 Real Estate	0.832**	1.104***	0.04	0.544	-1.446***
43 Legal & Accounting	0.520**	0.599**	0.16	0.018	-1.446***
44 Business Services	0.999***	0.993***	0.809***	0.413***	-1.446***
45 Research & Development	-0.134	-0.049	-0.138	-1.095***	-1.446***
46 Admin. & Support Services	0.229	-0.097	0.046	-0.509***	-1.446***
47 Public & Social Services	0.438	0.657	0.095	1.085***	-1.446***
48 Education	1.062***	1.503***	0.555	1.065***	-1.446***
49 Human Health & Social Work	0.271	0.959**	0.971***	1.058***	-1.446***
50 Other Services, Households	0.824	0.397	0.023	0.919***	-1.446***

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use Poisson Pseudo Maximum Likelihood (PPML) methods. Robust standard errors (not reported) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Sectors marked with ° report estimates based on tariff adjusted imports, applying overall trade elasticities for goods trade from Table (3.1) column (5). For services sectors, we calculate the trade elasticity for services according to Egger et al. (2012). Varying observations between 23,085 and 27,735. Detailed effects for the 22 goods and 28 services sectors can be found in Tables C.3 and C.4 in the Appendix.

Table 3.3: Average Real Wage Changes in a Hard Brexit Scenario (S1), in %, Based on Various NTB Estimations

	EU27	UK	RoW
Panel A: Broad sectoral disaggregation			
[1] Single EU dummy (col. (1) and (7))	-0.57	-3.20	-0.01
[2] Variable geometry (col. (2) and (8))	-0.51	-2.88	-0.01
[3] UK and EU treated differently (col. (3) and (9))	-0.49	-2.76	-0.01
[4] Allowing for directionality (col. (5) and (10))	-0.41	-2.53	-0.01
Panel B: Detailed sectoral disaggregation			
[5] Single EU dummy (col. (1) and (7))	-0.59	-3.50	-0.01
[6] Variable geometry (col. (2) and (8))	-0.43	-2.61	0.00
[7] UK and EU treated differently (col. (3) and (9))	-0.56	-3.29	0.00
[8] Allowing for directionality (col. (5) and (10))	-0.60	-3.45	0.00

Note: The estimates can be retrieved from table 3.1. RoW: Rest of the World. The baseline year is 2014. All reported numbers are statistically different from zero at the 10%-level based on 1,000 replications. Panel A uses estimates from Table 3.1, while those of Panel B stem from Table C.3 for goods sectors and Table C.4 for services sectors in the Appendix.

Table 3.4: Counterfactual Change in Real Consumption, in %

	Change in Real Consumption in %					Change in Real Consumption in %			
	S1	S2	S3	S4		S1	S2	S3	S4
UK	**-2.76**	**-0.93**	**-1.43**	**-0.50**	Portugal	**-0.45**	-0.12	**-0.46**	**-0.40**
	[-3.32, -2.19]	[-1.65, -0.21]	[-2.10, -0.76]	[-0.63, -0.37]		[-0.56, -0.35]	[-0.25, 0.01]	[-0.56, -0.35]	[-0.50, -0.29]
Austria	**-0.35**	**-0.09**	**-0.38**	**-0.28**	Romania	**-0.37**	**-0.16**	**-0.39**	**-0.32**
	[-0.42, -0.27]	[-0.19, -0.00]	[-0.45, -0.30]	[-0.35, -0.20]		[-0.45, -0.29]	[-0.25, -0.08]	[-0.47, -0.31]	[-0.39, -0.24]
Belgium	**-1.40**	-0.29	**-1.46**	**-0.96**	Slovakia	**-0.73**	**-0.33**	**-0.77**	**-0.38**
	[-1.71, -1.09]	[-0.71, 0.13]	[-1.77, -1.15]	[-1.28, -0.64]		[-0.86, -0.60]	[-0.52, -0.15]	[-0.91, -0.64]	[-0.46, -0.30]
Bulgaria	**-0.51**	**-0.24**	**-0.50**	**-0.46**	Slovenia	**-0.42**	**-0.17**	**-0.46**	**-0.33**
	[-0.62, -0.40]	[-0.36, -0.11]	[-0.60, -0.39]	[-0.56, -0.36]		[-0.50, -0.35]	[-0.25, -0.08]	[-0.54, -0.38]	[-0.41, -0.25]
Croatia	**-0.34**	-0.04	**-0.34**	**-0.29**	Spain	**-0.39**	**-0.13**	**-0.42**	**-0.29**
	[-0.43, -0.24]	[-0.17, 0.09]	[-0.43, -0.24]	[-0.38, -0.20]		[-0.48, -0.30]	[-0.23, -0.02]	[-0.50, -0.33]	[-0.38, -0.20]
Cyprus	**-1.37**	-0.35	**-1.36**	**-1.08**	Sweden	**-0.75**	-0.11	**-0.79**	**-0.64**
	[-1.80, -0.94]	[-0.91, 0.21]	[-1.79, -0.93]	[-1.50, -0.66]		[-0.91, -0.58]	[-0.34, 0.12]	[-0.95, -0.62]	[-0.80, -0.47]
Czech R.	**-0.75**	**-0.35**	**-0.84**	**-0.51**	Australia	-0.00	-0.00	**0.12**	**0.01**
	[-0.90, -0.60]	[-0.51, -0.20]	[-0.99, -0.69]	[-0.65, -0.36]		[-0.01, 0.00]	[-0.01, 0.00]	[0.08, 0.15]	[0.01, 0.01]
Denmark	**-0.89**	-0.12	**-0.91**	**-0.71**	Brasil	**-0.01**	0.00	**-0.01**	**0.00**
	[-1.10, -0.67]	[-0.46, 0.22]	[-1.12, -0.70]	[-0.93, -0.49]		[-0.01, -0.01]	[-0.00, 0.00]	[-0.01, -0.00]	[0.00, 0.01]
Estonia	**-0.70**	**-0.27**	**-0.71**	**-0.62**	Canada	0.00	-0.01	**0.26**	**0.01**
	[-0.88, -0.51]	[-0.46, -0.07]	[-0.89, -0.52]	[-0.79, -0.44]		[-0.00, 0.01]	[-0.03, 0.00]	[0.15, 0.37]	[0.00, 0.01]
Finland	**-0.50**	-0.08	**-0.52**	**-0.45**	China	**0.05**	**0.02**	**0.13**	**0.06**
	[-0.60, -0.39]	[-0.22, 0.06]	[-0.62, -0.41]	[-0.55, -0.35]		[0.04, 0.05]	[0.00, 0.03]	[0.11, 0.14]	[0.05, 0.06]
France	**-0.52**	-0.10	**-0.54**	**-0.40**	India	**0.02**	0.00	**0.20**	**0.07**
	[-0.66, -0.38]	[-0.32, 0.12]	[-0.68, -0.40]	[-0.54, -0.25]		[0.01, 0.02]	[-0.00, 0.01]	[0.16, 0.25]	[0.06, 0.08]
Germany	**-0.72**	**-0.20**	**-0.80**	**-0.48**	Indonesia	**0.01**	-0.00	**0.00**	**0.02**
	[-0.84, -0.59]	[-0.36, -0.04]	[-0.92, -0.67]	[-0.61, -0.36]		[0.01, 0.01]	[-0.01, 0.00]	[0.00, 0.01]	[0.01, 0.02]
Greece	**-0.39**	-0.12	**-0.37**	**-0.37**	Japan	-0.00	0.00	**0.06**	**-0.00**
	[-0.48, -0.29]	[-0.23, 0.00]	[-0.47, -0.28]	[-0.46, -0.27]		[-0.00, 0.00]	[-0.00, 0.01]	[0.05, 0.08]	[-0.01, -0.00]
Hungary	**-0.87**	**-0.34**	**-0.94**	**-0.60**	Korea	-0.03	**-0.09**	**0.15**	**0.06**
	[-1.01, -0.74]	[-0.49, -0.18]	[-1.07, -0.80]	[-0.74, -0.46]		[-0.08, 0.02]	[-0.16, -0.02]	[0.09, 0.21]	[0.05, 0.08]
Ireland	**-8.16**	**-3.08**	**-8.22**	**-5.39**	Mexico	-0.01	**-0.01**	**0.04**	**0.01**
	[-9.60, -6.72]	[-4.82, -1.34]	[-9.66, -6.78]	[-6.80, -3.98]		[-0.01, 0.00]	[-0.02, -0.00]	[0.02, 0.05]	[0.00, 0.01]
Italy	**-0.40**	-0.09	**-0.43**	**-0.31**	Norway	**0.52**	0.23	**0.61**	**-0.15**
	[-0.50, -0.31]	[-0.21, 0.04]	[-0.53, -0.34]	[-0.41, -0.22]		[0.10, 0.94]	[-0.37, 0.84]	[0.13, 1.09]	[-0.26, -0.04]
Latvia	**-0.58**	-0.16	**-0.58**	**-0.51**	Russia	0.01	**-0.08**	-0.02	**0.05**
	[-0.76, -0.40]	[-0.36, 0.04]	[-0.75, -0.40]	[-0.67, -0.34]		[-0.02, 0.03]	[-0.16, -0.01]	[-0.05, 0.00]	[0.02, 0.07]
Lithuania	**-0.51**	-0.07	**-0.55**	**-0.42**	Switzerland	-0.01	0.04	-0.04	**0.12**
	[-0.66, -0.35]	[-0.28, 0.14]	[-0.71, -0.40]	[-0.56, -0.29]		[-0.16, 0.14]	[-0.12, 0.20]	[-0.19, 0.11]	[0.05, 0.19]
Luxembourg	**-5.23**	2.15	**-5.46**	-3.15	Taiwan	**0.13**	0.06	**0.09**	**0.10**
	[-8.61, -1.85]	[-2.64, 6.95]	[-8.82, -2.09]	[-6.67, 0.36]		[0.11, 0.16]	[-0.49, 0.61]	[0.06, 0.12]	[0.08, 0.12]
Malta	**-5.19**	-0.76	**-5.16**	**-3.36**	Turkey	**-0.04**	**-0.07**	**-0.08**	**0.05**
	[-6.65, -3.73]	[-2.94, 1.43]	[-6.63, -3.69]	[-4.40, -2.32]		[-0.07, -0.01]	[-0.10, -0.04]	[-0.11, -0.05]	[0.05, 0.06]
Netherlands	**-1.64**	-0.37	**-1.71**	**-1.06**	USA	**-0.01**	-0.00	**0.11**	**-0.01**
	[-1.94, -1.33]	[-0.84, 0.10]	[-2.01, -1.40]	[-1.36, -0.76]		[-0.02, -0.01]	[-0.01, 0.00]	[0.08, 0.14]	[-0.01, -0.00]
Poland	**-0.69**	**-0.25**	**-0.73**	**-0.47**	ROW	-0.02	0.02	-0.02	0.02
	[-0.81, -0.57]	[-0.38, -0.12]	[-0.85, -0.61]	[-0.59, -0.35]		[-0.05, 0.01]	[-0.02, 0.06]	[-0.05, 0.01]	[-0.01, 0.06]
EU27	**-0.78**	**-0.20**	**-0.83**	**-0.56**					
	[-0.93, -0.63]	[-0.38, -0.01]	[-0.97, -0.68]	[-0.71, -0.40]					
ROW	0.00	0.00	**0.08**	**0.02**					
	[-0.00, 0.01]	[-0.01, 0.01]	[0.06, 0.10]	[0.02, 0.02]					

Note: The baseline year is 2014. Mean effects and [p5, p95] intervals. Bold characters indicate significance at the 10%-level based on 1,000 replications. Confidence intervals in square brackets. The results for EU27 and ROW are calculated as GDP weighted averages.

Table 3.5: Counterfactual Changes of Bilateral Exports of EU27, UK and RoW, in %

	Changes of Exports in %							
	EU27 to			UK to		ROW to		
	EU27	UK	ROW	EU27	ROW	EU27	UK	ROW
Panel A: S1								
Agriculture	-0.24	**-22.74**	**0.85**	-4.46	**-6.31**	**-1.19**	**10.05**	**0.25**
Manufacturing	-0.14	**-30.63**	**1.15**	**-32.19**	**-10.00**	**-0.91**	**9.80**	**0.24**
Services	**-0.30**	**-21.21**	**0.44**	**-20.85**	**-0.43**	**-0.96**	0.07	**0.20**
Total	**-0.18**	**-27.42**	**0.87**	**-24.69**	**-4.57**	**-0.97**	**7.16**	**0.23**
Panel B: S2								
Agriculture	-1.34	40.06	-0.13	96.05	**-7.20**	-1.96	9.62	-0.04
Manufacturing	-0.31	-4.71	**0.35**	7.16	**-7.58**	**-0.68**	1.80	0.06
Services	0.25	**-7.55**	**0.32**	**-7.16**	**-0.76**	-0.33	1.04	0.01
Total	-0.20	-4.15	**0.33**	3.15	**-3.80**	**-0.75**	2.40	0.03
Panel C: S3								
Agriculture	-0.34	**-19.87**	**0.95**	-6.70	7.11	**-1.49**	**22.05**	**0.27**
Manufacturing	**-0.35**	**-34.35**	**1.14**	**-32.33**	**14.80**	**-1.35**	**34.19**	0.03
Services	**-0.48**	**-19.76**	**0.37**	**-21.33**	**4.49**	**-1.13**	**9.04**	**0.11**
Total	**-0.39**	**-29.31**	**0.84**	**-25.11**	**8.81**	**-1.30**	**26.05**	**0.08**
Panel D: S4								
Agriculture	-0.28	**-10.90**	-0.12	2.50	**7.61**	-0.57	-2.51	**0.25**
Manufacturing	**-0.22**	**-11.52**	**-0.51**	**-17.84**	**9.93**	0.19	**9.96**	**0.16**
Services	**0.28**	**-4.29**	**0.21**	**-18.79**	**1.44**	-0.07	**-4.28**	**0.19**
Total	-0.09	**-9.23**	**-0.23**	**-17.47**	**5.15**	-0.01	**4.77**	**0.18**

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications. Table reports cross-border trade only (no domestic trade). Full results are presented in Tables C.7, C.8, and C.9 in the Appendix.

Table 3.6: Counterfactual Changes of Overall Trade, in %

	Initial Exports bn USD	Changes in Exports in %				Initial Imports bn USD	Changes in Imports in %			
		S1	S2	S3	S4		S1	S2	S3	S4
Panel A: UK										
Agriculture	29.93	-5.52	36.83	1.22	5.43	50.44	1.50	**17.56**	**11.12**	**-4.70**
Manufacturing	304.41	**-18.50**	-1.94	-3.25	-0.71	489.57	**-12.19**	-1.74	**-3.08**	**-1.72**
Services	413.60	**-8.35**	**-3.24**	**-5.52**	**-6.41**	225.95	**-11.96**	**-3.81**	**-7.24**	**-4.29**
Total	747.93	-12.36	-1.11	-4.33	-3.61	765.96	-11.22	-1.08	-3.37	-2.67
Panel B: EU27										
Agriculture	194.46	**-1.45**	1.80	-1.30	**-0.96**	462.82	**-1.02**	0.91	**-1.32**	**-0.41**
Manufacturing	4177.81	**-1.55**	-0.32	**-1.90**	**-1.06**	3474.84	**-1.48**	-0.18	**-1.76**	**-0.67**
Services	2064.33	**-1.20**	-0.20	**-1.22**	-0.04	1721.33	**-2.49**	**-0.68**	**-2.69**	**-1.64**
Total	6,436.60	**-1.43**	-0.22	**-1.67**	-0.73	5,659.00	**-1.75**	-0.25	**-2.01**	**-0.95**
Panel C: RoW										
Agriculture	2039.67	**0.20**	-0.17	**0.39**	0.07	1750.78	**0.21**	-0.11	**0.35**	**0.31**
Manufacturing	8115.92	**0.34**	0.00	**0.77**	**0.43**	8633.73	**0.20**	-0.05	**0.57**	**0.24**
Services	3209.29	**-0.07**	-0.03	**0.10**	-0.01	3739.93	**0.23**	0.05	**0.48**	**0.28**
Total	13,364.88	0.22	-0.03	**0.55**	0.27	14,124.44	**0.21**	-0.03	**0.52**	**0.26**

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications. Confidence intervals can be retrieved from Table C.10 in the Appendix.

Table 3.7: Counterfactual Changes of Sectoral Value Added, in %

		UK				EU 27			
		S1	S2	S3	S4	S1	S2	S3	S4
1	Crops & Animals	**7.87**	**6.71**	**8.30**	**-2.22**	**-1.36**	**-0.70**	**-1.46**	**-0.54**
2	Forestry & Logging	-1.96	-1.28	-1.22	-0.10	**-0.52**	0.04	**-0.63**	**-0.70**
3	Fishing & Aquaculture	**-15.83**	-7.68	-10.36	**-15.11**	1.08	0.91	1.00	0.71
4	Mining & Quarrying	**-7.93**	8.22	-3.60	6.77	**2.51**	**5.86**	**2.75**	**-1.07**
5	Food, Beverages & Tobacco	1.86	**2.39**	**3.50**	**-3.06**	**-1.55**	**-0.53**	**-1.67**	**-0.63**
6	Textiles, Apparel,Leather	**-6.82**	-2.97	**-10.62**	**-4.02**	-0.38	0.93	**-0.83**	**-1.15**
7	Wood & Cork	0.43	-3.86	-1.78	0.45	**-0.72**	0.16	**-0.88**	**-0.84**
8	Paper	0.81	0.36	1.00	0.46	**-0.83**	-0.29	**-0.88**	**-0.85**
9	Recorded Media Reproduction	**-1.13**	1.10	0.55	0.40	**-0.47**	**-0.23**	**-0.62**	**-0.49**
10	Coke, Refined Petroleum	4.13	18.84	**19.89**	0.75	-0.44	2.02	-0.82	**-1.02**
11	Chemicals	**-5.71**	0.34	**-4.12**	**-3.74**	**-1.10**	**-0.64**	**-1.33**	**-0.80**
12	Pharmaceuticals	-3.08	-5.82	**-11.94**	8.75	-0.67	**-2.16**	-0.02	**-1.92**
13	Rubber & Plastics	-0.68	0.93	0.66	**-3.25**	**-1.16**	**-0.49**	**-1.37**	**-0.51**
14	Other non-Metallic Mineral	-1.01	0.94	0.71	**-0.93**	**-0.70**	**-0.23**	**-0.84**	**-0.54**
15	Basic Metals	**-16.95**	**-9.73**	-6.11	-2.13	**-0.43**	-0.14	**-0.74**	**-0.43**
16	Fabricated Metal	-0.49	1.44	**2.63**	**1.21**	**-0.79**	**-0.26**	**-1.00**	**-0.61**
17	Electronics & Optical Products	-3.05	-2.15	-6.60	**13.07**	**-1.73**	**-2.69**	**-1.48**	**-2.43**
18	Electrical Equipment	**-8.48**	-0.35	**-8.93**	3.67	**-0.60**	-0.25	**-1.18**	**-1.10**
19	Machinery & Equipment	**-6.86**	-3.93	-4.11	**8.38**	-0.12	-0.24	-0.16	**-1.04**
20	Motor Vehicles	-2.52	-1.49	**5.13**	-3.33	**-1.57**	-0.21	**-2.24**	**-0.81**
21	Other Transport Equipment	-2.80	11.80	**23.45**	**10.01**	-0.77	1.22	**-3.86**	**-1.40**
22	Furniture & Other Manufacturing	-3.10	-1.29	-2.29	4.39	-0.27	**-0.58**	-0.05	**-1.34**
23	Electricity & Gas	**-1.08**	0.67	**0.99**	**-0.53**	**-0.67**	-0.12	**-0.86**	**-0.52**
24	Water Supply	**-0.67**	0.46	**0.91**	-0.35	**-0.61**	-0.07	**-0.80**	**-0.48**
25	Sewerage & Waste	**-1.72**	-0.79	-0.84	**-2.45**	**-0.62**	-0.14	**-0.79**	-0.16
26	Construction	-0.46	0.87	**1.15**	**-0.70**	**-0.70**	**-0.18**	**-0.89**	**-0.50**
27	Trade & Repair of Motor Vehicles	**-2.14**	-0.74	0.38	**-2.62**	**-0.45**	0.09	**-0.69**	-0.07
28	Wholesale Trade	**-7.91**	**-6.50**	**-5.40**	**-9.32**	0.05	**0.51**	-0.10	**0.52**
29	Retail Trade	-0.60	0.49	**1.01**	**-1.02**	**-0.65**	-0.14	**-0.83**	**-0.39**
30	Land Transport	**-1.86**	-0.58	-0.30	**-1.87**	**-0.51**	-0.01	**-0.68**	**-0.40**
31	Water Transport	0.78	-1.00	0.97	**1.45**	**-0.41**	0.33	**-0.52**	**-0.37**
32	Air Transport	-0.84	-0.25	0.49	-0.18	**-0.62**	0.06	**-0.68**	**-0.76**
33	Aux. Transportation Services	**-3.28**	**-2.08**	**-1.76**	**-3.15**	**-0.39**	0.06	**-0.55**	**-0.29**
34	Postal and Courier	0.03	**1.71**	**1.41**	-0.31	**-0.86**	**-0.48**	**-1.01**	**-0.43**
35	Accommodation & Food	**-0.76**	0.47	0.53	0.16	**-0.57**	**-0.15**	**-0.75**	**-0.46**
36	Publishing	**-1.59**	-0.73	-0.64	-0.18	**-0.82**	-0.18	**-0.96**	**-0.77**
37	Media Services	**-1.77**	-0.54	-0.67	-0.78	-0.17	0.15	**-0.34**	-0.08
38	Telecommunications	-0.65	0.62	0.64	-0.83	**-0.68**	-0.17	**-0.82**	**-0.45**
39	Computer & Information Services	**-0.64**	**1.02**	**0.89**	-0.22	**-0.43**	**-0.23**	**-0.56**	**-0.35**
40	Financial Services	0.38	**1.78**	**1.43**	0.16	**-0.78**	**-0.43**	**-0.94**	**-0.48**
41	Insurance	1.17	**3.17**	2.29	**2.73**	**-0.94**	**-0.61**	**-1.09**	**-0.94**
42	Real Estate	-0.35	0.73	**1.09**	**-0.58**	**-0.67**	**-0.17**	**-0.85**	**-0.45**
43	Legal and Accounting	**-1.51**	0.66	0.74	-0.87	**-0.46**	-0.05	**-0.62**	**-0.34**
44	Business Services	**-2.57**	0.51	0.78	**-2.05**	**-0.39**	-0.12	**-0.58**	-0.06
45	Research and Development	-0.68	0.41	0.52	0.38	**-0.56**	-0.12	**-0.73**	**-0.52**
46	Admin. & Support Services	-0.17	1.47	1.16	0.90	**-0.77**	-0.37	**-0.90**	**-0.69**
47	Public & Social Services	**-0.59**	0.61	**0.93**	**-0.56**	**-0.67**	**-0.15**	**-0.87**	**-0.50**
48	Education	**-0.66**	0.49	**0.84**	**-0.56**	**-0.68**	-0.14	**-0.87**	**-0.50**
49	Human Health and Social Work	-0.52	0.60	**0.94**	-0.51	**-0.71**	-0.14	**-0.91**	**-0.54**
50	Other Services, Households	-0.22	0.89	0.80	-0.37	**-0.70**	-0.21	**-0.89**	**-0.45**

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications. Full results and initial value added per sector in 2014 are provided in Tables C.12, C.13, C.14, and C.15 in the Appendix.

Chapter 4

Revisiting the Euro's Trade Cost and Welfare Effects

When, about twenty years ago, the Euro was created, one objective was to facilitate intra-European trade by reducing transaction costs. Has the Euro delivered? Using sectoral trade data from 1995 to 2014 and applying structural gravity modeling, we conduct an *ex post* evaluation of the European Monetary Union (EMU). In aggregate data, we find a significant average trade effect for goods of almost 8 percent, but a much smaller effect for services trade. Digging deeper, we detect substantial heterogeneity between sectors, as well as between and within country-pairs. Singling out Germany, and embedding the estimation results into a quantitative general equilibrium model of world trade, we find that EMU has increased real incomes in all EMU countries, albeit at different rates. E.g., incomes have increased by 0.3, 0.6, and 2.1 percent in Italy, Germany, and Luxembourg, respectively.

4.1 Introduction

The idea about a European Monetary Union was first discussed in 1970, when the so-called Werner report recommended a common European currency. The objective was to foster intra-European economic exchange, in particular trade, by eliminating currency related transaction costs, such as insurances for exchange rate fluctuations, or reduced price transparency.

The Euro received a lot of negative media attention in the last decade and it got exploited for arguments of populist movements across Europe. Research and political debates mainly focused on macroeconomic and monetary effects of the EMU, while benefits of having a joint currency, such as trade creation effects received less attention. In this chapter, we revisit the trade cost effects of the introduction of the Euro and ask the following question: What are the general equilibrium effects for EU member states and specifically Germany if the European Monetary Union was dissolved. The exercise informs us about the trade and welfare effects of having a common currency in the EU. We aim to highlight the importance and drawbacks of having a joint currency union.

To answer the question, we first employ a structural gravity model to identify country-sector specific trade cost changes observable due to the European Monetary Union. These trade cost changes are imputed into a general equilibrium model to derive sectoral value added, trade and welfare changes. We allow for trade cost effects to differ between sectors and country-pairs. More specifically, we single out Germany and allow its effects to differ between imports and exports as well as between old and new members of EMU. Identification relies on geographical and chronological heterogeneity in countries' adoption of the Euro and is facilitated by the inclusion of intra-country trade flows. To deal with the uncertainty associated to our econometric estimates in the simulation, we construct confidence intervals for all the simulated variables.

We are not the first to study the trade effects of a currency union. Rose (2000) uses a simple gravity model to show that sharing a common currency more than triples trade between the participating countries. Rose (2000) used a currency union dummy variable as a right-hand side regressor, which yields one coefficient for the assessment of the trade effect of currency unions. This chapter was followed by a vast literature that addressed problems, such as omitted variables, self-selection, and other econometric issues (see also Baldwin (2006); Baldwin et al. (2008)). Chen and Novy (2018) apply a modern gravity analysis that avoids the econometric problems of the earlier literature. The authors argue that the trade effect of currency unions is heterogeneous across and within country pairs. Glick and Rose (2016) emphasize the use of exporter and importer year-specific fixed effects. The authors find that currency unions increase trade on average by 40% and that the EMU increases trade even more.[1] Building on Yotov et al. (2016), Larch et al. (2017) show how to structurally estimate the effects of currency unions on trade. To cope with issues such as heteroscedasticity or zero trade flows, the authors employ Pseudo-Maximum-Likelihood estimation as advocated by Santos Silva and Tenreyro (2006). They control for exporter and importer year specific fixed effects to account for changes in multilateral resistance (Feenstra (2015); Baldwin and Taglioni (2007)), and time-invariant pair fixed effects that absorb the unobservable barriers to trade (Baier and Bergstrand, 2007).

[1] Other important papers are Glick and Rose (2002), Glick and Rose (2016), and De Sousa (2012).

We use the same empirical strategy but add to the literature by scrutinizing to what extent the formation of the EMU contributed to trade between Germany and its partners across sectors. We contribute to the literature by providing more detailed estimates on sectoral level. Further, instead of estimating one single average treatment effect, we allow for Germany-specific asymmetric effects. Third, we back out the trade cost effects of the Euro and use a quantitative general equilibrium trade model to simulate the welfare effects of the EMU. We account for parameter uncertainty in our simulation exercise.

Our empirical gravity model is derived from the general equilibrium framework proposed by Caliendo and Parro (2015), a multi-sector input-output version of the Ricardian trade model by Eaton and Kortum (2002), extended to services and non-tariff barriers by Aichele et al. (2016). Both the empirical and the simulation draw on data from the World Input-Output Database (WIOD); see Timmer et al. (2015) for a description. The data provide detailed intra- and international input-output linkages. We account for trade diversion effects, competitiveness effects through changing prices of intermediate inputs, and effects on real GDP.

On average, our empirical results are comparable to the literature (Micco et al. (2003); Baldwin and Taglioni (2007), Silva and Tenreyro (2010), Olivero and Yotov (2012)). However, we go beyond aggregates and report effects for detailed manufacturing and services sectors. We find that not all sectors benefited from the Euro; in particular, the services sectors did not profit as much as the manufacturing sectors. German outward trade costs fell more than inward trade costs. Our counterfactual analysis suggests, that German real GDP would have been 0.6% lower if the Euro had not existed in 2014. Among the large EMU members, this is the largest effect; small members such as Belgium or Luxembourg benefited more (1.4% and 2.1%, respectively). German gross trade is by about 1.1% to 1.5% higher with the Euro; within the other EMU members, the effect is even more pronounced.

The chapter is structured the following: In section 2, we explain the research design. Second 3 presents the data and empirical results. Section 4 discusses the results of the general equilibrium analysis. Section 5 concludes.

4.2 Research Design

Our theoretical model follows Caliendo and Parro (2015), who provide a multi-sector version of Eaton and Kortum (2002) with input-output linkages. We briefly derive the gravity equation to be estimated and describe how we simulate the counterfactual equilibrium.[2]

There are N countries indexed by i and n, as well as J sectors indexed by j and k. Sectoral goods are either used as inputs in production or consumed, with the representative consumer having Cobb-Douglas preferences over consumption C_n^j of sectoral final goods with expenditure shares $\alpha_n^j \in (0,1)$ and $\sum_j \alpha_n^j = 1$. Labor is the only production factor and labor markets clear. The labor force L_n is mobile across sectors such that $L_n = \sum_{j=1}^{J} L_n^j$, but not between countries. In each sector j, there is a continuum of intermediate goods producers indexed $\omega^j \in [0,1]$ who combine labor and composite intermediate input and who differ with respect to their productivity $z_i^j(\omega^j)$. Intermediate goods are aggregated into sectoral composites using CES production functions with elasticity η^j. In all markets, there is perfect competition.

A firm in country i can supply its output at price

$$p_{in}^j(\omega^j) = \kappa_{in}^j \frac{c_i^j}{z_i^j(\omega^j)} \text{ with } c_n^j = \Upsilon_n^j \, {w_n}^{\beta_n^j} \left[\prod_{k=1}^{J} {p_n^k}^{\gamma_n^{k,j}} \right]^{(1-\beta_n^j)}. \tag{4.1}$$

The minimum cost of an input bundle is c_n^j, where Υ_n^j is a constant, w_n is the wage rate in country n, p_n^k is the price of a composite intermediate good from sector k, $\beta_n^j \geq 0$ is the value-added share in sector j in country n and $\gamma_n^{k,j}$ denotes the cost share of source sector k in sector j's intermediate costs, with $\sum_{k=1}^{J} \gamma_n^{k,j} = 1$. κ_{in}^j denotes trade costs of delivering sector j goods from country i to country n such that

$$\kappa_{in}^j = (1 + t_{in}^j) D_{in}^{\rho^j} e^{\delta^j \mathbf{Z}_{in}}, \tag{4.2}$$

where $t_{in}^j \geq 0$ denotes ad-valorem tariffs, D_{in} is bilateral distance, and $\mathbf{Z}_{in}$ is a vector collecting trade cost shifters (such as FTAs or other trade policies).

Productivity of intermediate goods producers follows a Fréchet distribution with a location parameter $\lambda_n^j \geq 0$ that varies by country and sector (a measure of absolute advantage) and shape parameter θ^j that varies by sector (and captures comparative advantage).[3]

Producers of sectoral composites in country n search for the supplier with the lowest cost such that

$$p_n^j = \min_i \left\{ p_{in}^j(\omega^j); i = 1, \ldots, N \right\}. \tag{4.3}$$

[2] Details are relegated to the Appendix D.

[3] Convergence requires $1 + \theta^j > \eta^j$.

Caliendo and Parro (2015) show that it is possible to derive a closed form solution of composite intermediate goods price

$$p_n^j = A^j \left(\sum_{i=1}^{N} \lambda_i^j \left(c_i^j \kappa_{in}^j \right)^{\frac{-1}{\theta^j}} \right)^{-\theta^j}, \tag{4.4}$$

where $A^j = \Gamma \left[1 + \theta^j (1 - \eta^j)\right]^{\frac{1}{1-\eta^j}}$ is a constant.

4.2.1 Gravity

Given this structure, one can show that a country n's expenditure share π_{in}^j for source country i's goods in sector j is

$$\pi_{in}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{in}^j \right]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^{N} \lambda_i^j \left[c_i^j \kappa_{in}^j \right]^{\frac{-1}{\theta^j}}}, \tag{4.5}$$

which forms the core of a gravity equation.

Log-linearizing equation (B.8) and making use of (4.2), one obtains the following gravity equation:

$$M_{in,t}^j = \exp\left[-\frac{1}{\theta^j} \ln(1 + \tau_{in,t}^j) + \frac{\boldsymbol{\delta}_1^j}{\theta^j} \text{€}_{in,t} + \frac{\boldsymbol{\delta}_2^j}{\theta^j} \mathbf{Z}_{in,t}^j + \nu_{in}^j + \nu_{i,t}^j + \nu_{n,t}^j \right] + \varepsilon_{in,t}^j. \tag{4.6}$$

$M_{in,t}^j$ is the value of imports of country n from partner country i in sector j at time t. The interesting parameters are the sectoral tariff elasticities θ and shifters of sectoral trade costs δ. The vector $\text{€}_{in,t}$ takes the value of one if two countries i, n share the Euro at time t, and zero otherwise, where we allow for different parameters between different country groups and also with respect to directionality.

In the baseline gravity model, $\text{€}_{in,t}$ in equation (4.6) contains only one single binary variable which switches to one if two countries are both members of EMU. In further specifications the vector $\text{€}_{in,t}$ contains binary variables that specifically control for trade flows between Germany and the 'old' and 'new' EMU members.[4] In a symmetric gravity specification, the directional effects - whether Germany is the exporter or importer -

[4] Old EMU partner members: Austria, Belgium, Finland, France, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. The new EMU partners of Germany: Greece, Slovenia, Malta, Cyprus, Slovakia, Estonia, Latvia, Lithuania.

are ignored, while this distinction is made in the asymmetric gravity specification. The following sub-chapters explain the vector $\boldsymbol{€}_{in,t}$ in more detail.

Given the nature of the underlying theoretical model, these estimates can be translated into changes in ad valorem tariff equivalents of non-tariff trade costs. $1+\tau^j_{in,t}$ depicts the ad valorem tariff, with the trade elasticity $1/\theta^j > 0$. Since we can observe the data for these ad valorem tariffs for all bilateral pairs across sectors, the trade cost elasticity can be correctly identified and then later be used for the CGE simulations. Second, unbiased estimates of $\frac{\boldsymbol{\delta}^j_l}{\theta^j}$ are needed, where $l \equiv [1, 2]$.

Identifying variation stems from the membership accessions between 1995 and 2011, which is our available time frame. The Euro was officially launched on 1 January 1999 in 12 EU countries.[5] Between 2002 and 2015, the remaining members joined.[6] The vector $\boldsymbol{Z}_{in,t}$ contains dummy variables accounting for membership in the EU, the Schengen Area or other regional trade agreements.

In order to account for multilateral resistance, importer- and exporter-specific year fixed effects, $\nu^j_{i,t}$ and $\nu^j_{n,t}$, are included. These terms are generally unobserved and fully control for all exporter- and importer-specific time-varying determinants of trade (such as production or consumption). Effectively, they also control for nominal and real exchange rates movements relative to a third currency, and in combination (through triangle arbitrage) between countries i and n.

ν^j_{in} are bilateral country-pair fixed effects, which absorb all time-invariant bilateral trade frictions. The fixed effects may account for potential endogeneity issues of the EMU dummy if two countries that decide to join a currency union have traditionally traded a lot with each other (see e.g. Micco et al. (2003)). This fixed effect may also prevent potential selection bias. The selection of country pairs into plurilateral agreements may not be completely random, but is also not a purely bilateral decision. We further believe that reverse causality is not a major issue. Apart to potential endogeneity, this also addresses omitted variable bias in integration agreements (see, e.g., Baier and Bergstrand, 2007). $\varepsilon^j_{in,t}$ is the random error term. As recommended by Santos Silva and Tenreyro (2006), we estimate the model using Poisson Pseudo Maximum Likelihood (PPML) methods to address the OLS inconsistency and sample selection bias. We cluster standard errors at the country-pair level.

[5] Initial states included Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

[6] The 'new' wave of members include Slovenia, Cyprus, Malta, Slovakia, Estonia, Lithuania, and Latvia.

Following the common practice (see Baier and Bergstrand, 2007), we exploit variation within country-pairs and sectors over time to then identify the effects of policy changes. Thus, econometric identification relies on countries joining an agreement and the EMU in the period 1995-2011.

4.2.2 Comparative Statics

We wish to answer the question: How does welfare (real per capita income) in the observed baseline 2014 differ from a counterfactual situation in which the Euro did not exist. To answer this question, we need to close the model introduced in Section 5.3 above. We do this be requiring that in all countries, accounting for trade surpluses, income equals expenditure, and that for all sectors, goods markets clear. Appendix D.1 provides the essential equations.

We are interested in the effects of the decrease in transaction costs due to the membership of the EMU on income, trade, and value added. As shown by Dekle et al. (2008b), the model can be solved in changes. Let z denote the initial level of a variable and z' its counterfactual level. The Appendix D.2 provides more detail. The transaction cost shocks are then given by $\hat{\kappa}^j_{in} = \frac{1+t^{j'}_{in}}{1+t^j_{in}} e^{\delta^j (Z'_{in} - Z_{in})}$ and the change in real income (our measure for welfare) is

$$\hat{W}_n = \frac{\hat{I}_n}{\prod_{j=1}^{J} \left(\hat{p}^j_n\right)^{\alpha^j_n}}. \tag{4.7}$$

Solving the model in changes has several important advantages. First, certain constant parameters which would be difficult to estimate such as the level of absolute advantage, the level of non-tariff trade barriers, or the elasticity of substitution drop out from the analysis. This should reduce measurement error. Second, the procedure has computational advantages as one does not need to solve for the baseline and the counterfactual equilibria separately.

4.2.3 Construction of Confidence Intervals

We simulate confidence intervals for all endogenous outcome variables. More specifically, we use the variance-covariance matrix of the sectoral gravity regressions and, assuming joint normality, we draw a thousand different parameter sets for each sector. We use these to calibrate a thousand simulation exercises, obtaining a distribution of changes in outcome variables. We report the 5th and the 95th percentiles of these distributions (the

90% confidence interval) together with the mean. This allows for a sound treatment of statistically insignificant gravity coefficients and for a proper quantification of parameter uncertainty.

4.3 Data and Empirical Results

4.3.1 Data

The World Input-Output Database (WIOD) is our main data source. It is described in detail by Timmer et al. (2015). It provides information on the expenditure shares α, the cost shares β and γ, as well as data on bilateral trade shares π, bilateral trade in final and intermediate goods in producer and consumer prices detailed by sector, countries' total value added $w_n L_n$, values of production, and trade surpluses S.

There are two waves of WIOD data. The first wave includes data for 40 countries, 16 goods sectors and 19 services sectors for the years 1995 until 2011. The second wave, which was published in 2016 includes information about 43 countries, a rest-of-the-world aggregate and 56 sectors for the years 2000 to 2014. Unfortunately, no official concordance between the two waves exists, and any mapping of sectors is likely to contaminate the crucial time variance in the data required for proper estimation. For this chapter, we use the first WIOD wave to be able to cover the first Euro accessions by Germany, Italy, Belgium, Finland, France, Ireland, Luxembourg, Netherlands, Portugal, and Spain in 1999. One disadvantage of the first WIOD wave is the fact that we cannot take account of the most recent Euro accessions of Lithuania and Latvia in 2014 and 2015. Single Market and Customs Union effects are identified through the enlargement of the EU between 1995 and 2011 and thus do not cover the most recent accessions by Croatia. We thus cover almost all Euro and EU accessions, which leaves us confident to correctly proxy the Euro effects.

However, to pin down the baseline, we have constructed a concordance between the two waves and work with the year 2014, the most recent one available. We use WIOD data on sectoral outputs, bilateral aggregated intermediate and final trade shares final expenditure and intermediate cost shares. Moreover, we match the cross-section of tariffs in 2014.[7] Data on bilateral preferential and MFN tariffs stem from Felbermayr et al.

[7] We use the approach outlined in Aichele and Heiland (2016) to account for the fact that WIOD expenditure shares are valued in "basic" (or "producer") prices (net of tariffs), while expenditure shares in the model are defined in "market" prices (including tariffs). Further, we utilize their approach to

(2018d). Sectoral trade cost elasticities θ and the trade cost changes $\boldsymbol{\delta}$ are identified through structural state-of-the-art gravity estimation. Data on tariffs and on trade from WIOD are used to estimate trade elasticities for the 16 manufacturing and agricultural sectors – jointly with the ad-valorem equivalent changes in NTBs associated with the different steps of European and trade integration in general.[8] We use data on RTA membership from the WTO.[9] Data on membership in the EU, the Eurozone and the successive accession of countries to the Schengen Agreement stem from the European Commission. Information about the EU membership and RTA membership is taken the website of the European Commission.

4.3.2 Gravity Analysis of Average Effects

The first baseline gravity model estimates the average trade effect of bilateral country pairs being members of the EMU at time t. So, $€_{in,t}$ in equation (4.6) is not a vector, but rather contains only one single binary variable which switches to one if two countries are both members of EMU. Further, control variables, such as being a member of the European Union, the Schengen Area, a customs union or a trade agreement are also included ($\mathbf{Z}^j_{in,t}$). We start with this simple specification to make our results comparable to earlier literature. The first line in Table 4.1 shows the estimates for aggregate goods and services trade.

On average, becoming a EMU member increased imports of goods by 7.8% and is statistically significant. This average result is in line with literature, (see e.g. Felbermayr et al. (2018b) and Larch et al. (2017)); the authors find rather small, but positive effects, although lacking significance in the latter example. Interestingly, the effect on services trade is small and statistically not significant.

The rest of Table 4.1 shows the gravity estimation results for all 16 goods sectors. The EMU has heterogeneous effects across the sectors, but with the only exception of the textiles sector, effects are positive. Many coefficients have large standard errors. As a consequence, we expect sizeable confidence intervals in our simulation exercise. In the

account for changes in inventory as part of the accounting system of WIOD but do not feature in our model.

[8] For services sectors, we borrow an average estimate of the elasticity of services trade with respect to trade cost from Egger et al. (2012). We adapt their method to obtain a trade elasticity of services and apply it to our estimated goods elasticity from our aggregated gravity estimation. This is given by $\beta = \theta_{\text{Goods}} - \theta_{\text{Services}}$, which is $\theta_{\text{Services}} = 1.446 = 3.471 - 2.026(\hat{\beta})$ and a relative standard error of $0.144 = 0.924/6.404$ (t-value).

[9] The RTA gateway is accessible via http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx.

area of services industries, sales and repair of vehicles, or accommodation (hotels) have strongly benefitted. Again, most estimated effects are positive but standard errors are large.

4.3.3 Singling Out Germany and Allowing For Directionality

Table 4.2 goes one step further and singles out Germany from the other EMU members. Moreover, it distinguishes between 'old' and 'new' EMU members.[10] However, effects are still symmetric in the sense that German exports and imports are affected similarly. Dropping time indices to avoid clutter, the vector $\boldsymbol{€}_{in}$ in equation 4.6 becomes

$$\boldsymbol{€}_{in,t} = \{sym€_{old,DEU}; sym€_{new,DEU}; €_{Rest}\}, \tag{4.8}$$

Columns (1) and (2) show that especially trade between Germany and the other 'old' EMU members was enhanced due to EMU. On average trade in goods increased by 13.8% and trade in services by 7.2%, with both being statistically significant. Trade between Germany and the 'new' member states significantly decreased by 11.5% in manufacturing sectors, and by 10.5% in services sectors (Column (2) and (5)). Next, columns (3) and (4) (broad goods), and column six (broad services) differentiate between Germany being an exporter and an importer. So, we have

$$\boldsymbol{€}_{in,t} = \{€_{old,DEU}; €_{DEU,old}; €_{new,DEU}; €_{DEU,new}; €_{Rest}\}, \tag{4.9}$$

which allows Germany's Euro-effects to be asymmetric. To save degrees of freedom, in this specification, we do not decompose the effect for the remaining Euro zone members. Estimation results suggest that German exports of goods towards the old members increased by 18.2% (see column (4), line $asym.€_{DEU,old}$) and goods' imports from old EMU members increased by 7.5% (see column (4), line $asym.€_{old,DEU}$). German services exports towards old EMU members increased by 16.3% (see column (6)). But, as for imports, the effect is not distinguishable from zero. In contrast, exports and imports of goods from and to Germany to and from the new members even decreased by 11.2% (see column (4), line $asym.€_{DEU,new}$) and 11.8% (see column (4), line $asym.€_{new,DEU}$). The trade effects for the German service industry are even more pronounced: German exports

[10] Old EMU partner members: Austria, Belgium, Finland, France, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. The new EMU partners of Germany: Greece, Slovenia, Malta, Cyprus, Slovakia, Estonia, Latvia, Lithuania.

Table 4.1: The Impact of EMU on sectoral Bilateral Imports

Dep. var.:	Bilateral Imports				
ID	Goods	both Euro *b/se*	ID	Services	both Euro *b/se*
	Broad Goods	**0.0753***** **(0.03)**		**Broad Services**	**0.0104** **(0.03)**
1	Agriculture	0.08516*** (0.03)	17	Electricity	0.26883*** (0.06)
2	Mining	0.00194 (0.07)	18	Construction	0.00239 (0.02)
3	Food, Beverages	0.16106*** (0.03)	19	Sale, Repair Vehicles	0.11129*** (0.03)
4	Textiles	-0.15815*** (0.04)	20	Wholesale Trade	0.01043 (0.06)
5	Leather	0.04468 (0.06)	21	Retail Trade	0.02799 (0.03)
6	Wood	0.22584*** (0.03)	22	Hotels	0.13393*** (0.04)
7	Pulp, Paper	0.07960** (0.03)	23	Inland Transport	0.04196 (0.04)
8	Coke, Petroleum	0.85288*** (0.14)	24	Water Transport	-0.10906 (0.11)
9	Chemicals	0.08157** (0.04)	25	Ait Transport	0.02897 (0.07)
10	Rubber, Plastics	0.00675 (0.03)	26	Auxiliary Transport	0.01410 (0.06)
11	Other Minerals	0.06857** (0.03)	27	Telecommunications	-0.00197 (0.04)
12	Basic Metals	0.04256 (0.03)	28	Financial Interm.	-0.06000 (0.09)
13	Machinery	0.03305 (0.03)	29	Real Estate	0.00166 (0.07)
14	Electronics	0.00180 (0.04)	30	Business Activities	0.00839 (0.04)
15	Transport Equipment	0.01186 (0.03)	31	Public Admin	0.11808** (0.05)
16	Manufacturing	0.03578 (0.02)	32	Education	0.03826 (0.05)
			33	Health	0.07489** (0.03)
			34	Other	0.01217 (0.04)

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Further controls, such as membership of EU, RTA, FTA, Schengen and Tariffs are included in estimation but not reporte, but can be retrieved from the tables D.1 and D.2 in the Appendix. Number of observations: 27,200.

in services to the new members decreased by 16.9%, which is also significant, whereas German services imports decreased by 4.7%. But this result is not significant.

Table 4.2: The Impact of EMU on German Bilateral Imports from Old and New EMU Members

Dep. var.:	Bilateral Imports					
	Goods				Services	
	(1)	(2)	(3)	(4)	(5)	(6)
sym. €$_{DEU,old}$	0.1291***	0.1367***			0.0698*	
	(0.03)	(0.03)			(0.04)	
sym. €$_{DEU,new}$	-0.1251***	-0.1227***			-0.1107***	
	(0.03)	(0.03)			(0.04)	
asym. €$_{DEU,new}$			-0.1135*	-0.1191*		-0.1851**
			(0.07)	(0.07)		(0.09)
asym. €$_{new,DEU}$			-0.1376**	-0.1263**		-0.0485
			(0.06)	(0.06)		(0.06)
asym. €$_{DEU,old}$			0.1876**	0.1922***		0.1734*
			(0.07)	(0.07)		(0.10)
asym. €$_{old,DEU}$			0.0719	0.0823		-0.0206
			(0.07)	(0.06)		(0.08)
Both €$_{Rest}$	0.0137	0.0211	0.0138	0.0212	-0.0332	-0.0333
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
Both EU	0.4444***	0.4493***	0.4447***	0.4496***	0.2277***	0.2275***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
RTA	0.2609***	0.2328***	0.2606***	0.2325***	0.1999***	0.1997***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)
Schengen	0.0345***	0.0336***	0.0345***	0.0336***	0.0200*	0.0202*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Tariffs		-3.4704***		-3.4666***		
		(0.83)		(0.83)		

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Number of observations: 27,200.

To sum up, the effect on German exports and imports varies substantially. Further it also differs across the trading partners. Trade with old EMU members expanded, whereas, trade with the new members decreased, both across services and goods and for German exports and imports. Note that this is not due to a 'wrong' initial exchange rate between Germany and the new members, as initial conditions are accounted for by country-year fixed effects. The effects can also not be explained by different paths of prices (i.e., inflation) or even nominal exchange rates, which are effectively dealt with by fixed effects. Also, trade diversion cannot be blamed, because it is taken into account by the inclusion of fixed effects (which proxy for multilateral resistance terms). Note, that the welfare effects of the EMU do not depend on whether outward trade costs have gone down; of course, inward trade costs are at least of equal importance for welfare gains.

Tables 4.3 and 4.4 take the gravity specification, which accounts for directional trade between Germany and the new and old EMU members to a more disaggregated sectoral level. This specification informs the general equilibrium simulations. The respective tables solely show the results for the effects of the Euro between Germany, the old and new members, and the average effects for the remaining EMU members. Estimates of coefficients on additional control variables can be retrieved from the Table D.3 and D.4 in the Appendix D.

Exports of German agricultural products to old EMU members went up, while the respective effect on imports is less pronounced. Trade between Germany and new EMU members did not experience a decrease in transaction costs. German trade with old members solely increased in the manufacturing industries, except for textile and leather products. German exports towards the new members decreased for almost all manufacturing products, except Coke, Refinery, Printing, Paper Services. Trade with new EMU members decreased through Euro membership. Only a few services sectors could profit.

4.4 Counterfactual Analysis

In the next and final step, we use the econometric ex post evaluation of EMU in our general equilibrium model to conduct a counterfactual analysis: what, if, in 2014, the Euro had not existed? Our empirical exercise provides the needed estimates of the inverse trade elasticity so that we can back out the transaction cost effects of EMU membership; see equation (6).[11] This allows us to compute the shock $\hat{\kappa_{in}}^j$ associated to an end of EMU, which we use in our simulations. Essentially, these amount to solving the system of equations in the Appendix D. The econometric exercise also provides us with estimates of the variance-covariance matrices to simulate confidence intervals.[12]

Table 4.5 shows the changes in real income for all members of EMU and the remaining non-EMU members available in the data. The real income effect for Germany is comparable to the average effect across EMU members. Our simulations suggest that Italy and

[11] However, since we do not have trade cost shifters such as tariffs for the services industries, we take the trade cost elasticity from Egger et al. (2012).

[12] We draw 1000 realizations of parameter sets based on our gravity estimates and use them to simulate the model a 1000 times. The resulting distribution of endogenous variables is then characterized using the mean and the 5% and 95% percentiles.

Table 4.3: The Impact of EMU on sectoral Bilateral Imports of Goods

		€$_{Deu,old}$	€$_{old,DEU}$	€$_{Deu,new}$	€$_{new,DEU}$	€$_{Rest}$
1	Agriculture	0.1775*	0.0901	-0.3042***	0.0198	0.0552**
		(0.10)	(0.06)	(0.09)	(0.05)	(0.03)
2	Mining	0.3782***	-0.2119	-0.1306	-0.1870	-0.1081*
		(0.13)	(0.16)	(0.10)	(0.12)	(0.06)
3	Food, Beverages	0.3172***	0.1923***	0.0104	0.0652	0.0863**
		(0.09)	(0.07)	(0.19)	(0.07)	(0.04)
4	Textiles	-0.3612***	0.0389	-0.0467	-0.2175	-0.1600***
		(0.10)	(0.08)	(0.10)	(0.13)	(0.06)
5	Leather	-0.2373	0.1017	0.2037	-0.2390	0.1122
		(0.16)	(0.12)	(0.15)	(0.15)	(0.07)
6	Wood	0.3861***	0.3228***	-0.1535	-0.0450	0.1245***
		(0.10)	(0.08)	(0.17)	(0.10)	(0.03)
7	Pulp, Paper	0.2743**	0.0881	0.0731	0.0015	-0.0252
		(0.11)	(0.08)	(0.07)	(0.06)	(0.04)
8	Coke, Petroleum	1.0338***	0.4842	0.0986	0.2097	0.9409***
		(0.35)	(0.36)	(0.28)	(0.29)	(0.17)
9	Chemicals	0.1858*	0.1456**	-0.2245**	-0.1022	-0.0074
		(0.10)	(0.07)	(0.10)	(0.09)	(0.04)
10	Rubber, Plastics	0.0844	0.0963	-0.1444*	-0.1156	-0.0970***
		(0.08)	(0.06)	(0.09)	(0.09)	(0.03)
11	Other Minerals	0.2446**	0.1065	-0.0496	-0.0250	-0.0323
		(0.12)	(0.10)	(0.08)	(0.07)	(0.04)
12	Basic Metals	0.2572***	0.0297	-0.2437***	-0.1669**	-0.0628*
		(0.08)	(0.08)	(0.07)	(0.08)	(0.03)
13	Machinery	0.1325*	0.0325	-0.0178	-0.1023*	-0.0438
		(0.07)	(0.08)	(0.07)	(0.06)	(0.03)
14	Electronics	0.1293	0.0356	-0.0475	-0.1838**	-0.0843*
		(0.09)	(0.09)	(0.10)	(0.07)	(0.05)
15	Transport Equipment	0.0626	0.0566	-0.3067***	-0.2244**	-0.0127
		(0.06)	(0.08)	(0.09)	(0.09)	(0.04)
16	Manufacturing	0.0032	0.1389**	-0.1079	-0.1679***	0.0120

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Further controls, such as membership of EU, RTA, FTA, Schengen and Tariffs are included in estimation but not reported. The remaining control variables can be retrieved from the tables D.3 and D.4 of the Appendix. Number of observations: 27,200.

Greece benefited slightly less from the currency union than the other EMU members. One should keep in mind that, in principle, the model could also lead to negative welfare effects for countries inside and outside of the EMU. The reason for this is that terms of trade can move against countries and offset the direct transaction cost savings. However, the analysis suggests that this is not the case for any of the EMU members. All average real income changes are statistically significant at the 10%-level. Also, European Union members, which are not part of the EMU (such as the UK or Sweden), also indirectly

Table 4.4: The Impact of EMU on sectoral Bilateral Imports of Services

		$€_{Deu,old}$	$€_{old,DEU}$	$€_{Deu,new}$	$€_{new,DEU}$	$€_{Rest}$
		(0.07)	(0.06)	(0.10)	(0.04)	(0.03)
17	Electricity	0.5398***	0.2966**	-0.0388	0.1221	0.1798***
		(0.16)	(0.14)	(0.15)	(0.20)	(0.06)
18	Construction	0.1903**	-0.0125	-0.0224	-0.0991*	-0.0838***
		(0.08)	(0.08)	(0.07)	(0.06)	(0.02)
19	Sale, Repair Vehicles	0.1218	0.1427	-0.2197***	-0.2171**	0.1079***
		(0.10)	(0.11)	(0.07)	(0.10)	(0.04)
20	Wholesale Trade	0.3898***	0.0085	-0.1911	0.2126**	-0.1029
		(0.14)	(0.11)	(0.13)	(0.09)	(0.09)
21	Retail Trade	0.1761*	-0.0377	-0.0867	-0.1150	0.0060
		(0.10)	(0.09)	(0.12)	(0.11)	(0.04)
22	Hotels	0.2570**	0.1132	-0.1166	0.1267	0.1010*
		(0.12)	(0.12)	(0.20)	(0.09)	(0.05)
23	Inland Transport	0.2171**	-0.0628	-0.5063***	-0.2403	0.0362
		(0.11)	(0.09)	(0.16)	(0.23)	(0.05)
24	Water Transport	0.4966**	-0.5947***	-0.2404	-0.0083	-0.0690
		(0.22)	(0.20)	(0.26)	(0.29)	(0.12)
25	Ait Transport	0.3845**	-0.0456	-0.6180***	-0.0083	-0.0881
		(0.15)	(0.13)	(0.13)	(0.21)	(0.08)
26	Auxiliary Transport	-0.2000	0.1951**	-0.3187*	-0.1452	0.0417
		(0.18)	(0.10)	(0.18)	(0.28)	(0.06)
27	Telecommunications	0.0759	-0.0883	-0.0073	-0.2057	0.0093
		(0.13)	(0.12)	(0.15)	(0.13)	(0.05)
28	Financial Interm.	0.4427**	-0.3384**	-0.3628**	-0.1437	-0.0974
		(0.17)	(0.15)	(0.17)	(0.16)	(0.12)
29	Real Estate	0.1223	-0.0492	-0.0900	-0.0259	-0.0240
		(0.20)	(0.20)	(0.12)	(0.09)	(0.08)
30	Business Activities	0.1800	-0.1078	-0.1410	-0.1905**	0.0102
		(0.14)	(0.11)	(0.11)	(0.09)	(0.05)
31	Public Admin	0.3648***	0.0521	-0.1906	-0.1978***	0.0372
		(0.14)	(0.10)	(0.12)	(0.07)	(0.04)
32	Education	0.0611	-0.0088	-0.2806*	-0.1118	0.0600
		(0.15)	(0.14)	(0.15)	(0.07)	(0.05)
33	Health	0.2125**	0.1420**	-0.2594**	-0.0596	-0.0326
		(0.09)	(0.07)	(0.11)	(0.06)	(0.03)
34	Other	0.0273	0.1128	-0.1240	0.0116	-0.0327
		(0.15)	(0.13)	(0.25)	(0.16)	(0.04)

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Further controls, such as membership of EU, RTA, FTA, Schengen and Tariffs are included in estimation but not reported. The remaining control variables can be retrieved from the tables D.3 and D.4 of the Appendix. Number of observations: 27,200.

profited from the Eurozone, often because they benefit from an increased level of economic activity in the Eurozone and the associated boost in demand for imported inputs. This is even true for some non-EU and non-EMU countries, such as Australia, who profited from the creation of the Eurozone. Note that high levels of trade with the EMU member states prior to the introduction of the Euro magnify the positive effects because resource savings due to lower transaction costs are larger. Therefore, we do not expect that EMU has benefited member states symmetrically. This is the reason why small and more central countries such as Luxembourg or the Netherlands belong to the countries that benefited the most in terms of real income gains. Similarly, the Baltic countries and particularly Estonia also experienced an increase in their real incomes through the lowering of transaction costs.

Table 4.5: Real Income Changes, in %

European Monetary Union Member States				**Non-EMU Countries**			
	Change in Real Income in %		Change in Real Income in %		Change in Real Income in %		Change in Real Income in %
Austria	**0.90**	Latvia	**1.34**	Australia	**0.01**	Mexico	**0.01**
	[0.90, 0.91]		[1.33, 1.35]		[0.01, 0.01]		[0.01, 0.01]
Belgium	**1.43**	Lithuania	**0.85**	Brasil	**0.00**	Norway	**0.01**
	[1.42, 1.44]		[0.84, 0.85]		[0.00, 0.00]		[0.01, 0.01]
Cyprus	**0.88**	Luxembourg	**2.05**	Bulgaria	**0.05**	Poland	**0.02**
	[0.87, 0.89]		[2.03, 2.07]		[0.05, 0.05]		[0.02, 0.02]
Estonia	**1.36**	Malta	**0.22**	Canada	**-0.00**	ROW	**0.01**
	[1.35, 1.37]		[0.20, 0.24]		[-0.00, -0.00]		[0.01, 0.01]
Finland	**0.43**	Netherlands	**1.16**	China	0.00	Romania	**0.05**
	[0.43, 0.43]		[1.16, 1.17]		[-0.00, 0.00]		[0.05, 0.05]
France	**0.45**	Portugal	**0.75**	Croatia	**0.04**	Russia	**-0.05**
	[0.44, 0.45]		[0.74, 0.75]		[0.04, 0.04]		[-0.05, -0.05]
Germany	**0.57**	Slovakia	**0.65**	Czech R.	**0.02**	Sweden	**0.01**
	[0.57, 0.57]		[0.64, 0.65]		[0.01, 0.02]		[0.01, 0.01]
Greece	**0.35**	Slovenia	**1.13**	Denmark	**-0.01**	Switzerland	**0.01**
	[0.35, 0.35]		[1.12, 1.13]		[-0.01, -0.01]		[0.01, 0.01]
Ireland	**0.61**	Spain	**0.42**	Hungary	0.00	Taiwan	**-0.01**
	[0.60, 0.62]		[0.42, 0.42]		[-0.00, 0.00]		[-0.01, -0.00]
Italy	**0.33**			India	**-0.00**	Turkey	**0.03**
	[0.33, 0.33]				[-0.00, -0.00]		[0.03, 0.03]
				Indonesia	**-0.00**	UK	**0.02**
					[-0.00, -0.00]		[0.02, 0.02]
				Japan	**0.01**	USA	**0.01**
					[0.01, 0.01]		[0.01, 0.01]
				Korea	**-0.01**		
					[-0.01, -0.01]		

Note: The baseline year is 2014. Mean effects and [p5,p95] intervals. Bold characters indicate significance at the 10%-level based on 1,000 bootstrap replications. Confidence intervals in square brackets.

Table 4.6 shows the effects on overall trade, i.e., across all trade partners for Germany, the remaining EMU members and the non-EMU members across the three sector categories and an aggregate (total). Across all sector categories, overall German exports and imports increase; compared to the change in real income, trade increases more, which indicates that the openness of the German economy, measured as total trade over GDP, increases substantially. The same is evident for the remaining EMU members. Non-EMU members, on the other hand, are confronted with overall decreases in exports and imports. Only exports of services expand (statistically significant at the 10%-level).[13]

Table 4.6: Change in Aggregate Trade, in %

	Germany		**Rest of EMU**		**Non-EMU members**	
	Change in %		Change in %		Change in %	
	Exports	Imports	Exports	Imports	Exports	Imports
Agriculture	**1.54**	0.23	**1.49**	**2.12**	0.04	**-0.17**
	[0.39, 2.69]	[-0.35, 0.82]	[0.04, 2.94]	[1.37, 2.87]	[-0.04, 0.12]	[-0.24, -0.11]
Manufacturing	**1.35**	**2.01**	**2.57**	**2.27**	**-0.18**	**-0.05**
	[0.93, 1.76]	[1.41, 2.60]	[1.78, 3.35]	[1.60, 2.94]	[-0.26, -0.11]	[-0.08, -0.02]
Services	0.27	0.49	0.30	0.97	**0.09**	**-0.09**
	[-0.45, 0.98]	[-0.52, 1.50]	[-0.63, 1.23]	[-0.12, 2.06]	[0.05, 0.13]	[-0.13, -0.06]
Total	1.13	**1.48**	1.69	**1.83**	-0.08	-0.08
	[-0.10, 2.36]	[0.13, 2.82]	[-0.07, 3.46]	[0.63, 3.03]	[-0.27, 0.11]	[-0.17, 0.02]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 bootstrap replications and an approximate normal distribution. Confidence intervals in square brackets. Domestic trade is not taken into account.

The positive change in exports and imports of the EMU members, including Germany, can be explained through trade creation effects among the EMU members and by trade diversion effects with non-members. Table 4.7 reports the changes in bilateral trade flows for Germany, the remaining EMU members (Rest of EMU) and the rest of the world (ROW). Trade flows are shown for three broad categories, agriculture, manufacturing, and services. The bold values denote the mean effects which are statistically different from zero at the 10% level.

Our simulations suggest that the introduction of the EMU led to a significant increase in trade among EMU members. Especially agricultural and manufacturing trade could be expanded, while trade in services seems to be less affected. In relative terms, imports from the EMU members towards Germany increased to a higher extent than vice versa. Trade diversion effects are more pronounced in the agricultural and services sectors. EMU members substitute initial agricultural and services trade of non-EMU members with trade among each other, while manufacturing exports of EMU members towards non-EMU and among each other increased. The formation of EMU strengthened the region in terms of purchasing power, which led to an increase of imports from the non-EMU members. Former trade among non-EMU is now substituted with trade towards the Eurozone.

[13] Note that positive effects on openness do not necessarily imply positive welfare effects. The reason is that the latter are not driven by gross trade but by changes in domestic value added and in the aggregate price index.

Table 4.7: Counterfactual Change of Bilateral Trade, in %

	Change of bilateral trade, in %		
	Germany	Rest of EMU	ROW
Panel A: Germany			
Agriculture		**3.97**	-0.10
		[6.63, 1.30]	[0.39, -0.60]
Manufacturing		**3.96**	0.04
		[5.30, 2.62]	[0.17, -0.10]
Services		1.27	**-0.11**
		[3.90, -1.35]	[-0.02, -0.19]
Total		**3.50**	0.00
		[4.88, 2.13]	[0.12, -0.11]
Panel B: Rest of EMU			
Agriculture	1.00	**4.09**	-0.37
	[3.80, -1.81]	[6.52, 1.66]	[0.06, -0.79]
Manufacturing	**5.57**	**5.48**	**0.19**
	[7.40, 3.74]	[7.26, 3.70]	[0.36, 0.03]
Services	0.67	1.39	**-0.17**
	[3.03, -1.69]	[4.10, -1.31]	[-0.05, -0.29]
Total	**3.94**	**4.07**	0.03
	[5.46, 2.42]	[5.74, 2.41]	[0.15, -0.09]
Panel C: Non-EMU members			
Agriculture	-0.18	**1.67**	**-0.17**
	[1.08, -1.43]	[2.49, 0.85]	[-0.11, -0.23]
Manufacturing	**-0.69**	**-0.60**	**-0.10**
	[-0.31, -1.07]	[-0.21, -0.99]	[-0.04, -0.15]
Services	**0.34**	**0.74**	**-0.07**
	[0.58, 0.10]	[0.98, 0.49]	[-0.03, -0.11]
Total	**-0.38**	**0.18**	**-0.10**
	[-0.08, -0.68]	[0.32, 0.04]	[-0.05, -0.15]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 bootstrap replications and an approximate normal distribution. Confidence intervals in square brackets. Domestic trade is not taken into account.

Table 4.8 shows the changes in sectoral value added for Germany. All sectors, except the textile industry and the coke and petroleum industry can generate positive value-added effects. The largest gains in relative terms are seen in the chemicals and agri-food.

Table 4.8: German Sectoral Value Added Changes, in %

	Value Added			Value Added	
	Initial in mn Euro	Change in %		Initial in mn Euro	Change in %
Panel A: Agriculture and Manufacturing Goods					
Agriculture	26199	**0.75**	Rubber and Plastics	38050	**0.71**
		[0.43, 1.08]			[0.31, 1.11]
Mining and Quarrying	6785	0.34	Other Non-Metallic Mineral	22719	**0.69**
		[-0.84, 1.51]			[0.40, 0.97]
Food, Beverages and Tobacco	59688	**1.10**	Basic Metals	104364	**0.57**
		[0.76, 1.45]			[0.35, 0.79]
Textiles	10552	**-1.90**	Machinery, Nec	149590	**0.51**
		[-3.11, -0.69]			[0.20, 0.83]
Wood Products	9030	**0.72**	Electrical Equipment	107097	0.10
		[0.49, 0.96]			[-0.44, 0.64]
Pulp, Paper, etc.	26606	**0.68**	Transport Equipment	17951	0.60
		[0.46, 0.91]			[-0.09, 1.30]
Coke, Petroleum, etc.	13264	**-1.64**	Manufacturing, Nec	31631	**0.59**
		[-3.09, -0.18]			[0.31, 0.88]
Chemicals	92288	**1.33**			
		[0.53, 2.12]			
Panel B: Services					
Electricity, Gas, etc.	76277	**0.63**	Auxiliary Transport Activities	65821	**0.52**
		[0.40, 0.86]			[0.34, 0.71]
Construction	164523	**0.54**	Telecommunications	98577	**0.52**
		[0.33, 0.76]			[0.32, 0.72]
Sale, Repair of Vehicles	200340	**0.50**	Financial Intermediation	155998	**0.52**
		[0.35, 0.64]			[0.35, 0.69]
Wholesale Trade, except vehicles	161246	**0.50**	Real Estate Activities	447330	**0.56**
		[0.34, 0.67]			[0.35, 0.76]
Retail Trade, except vehicles	114236	**0.55**	Other Business Activities	341557	**0.48**
		[0.35, 0.75]			[0.31, 0.65]
Hotels, Restaurants	85804	**0.52**	Public Admin, Defence, etc.	400351	**0.53**
		[0.32, 0.72]			[0.33, 0.74]
Inland Transport	67411	**0.45**	Education	190796	**0.56**
		[0.25, 0.65]			[0.35, 0.77]
Water Transport	10621	0.37	Health and Social Work	275879	**0.57**
		[-0.01, 0.75]			[0.35, 0.79]
Air Transport	8878	**0.76**	Other Social Services	30479	**0.60**
		[0.24, 1.29]			[0.35, 0.84]

Note:The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 bootstrap replications and an approximate normal distribution. Confidence intervals in square brackets.

4.5 Conclusion

This chapter conducts an ex-post analysis of the trade effects of the European Monetary Union and of the welfare effects that these effects entail. The economic consequences of the currency union are quantified allowing for asymmetries in the relation between Germany and the other EMU economies across sectors. The analysis is based on a quantitative trade theory framework, which gives rise to a structural gravity equation. The model's setup allows us to simulate confidence intervals for all endogenous variables, which is important since many of the Euro-related parameter estimates come with very substantial standard errors. Interestingly, though, we find that confidence intervals are quite narrow in most cases.

In the partial equilibrium gravity analysis, we find that the EMU has been successful in increasing trade between its members, but that effects differ quite a bit across sectors, country pairs, and direction. We exploit the heterogeneity identified at the sectoral level and of the structure of our quantitative general equilibrium model to back out the trade cost effects of EMU membership. We use these trade cost effects in the counterfactual analysis to simulate the real income, trade, and value-added changes associated to the trade cost savings of introducing the Euro. We find that all EMU members could increase their real income and that non-EMU could generate small gains, too, despite the presence of trade diversion effects. Trade ties between the EMU members intensified, some trade relationships within the currency union substituted former trade with non-EMU members. Overall, we obtain very clear evidence for positive welfare effects from the transaction cost savings generated by the creation of the EMU.

We believe that highlighting transaction cost savings and the benefits is crucial if one is to show a profound picture of the advantages and disadvantages of the European Monetary Union. We are aware that our analysis does not show the entire picture because we ignore additional channels of the common currency. However, much other work (e.g., as surveyed by Hartman and Smets, 2018) that focuses on the macroeconomic implications of the Euro is partial, too, as it ignores the transaction cost savings that we stress. Future work should try to integrate both strands of literature.

Chapter 5

Quantifying the EU-Japan Economic Partnership Agreement

This chapter provides a quantitative analysis of the new EU-Japan Economic Partnership Agreement (EPA), the biggest bilateral deal that both the EU and Japan have concluded so far. It employs a generalized variant of the Eaton-Kortum (2002) model, featuring multiple sectors, input-output linkages, services trade, and non-tariff barriers (NTBs). It uses the results of an econometric ex post analysis of a related existing FTA, the one between the EU and Korea, to approximate the expected reductions in the costs of NTBs. This approach yields long-run welfare effects for Japan of about 18 bn USD per year (0.31% of GDP) and of about 15 bn USD (0.10%) for the EU. On average, the agreement does not appear to harm third countries. 14% of the welfare gains inside the EPA stem from tariffs, the remaining 86% from NTB reform, and the services sector account for more than half. In the EU, value added in the agri-food sector goes up most, while in Japan the manufacturing and services sectors gain.

5.1 Introduction

On 1 February 2019, the Economic Partnership Agreement (EPA) between the EU and Japan entered into force. As of today, it is the largest free trade area in the world. In the times of growing protectionism and unilateralism, it is of strategic importance for both the EU and Japan. In this paper, we provide a quantitative analysis of the trade and welfare effects of the EU-Japan EPA. We employ what Ottaviano (2014) has called "New Quantitative Trade Theory". More precisely, we rely on the model of Eaton and Kortum (2002), extended by Caliendo and Parro (2015), and generalized to include tariffs and non-tariff barriers (NTBs) by Aichele et al. (2016). We employ a state-of-the-art sector level gravity model to ex-post estimate the trade cost changes of a free trade agreement, which is similar in the scope, namely the EU-Korea FTA. The estimated trade cost changes are used as a proxy for the potential trade cost shocks between EU and Japan. Together with observable tariff reductions, these trade cost changes are induced as trade cost shocks to inform the CGE model, which provides a data-driven ex-ante analysis of the potential effects of the EU-Japan EPA. We perform the counterfactual EPA scenario on three different baselines. First, we analyze the effects of the trade cost reductions due to the EU-Japan EPA based on a world as of today, without Brexit, TPP and other future FTAs, such as CETA. The second baseline assumes an economy with Brexit, thus UK left the European Union. The EU-Japan EPA is only implemented between the EU27 and Japan and excludes UK as a EPA partner. The third baseline includes Transpacific Partnership (TPP) agreement in the baseline.

We are not the first to study the impact of the EU-Japan EPA. Sunesen et al. (2010) assesses the impact of bilateral barriers to trade and investment between the EU and Japan. He approximates trade cost shocks through qualitative expert judgments. Benz and Yalcin (2015) quantify the EU-Japan EPA by using a single-sector Melitz (2003) type model featuring three regions, the EU, Japan and a rest of the world aggregate.The European Commission (2016) published a report about the potential impact of the EPA, using qualitative exercises and stakeholder consultations. Further, the European Commission (2018) published an economic impact assessment report of the EU-Japan EPA by using the general equilibrium tools provided by GTAP. The authors further qualitatively assess the potential reduction of technical barriers to trade and Sanitary and Phytosanitary Standards. A study of Lee-Makiyama (2018) shows descriptive evidence about the relationship of the EU and Japan and its potential fro growth. Kawasaki (2017) also uses the GTAP model to measure the impact of an EPA under the assumption that tariff rates go to zero immediately and non-tariff barriers (NTBs) are reduced by 50%. We contribute to the literature by providing a more data-driven approach to quantify the potential effects of the EU-Japan EPA. Our strategy does not require initial non-tariff barrier levels, expert judgments or qualitative assessments.

We document several novel results: First, the ex post evaluation of the EU-Korea agreement shows that the EU market opening has led to less substantial trade cost reductions than the one of its Asian partner and is quite heterogeneous across sectors. The counterfactual simulation shows that both, Japan and the EU experience very similar welfare gains in absolute terms. In relative terms, Japan's gains are three times as large as the EU's. The EPA leads to trade diversion in Japan towards Europe, especially Eastern Europe and away from former ASEAN countries. Within the EU, Italy is benefits more than Germany due to gains in agri-food and an fashion.While the German automotive sector is set nuder pressure. In the EU, the agri-food sector profits the most in relative terms. In absolute terms, the services sectors benefit the most, while the European automotive industry, the energy sector and the metal industry lose slightly due to the EPA. In Japan, the agri-food sector loses slightly. The largest Japanese gains are generated in various manufacturing sectors, such as the automotive industry and the chemical sector, followed by services. These findings are in line with previous, more qualitative studies. The second counterfactual scenario includes Brexit in the baseline. The welfare gains turn out to be substantially smaller for Japan if UK is not a member of the EU anymore. The third counterfactual scenario includes the implementation of the Transpacific Partnership (TPP) agreement in the baseline. It has little importance for the effects of the EU-Japan EPA.

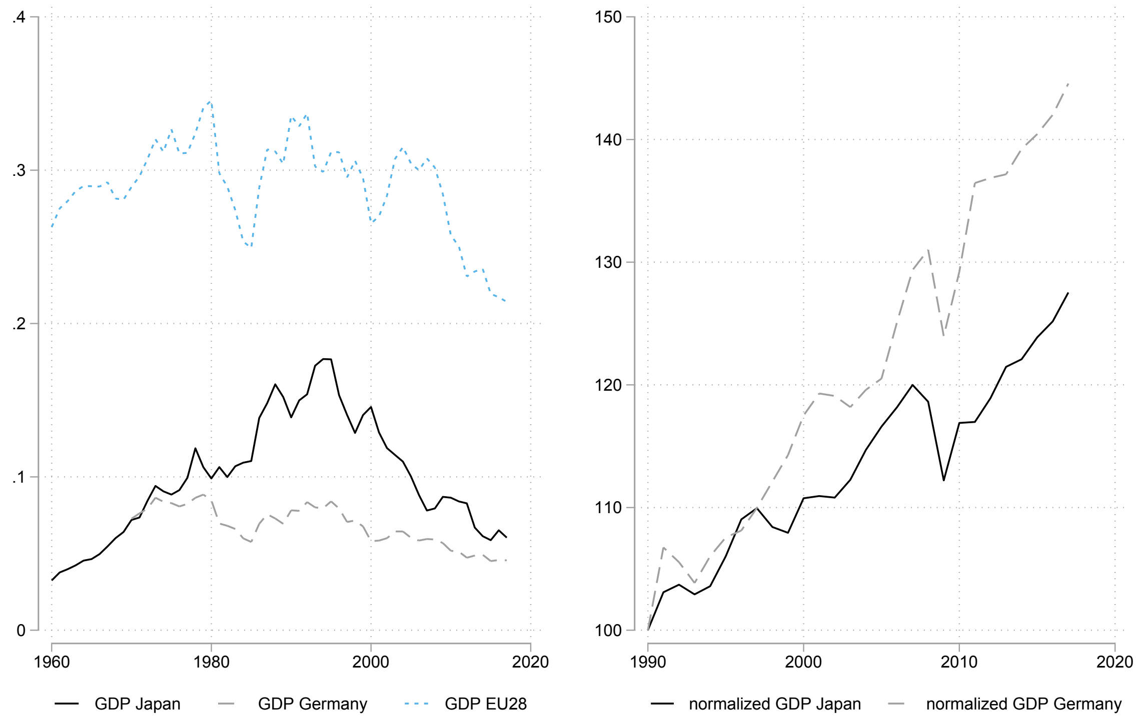
The remainder of the paper is organized as follows. Section 2 presents the methodological framework. Section 3 discusses the main data sources. Section 4 explains the empirical estimation method and discusses the gravity results. Based on the defined EU-Japan scenarios, we examine general equilibrium consistent results on trade and welfare in section 5. The final section concludes.

5.2 Descriptive Evidence of potential growth opportunities between EU and Japan

The ratification of the EU-Japan EPA is an agreement among two of the most advanced economies of the world. It is the culmination of a long history of cooperation between Japan and the EU. Since 1979 the European Commission has been encouraging European enterprises to enter the Japanese market and has given them concrete assistance through promotion programs such as the Executive Training Program and the EU Gateway Program. Since 1999, EU and Japan have a so called Business Round Table whose aim is to facilitate dialogue and exchange of views between EU and Japanese businesses. Since 2004, a cooperation framework to promote two-way investments exists. At the EU-Japan Summit of 28 May 2011, the EU and Japan agreed to work towards a new framework for their bilateral relations and to explore the feasibility to pursue an EPA. In line with the summit conclusions, a joint scoping exercise was conducted to determine the scope and the level of ambition of the joint undertaking. The exercise defined non barriers to trade that both sides considered as obstacles in bilateral trade and investment. Following the successful completion of the scoping exercise, in July 2012 the Commission recommended the Council to launch negotiations for an FTA and in November 2012 the Council authorized the Commission to start the negotiations. The first round of negotiations took place in Brussels in April 2013. In December 2017, negotiations were formally concluded.

The next part shows descriptive evidence why forming a trade partnership can potentially be of strategic relevance for the EU and Japan. Both regions are technologically advanced and belong to the category of high income countries.[1] But the share of world economic activity fell in both regions over the last two decade (see the left hand-side of figure 5.1). Compared to Germany, one of the most technologically advanced countries, Japan's GDP at a slower rate (see right hand-side of figure 5.1). Joining forces by forming a trade union could help to reverse this declining trend.

Figure 5.1: Shares in World GDP, current USD (1970-2015) and Evolution of real GDP per capita in Purchasing Power Parities, 1990=100, 1990-2015



Note: The left figure shows the share of the world GDP for Japan, Germany and the European Union from 1960 until 2017. The figure on the right hand-side shows the real GDP per capita in purchasing power parities with 1990 equal to 100, from 1990 to 2015. **Source:** World Development Indicators (2018), World Bank; own calculations.

[1] Measured at current market prices, the Japanese and EU economies combined account for 22 150 billion US-Dollar of GDP and 640 million consumers. The EU's GNI per capita lies at 32 778 and 38 550 US-Dollar for Japan in 2017 (measured in current USD), which lies at the upper bound of the World Bank's classification 'high income countries'.

Japan is an extremely interesting but ambivalent market for the European Union. The potential for growth opportunities becomes evident if one looks at very simple trade data. Japan is is technologically very advanced and is one of the main innovators of automated and robotized manufacturing. Compared to China, who surpassed Japan in terms of real GDP in 2012, Japan remains almost equal to the size of the Chinese market measured in consumption. As investors, Japan and China are of equal importance, at 8.4 and 8.6% respectively of global FDI outflows. Thus, the market is very promising.

A trade agreement and a reduction in trade barriers offers promising potential for welfare gains, because Japan is still relatively protectionist, in particular when looking at non-tariff barriers; see European Commission (2016). Compared to other OECD countries, Japan is a relatively closed economy. In 2011, only about 13.5% of its final demand is spent on foreign value added. In comparison, the share in Germany is about 25%; in the USA it is about 15%. Larger economies tend to serve a larger fraction of domestic demand with domestic production. The EU-Japan Economic Partnership Agreement can yield positive effects on Japan's economy and for the EU members. Table 5.1 illustrates the initial bilateral trade relationship between the EU and Japan in 2011, our baseline year of the simulation. It shows the volume of bilateral exports between EU28 and Japan. Further, the share of EU exports to Japan relative to the total EU exports are illustrated. The right part of the table shows the same columns for Japan. Although Japan amounts to almost 8% of world GDP (excluding the EU), the EU countries deliver not more than 3% of their overall exports to Japan. Room for expansion is evident. The export shares are especially small for EU's competitive manufacturing sectors, such as the machinery, automotive, or electronic equipment sectors. In contrast, the EU already constitutes an important trading partner for Japan.

Tariffs still represent a sizable barrier and their elimination is relevant for additional welfare gains. At the same time, it is worth to emphasize, that in comparison to other countries the average tariff rates between the EU and Japan are on average relatively low (e.g., China has a simple average MFN-bound rate of 10 per cent). A large share of these traded products between Japan and the EU is subject to tariffs which comply with the World Trade Organization's (WTO) regulations. At the same time, in both regions around one quarter of products are not subject to such import duties. Across all goods that are protected by tariffs around 85% of the bound duties turn out to be below 10%-points. Except for a handful of traded goods with tariff peaks, the remaining product lines reach import duties of around 30 per cent in the EU and 35 per cent in Japan. Peak tariff rates reach 60 per cent in Japan and 75 per cent in the EU. Figure 5.2 summarizes the prevailing applied tariff rates for EU industries for which trade data is available. The figure illustrates the simple average tariffs, which sometimes substantially

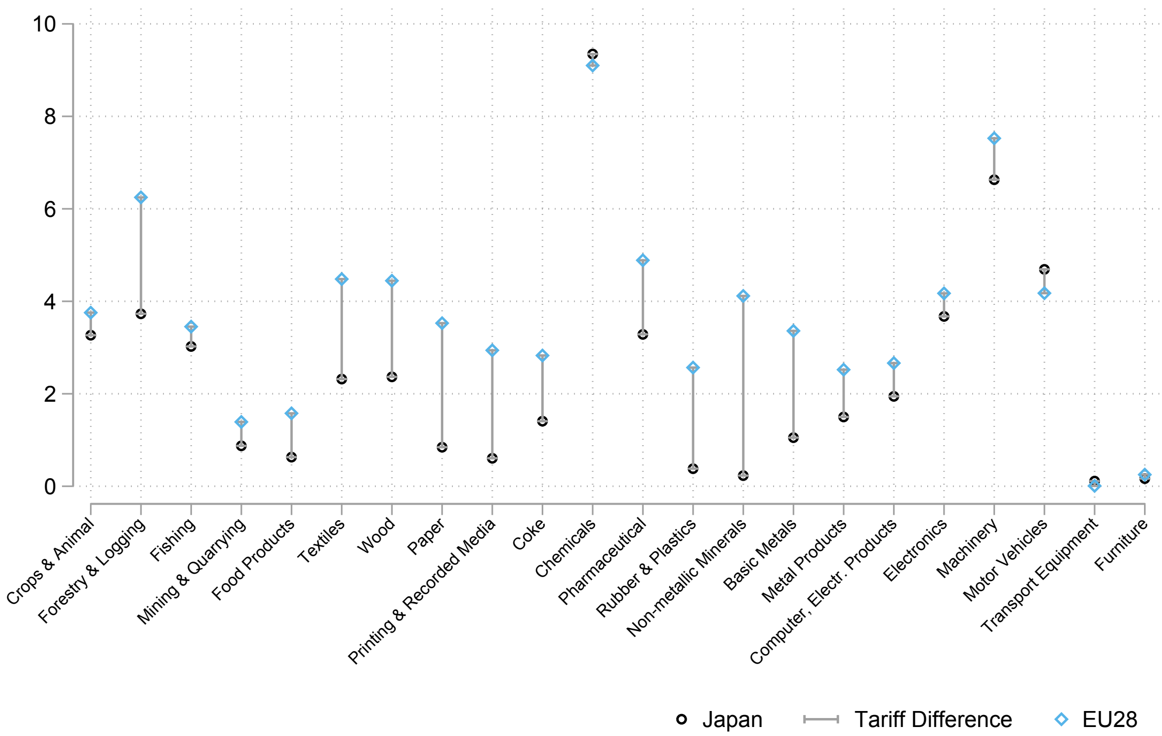
Table 5.1: Initial Bilateral Trade between EU and Japan, in bn USD & %

	Exports EU28		Exports JPN	
	total in bn USD	share EU-JPN in %	total in bn USD	share JPN-EU in %
Agri-Food	538	1.3	538	1.3
Automotive	679	1.4	163	11.5
Chemicals	1067	2.1	124	11.8
Electronic Equipment	241	0.8	89	11.8
Energy	32	0.1	0	0.7
Financial & Business Services	722	2.3	30	30.8
Machinery and Equipment	1234	1.3	294	13.5
Other Manufacturing	93	1.7	10	16.4
Metals	537	0.7	91	8.0
Raw Materials	585	0.8	39	8.5
Other Services	341	2.0	21	25.8
Textiles & Apparel	226	1.7	11	9.4
Trade and Transportation	515	2.9	39	31.9

Note: GTAP 9.1 (2011); Column 2 shows the initial export volume for EU28 countries to all destination including intra-EU markets. Column 3 shows the share of EU28 exports that go to Japan. Column 4 shows the total Japanese export volume to all destinations. Column 5 shows the share of these exports that go to the EU.

differ from the weighted ones. While Japan also shows a strong tariff variation across the listed industries, interestingly tariff rates in most of the industries turn out to be on average lower than in the respective European industry, except in the chemical industry. Tariffs for machinery products are on average 7.5% in the EU and 6.6% in Japan.

Figure 5.2: Bilateral Tariffs between EU28 and Japan, %



Note: The figure illustrates the simple average tariffs (in %) for Japan (in gray) and the EU28 (in blue). The figure shows the differences in the tariff heights between Japan and the EU28. **Source:** WTO Tariff Profiles; own illustration.

5.3 Theoretical Framework

The model is described in detail in Aichele et al. (2016) who extend the model of Caliendo and Parro (2015). The framework is a multi-sector version of the Eaton and Kortum (2002) model, a multi-country Ricardian general equilibrium model extended to incorporate rich value chain interactions, and non-tariff trade costs. The general class of models is described in detail by Costinot and Rodriguez-Clare (2014).

Consumption and Production The model has N countries, which are indexed by i, n and the J sectors by j, k. The representative consumer utility over final goods consumption is indexed by C_n^j and follows Cobb-Douglas preferences. α_n^j denotes the sectoral expenditure shares

$$u(C_n) = \prod_{j=1}^{J} {C_n^j}^{\alpha_n^j}, \tag{5.1}$$

with $\sum_j \alpha_n^j = 1$ and a country's labor force L_n is mobile across sectors (e.g. $L_n = \sum_{j=1}^{J} L_n^j$), but not across countries.

A continuum of goods ω^j is produced with labor $l_n^j(\omega^j)$ in each sector j and with a composite intermediate input $m_n^{k,j}(\omega^j)$ of each source sector k. This gives us the following production function:

$$q_n^j(\omega^j) = x_n^j(\omega^j)^{-\theta^j} \left[l_n^j(\omega^j)\right]^{\beta_n^j} \left[\prod_{k=1}^{J} m_n^{k,j}(\omega^j)^{\gamma_n^{k,j}}\right]^{(1-\beta_n^j)}, \tag{5.2}$$

Every sector j of each country n has a value added share, $\beta_n^j \geq 0$ and the cost share of source sector k in sector j's intermediate costs$\gamma_n^{k,j}$, with $\sum_{k=1}^{J} \gamma_n^{k,j} = 1$, which indicates that sectors are interrelated because sector j uses sector k's output as intermediate input and vice versa. The inverse efficiency of good ω^j in sector j and country n is the $x_n^j(\omega^j)$, while θ^j is the dispersion of efficiencies in a sector j. The lower θ^j the lower is the dispersion of productivity across the goods ω^j.

An input bundle's dual cost c_n^j depends on the wage rate w_n and the price of the composite intermediate goods k of country n.

$$c_n^j = \Upsilon_n^j \, w_n{}^{\beta_n^j} \left[\prod_{k=1}^{J} p_n^k{}^{\gamma_n^{k,j}}\right]^{(1-\beta_n^j)}, \tag{5.3}$$

The only difference between the sectoral goods ω^j is their efficiency $x_n^j(\omega^j)$, thus the goods can be depicted as x_n^j. Υ_n^j is a constant.

We denote by the trade costs of delivering sector j goods from country i to country n by κ_{in}^j. They consist of ad-valorem tariffs $\tau_{in}^j \geq 0$ and iceberg trade costs $d_{in}^j \geq 1$. So, $\kappa_{in}^j = (1+\tau_{in}^j)d_{in}^j$. In line with the gravity literature, the iceberg trade costs are modeled as a function of bilateral distance, regional trade agreements, and observable trade cost proxies as $d_{in}^j = D_{in}^{\rho^j} e^{\delta^j \mathbf{Z}_{in}}$. D_{in} is the measure for bilateral distance while $\mathbf{Z}_{in}$ is a trade cost shifting vector (e.g. RTAs or other trade policies). With perfect competition and constant returns to scale, firms charge the following unit costs:

$$p_{in}^j(x_i^j) = \kappa_{in}^j \left[x_i^j\right]^{\theta^j} c_i^j. \tag{5.4}$$

Intermediate goods are characterized by the efficiency $x^j = (x_1^j, \ldots, x_N^j)$ of producing countries, and country n searches across all trading partners for the cheapest supplier. Good x^j is bought for price

$$p_n^j(x^j) = \min_i \left\{p_{in}^j(x_i^j); i = 1, \ldots, N\right\}. \tag{5.5}$$

Countries differ in their productivity across sectors, which introduces for comparative advantage. A country's produced set of goods follows an exponential cumulative distribution function, and the productivity distribution is assumed to be independent across countries, sectors, and goods. The joint density of x^j is

$$\phi^j(x^j) = \left(\prod_{n=1}^{N} \lambda_n^j\right) \exp\left\{-\sum_{n=1}^{N} \lambda_n^j x_n^j\right\}, \tag{5.6}$$

where λ_n^j shifts the location of the distribution, and measures the absolute advantage. In contrast, $\theta^j > 0$ indexes productivity dispersion, thus comparative advantage.

Each sector j's composite intermediate good q_n^j is produced with a Dixit-Stiglitz CES technology and η^j denotes the elasticity of substitution. $r_n^j(x^j)$ depicts the demand for intermediate good x^j, with sum of costs for all the intermediate goods x^j being minimized, subject to

$$\left[\int r_n^j(x^j)^{\frac{\eta^j-1}{\eta^j}} \phi^j\left(x^j\right) dx^j\right]^{\frac{\eta^j}{\eta^j-1}} \geq q_n^j. \tag{5.7}$$

The demand for x^j is dependent on the variety's price relative to the sectoral price index $p_n^j = \left[\int p_n^j\left(x^j\right)^{1-\eta^j} \phi^j\left(x^j\right) dx^j\right]^{\frac{1}{1-\eta^j}}$:

$$r_n^j(x^j) = \left(\frac{p_n^j(x^j)}{p_n^j}\right)^{-\eta^j} q_n^j. \tag{5.8}$$

The composite intermediate good q_n^j can then be used to produce intermediate inputs of each sector k, for the production of final consumption goods.

Trade Once one solves for the price distribution and integrates over the sets of goods where each country i is the lowest cost supplier to country n, the composite intermediate goods price is given by

$$p_n^j = A^j \left(\sum_{i=1}^{N} \lambda_i^j \left(c_i^j \kappa_{in}^j\right)^{\frac{-1}{\theta^j}}\right)^{-\theta^j}, \tag{5.9}$$

where $A^j = \Gamma\left[1 + \theta(1-\eta^j)\right]^{\frac{1}{1-\eta^j}}$ is a constant. The prices are correlated across all sectors (via c_i^j) and the strength of the correlation depends on the input-output table coefficients $\gamma_n^{k,j}$.

The expenditure share π_{in}^j for source country i's goods in sector j of country n follows the common gravity equation, can be applied to gross exports:

$$\pi_{in}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{in}^j\right]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^N \lambda_i^j \left[c_i^j \kappa_{in}^j\right]^{\frac{-1}{\theta^j}}}. \tag{5.10}$$

General equilibrium Y_n^j denotes the gross production's value of varieties in sector j. Sector j, Y_n^j has to be equal to the value of demand for sectoral varieties from all countries $i = 1, \ldots, N$.[2] The goods market clearing condition is given by

$$Y_n^j = \sum_{i=1}^N \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_i^j \quad \text{with} \quad X_i^j = \sum_{k=1}^J \gamma_i^{j,k}(1-\beta_i^k)Y_i^k + \alpha_i^j I_i, \tag{5.11}$$

where national income consists of labor income, tariff rebates R_i and the (exogenous) trade surplus S_i, i.e. $I_i = w_i L_i + R_i - S_i$ and X_i^j is country i's expenditure on sector j goods. The first term on the right hand side gives demand of sectors k in all countries i for intermediate usage of sector j varieties produced in n, the second term denotes final demand. Tariff rebates are $R_i = \sum_{j=1}^J X_i^j \left(1 - \sum_{n=1}^N \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)}\right)$.[3]

The model is closed with an income-equals-expenditure condition, which takes into trade imbalances for each country n into account. The value of total imports, domestic demand and the trade surplus has to equal the value of total exports including domestic sales, which is equivalent to total output Y_n:

$$\sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{in}^j}{(1+\tau_{in}^j)} X_n^j + S_n = \sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_i^j = \sum_{j=1}^J Y_n^j \equiv Y_n \tag{5.12}$$

5.3.1 Comparative Statics in General Equilibrium

In accordance with Dekle et al. (2008b), the relative, global change in a variable from its initial level z to counterfactual z' is denoted by $\hat{z} \equiv z'/z$. $\hat{\kappa}_{in}^j = \frac{1+\tau_{in}^{j'}}{1+\tau_{in}^j}(e^{\delta^j(Z'_{in} - Z_{in})})$ is the change in trade cost due to the implementation of trade integration agreements.

[2] Our exposition differs from Caliendo and Parro (2015) in that they use total expenditure on composite goods instead of total production of varieties as endogenous variable. So, in Caliendo and Parro (2015) the value of gross production comprises all foreign varieties that are bundled into the composite good without generation of value added.

[3] Instead of the goods market clearing condition, one can also use the expenditure equation $X_i^j = \left(\sum_{k=1}^J \gamma_i^{j,k}(1-\beta_i^k)(F_i^k X_i^k + S_i^k) + \alpha_i^j I_i\right)$ as in Caliendo and Parro (2015).

The counterfactual changes in all variables of interest can be solved by using the following system of equations:[4]

$$\hat{c}_n^j = \hat{w}_n^{\beta_n^j} \left(\prod_{i=1}^{N} [\hat{p}_n^j]^{\gamma_n^{k,j}} \right)^{1-\beta_n^j}, \tag{5.13}$$

$$\hat{p}_n^j = \left(\sum_{i=1}^{N} \pi_{in}^j [\hat{\kappa}_{in}^j \hat{c}_i^j]^{-1/\theta^j} \right)^{-\theta^j}, \tag{5.14}$$

$$\hat{\pi}_{in}^j = \left(\frac{\hat{c}_i^j}{\hat{p}_n^j} \hat{\kappa}_{in}^j \right)^{-1/\theta^j}, \tag{5.15}$$

$$X_n^{j\prime} = \sum_{j=1}^{J} \gamma_n^{j,k} (1-\beta_n^k) \left(\sum_{i=1}^{N} \frac{\pi_{ni}^{k\prime}}{1+\tau_{ni}^{k\prime}} X_i^{k\prime} \right) + \alpha_n^j I_n', \tag{5.16}$$

$$\frac{1}{B} \sum_{j=1}^{J} F_n^{j\prime} X_n^{j\prime} + s_n = \frac{1}{B} \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{j\prime}}{1+\tau_{ni}^{j\prime}} X_i^{j\prime}, \tag{5.17}$$

where $\hat{w}_n$ are wage changes, X_n^j are sectoral expenditure levels, $F_n^j \equiv \sum_{i=1}^{N} \frac{\pi_j^{in}}{(1+\tau_{in}^j)}$, $I_n' = \hat{w}_n w_n L_n + \sum_{j=1}^{J} X_n^{j\prime}(1-F_n^{j\prime}) - S_n$, L_n denotes country n's labor force, and S_n is the (exogenously given) trade surplus. We fix $s_n \equiv S_n/B$, where $B \equiv \sum_n w_n L_n$ is global labor income, to make sure that the system is homogenous of degree zero in prices.

Equation D.3 shows the shift in unit costs occurring due to changes in input prices (i.e., wage and intermediate price changes). The trade cost changes directly affect the sectoral price index p_n^j, and the changes in unit costs have an indirect effect (see equation (D.4)).

Once the trade costs, unit costs and prices change, the trade shares will change in response. The intensity of this reaction is driven by the productivity dispersion θ^j. A higher θ^j implies bigger trade changes.

Equation (D.6) ensures goods market clearing in the new equilibrium and the counterfactual income-equals-expenditure or balanced trade condition is given by equation (D.7). The change in real income $\hat{W}_n$ is given by

$$\hat{W}_n = \frac{\hat{I}_n}{\prod_{j=1}^{J} (\hat{p}_n^j)^{\alpha_n^j}}, \tag{5.18}$$

which is the appropriate welfare measure in this model.

[4] See also Caliendo and Parro (2015). The feature of solving in counterfactual changes rather than levels reduces the set of parameters and moments that have to be estimated or calibrated. In particular, no information on price levels, iceberg trade costs, or productivity levels is needed.

To solve the system of equations for multiple sectors, we again relate to Caliendo and Parro (2015), who extend the single-sector solution algorithm proposed by Alvarez and Lucas (2007). We start with an initial guess about a vector of wage changes. Using (D.3) and (D.4), it computes changes in prices, trade shares, expenditure levels, evaluates the trade balance condition (D.7), and updates the change in wages based on deviations in the trade balance.

The model provides static level effects on real income and trade. As dynamic effects of trade disintegration are not taken into account, it provides a lower bound for the potential effects. Contrary to trade agreements, where effects occur after a phase-in[5], disintegration effects would potentially occur immediately.

5.4 Model Calibration and Scenario Definition

5.4.1 Data

Information on bilateral preferential and MFN tariffs is taken from Felbermayr et al. (2018d). The trade elasticities for the manufacturing sectors stem from Aichele et al. (2016) and for services sectors from Egger et al. (2015); see Table E.2 in the Appendix. To inform our scenarios, we estimate the sector-level trade cost effects of the EU-Korea agreement. For this purpose, we use the World Input-Output Database (WIOD) panel data from 2000 to 2014. The data because provides us with need information to properly identify the estimates of the gravity analysis.

Second, to calibrate the model, we use the Global Trade Analysis Project (GTAP) 9.1 database that provides us the data on expenditure shares α, cost shares β and γ, bilateral trade shares π, countries' total value added $w_n L_n$, and trade surpluses S.[6] The GTAP data is available for the year of 2011. Hence, in what follows, our assumption is that the structure of the world has remained approximately constant since 2011.[7] We do adjust

[5] This is particularly relevant for non-tariff trade costs. Evidence from existing FTAs shows that this phasing-in process usually takes between 10 and 12 years (see, e.g., Jung, 2012).

[6] We could calibrate the model using WIOD, but GTAP has much richer country detail; see Table E.4 in the Appendix. This is needed to properly capture the Japanese production networks in the ASEAN region. Further, it can distinguish 56 sectors with 15 of these representing services, while the rest shows agri-food and manufacturing sectors. The GTAP data has no panel dimension, and it does not provide information on intra-national trade.

[7] One could, of course, produce out-of-sample projections on the GTAP data, but we refrain from doing so since this would entail additional measurement error.

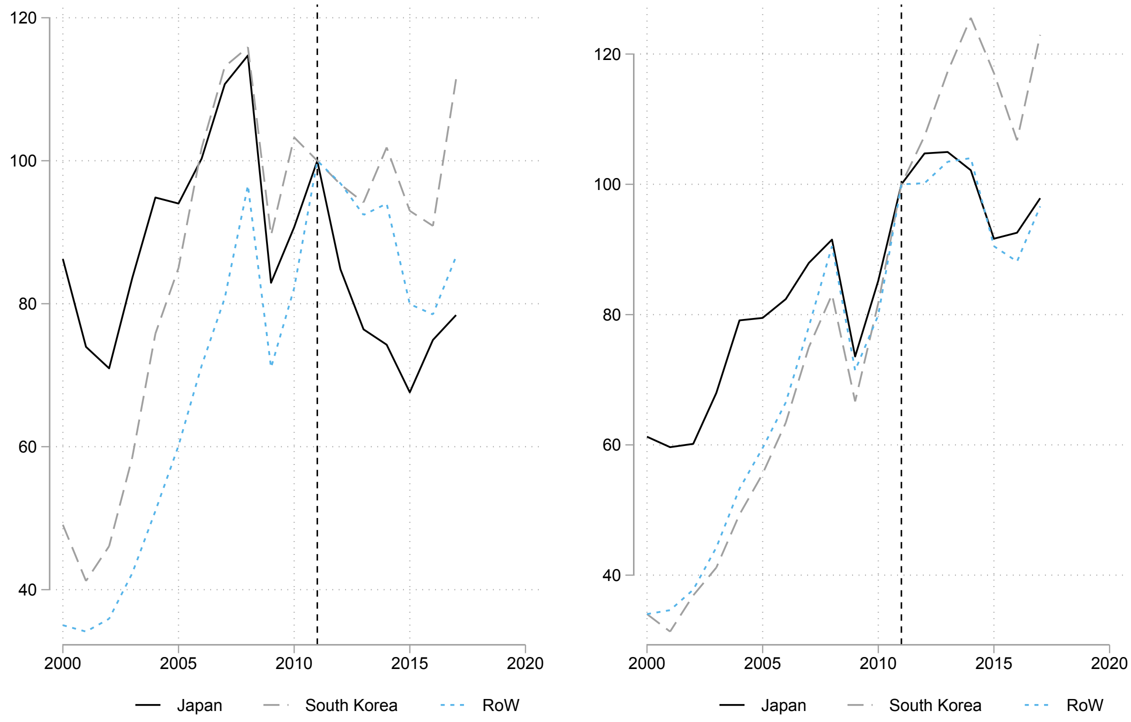
our baseline for observed trade policy changes (new FTAs concluded, changes in tariffs) that occurred between 2011 and 2018.

5.4.2 Learning from EU-Korea for EU-Japan

While the tariff changes agreed upon in the EU-Japan EPA can be simply taken from the published text, it is harder to predict the extent of trade costs, which might be reduced due to the numerous vertical and horizontal provisions on NTBs. In this paper, we prefer a data-driven approach over the more conventional strategy to use expert judgment. More specifically, we use an econometric ex-post estimation of the trade cost effects of the EU-Korea trade agreement, which is in force since 2011, to approximate the trade cost savings expected from the EU-Japan free trade agreement. This allows us to incorporate sectoral heterogeneity, asymmetry between trade partners, and it also ensures that the scenarios are feasible.

Data availability constraints allow us to solely exploit the EU Korea FTA as a proxy for the EU-Japan EPA because CETA was provisionally applied in 2017, thus it is not observable in our data. The Singapore FTA is still under negotiation and can therefore not be exploited either. We argue that the EU Korea FTA sufficiently proxies the potential trade cost reductions between the EU and Japan. Chowrdy et al. (2018) provide a detailed study on the similarities between the EU-Japan EPA and the three new generation FTAs (CETA, EU-Singapore, EU-Korea). The EU-Korea agreement is a modern agreement, which, however, falls short from the most ambitious pacts that the EU (EU-Canada) and Japan (TPP-11) have concluded so far. According to Chowrdy et al. (2018), the EU-Japan EPA is still more similar to the EU-Korea FTA in terms of structure, coverage, and depth. Both, the EU-Japan EPA and the EU-Korea FTA include commitments on goods and services trade, public procurement, intellectual property and technical barriers. A descriptive analysis of underlying trade patterns between the EU and the comparison country substantiates similarities between South Korea and Japan. Korea has more similarities to Japan in its economic structure than any other large economy with which the EU has an FTA, i.e., it is a resource-importing country, has significant machinery and automotive sectors, and operates production networks in Asia. Also, Korea and Japan have similar bureaucratic systems and heavy government regulations. Thus, it is plausible that NTBs share similar characteristics. Further, geographical distance from the EU is similar to Korea and Japan. Likewise, cultural distance (language, business culture) are also comparable. Clearly, our assumption is bold. We view it as complementary to other papers that base scenario definitions on expert judgment.

Figure 5.3: Bilateral Imports and Exports of EU28 with Japan, Korea and Rest of the World, 2011=100, 2000-2020



Note: The figure on the left hand-side shows the evolution of European imports from Japan, South Korea and the Rest of the World. The figure on the right hand-side shows the European exports to Japan, South Korea, and the Rest of the World. The data is normalized with 2011 equal 100. **Source:** UN-Comtrade (2017), own calculations.

The subfigures of 5.3 depict the bilateral imports to (left) and bilateral exports (right) from the EU28 member states from and to Japan, South Korea and the rest of the world. Both figures are normalized (2011 = 100). Since the inception of the EU-Korea free trade agreement in July 2011, both EU exports and EU imports to and from Korea have outperformed Japanese trade with the EU as well as overall EU trade. Without providing a formal proof, the illustrations highlight the possibility that the divergence is due to the FTA. It also visualizes the hope that a trade agreement with Japan could trigger a similar development. We turn to a more rigorous econometric analysis below.

We use a gravity model consistent with our theoretical framework to estimate the effects of the EU-Korea FTA. The econometric technique isolates the effects of the trade agreement from other determinants of bilateral trade such as price levels, the development of the GDP, other trade policy initiatives, or changes in the structure of comparative advantage. The gravity analysis follows exactly the work of Yotov et al. (2016). The specification uses econometric panel data methods on bilateral sector-level trade flows for the period 2000-2014, which stems from the latest version of the WIOD data. The sample for the main estimation includes all 56 sectors and the estimation is based on more than 1.5 million observations. The use of panel data is necessary because it ensures to comprehensively treat time-invariant trade costs. Second, following Baier and Bergstrand (2007), we are able to treat potential endogeneity of the policy variables of interest. We follow gravity theory to properly define the set of fixed effects that are needed for the estimations. Informed by the sectoral and by the panel gravity literature, the main specification is estimated with exporter-sector-time and importer-sector-time fixed effects to account for the unobservable multilateral resistance terms highlighted by Anderson and Van Wincoop (2003). These fixed effects also absorb all other observable and unobservable characteristics on the importer and on the exporter side. Following the recommendations of Santos Silva and Tenreyro (2006) to account for heteroskedasticity and to take into account the information that is contained in the zero trade flows, we use the PPML estimator in order to obtain our main estimates. In the sensitivity analysis we also obtain OLS estimates in the usual log form, hence zero trade flows drop out.

In order to take advantage of all the information contained in the data, we estimate the main specification with data for all years in the sample. This is important because we only have four post-agreement years in the data, namely 2011 until 2014. Bergstrand et al. (2015) argue that the RTA estimates from panel gravity specifications may be biased upward because they may capture general effects of globalisation. To address this issue, our main specification follows Bergstrand et al. (2015) and introduces yearly dummy variables.

Baier et al. (2016) further show that the effects of FTAs might be asymmetric. Following Baier et al. (2016), we allow for the effects of the EU-Korea FTA to be different for EU exports to Korea and for Korean exports to the European Union. In addition, we also allow the pair fixed effects to be directional. Finally, in addition to accounting for the specific effects of the EU-Korea FTA, which are of primary interest here, the main estimate also controls for the presence of any other regional trade agreement that may have impacted trade between the countries in our sample during the period of investigation.

Our main estimating equation is derived from equation (B.8):

$$X_{ij,t}^{k} = \exp\left[\frac{\delta_1^k}{\theta^k} EUKOR_{ij,t} + \frac{\delta_2^k}{\theta^k} KOREU_{ij,t} + \frac{\delta_3^k}{\theta^k} \mathbf{Z}_{ij,t} + \pi_{ij,t}^k + \chi_{ij,t}^k + \mu_{ij,t}^k\right] + \varepsilon_{ij,t}^k. \tag{5.19}$$

$X_{ij,t}^{k}$ denotes the nominal bilateral trade flows from exporter i to importer j in sector k at time t, which also include intra-national trade flows. $EUKOR_{ij,t}^{k}$ is an indicator variable that is equal to one for exports from EU to Korea for the years after 2010 and it is equal to zero otherwise. Similarly, $KOREU_{ij,t}$ is a dummy variable that takes a value of one for Korea's exports to EU after 2010, and it is equal to zero otherwise. $\mathbf{Z}_{ij,t}$ is a vector of included explanatory variables, such as $RTA_{ij,t}$, which is an indicator for the presence of any other regional trade agreement.[8] The control variable is a dummy variable, which takes the value one if both trading partners are part of the agreement at time t and zero otherwise. Further, the vector includes an FTA dummy variable, which takes the value one, if both partners agree to ratify a free trade agreement and again zero otherwise. Moreover, dummy variables for being member of a customs union and GSP-type agreements are included. Further, the difference between Economic Integration Agreements and other free trade agreements is made. Economic integration agreements go beyond pure tariff reductions and which are more difficult to quantify because they also affect investments.

Finally, $\pi_{ij,t}^{k}$, $\chi_{ij,t}^{k}$ and $\mu_{ij,t}^{k}$ are exporter-sector-time, importer-sector-time, and directional sector-pair fixed effects, respectively. The two first ones control perfectly for the theoretical multilateral resistances and for all other observable and unobservable variables at the exporter-sector-time and the importer-sector-time dimensions. The latter one absorbs all time-invariant trade costs by allowing them to vary by sector and in each direction of trade. In addition, it is equivalent to implementing the average treatment effect methods to account for endogeneity of regional trade agreements following Baier and Bergstrand (2007).

A key aspect for the simulation exercise are unbiased estimates to back out the actual non-tariff barrier effects. Since we are able to also control for observable tariff lines, which then gives us the trade cost elasticities, we can back out the pure non-tariff barrier trade creation effects.[9]

Results based on aggregate trade data. Table 5.2 shows results based on aggregate trade. The EU-Korea FTA seemingly promoted trade between the EU and Korea, which is supported by the positive and significant estimates of the coefficients on each of the two indicator variables. The agreement increased EU exports to Korea on average by

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[8] The EU Korea FTA is excluded.

[9] adding $\frac{1}{\theta^k}(1+\tau_{ij,t})$, to the right hand-side of the gravity equation. Since we know the trade cost elasticity $\frac{1}{\theta^k}$, we can then back out the pure non-tariff barrier increase.

52% and Korean exports to the EU by 14%.[10] Interestingly, EU exports increased by much more than Korean exports, reflecting an asymmetric reduction in trade costs due to the FTA. This is not surprising, as evidence suggests that NTBs are more pronounced in Korea than in the EU; a similar observation is made for Japan by Lakatos and Nilsson (2017).[11]

Column (2) presents an OLS estimator and finds very similar results. In column (3) we revert to PPML but differentiate between different regional trade agreements. Not surprisingly, we find that membership to the European Customs Union boosts trade quite substantially.[12] One has to be aware of the fact that the estimates presented here are to be understood as partial equilibrium effects, and that additional trade effects from higher incomes as well as trade diversion effects are not accounted for. These will be dealt with in the subsequent GE analysis.

Results based on sectoral trade data. The above evaluation of aggregate data illustrates general patterns. However, for our multi-sector trade model, we require sectoral estimates. Consistent with our theoretical model, we specify sector-level gravity regressions that are similar to the aggregate one used above. Results are shown in Table 5.3 and in table E.1.[13]

The table reveals several interesting results. First, in line with the findings of Table 5.2, on average, the effects on EU exports are stronger than on Korean exports. However, there is substantial heterogeneity across the sectors, and the available time span is relatively short. 92% of the effects of EU-Korea FTA on EU exports to Korea are positive, with 84% being statistically significant. 73% of the estimates of the EU-Korea FTA's effects on Korean exports to the EU are positive, with more than half of them being statistically significant. Another interesting pattern is the fact that the effects are on average stronger for goods than for services.

The results suggest a relatively symmetric trade-creating effect ranging between 28% (EU exports) and 34% (Korean exports) for the crop and animal production. This result can

[10] The trade creation effects are computed from the estimated effects by applying the formulas $100\% * \exp 0.42 - 1 = 52\%$. All other point estimates presented in the table can be interpreted similarly.

[11] Note that as of 2014, the last year in our sample, the agreement is not fully phased in and the economic effects have certainly not fully ramped up either. Hence, the estimated effects can be understood as lower bounds of the long-run effects. Also note that the asymmetry is not driven by the strong depreciation of the Euro vis-à-vis the Won, as the inclusion of country-year fixed effects effectively controls for currency movements.

[12] Note that this effect is identified through the Eastern Enlargement of the EU only; this explains the relative low effects.

[13] The sector classification is based on the WIOD data. We map the WIOD sectors into GTAP sectors using an appropriate concordance table.

Table 5.2: Gravity Estimates of the Aggregate Trade Effects of the EU-Korea FTA

	(1) Main	(2) OLS	(3) Type of agreement
EU → KOR	0.42	0.42	0.43
	(0.04)**	(0.03)**	(0.04)**
KOR → EU	0.13	0.17	0.14
	(0.04)**	(0.02)**	(0.04)**
Other RTAs	0.02	0.2	
	-0.02	(0.01)**	
Economic Integration Agreements			0.07
			(0.02)**
FTAs			-0.07
			(0.02)**
Customs Unions			0.28
			(0.02)**
GSP-type Agreements			0.22
			(0.05)**

Note: Own estimation, based on WIOD (2017) data. Note: Standard errors in parentheses, + $p < 0.10$, * $p < .05$, ** $p < .01$. Number of observations: 1,515,818. All regressions include a full set of yearly dummy variables for international borders for each year in our sample. All regressions use PPML estimates, except (2).

be translated to the EU and Japan case because both regions have relatively restrictive barriers for the agricultural sectors and once these decrease, we can expect equal trade creation effects in both regions.

The Japanese market for agricultural products is the fourth important one for EU's respective exports. In total, EU's agricultural exports to Japan are worth more than 20 times of Japanese exports towards the EU. Up until today, European firms face lots of trade barriers for exports. The EU-Japan EPA will grant easier access to the Japanese market. Equally, the Japanese exports in the agricultural sector will be granted more opportunities to sell the products to the European consumers. In fishing and aquaculture, the trade creating effects amount to 102% for the EU, while we have no evidence for higher exports from Korea to the EU. This result is also plausible for the EU-Japan example because Japan's non-tariff barriers seem to be stricter compared to international standards in the fishery sector. Satisfying the required quality and safety standards can be costly. A trade liberalization with accompanying decreases of strict non-tariff barriers will lead to higher trade creation effects for the respective trading partners (here: the EU). In the area of processed food, beverages, and tobacco, the situation is relatively balanced with positive effects of 29% on EU exports and of 18% on Korean exports. Trade in textiles, apparel, and leather was stimulated as well, but the effects do not come

Table 5.3: Aggregated Sectoral Trade Creation Effects (%) of the EU-Korea FTA

	Trade Creation Effects in %			
	Mean EU(%)	p-value	Mean KOR(%)	p-value
Agri-Food	32.24	0.02	25.63	0.07
Raw Materials	43.20	0.07	38.67	0.01
Textiles & Apparel	13.00	0.48	21.05	0.08
Energy	76.30	0.00	44.80	0.00
Chemicals	547.00	0.00	130.00	0.00
Metals	57.10	0.01	12.67	0.65
Automotive	53.60	0.00	30.60	0.02
Machinery and Equipment	50.15	0.03	15.45	0.49
Electronic Equipment	31.00	0.00	24.20	0.01
Other Manufacturing	60.50	0.00	15.40	0.17
Trade and Transportation	158.32	0.07	-11.20	0.11
Financial & Business Services	57.13	0.00	24.03	0.12
Other Services	54.49	0.00	15.25	0.52

Note: Own estimates, based on WIOD (2014) data. The table illustrates the simple mean of the coefficients and p-values of all GTAP sectors, which aggregated into the depicted broad categories. A detailed table can be found in the appendix (see table E.1). It depicts each of the coefficients, which are translated into percentage trade creation effects. P-values below 0.10 denote statistical significance at least at the 10 percent level. If cell is blank it means that no sectoral estimate could be provided due to the lack of sufficient transactions in this area. + $p < 0.10$, * $p < .05$, ** $p < .01$.

out as statistically significant. This is different for the manufacture of wood and cork, where, albeit from low initial levels, exports went up by 41% and 36%, respectively.

Substantial trade creation effects are reported in the manufacturing sectors. The effects tend to be stronger for the EU than for Korea. The automotive sector (ID 20) plays an especially important role. While Korean exports have grown by 47%, the EU exports increased by some 41%. In contrast, EU exports in the transport equipment sector expanded by almost 80% and is thus a much more asymmetric development. The effect is mainly driven by the aircraft sector. Korean exports, on the other hand, did not grow.[14] Easier access towards each of the markets will likely make imports of Japanese manufacturing products and its components cheaper. The same is true for Japan's exports towards the EU. Further, the econometric analysis shows strong heterogeneity across the services sectors. Though, some effects are very large numerically, one has to be aware

[14] The point estimates of the petroleum sector (ID 10) is 1.867 for EU exports and suggests that trade has multiplied by a factor of 5. This is a somewhat surprising result, but has also been noticed by Forizs et al. (2016). Accordingly, the EU mineral product exports increased substantially in 2012 and tapered off in the subsequent years. Supposedly the main drivers were increased EU oil exports, liquefied natural gas and oil preparations.

that they are mostly not statistically significant because the level of trade was almost zero in the initial situation. The analysis reveals rather symmetric trade creation effects for the construction industry (ID 27). While, the EU exports increased by 39%, the Korean exports expanded by 26%. Retail trade is confronted with positive effects of 54% for the EU and of 27% for Korea. The air transport services expanded substantially (In the EU by 84% and 33% in Korea). The effects on trade in postal services (ID 35) or in audiovisual media (ID 38) are not statistically significant. The publishing and telecommunication services exports from Korea to the EU could not benefit, while the effect is positive for the vice versa case. Large trade creation effects are evident in both financial services sectors, but the EU benefits more than Korea. This can also be seen in other services sectors. Exports in the EU's insurance sector (ID 42) more than doubled while Korean exports grew by only 30%. The advertising sector (ID 48), public administration and defense do not experience trade creation effects. Opposed to that, EU exports to Korea increase by 117% in the health care sector. Korean exports to the EU in this sector increased as well, but only by 6%.

5.4.3 Counterfactual Scenarios

In our scenarios, we assume that tariffs are decreased to zero, and non-tariff barriers are reduced exactly as observed for the EU-Korea FTA. For that purpose, we use the results of our ex-post evaluation of the EU-Korea FTA and the estimates of $1/\theta^k$ reported in Table E.2 in the Appendix to calculate the implied changes in iceberg trade costs following equation (5.4).

There are several reasons why our results show a lower bound of the potential outcomes: First, Japan is a larger economy than Korea. Evidence from the literature shows that larger countries have more bargaining power in trade negotiations, which might lead to higher benefits for the ones estimated for Korea. Second, the data available for the structural gravity estimation to identify the causal effects for the NTBs goes from 2011 to 2014. Thus, the effects stemming from the EU-Korea FTA might not fully be observed in the data because FTAs take longer time to fully unfold. Further, the model features only static gains; the dynamic gains from trade are not modeled. They can be very substantial; see Felbermayr and Gröschl (2013) for empirical evidence. Moreover, Japan has a different way of serving foreign markets compared to most EU countries. Rather than producing at home and to export, its firms serve foreign markets via local production. Through this strategy, Japanese firms have insulated themselves from trade costs; however, as a consequence, lowering trade costs is of relatively little advantage to them. So, Japanese exports do not rise too much in absolute and in percentage terms. Imports, bound by the model to exports in order to keep trade surpluses constant at their 2014 level, and cannot increase very strongly, neither. This also keeps welfare gains down. Since Jung (2012) finds that FTAs take between 8 and 12 years to fully unfold, we square the trade cost savings factors, such that we effectively estimate the general equilibrium effects after an implementation period of 8 years. Given the findings of Jung (2012), we may underestimate the true effects by as much as 50%.

S1: The counterfactual scenario replicates a deep and comprehensive free trade agreement with complete tariff elimination in all sectors, between the EU and Japan. Further, the non-tariff measures, modeled to the example of the EU-Korea agreement of 2011, are reduced at the respective amount for the EU-Japan trade partners. NTBs are not directly reduced for third countries, but will unambiguously affect third countries via spillover effects. The baseline of this counterfactual scenario assumes a world as of January 1st, 2018. Rising protectionist measures, such as Brexit or ongoing trade war measures (e.g. tariff increase between the US and China) are not regarded.

S2: Additionally, we compute a scenario that accounts for the exit of the UK from the EU. We therefore construct a baseline, which anticipates Brexit. We model a tough Brexit; i.e., the EU and the UK reintroduce tariff barriers, and non-tariff barriers reemerge to the level observed with other WTO members. Brexit implies that the EU-Japan EPA does not apply to UK. The actual counterfactual scenario introduces the EU-Japan EPA between the EU27 and Japan, with the baseline including Brexit. Tariffs are eliminated in all sectors. The change in non-tariff barriers stems from the ex-post trade cost estimation of the EU-Korea agreement of 2011. They are reduced at the respective amount for the EU27-Japan trade partners.

S3: In the baseline of the third scenario the TPP-11 agreement of Japan with 10 other pacific nations is already in place. On such a modified baseline, the counterfactual scenario S1 is applied.

5.5 General Equilibrium Results

Our general equilbrium analysis captures all general equilibrium feedbacks, e.g. those through trade diversion effects or changes in aggregate income. In contrast, the gravity estimates presented in the previous section refer to partial equilibrium effects of the agreement because incomes and aggregate prices are taken as given. The advantage of our approach is that no direct measures of observed reductions in non-tariff trade costs are needed, and the simulation exercise is cleanly tied to the gravity estimation. The model framework allows for drawing conclusions about the EU-Japan EPA on the structure of bilateral trade flows at the GTAP 9.1. level of aggregation, aggregate trade (volumes and openness measures), levels of value added, employment, emissions, and price levels, both at the sectoral and on the aggregate levels, wages and overall price levels, measures of real per capita GDP and of welfare (compensating variation measures). Simulating the effects of the EU-Japan EPA in the frame of the model, two vectors will change compared to the status quo: first, the vector that reflects tariffs between the EU and Japan and second, the vector that reflects non-tariff measures. While the former is directly observable, the latter one is indirectly estimated by the partial equilibrium analysis.

We report effects on marco- and microeconomic outcomes, such as the real income changes, or sectoral value added and trade changes. In our Ricardian trade model, lowering trade costs allows countries to specialize more strongly in sectors in which the comparative advantage is the strongest. But such a trade liberalization does not necessarily lead to an overall welfare gain. Consumers benefit from lower prices, but they may source from more inefficient countries. At the same time, governments lose tariff income. Moreover, the preferential nature of trade liberalization gives rise to the Viner-ambiguity. The FTA may affect world market prices such that some partner countries could be hurt. Further, the European Union and Japan are both advanced economies with quite similar patterns of their comparative advantage in the manufacturing industry. Once countries have similar technological structures with similar domestic prices, a removal of trade barriers incites small trade flow changes and relatively small welfare gains, respectively. This makes the analysis of the EU-Japan trade agreement especially interesting. The next part will now present the results of the simulations and gives insights about the loser and winners in respect to the trade agreement members, other regions (e.g. Taiwan, ASEAN, etc.) and sectors within these regions.

5.5.1 Changes in Real Income

This section depicts the real income changes for certain countries and regions (also see equation 5.18). Table 5.4 shows the respective real income changes occurring because of the EPA between the EU and Japan under the three different baseline scenarios. The changes are sorted by the magnitude of effects of S1.[15]

[15] The aggregation of the regions can be found in the Appendix E.4.

The potential for growth in both regions is evident if one looks at the positive changes in real income across all scenarios. Japan's economy has been growing slowly after the burst of a real estate bubble in 1992. Measured in purchasing power parities the real per capita income has grown by only about 0.77% per year, while Germany's real per capita income increased by 1.35% per year. This resulted in a strong collapse of Japan's share in the value of world output (and demand, both measured in USD) from about 15% in 1990s to the value of 5.6% observed today (Germany: 4.6%). Nonetheless, together the EU and Japan account for more than a third of the world's GDP. Indeed, Japan is the third biggest economy of the world, after the US and China, and about 25% greater than Germany. An impulse in the form of such a trade agreement can therefore lead to relatively high changes of Japan's and EU's real income.

The effects for Japan are positive in all depicted scenarios. The largest positive changes can be seen in scenario S1 and S3. When Japan ratifies the TPP (with Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, and Vietnam) the changes in real income increase slightly (0.308 to 0.314%) (S3) compared to the scenario S1 because Japan's economy is stronger under the existence of TPP and can therefore also indirectly trade more with the European Union. The positive change on Japan's real income shrinks, once the baseline takes account of Brexit. Not only will a Brexit lead to UK leaving the European Union, but this also connotes that the UK dissolves from existing trade agreements. Japan will then have access to a smaller market with less consumers and potential buyers of Japanese products, which explains the smaller positive real income effects of Japan in scenario S2.

All EU countries are expected to benefit. Japan is one of Europe's most important trading partners, which explains the relatively large results for the European countries. For Germany, the fourth largest economy in the world (measured in current market prices), the effect of the EPA is the largest under Brexit because Germany will be able to substitute large parts of UK's initial trade with Japan.[16] The ratification of a TPP leads to slightly smaller positive changes than under S1. The positive change of the EPA almost vanishes for the UK once it leaves the European Union (S2). Only indirect trade channels lead to a small positive increase in real income of 0.01%.

The remaining countries and regions loose slightly because of the simulated trade agreement. The largest losses can be expected in Taiwan, Thailand and South Korea, which maintain close trade relationships with Japan. With the EPA in place, existing trade relationships between Japan and these respective countries will be substituted with trade

[16] Germany's real income increases by 0.0775% in scenario 1 and by 0.0804% in scenario 2.

Table 5.4: Counterfactual Real Income Changes, in %

	Real Income Changes in %				Real Income Changes in %		
	S1	S2	S3		S1	S2	S3
Japan	0.31	0.27	0.31	Europe, n.e.c.	0.00	0.00	0.00
UK	0.11	0.01	0.11	India	0.00	0.00	0.00
RoEU	0.10	0.10	0.10	Middle East	-0.00	-0.00	-0.00
Germany	0.08	0.08	0.07	Africa	-0.00	-0.00	-0.00
France	0.07	0.07	0.07	Latin America	-0.00	0.00	0.00
Italy	0.06	0.06	0.07	ASEAN, n.e.c.	-0.00	-0.00	-0.01
Vietnam	0.01	0.01	0.00	Malaysia	-0.01	-0.01	-0.01
Rest of World	0.01	0.01	0.01	China	-0.01	-0.01	-0.01
Oceania	0.01	0.00	0.00	Singapore	-0.01	-0.00	-0.01
Philippines	0.00	0.00	0.00	South Korea	-0.01	-0.01	-0.01
USA & Canada	0.00	0.01	-0.00	Thailand	-0.02	-0.02	-0.02
Indonesia	0.00	0.00	0.00	Taiwan	-0.03	-0.02	-0.03
World	0.05	0.04	0.05				

Note: S1 simulates the EU-JPN FTA based on the baseline that assumes the world existing as of January 1st 2018. S2 simulates the EU-JPN FTA under a hard Brexit. S3 simulates the EU-JPN FTA based on a world with a ratified TPP11.

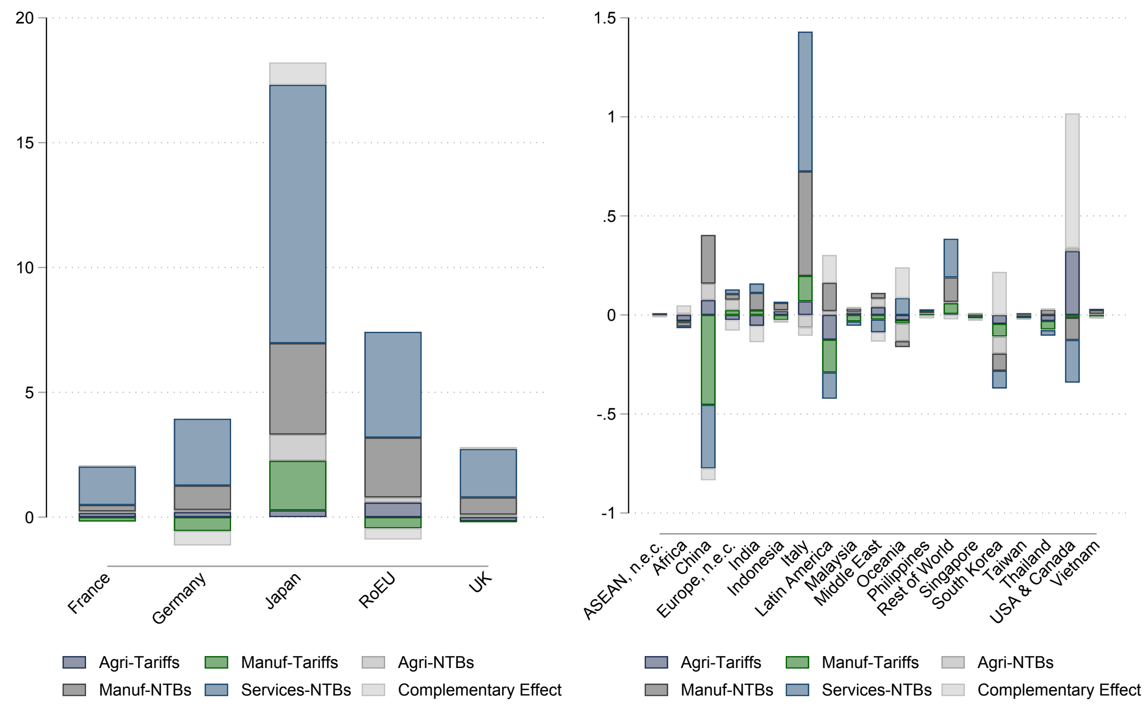
towards the EU. A more profound explanation can be found in section 5.5.4. Interestingly, Vietnam will be able to generate income gains as soon as Japan ratifies the agreement. The gains will even be larger without the TPP 11 than with its existence.

5.5.2 Welfare Decomposition

The remaining analysis concentrates on the first scenario because the three main scenarios deviate only slightly. Next, we decompose the aggregate welfare effects shown above into different parts. More specifically, we distinguish the welfare effect attributable to (a) the elimination of agri-food tariffs, (b) the elimination of manufacturing tariffs, the reduction of NTBs in (c) the agri-food sector, (d) the manufacturing sector and (e) the services sector. This different liberalization steps interact with each other: e.g., the benefits that accrue from NTB liberalization increase when tariffs are lowered, too, as the lowering of NTBs applies to a larger trade base. However, that complementarity effect (f) need not be positive, e.g., if tariff liberalization leads to expansion of trade which is relatively strongly affected by NTBs.

Figure 5.4 shows the main trade cost drivers of scenario S1. In both panels, the total gains in real income changes are sorted in decreasing order. The sum of income gains

Figure 5.4: Welfare Decomposition: Real Income Changes, in bn USD



Note: Both figures show the welfare decomposition of selected countries for scenario 1. The sum is equal to the change in welfare in scenario 1.

for Japan is 18.8 bn USD. 11% of the total is due to the reduction of manufacturing tariffs; agri-food tariffs add almost nothing. In Europe, the share of gains due to agricultural tariffs is 6%, while tariffs in manufacturing sectors almost shred the increase. The reduction of NTBs in the services sectors contribute 57% and 73% of welfare gains in Japan and the EU, respectively. The relatively minor role of tariffs for welfare gains is easily understood, given their low initial levels.[17] The complementarity effect is positive in Japan, contributing about 6% to total gains from trade. The reduction of NTB costs allows Japan to diversify its input sourcing particularly in those sectors which benefit strongly from tariff cuts (e.g., automotive). For the EU, in total, the complementarity effect is almost zero.

A couple of interesting additional observations stand out: The UK slightly loses from the elimination of agri-food tariffs between the EU and Japan because it is a strong net importer of food from the EU where additional demand from Japan drives up prices. The Rest of the World loses from tariff liberalization between the EU and Japan, but

[17] As tariff levels are low to start with, "triangular" welfare losses associated to them are small, too. NTB changes, in contrast, give rise to "rectangular" gains.

slightly benefits from lower NTBs. The reason is that the former measure tends to damage RoW's terms-of-trade, while the latter leads to resource savings which tend to benefit third parties as well. Finally, China is interesting: it loses from the elimination of manufacturing tariffs, but benefits from the elimination of agri-food barriers: as Japanese imports are diverted away from the US from where China imports a lot of agricultural goods, China benefits from better prices.

5.5.3 Changes in Sectoral Value Added

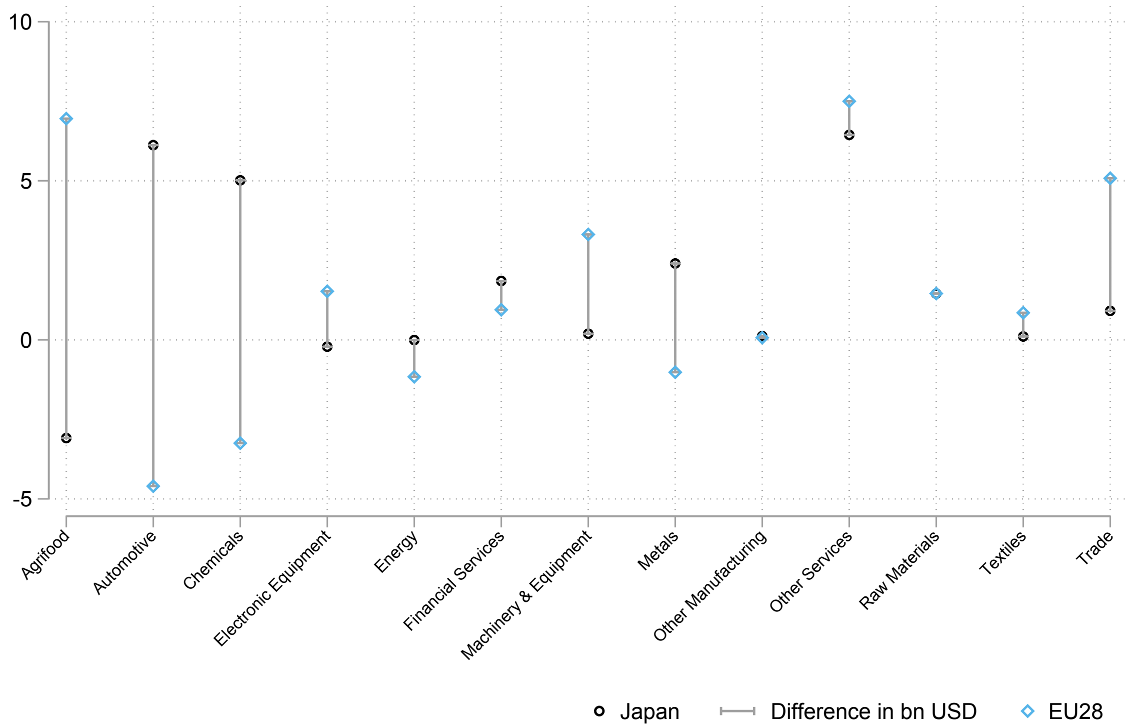
The next part looks at the sectoral value added effects of the EU and Japan. For this purpose, we concentrate on Scenario S1. When interpreting the findings illustrated by Figure 5.5 one should bear in mind that a reduction in a sector's value added does not necessarily mean that that sector's output shrinks and its gross exports shrink, since the FTA can affect the sectoral depth of value added.

In the services sectors, value added tends to increase in both regions (except finance, which shrinks in the EU). The value added in the service industries increases by a total of 13.5 bn US-Dollar in the EU and by 9.2 bn US-Dollar in Japan. Generally, the services sectors tend to absorb resources shed in the shrinking manufacturing (EU) and agri-food sectors (Japan). This is due to the fact that substantial NTB (i.e. iceberg) cost reductions act like productivity boosters for manufacturing, and this frees up resources to be used in the sector with the smaller NTB cuts. The reduction of non-tariff barriers provides great opportunities for the Japanese services sector. Compared to other OECD countries, Japanese services still have a lower average labor productivity, which can be ascribed to the relatively high protectionism against foreign firms in the domestic market. The protectionist measures comprise market entry restrictions, licensing, or regulations on foreign ownership. A liberalization will thereby enhance productivity in the competitive sectors.

The sector with the largest action appears to be agri-food. It adds 7 bn US-Dollars value added in EU while it sheds 3.1 bn US-Dollars in Japan. As detailed in the tables E.5 and E.6 in the Appendix, this is an increase of 0.82% of value added in Europe and a decrease of almost 1.5% in Japan. This result suggests the danger of a disruption in Japanese agriculture, but one needs to bear in mind that the results pertain to the (very) long run, as agri-food liberalization is staged over periods of up to 15 years.

Another sector of substantial churning would be automotive sector. Value added goes up by 6.1 bn US-Dollars (6.6%) in Japan, while it shrinks by 4.6 bn USD (1.6%) in the EU. This is because the EU has the higher tariffs, and NTB cost reduction is quite symmetric. A similar situation exists in the chemicals sector, which grows by 3.7% in Japan but shrinks in the EU by 0.5%.

Figure 5.5: Counterfactual Change of Sectoral Value Added in EU28 and Japan, in bn US-Dollars



Note: The figure shows the height of the value added changes in the EU28 (blue) and Japan (gray) , in bn USD, in scenario 1. **Source:** World Development Indicators, World Bank..

5.5.4 Changes in Trade

Outcomes of the two trading regions look quite complementary in the agri-food and goods sector. All the sectors that can generate gains in terms of value added are losing in the other region and vice versa. The only exceptions are the electronic equipment, machinery sector and the textiles and apparel sector. The services sectors behave similarly and are confronted with positive value added effects in both regions. The EU-Japan trade agreement would seemingly lead to diversion effects in the agri-food and goods sectors and to output creation in the service industry. The next part will now look into the changes of the trade patterns between Japan and its trade partners on an aggregate and sectoral level. Table 5.5 shows the change of Japanese exports, while table 5.6 shows the respective imports. Both tables are identical in their structure. The first column depicts the sectors, which were already shown in the table E.5. The remaining columns show the changes of Japanese exports/imports with the EU28, China, ASEAN, Rest of the World and USA/Canada as relative and absolutes changes (in mn USD). The last line shows the aggregate, bilateral trade change per bilateral partner. Let's first concentrate on the Japanese export structure:

Overall, Japan is able to increase its exports towards all countries and regions. Not surprisingly, Japan's exports to the EU increase to the largest extent, by 79 bn USD, which is equivalent to a 64% increase in Japanese exports towards the EU. The export increases towards the remaining countries and regions cannot be neglected either. Chinese imports of Japanese products increase by 23% (470 mio USD), ASEAN by 0.2% (200 mio USD), USA/Canada by 0.33% (520 mio USD) and imports of the Rest of the World from Japan by .2% (690 mio USD). Japanese imports from the EU increase by 74%, which is equal to an increase of 83 bn USD. Other than on the export side, Japanese imports from the remaining world decreases by 6.5 bn USD. Trade diversion away from third countries and towards the EU is evident on the import side.

The largest export increase towards the EU can be expected in the automotive sector (20.8 bn USD). Further, Japanese exports towards the EU increase in the chemical industry (14.9 bn USD). The same is true for the machinery and equipment, raw materials and metal industry that export additional products worth 25.3 bn USD more towards the EU. The increase of exports in the Japanese service industry is not negligible either.

The EU is already successfully active in Japan in some service sectors, such as in the construction, health and machinery services, with an export volume of around 2.5 billion, 760 million, and 670 million Euros in 2014. Japanese exports in these sectors turn out to be negligible so far, while in other industries a reversed pattern is prevailing. E.g. in the whole sale services, water transport, and technical activities Japan achieves trade volumes between 2.3 billion and 1 billion Euros while EU exports in the same industries remain on a relative low level. Implicitly, the new trade agreement somewhat balances the observed asymmetries across the different service sectors while at the same time there are several service industries in which both Japan and the EU can increase bilateral trade by eliminating non-tariff barriers and market access regulations, which are the only trade restricting measures in services compared to the primary and secondary industries.

Table 5.5: Change of Japanese bilateral Exports, in bn USD

	Change of Japanese Exports to				
	EU28 in bn USD	China in bn USD	ASEAN in bn USD	USA & Canada in bn USD	Total in bn USD
Agri-Food	0.39	0.01	0.00	0.01	0.41
Automotive	20.76	0.07	0.05	0.21	21.29
Chemicals	14.93	0.01	0.01	0.01	15.00
Electronic Equipment	0.71	0.08	0.03	0.03	0.91
Energy	0.00	-0.00	-0.00	-0.00	-0.00
Financial & Business Services	7.11	-0.01	-0.02	-0.07	6.96
Machinery and Equipment	9.18	0.40	0.17	0.37	10.66
Metals	5.48	-0.02	-0.02	-0.01	5.39
Other Manufacturing	0.11	0.00	0.00	0.00	0.11
Other Services	2.29	-0.02	-0.01	-0.04	2.18
Raw Materials	10.61	-0.03	-0.01	-0.01	10.53
Textiles & Apparel	0.94	0.01	0.01	0.00	0.98
Trade and Transportation	6.71	-0.03	-0.02	0.00	6.66
Total per region	79.21	0.47	0.20	0.52	81.09

Note: The list shows the aggregated sector categories. A detailed sector list can be found in the Appendix, table E.3.

Table 5.6: Change of Japanese bilateral Imports, in % and mn USD

	Change of Japanese Imports from				
	EU28 in bn USD	China in bn USD	ASEAN in bn USD	USA & Canada in bn USD	Total in bn USD
Agri-Food	11.51	-1.74	-1.71	-6.15	-5.45
Automotive	2.83	0.09	0.08	0.06	3.13
Chemicals	3.91	0.17	0.14	-0.02	4.16
Electronic Equipment	4.41	-0.30	-0.13	-0.06	3.77
Energy	0.00	0.01	0.29	0.03	2.71
Financial & Business Services	7.29	0.03	0.02	0.14	7.56
Machinery and Equipment	14.62	-1.24	-0.57	-1.03	11.22
Metals	1.15	0.07	0.10	0.02	1.62
Other Manufacturing	0.18	-0.01	-0.00	-0.02	0.13
Other Services	7.19	0.02	0.01	0.12	7.38
Raw Materials	10.46	-0.23	-0.22	-0.06	9.99
Textiles & Apparel	2.20	-4.18	-0.19	-0.12	-2.62
Trade and Transportation	17.36	-0.38	-0.27	-0.84	14.91
Total per region	83.10	-2.93	-0.99	-2.77	76.63

Note: The list shows the aggregated sector categories. A detailed sector list can be found in the Appendix, table E.3.

5.6 Conclusion

This paper provides a quantitative analysis of the trade and welfare effects of the forthcoming EU-Japan Economic Partnership Agreement, the so far largest agreement that both the EU and Japan have concluded as of today. Its conclusion is of strategic importance for both the EU and Japan in times of growing protectionism and unilateralism.

We argue that the EU-Japan EPA is comparable to the existing agreement between the EU and Korea in terms of how NTBs are treated by the text. Thus, we carry out an econometric ex post evaluation of the EU-Korea, which entered into force in 2011, to form expectations about how the Japan-EU FTA can affect NTBs. We find substantial NTB cost reductions in all sectors. However, NTBs have fallen more in the Asian country than in Europe. Interestingly and importantly, trade costs appear to go down in sectors which are not explicitly covered by sector-specific provisions, probably due to horizontal provisions and complementarity effects.

Feeding tariff cuts and NTB reductions into our general equilibrium trade model, we find that EU exports to Japan go up by 73% (83 bn USD); Japanese exports to EU go up by 63% (79 bn USD). In particular, there is very strong growth in Agri-Food exports for EU, but from much lower level; substantial growth in automotive trade; large growth in chemicals (pharma) exports for Japan. We find some evidence that Japanese firms switch input sourcing from ASEAN countries to Eastern Europe.

Europe has large value added gains in the electronic equipment sector which shrinks in Japan. In contrast, Japan gains in automotive and chemicals; both gain in services and machinery. Overall, aggregate welfare effects are quite balanced in absolute size (between 15.2 and 18.2 bn USD), but three times larger in relative terms in Japan (0.31%) than in EU (0.10%)

In general, the conclusion of the Transpacific Partnership (TPP) agreement (Japan plus 10 other Pacific countries) has little importance for the effects of the EU-Japan EPA. The exit of Britain from the EU, in contrast, slightly reduces gains for Japan. In general, third country welfare effects are small as input-output linkages contribute towards a diffusion of the gains from trade; some ASEAN countries benefit while the Americas, Africa tend to lose a bit from the FTA.

Appendix A

Appendix to Chapter 1 - Globalization in the Time of COVID-19

A.1 Data Sources and Description

This section describes the data sources used for the construction of the COVID-19 shocks and for the counterfactual simulations.

Data Needed for the Counterfactual Simulations. We use data from World Input-Output database (WIOD) as our main data source for the simulations. It provides information on bilateral intermediate and final trade, sectoral output and value-added information, consumer and producer prices. With this data, one can construct bilateral input-output tables, intermediate consumption and expenditure levels for 43 countries and a rest of the world aggregate (RoW) (Timmer et al., 2015). In total each country consists of 56 sectors, which we aggregate into 50 industries (see table A4) in the Appendix. This aggregation concerns mostly services; we keep the sectoral detail in the manufacturing and agricultural industries. Data on bilateral preferential and MFN tariffs stem from the World Integrated Trade Solutions (WITS-TRAINS) and the WTO's Integrated Database (IDB). The parameter for the productivity dispersion, hence the trade cost elasticity is taken from Caliendo and Parro (2015).

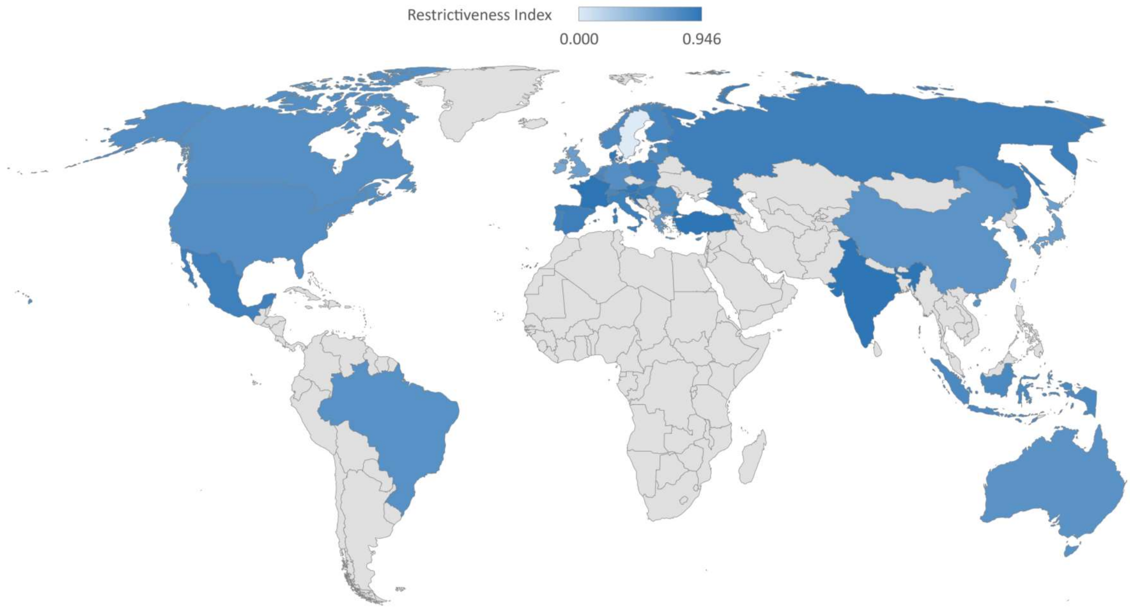
Construction of the Shock. As described in the main body of the paper, we construct a simple measure that quantifies the intensity of the economic shock. To construct the shock, as detailed in equation 2.1, we need employment data across countries, regions and sectors, the duration of the policy interventions on regional and national level, data on the severity of the policy interventions, and information on teleworkability of the sectors.

Duration of the Policy Interventions. To construct the measure of policy intervention, we need the country-region-sector specific duration of the policy intervention, which occurred due to Covid-19. We exploit the data from national ministries (e.g. Estonia, Germany, France) and the Corona Net project, which is a joint project of the TU Munich and partner universities. They collect data almost real time data on the laws, regulations and other measures with which governments and public authorities at the national and sub-national levels have reacted to the COVID-19 pandemic. The project has so far identified over 15 thousand different Corona interventions in 195 countries, which provides us with the largest, most comprehensive source of information on government action related to the Corona crisis. Most important, the database distinguishes between different types of national and subnational policies and the time period implemented.(Cheng et al., 2020). This provides us with a regional variation of duration of different policy interventions. As seen in the sensitivity analysis, the distinction plays a crucial role. Data about the regional restrictiveness of the policy interventions are not available for four European member states (France, Belgium, Sweden, and Lithuania). Hence, we take a different source for the construction of the restrictiveness index for those countries, namely data from the Oxford university about countries' duration of quarantine.

Data on Covid-19 Policy Interventions. For the construction of this quarantine index ψ_i^j we require information on the degree of restriction for each country ($IndexClosure_i$). We use the index on government responses to the COVID-19 diffusion of the University of Oxford, where $IndexClosure_i$ is an index of restrictiveness of government responses ranging from 0 to 100 (see Hale et al. (2020) for a detailed description of the index), where 100 indicates full restrictions. The index is meant to capture the extent of work, school, transportation and public event restrictions in each country. Further, using the information contained in the data-set on government responses to the COVID-19 from the University of Oxford, we account for the average duration of strict quarantine for the respective countries. COVID-pandemics is still ongoing, which is why we do not have the final number of quarantine days across countries.

Employment Data. Information on employment by country-region and sector is crucial to account for the geographical distribution of sectors across each country. In Italy, for example, Covid-19 hit the region Lombardy the worst, which lead to a longer shutdown of specific businesses compared to other regions in the country. A sector that is solely

Figure A1: Restrictiveness Index Across Countries



Note: The map reports the restrictiveness index for all countries in our sample. An index equal to zero means no restrictions (i.e. in Sweden), while an index equal 100 means that the entire economy is set under a complete shutdown (i.e. France it is 0.97. No information is available for countries shaded in gray.

located in Lombardy will therefore be hit more than a sector that is only located in another region, such as Molise.[1]

The data of duration on regional level is then merged with the regional, sector level employment data. This way, we can construct a measure that accounts for the sector and region specific length of the restriction with which a sector is hit by the COVID-19 pandemic. This way, the severity of the effect in a sector depends on the geographical distribution of the sector across regions, on the share of employment affected in each region and on the labor intensity of each sector.

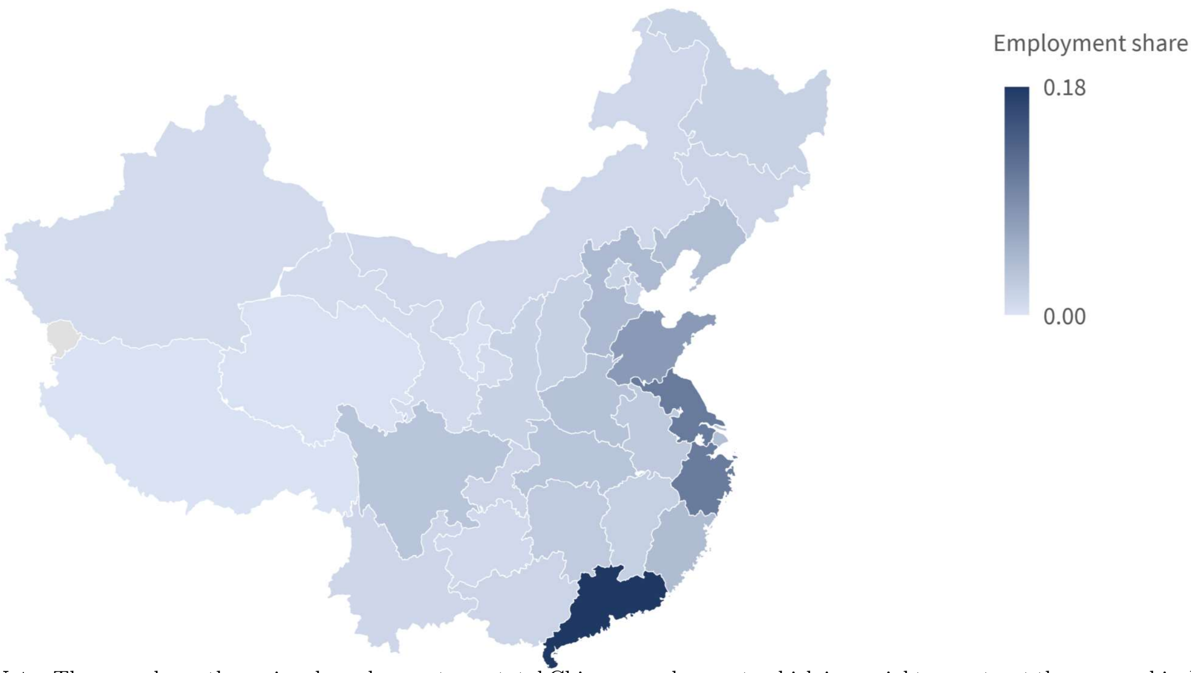
For the *EU*, we use the information contained in Eurostat. For the *US* we use IPUMScps to construct employment by state(region) and sector of activity. To construct the employment shares across regions and sectors for *China*, we use two data sources: first, we use data from the National Bureau of Statistic of China for the year 2018 on employment by region and sector.[2] The second data source comes from the 2000 census. The National

[1] Data on employment at sector-region level are not available for some countries in the sample, we therefore construct a simpler version of equation 2.1. In this case, the formula does not capture the geographical distribution of sectors in the country, but accounts for the sectoral distribution of employment and for their labor intensity. This is the case for Australia, Brazil, Canada, India, Indonesia, Japan, Korea, Mexico, Russia, Taiwan, RoW.

[2] See http://www.stats.gov.cn/english/ for a general overview of the data collected by the NBSC, and http://data.stats.gov.cn/english/ for employment data at regional level.

Bureau of Statistic of China provides the sector information for 19 sectors and 31 regions. Sectors consist of one agricultural sector, one mining sector, one manufacturing sector and 16 services sectors, hence a more aggregated sector level than provided in the paper. We therefore complement the available data with the employment shares by prefectures and sector from the 2000 census to construct the regional employment level for each of the WIOD sectors. The census data is used to retrieve the employment shares in each Chinese region and sector. We now have information for China divided into 340 prefectures and 151 sectors (SIC industry code), which is then aggregated to 31 Chinese regions and the 50 WIOD sectors.[3] We then redistribute the most recent available number of employment from the National Bureau of Statistic of China according to the shares from the 2000 census data (see figure A2).[4] This returns regional employment shares for each WIOD sector and region in China.

Figure A2: Employment Shares Across Chinese Regions



Note: The map shows the regional employment over total Chinese employment, which is crucial to construct the geographical distribution of the extent of the shock. We further have data on the within regional sector distribution needed to construct the shock 1.

Teleworkability. We follow Dingel and Neiman (2020) to construct a measure of the degree of *teleworkability* of each occupation. The information contained in the Occupa-

[3] The concordance of SIC industry codes to WIOD can be retrieved from the authors. We aggregate the 340 Chinese prefectures to 31 regions, because the COVID-19 data is only available at the more aggregated, regional level.

[4] The correlation of the employment shares across regions of the census 2000 data and the data from the National Bureau of Statistics is 0.93.

tional Information Network (O*NET) surveys is used to construct a measure of feasibility of working from home for each sector. The information on O*NET is provided as NAICS classification, for which we provide a concordance to match the WIOD sector classification (see table A1). The policy interventions implemented due to COVID-19 explicitly exempt the sensitive sectors from all restrictive measures, which is the reason why we increase the share of teleworkable employment for such sensitive sectors to 0.8. Precisely, the sensitive sectors are still producing their goods and services without a complete shutdown. The list of sensitive sectors includes (ISIC rev 3 sectoral classification): Agriculture (sector 1), Fishing (sector 3), Electricity and gas (sector 23), Water supply (sector 24), Sewage and Waste (sector 25), Postal and courier (sector 34), Human health and social work (sector 49).

Table A1: Teleworkability by Sector

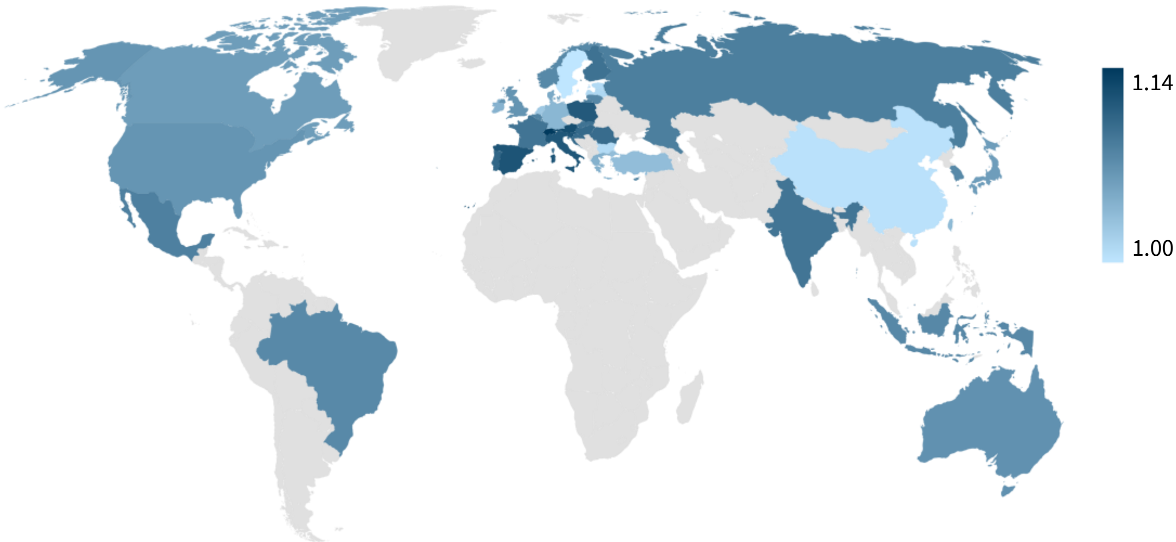
NAICS sec-id	WIOD sec-id	Sector Description	sec-id	Teleworkability sec-id	NAICS Description	WIOD	Sector
11	1	Crops, Animals	0.08	23	26	Construction	0.19
11	2	Forestry, Logging	0.08	42	27	Trade, Repair of Motor Vehicles	0.52
11	3	Fishing, Aquaculture	0.08	42	28	Wholesale Trade	0.52
21	4	Mining, Quarrying	0.25	44-45	29	Retail Trade	0.14
11	5	Food, Beverages, Tobacco	0.08	48-49	30	Land Transport	0.19
31-33	6	Textiles, Apparel,Leather	0.22	48-49	31	Water Transport	0.19
31-33	7	Wood, Cork	0.22	48-49	32	Air Transport	0.19
31-33	8	Paper	0.22	48-49	33	Aux. Transportation Services	0.19
31-33	9	Recorded Media Reproduction	0.22	48-49	34	Postal and Courier	0.19
31-33	10	Coke, Refined Petroleum	0.22	72	35	Accommodation and Food	0.04
31-33	11	Chemicals	0.22	51	36	Publishing	0.72
31-33	12	Pharmaceuticals	0.22	51	37	Media Services	0.72
31-33	13	Rubber, Plastics	0.22	51	38	Telecommunications	0.72
31-33	14	Other non-Metallic Mineral	0.22	55	39	Computer, Information Services	0.79
31-33	15	Basic Metals	0.22	52	40	Financial Services	0.76
31-33	16	Fabricated Metal	0.22	52	41	Insurance	0.76
31-33	17	Electronics, Optical Products	0.22	53	42	Real Estate	0.42
31-33	18	Electrical Equipment	0.22	54	43	Legal and Accounting	0.80
31-33	19	Machinery, Equipment	0.22	54	44	Business Services	0.80
31-33	20	Motor Vehicles	0.22	54	45	Research and Development	0.80
31-33	21	Other Transport Equipment	0.22	56	46	Admin., Support Services	0.31
31-33	22	Furniture, Other Manufacturing	0.22	99	47	Public, Social Services	0.41
22	23	Electricity, Gas	0.37	61	48	Education	0.83
22	24	Water Supply	0.37	62	49	Human Health and Social Work	0.25
22	25	Sewerage, Waste	0.37	71	50	Other Services, Households	0.30

Note: The table shows the degree of teleworkability of each WIOD sector. Zero would indicate that work cannot be done from home, while teleworkability equal to 1 indicates that the entire work is independent of the location.

A.2 Additional results

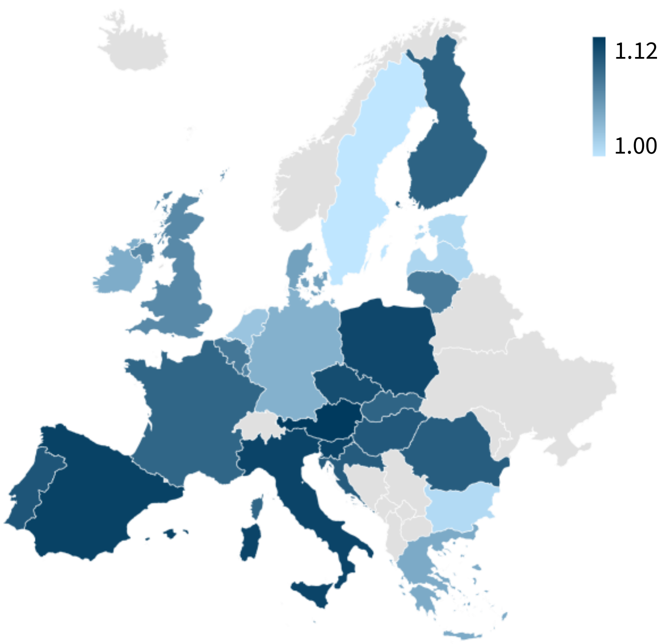
In this subsection, we present different scenarios in which we gradually increase trade costs in each economy. In practice, we increase trade costs from 10 percentage points to

Figure A3: Size of Shock Across All Countries



Note: The map reports the intensity of the shocks imputed into the model for all countries in our sample. A shock equal to 1 means no changes from the baseline, while a shock of 2 would imply an increase in the production barrier by a hundred percent. See equation 2.1 for the precise construction of the shock.

Figure A4: Size of the Shock for EU28 Member States



Note: The map for the EU28 shows the size of the shock, which are imputed into the model for the EU28 member states. A shock equal to 1 means no changes from the baseline, while a shock of 2 would imply an increase in the production barrier by a hundred percent for an entire year. See equation 2.1 for the precise construction of the shock. The darker the shade of blue, the higher is the size of the effect. The scale goes from 1, the least restrictive country (Sweden) to 1.12, the most restrictive country (i.e. Spain).

100 percentage points in each sector-country.[5] For both shocks, the additional increases in trade costs by 10 percentage points on average decreases the size of the real income drops by 0.02 for Germany and China, 0.18 for Italy, 0.013 for the USA, and by 0.03 across all countries. Figure A5 shows the real income changes for Italy, Germany, USA, and China and for an aggregate EU28 and the RoW. At the point 0, the real income changes are identical to the changes of shock 1 shown in table 1.1. 100 is identical to our less integrated economy scenario shown in the main body. The black solid lines indicate the decrease in real income due to the increase in trade costs plus the shock (1) under different degrees of openness of the economy. The grey dashed line shows the drop in real income that solely comes from the trade cost increases. The blue bars show the decrease in real income due to the shock (2). The green bar (at x-axis 0 - no trade costs) shows the decrease in real income that stems from the shock. It is identical to the decreases shown in table 1.1.

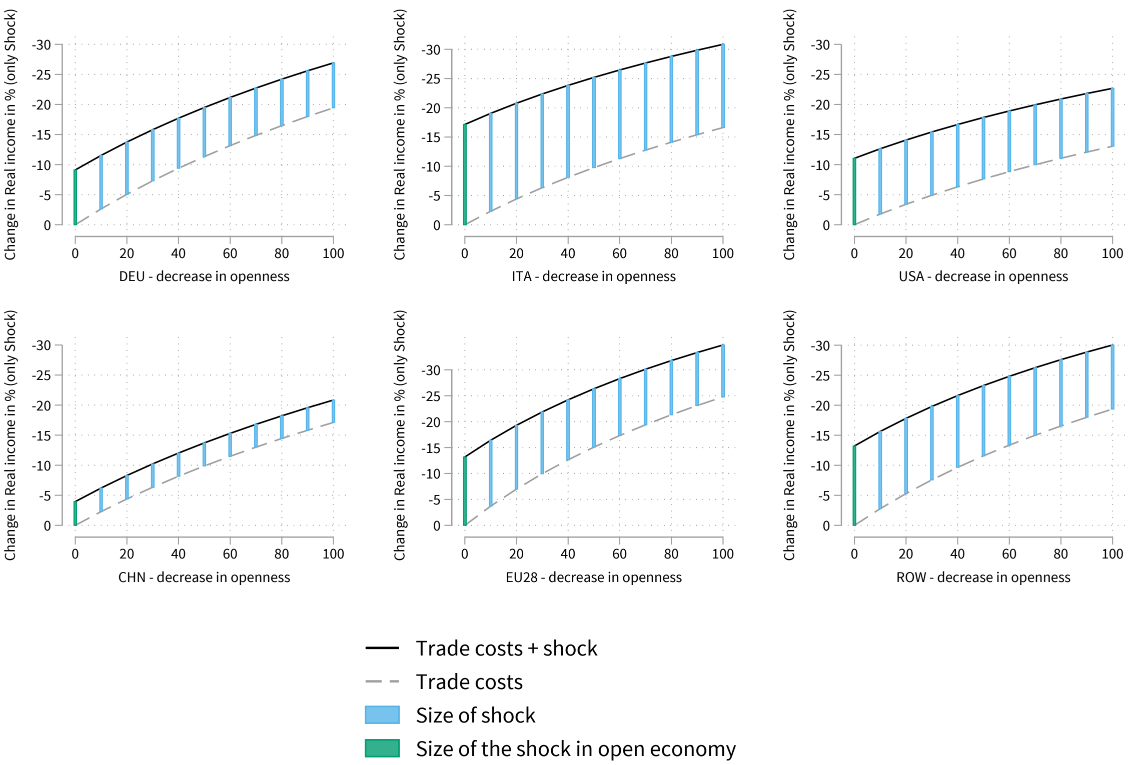
Table A2: Change in Value Added (in %) - Open Economy

Sector	Italy in %	Germany in %	USA in %	China in %	EU28 in %	Rest of World in %
Agriculture	-17.44	-8.52	-11.07	-3.41	-13.90	-14.76
Food, Beverages, Tabacco	-16.94	-9.11	-11.01	-3.76	-13.04	-13.50
Mining, Quarrying	-18.26	-6.36	-11.02	-3.45	-11.75	-14.92
Textiles	-18.92	-5.92	-10.83	-2.05	-15.08	-13.40
Electrical Equipment	-19.47	-7.21	-11.21	-1.52	-11.53	-13.69
Machinery, Equipment	-15.77	-9.87	-11.04	-4.97	-12.35	-12.52
Motor Vehicles	-15.62	-10.71	-11.10	-5.11	-12.05	-12.89
Intm. Resources Manufacturing	-17.65	-8.70	-10.99	-3.57	-12.92	-13.55
Manufacturing, nec.	-15.55	-10.06	-11.36	-5.65	-12.49	-12.97
Pharmaceuticals	-16.59	-11.33	-11.27	-4.48	-12.92	-13.57
Chemicals	-20.01	-6.32	-11.04	-2.93	-11.42	-14.40
Electricity, Water, Gas	-17.47	-8.75	-11.04	-3.49	-12.97	-14.23
Construction	-17.21	-9.03	-11.05	-3.92	-12.91	-13.75
Wholesale, Retail Trade	-17.45	-8.77	-11.02	-2.97	-12.93	-13.85
Transport	-17.60	-8.64	-11.08	-3.30	-12.94	-13.79
Accommodation and Food	-17.17	-8.95	-11.05	-3.76	-13.89	-13.41
Real Estate	-17.25	-9.04	-11.04	-3.75	-12.92	-13.06
Public Services	-17.28	-8.96	-11.04	-3.91	-12.52	-13.63
Social Services	-17.19	-9.11	-11.05	-3.94	-12.26	-13.04
Services, nec.	-17.38	-8.87	-11.03	-3.60	-12.48	-13.73

Note: The table shows the sectoral value added changes, in % for selected countries, Italy, Germany, USA, and China. Column 6 presents the value added results (in %) for EU28, which are weighted by the initial value added by country. Column 7 shows the value added weighted results for all remaining countries. Further, sectors are aggregated into broader categories (see table A3 in the Appendix)).

[5] The main body of the text presents the results for a less integrated world with an increase of trade costs by a hundred percentage points.

Figure A5: Real Income Changes with Different Openness Degrees of the Economy



Note: The 6 sub-figures show the real income changes for the four selected countries, Italy, Germany, USA, and China and the regions EU28, ROW. The x-axis presents the scenarios with different trade cost increases. At the point 0, the real income changes are identical to the changes of shock 1 shown in table 1.1. 50 equals the increase in trade costs for every country by 50 percentage points. 100 is identical to our less integrated economy scenario shown in the main body. The black solid line indicates the decrease in real income due to the increase in trade costs plus the shock 1 under different degrees of openness of the economy. The grey dashed line shows the drop in real income that solely comes from the trade cost increases. The blue bars show the decrease in real income due to the shock 1. The green bar (at x-axis 0 - no trade costs) shows the decrease in real income that stems from the shock. It is identical to the decreases shown in table 1.1.

Table A3: WIOD Sector Aggregation

WIOD sec-id	Sector Description	WIOD sec-id	Sector Description
	Agriculture	23	Electricity, Gas
2	Forestry, Logging	24	Water Supply
1	Crops, Animals		**Construction**
3	Fishing, Aquaculture	26	Construction
	Food, Beverages, Tobacco		**Wholesale and Retail Trade**
5	Food, Beverages, Tobacco	29	Retail Trade
	Mining, Quarrying	28	Wholesale Trade
4	Mining, Quarrying	27	Trade, Repair of Motor Vehicles
	Textiles		**Transport**
6	Textiles, Apparel,Leather	30	Land Transport
	Electrical Equipment	33	Aux. Transportation Services
18	Electrical Equipment		**Transport**
17	Electronics, Optical Products	32	Air Transport
	Machinery, Equipment	31	Water Transport
19	Machinery, Equipment		**Accommodation and Food**
	Motor Vehicles	35	Accommodation and Food
20	Motor Vehicles		**Real Estate**
	Intm. Resources Manufacturing	42	Real Estate
9	Recorded Media Reproduction		**Public Services**
8	Paper	46	Admin., Support Services
10	Coke, Refined Petroleum	47	Public, Social Services
16	Fabricated Metal		**Social Services**
13	Rubber, Plastics	49	Human Health and Social Work
7	Wood, Cork		**Services, nec.**
15	Basic Metals	37	Media Services
14	Other non-Metallic Mineral	40	Financial Services
	Manufacturing, nec.	36	Publishing
22	Furniture, Other Manufacturing	45	Research and Development
21	Other Transport Equipment	50	Other Services, Households
	Pharmaceuticals	44	Business Services
12	Pharmaceuticals	48	Education
	Chemicals	38	Telecommunications
11	Chemicals	34	Postal and Courier
	Electricity, Water, Gas	41	Insurance
25	Sewerage, Waste	43	Legal and Accounting
		39	Computer, Information Services

Note: The sectors written in bold indicate the broad categories each WIOD sector belongs to.

Table A4: Concordance WIOD Sectors - ISIC Rev. 4

WIOD		ISIC Rev. 4	WIOD		ISIC Rev. 4
ID	Description		ID	Description	
1	Crops & Animals	A01	26	Construction	F
2	Forestry & Logging	A02	27	Trade & Repair of Motor Vehicles	G45
3	Fishing & Aquaculture	A03	28	Wholesale Trade	G46
4	Mining & Quarrying	B	29	Retail Trade	G47
5	Food, Beverages & Tabacco	C10-C12	30	Land Transport	H49
6	Textiles, Apparel,Leather	C13-C15	31	Water Transport	H50
7	Wood & Cork	C16	32	Air Transport	H51
8	Paper	C17	33	Aux. Transportation Services	H52
9	Recorded Media Reproduction	C18	34	Postal and Courier	H53
10	Coke, Refined Petroleum	C19	35	Accommodation and Food	I
11	Chemicals	C20	36	Publishing	J58
12	Pharmaceuticals	C21	37	Media Services	J59_J60
13	Rubber & Plastics	C22	38	Telecommunications	J61
14	Other non-Metallic Mineral	C23	39	Computer & Information Services	J62_J63
15	Basic Metals	C24	40	Financial Services	K64
16	Fabricated Metal	C25	41	Insurance	K65_K66
17	Electronics & Optical Products	C26	42	Real Estate	L68
18	Electrical Equipment	C27	43	Legal and Accounting	M69_M70
19	Machinery & Equipment	C28,C33	44	Business Services	M71,M73-M75
20	Motor Vehicles	C29	45	Research and Development	M72
21	Other Transport Equipment	C30	46	Admin. & Support Services	N
22	Furniture & Other Manufacturing	C31_C32	47	Public & Social Services	O84
23	Electricity & Gas	D35	48	Education	P85
24	Water Supply	E36	49	Human Health and Social Work	Q
25	Sewerage & Waste	E37-E39	50	Other Services, Households	R-U

Appendix B

Appendix to Chapter 2 - COVID-19 Pandemic, Trade and Inequality

B.1 Fit of the Data - WIOD and Interpolated Eurostat Data

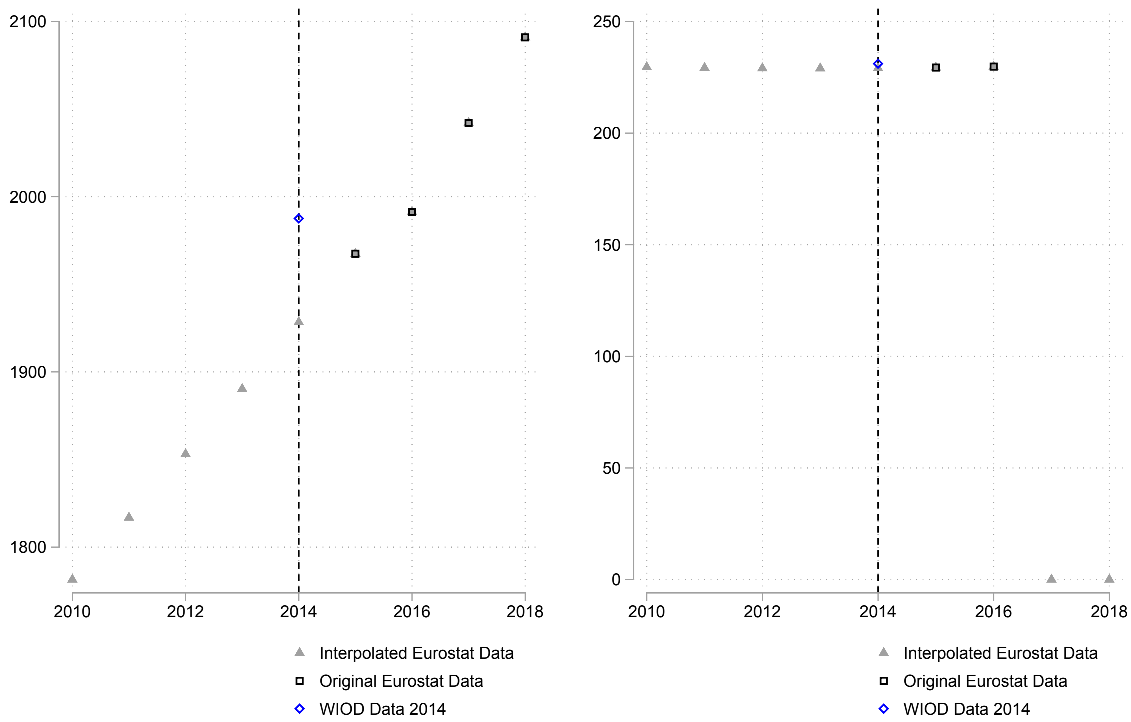
The back of the envelope calculation distributes the sectoral value added changes of the counterfactual simulation across regions within a country. The exercise requires that the sum of the regional data from Eurostat matches the sectoral data of WIOD for each country. Missing Eurostat data for the year 2014, the year of the World input-output tables, is therefore interpolated with the average growth trend of the previous, and following years on the most disaggregated sector region country level.[1] The following formula is used to interpolate the missing years: Given time $t \in [2010, 2018]$ and $i \in [2010, 2018]$, the interpolated value added ϕ_{2014} for the missing year 2014 (i.e. $t-1$) is given as, $\phi_{t-1} = \phi_t * \frac{\sum_i^I \frac{\phi_i - \phi_{i+1}}{\phi_i}}{I}, \forall \phi_i \neq \emptyset$ and $\phi_{t-1} = \emptyset$.

Figure B1 shows one example of the fit of the sum of regional Eurostat data with the WIOD data for France. The left figure displays the sum of the French regional value added across all sectors, while the figure on the right shows the sum of the French regional value added of the manufacturing sector. The black dots show the original Eurostat data, while the grey triangles display the interpolated values. The difference between WIOD and the sum of the regional manufacturing value added is close to zero, hence the both datasets

[1] If data for 2014 is missing, information for the years after 2009 are taken, to not capture the trends of the last great economic shock.

match perfectly. The total French value added (left side of figure B1) deviates slightly. The total value added from WIOD is 2% higher than the one from Eurostat.

Figure B1: Interpolation Exercise WIOD - Eurostat: French Value Added



Note: The figures display value added (in bn. Euro) for France for the WIOD and Eurostat data. The figure on the left handside shows the total French value added between 2010 and 2018, while the figure on the right handside displays the value added of France in the manufacturing sector between 2010 and 2018. The blue square in both graphs shows the size of the value added shown in WIOD for the year 2014. The black squares show the available data for the value added across all regions in France. The grey triangles show the interpolated values for the missing years.

Figure B2 shows all differences between the the value added values of WIOD for each country and the interpolated data of Eurostat. The correlation of the two datasets is 0.998, which shows that the back of the enevelope calculation can be performed properly. The subfigures, B3a to B3c, show the sectoral differences of the two datasets within the selected countries. The largest differences in absolute terms can be found in the public services sectors (i.e. Germany, France, Netherlands).

Figure B2: Data Fit of Wiod and Interpolated Eurostat across EU28

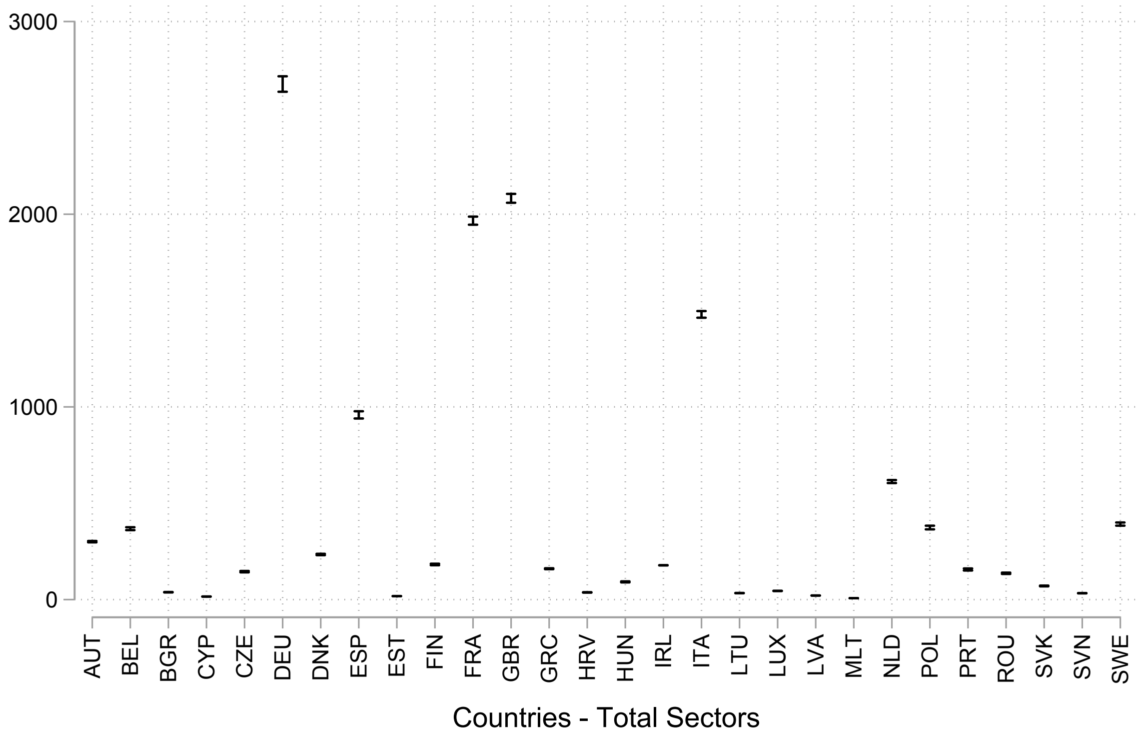
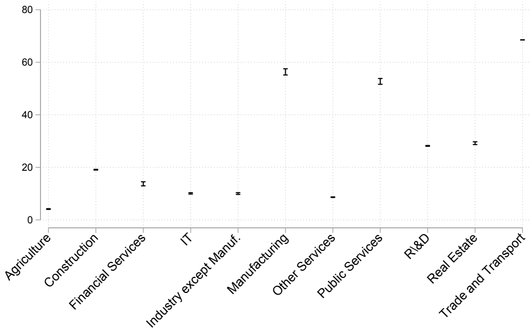
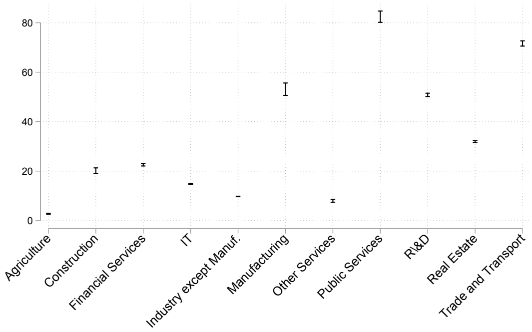


Figure B3: Data Fit of Wiod and Eurostat across sectors of selected countries

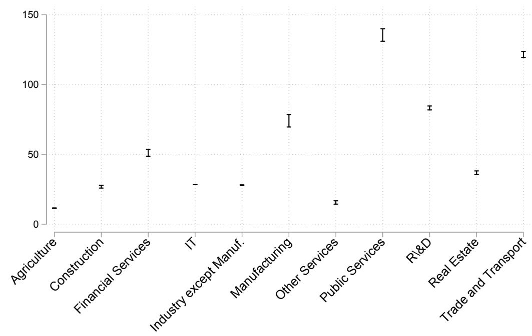
(a) Austria



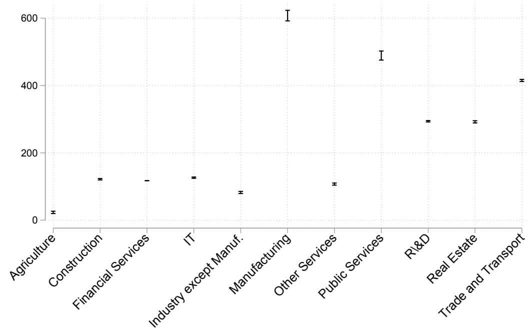
(b) Belgium



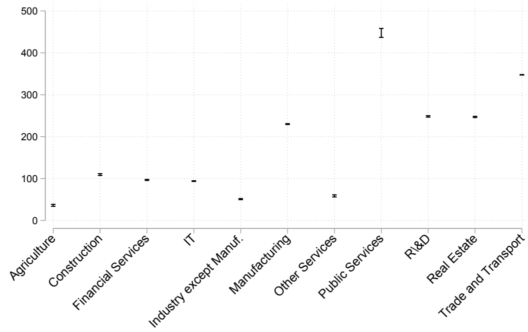
(c) Netherlands



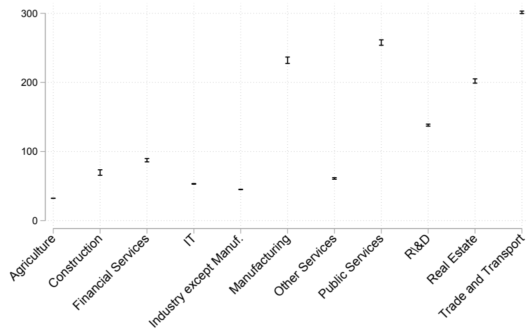
(d) Germany



(e) France



(f) Italy



Note: The figures show the value added (in bn. Euro) over the number of employees (in thousands) across regions of all sectors. The figures highlight the region with the highest ratio (max), the region with lowest ratio (min) and the average. The ratio, value added over employment is a simple measure of productivity.

B.2 Technical Explanation of the Theory

Production of intermediate products. A continuum of intermediates can be used for production of each ω^j and producers differ in the efficiency $z_n^j(\omega^j)$ to produce output. The production technology of a good ω^j is

$$q_n^j\left(\omega^j\right) = z_n^j\left(\omega^j\right)\left[l_n^j\left(\omega^j\right)\right]^{\gamma_n^j}\prod_{k=1}^{J}\left[m_n^{k,j}\left(\omega^j\right)\right]^{\gamma_n^{k,j}}$$

with labor $l_n^j\left(\omega^j\right)$ and composite intermediate goods $m_n^{k,j}\left(\omega^j\right)$ from sector k used in the production of the intermediate good ω^j. $\gamma_n^{k,j} \geq 0$ are the share of materials form sector k used in the production of the intermediate good ω^j. The intermediate goods shares $\sum_{k=1}^{J}\gamma_n^{k,j} = 1 - \gamma_n^j$ and $\gamma_n^j \geq 0$, which is the share of value added vary across sectors and countries.

Due to constant returns to scale and perfect competition, firms price at unit costs,

$$c_n^j = \Upsilon_j^j w_n^{\gamma_n^j}\prod_{k=1}^{J}P_n^{k\gamma_n^{k,j}} \tag{B.1}$$

with the constant Υ_j, and the price of a composite intermediate good from sector k, $P_n^{k\gamma_n^{k,j}}$.

Production Barriers and Trade Costs. Trade can be costly due to tariffs $\tilde{\tau}_{in}^j$ and non-tariff barriers d_{ni}^j (i.e. FTA, bureaucratic hurdles, requirements for standards, or other discriminatory measures). Combined, they can be represented as trade costs κ_{ni}^j when selling a product of sector j from country i to n

$$\kappa_{in}^j = \underbrace{\left(1 + t_{in}^j\right)}_{\tilde{\tau}_{in}^j}\underbrace{D_{in}^{\rho^j}e^{\delta^j\mathbf{Z}_{in}}}_{d_{ni}^j} \tag{B.2}$$

where $t_{in}^j \geq 0$ denotes ad-valorem tariffs, D_{in} is bilateral distance, and $\mathbf{Z}_{in}$ is a vector collecting trade cost shifters.[2]

Additionally, intermediate and final goods are now subject to barriers arising from domestic policy interventions, v_i^j that can potentially deter production. As described in section 1.2, COVID-19 is modeled as a barrier to production in the affected areas. The

[2] Iceberg type trade cost in the formulation of Samuelson (1954) are captured by the term $\mathbf{Z}_{in}$

key difference when compared to trade costs is that the latter one only directly affects tradable goods, while production barriers can also directly affect non-tradable goods.

Under perfect competition and constant returns to scale, an intermediate or final product (trade and non-tradable) is provided at unit prices, which are subject to v_i^j , κ_{ni}^j and depend on the efficiency parameter $z_i^j\left(\omega^j\right)$.

Producers of sectoral composites in country n search for the supplier with the lowest cost such that

$$p_n^j\left(\omega^j\right) = \min_i \left\{ \frac{c_i^j \kappa_{ni}^j v_i^j}{z_i^j\left(\omega^j\right)} \right\}. \tag{B.3}$$

Note that v_i is independent of the destination country and thus will also have effects on non-tradeable and domestic sales. In the non-tradable sector, with $k_{in}^j = \infty$, the price of an intermediate good is $p_n^j\left(\omega^j\right) = c_n^j v_n^j / z_i^j\left(\omega^j\right)$.

Composite intermediate product price. The price for a composite intermediate good is given by

$$P_n^j = A^j \left(\sum_{i=1}^{N} \lambda_i^j \left(c_i^j \kappa_{in}^j v_i^j \right)^{\frac{-1}{\theta^j}} \right)^{-\theta^j} \tag{B.4}$$

where $A^j = \Gamma\left[1 + \theta^j(1-\eta^j)\right]^{\frac{1}{1-\eta^j}}$ is a constant. Following Eaton and Kortum (2002), Ricardian motives to trade are introduced in the model and allow productivity to differ by country and sector.[3] Productivity of intermediate goods producers follows a Fréchet distribution with a location parameter $\lambda_n^j \geq 0$ that varies by country and sector (a measure of absolute advantage) and shape parameter θ^j that varies by sector and captures comparative advantage.[4]. Equation B.4 also provides the price index of non-tradable goods and goods confronted with production barriers, which can affect tradable and non-tradable goods. For non-tradable goods the price index is given by $P_n^j = A^j \lambda_n^{j-1/\theta^j} c_n^j v_n^j$.

Firm's output price. Due to the interrelation of the sectors across countries, the existence of production barriers v_i^j has also an indirect effect on the other sectors across

[3] see Caliendo and Parro (2015) for more details.

[4] Convergence requires $1 + \theta^j > \eta^j$.

countries. A firm in country i can supply its output at price,[5]

$$p_{in}^{j}(\omega^{j}) = v_i^j \kappa_{in}^j \frac{c_i^j}{z_i^j\left(\omega^j\right)} \tag{B.5}$$

Consumption prices. Under Cobb-Douglas preferences, the consumers can purchase goods at the consumption prices P_n, which are also dependent on production barriers v_i^j. In fact, with perfect competition and constant-returns to scale, an increase in the costs of production of final goods will directly translate into an increase in consumption prices.

$$P_n = \prod_{j=1}^{J} \left(P_n^j / a_n^j\right)^{a_n^j} \tag{B.6}$$

Households. In each country the representative households maximize utility over final goods consumption C_n, which gives rise to the Cobb-Douglas utility function $u(C_n)$ of sectoral final goods with expenditure shares $\alpha_n^j \in (0,1)$ and $\sum_j \alpha_n^j = 1$.

$$u(C_n) = \prod_{j=1}^{J} C_n^{j\,\alpha_n^j} \tag{B.7}$$

Income I_n is generated through wages w_n and lump-sum transfers (i.e. tariffs).

Expenditure Shares. The total expenditure on goods of sector j from country n is given by $X_n^j = P_n^j Q_n^j$. Country n's share of expenditure on goods from i is given by $\pi_{ni}^j = X_{ni}^j / X_n^j$, which gives rise to the structural gravity equation.

$$\pi_{in}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{in}^j v_i^j\right]^{\frac{-1}{\theta^j}}}{\sum_{i=1}^{N} \lambda_i^j \left[c_i^j \kappa_{in}^j v_i^j\right]^{\frac{-1}{\theta^j}}} \tag{B.8}$$

[5] c_i^j is the minimum cost of an input bundle (see equation 1.5), where Υ_i^j is a constant, w_i is the wage rate in country i, p_i^k is the price of a composite intermediate good from sector k, which can be affected by production barriers. $\gamma_i^j \geq 0$ is the value added share in sector j in country i, the same parameter we use in equation 2.1 when defining the shock v_i^j. $\gamma_i^{k,j}$ denotes the cost share of source sector k in sector j's intermediate costs, with $\sum_{k=1}^{J} \gamma_i^{k,j} = 1$.

The bilateral trade shares are affected by the production barriers v_i^j both directly and indirectly through the input bundle c_i^j from equation B.2, which contains all information from the IO-tables.

Total expenditure and Trade Balance. Total expenditure on a good j in country n, X_n^j, has to equal the total expenditures on the composite intermediate goods of firms and households.[6]

$$X_n^j = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^k \frac{\pi_{in}^k}{(1+\tau_{in}^k)} + \alpha_i^j I_i \tag{B.9}$$

To close the model, the value of total imports, trade surplus and domestic demand need to be equal to the value of domestic sales and exports,

$$\sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_n^j + D_n = \sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi_{in}^j}{(1+\tau_{in}^j)} X_i^j \tag{B.10}$$

Given the trade surplus D_n, labor l_n, the measure of absolute advantage λ_n^j and the trade costs d_{ni}^j, the equilibirum under the domestic production barriers is a wage vector, as in Caliendo and Parro (2015).

Equilibrium in relative changes. We follow Caliendo and Parro (2015) and Dekle et al. (2008a) and define the equilibrium in relative changes, which has the advantage of an exact mapping of the model to the data, and allows to identify the outcomes from the change in the above defined policy intervention, the production barrier $\hat{v}_i^j$. [7]

This provides an equilibrium under the change of policy interventions as inCaliendo and Parro (2015). $\hat{c}_n^j$ are the cost changes, which are dependent on the wage changes, $\hat{w}_n$ and the prices changes $\hat{P}_n^{k\gamma_n^{k,j}}$. These changes directly affect the sectoral price index P_n^j, and translate into changes of the unit costs (see equation B.12). X_n^j are the sectoral expenditure levels, the prime income is given as $I_n' = \hat{w}_n w_n L_n + \sum_{j=1}^{J} X_n^{j\prime}(1 - F_n^{j\prime}) - S_n$, with $F_n^j \equiv \sum_{i=1}^{N} \frac{\pi_j^{in}}{(1+t_{in}^j)}$. L_n is a country n's labor force, and D_n depicts the trade surplus.

[6] The national income is a function of labor income, tariff rebates R_i and the trade surplus D_i, hence $I_i = w_i L_i + R_i - S_i$. X_i^j is a country i's expenditure on sector j goods and services, $M_n^j = \frac{\pi_{ni}^j}{(1+\tau_{ni}^j)} X_i^j$ a imports of country n in sector j good from a country i. More details can be found in Caliendo and Parro (2015).

[7] The interested reader can go to the work of Caliendo and Parro (2015), which provide a complete explanation of the hat algebra.

The trade shares (see equation B.13) then respond to changes in the production costs, unit costs, and prices. The productivity dispersion parameter θ^j determines the intensity of the reaction. Equation B.14 ensures that the goods' market is clear and trade is balanced (see equation B.15).

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \prod_{k=1}^{J} \hat{P}_n^{k\gamma_n^{k,j}} \tag{B.11}$$

$$\hat{P}_n^j = \left[\sum_{i=1}^{N} \pi_{in}^j [\hat{\kappa}_{in}^j \hat{v}_i^j \hat{c}_i^j]^{-1/\theta^j}\right]^{-\theta^j} \tag{B.12}$$

$$\hat{\pi}_{in}^j = \left[\frac{\hat{c}_i^j}{\hat{p}_n^j} \hat{\kappa}_{in}^j \hat{v}_i^j\right]^{-1/\theta^j} \tag{B.13}$$

$$X_n^{j\prime} = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^k \frac{\pi_{in}^{k\prime}}{(1+\tau_{in}^{k\prime})} + \alpha_i^j I_i^{\prime} \tag{B.14}$$

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{k\prime}}{(1+\tau_{ni}^{k\prime})} X_n^{j\prime} - D_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{in}^{k\prime}}{(1+\tau_{in}^{k\prime})} X_i^{j\prime} \tag{B.15}$$

$$\tag{B.16}$$

Table B1: Concordance WIOD- Isic4 and NACE

Wiod sec-id	Wiod Description	Isic4 sec-id	Nace sec-id	Nace Description
1	Crops & Animals	A01	A	Agriculture
2	Forestry & Logging	A02	A	Agriculture
3	Fishing & Aquaculture	A03	A	Agriculture
4	Mining & Quarrying	B	BE-C	Industry (except construction and manuf.)
5	Food, Beverages & Tabacco	C10-C12	C	Manufacturing
6	Textiles, Apparel,Leather	C13-C15	C	Manufacturing
7	Wood & Cork	C16	C	Manufacturing
8	Paper	C17	C	Manufacturing
9	Recorded Media Reproduction	C18	C	Manufacturing
10	Coke, Refined Petroleum	C19	C	Manufacturing
11	Chemicals	C20	C	Manufacturing
12	Pharmaceuticals	C21	C	Manufacturing
13	Rubber & Plastics	C22	C	Manufacturing
14	Other non&Metallic Mineral	C23	C	Manufacturing
15	Basic Metals	C24	C	Manufacturing
16	Fabricated Metal	C25	C	Manufacturing
17	Electronics & Optical Products	C26	C	Manufacturing
18	Electrical Equipment	C27	C	Manufacturing
19	Machinery & Equipment	C28,C33	C	Manufacturing
20	Motor Vehicles	C29	C	Manufacturing
21	Other Transport Equipment	C30	C	Manufacturing
22	Furniture & Other Manufacturing	C31-C32	C	Manufacturing
23	Electricity & Gas	D35	BE-C	Industry (except construction and manuf.)
24	Water Supply	E36	BE-C	Industry (except construction and manuf.)
25	Sewerage & Waste	E37-E39	BE-C	Industry (except construction and manuf.)
26	Construction	F	F	Construction
27	Trade & Repair of Motor Vehicles	G45	GI	Trade and Transport
28	Wholesale Trade	G46	GI	Trade and Transport
29	Retail Trade	G47	GI	Trade and Transport
30	Land Transport	H49	GI	Trade and Transport
31	Water Transport	H50	GI	Trade and Transport
32	Air Transport	H51	GI	Trade and Transport
33	Aux. Transportation Services	H52	GI	Trade and Transport
34	Postal and Courier	H53	GI	Trade and Transport
35	Accomodation and Food	I	GI	Trade and Transport
36	Publishing	J58	J	IT
37	Media Services	J59-J60	J	IT
38	Telecommunications	J61	J	IT
39	Computer & Information Services	J62-J63	J	IT
40	Financial Services	K64	K	Financial Services
41	Insurance	K65-K66	K	Financial Services
42	Real Estate	L68	L	Real Estate
43	Legal and Accounting	M69-M70	MN	R&D
44	Business Services	M71,M73-M75	MN	R&D
45	Research and Development	M72	MN	R&D
46	Admin. & Support Services	N	MN	R&D
47	Public & Social Services	O84	OQ	Public Services
48	Education	P85	OQ	Public Services
49	Human Health and Social Work	Q	OQ	Public Services
50	Other Serivces, Households	R-U	RU	Other Services

Note: This tables shows the concordances of WIOD, ISIC4 and NACE, which are used in the paper. It further shows how the sectors are aggregated.

B.2.1 List of EU Regions in the Sample

The following countries and regions are used in the exercise. **AUT**, Burgenland (AT), AT11, Niederoesterreich, AT12, Wien, AT13, Kaernten, AT21, Steiermark, AT22, Oberoesterreich, AT31, Salzburg, AT32, Tirol, AT33, Vorarlberg, AT34, **BEL**, Region de BruxellesCapitale / Brussels Hoofdstedelijk Gewest, BE1, Vlaams Gewest, BE2, Region wallonne, BE3, **BGR**, Severna i yugoiztochna Bulgaria, BG3, Yugozapadna i yuzhna tsentralna Bulgaria, BG4, **CYP**, Cyprus, CY, Kypros, CY0, Kypros, CY00, **CZE**, Praha, CZ01, Stredni Cechy, CZ02, Jihozápad, CZ03, Severozápad, CZ04, Severovychod, CZ05, Jihovychod, CZ06, Stredni Morava, CZ07, Moravskoslezsko, CZ08, **DEU**, BadenWuerttemberg, DE1, Bayern, DE2, Berlin, DE3, Brandenburg, DE4, Bremen, DE5, Hamburg, DE6, Hessen, DE7, MecklenburgVorpommern, DE8, Niedersachsen, DE9, Nordrhein-Westfalen, DEA, RheinlandPfalz, DEB, Saarland, DEC, Sachsen, DED, SachsenAnhalt, DEE, SchleswigHolstein, DEF, Thueringen, DEG, **DNK**, Hovedstaden, DK01, Sjaelland, DK02, Syddanmark, DK03, Midtjylland, DK04, Nordjylland, DK05, **ESP**, Galicia, ES11, Principado de Asturias, ES12, Cantabria, ES13, Pais Vasco, ES21, Comunidad Foral de Navarra, ES22, La Rioja, ES23, Aragon, ES24, Comunidad de Madrid, ES30, Castilla y Leon, ES41, Castillala Mancha, ES42, Extremadura, ES43, Cataluna, ES51, Comunidad Valenciana, ES52, Illes Balears, ES53, Andalucia, ES61, Region de Murcia, ES62, Ciudad Autonoma de Ceuta (ES), ES63, Ciudad Autonoma de Melilla (ES), ES64, **EST**, Eesti, EE00, **FIN**, LaensiSuomi, FI19, HelsinkiUusimaa, FI1B, EtelaeSuomi, FI1C, Pohjois ja ItaeSuomi, FI1D, Aland, FI20, **FRA**, Ile de France, FR10, Centre Val de Loire, FR24, Bourgogne, FR26, FrancheComte, FR43, BasseNormandie, FR25, HauteNormandie, FR23, NordPasdeCalais, FR30, Picardie, FR22, Alsace, FR42, ChampagneArdenne, FR21, Lorraine, FR41, PaysdelaLoire, FR51, Bretagne, FR52, Aquitaine, FR61, Limousin, FR63, PoitouCharentes, FR53, LanguedocRoussillon, FR81, MidiPyrenees, FR62, Auvergne, FR72, RhoneAlpes, FR71, ProvenceAlpesCote d'Azur, FR82, Corse, FRM0, Guadeloupe, FRY1, Guyane, FRY3, Mayotte, FRY5, **GBR**, North East (UK), UKC, North West (UK), UKD, Yorkshire and The Humber, UKE, East Midlands (UK), UKF, West Midlands (UK), UKG, East of England, UKH, London, UKI, South East (UK), UKJ, South West (UK), UKK, Wales, UKL, Scotland, UKM, Northern Ireland (UK), UKN, **GRC**, Attiki, EL30, Voreio Aigaio, EL41, Notio Aigaio, EL42, Kriti, EL43, Anatoliki Makedonia, Thraki, EL51, Kentriki Makedonia, EL52, Dytiki Makedonia, EL53, Ipeiros, EL54, Thessalia, EL61, Ionia Nisia, EL62, Dytiki Ellada, EL63, Sterea Ellada, EL64, Peloponnisos, EL65, **HRV**, Jadranska Hrvatska, HR03, Kontinentalna Hrvatska, HR04, **HUN**, KoezepMagyarország (NUTS 2013), HU10, Budapest, HU11, Pest, HU12, KoezepDunántúl, HU21, NyugatDunántúl, HU22, DelDunántúl, HU23, EszakMagyarország, HU31, EszakAlfoeld, HU32, DelAlfoeld, HU33, **IRL**, Border, Midland and Western (NUTS 2013), IE01, Southern and Eastern (NUTS 2013), IE02, Northern and Western, IE04, Southern, IE05, Eastern and Midland, IE06, **ITA**, Piemonte, ITC1, Valle d'Aosta/Vallee d'Aoste, ITC2, Liguria, ITC3, Lombardia, ITC4, Abruzzo, ITF1, Molise, ITF2, Campania, ITF3, Puglia, ITF4, Basilicata, ITF5, Calabria, ITF6, Sicilia, ITG1, Sardegna, ITG2, Provincia Autonoma di Bolzano/Bozen, ITH1, Provincia Autonoma di Trento, ITH2, Veneto, ITH3, FriuliVenezia Giulia, ITH4, EmiliaRomagna, ITH5, Toscana, ITI1, Umbria, ITI2, Marche, ITI3, Lazio, ITI4, **LTU**, Lietuva (NUTS 2013), LT00, Sostines regionas, LT01, Vidurio ir vakaru Lietuvos regionas, LT02, **LUX**, Luxembourg, LU00, **LVA**, Latvija, LV00, **MLT**, Malta, MT00, **NLD**, Groningen, NL11, Friesland (NL), NL12, Drenthe, NL13, Overijssel, NL21, Gelderland, NL22, Flevoland, NL23, Utrecht, NL31, NoordHolland, NL32, ZuidHolland, NL33, Zeeland, NL34, Noord-Brabant, NL41, Limburg (NL), NL42, **POL**, Makroregion Poludniowy, PL2, Makroregion PolnocnoZachodni, PL4, Makroregion PoludniowoZachodni, PL5, Makroregion Polnocny, PL6, Makroregion Centralny, PL7, Makroregion Wschodni, PL8, Makroregion Wojewodztwo Mazowieckie, PL9, **PRT**, Norte, PT11, Algarve, PT15, Centro (PT), PT16, Area Metropolitana de Lisboa, PT17, Alentejo, PT18, **ROU**, NordVest, RO11, Centru, RO12, NordEst, RO21, SudEst, RO22, Sud Muntenia, RO31, Bucuresti Ilfov, RO32, SudVest Oltenia, RO41, Vest, RO42, **SVK**, Bratislavsky kraj, SK01, Západne Slovensko, SK02, Stredne Slovensko, SK03, Vychodne Slovensko, SK04, **SVN**, Vzhodna Slovenija (NUTS 2010), SI01, Zahodna Slovenija (NUTS 2010), SI02, Vzhodna Slovenija, SI03, Zahodna Slovenija, SI04, **SWE**, Oestra Sverige, SE1, Soedra Sverige, SE2, Norra Sverige, SE3,

Appendix C

Appendix to Chapter 3 - Quantifying Brexit: From Ex Post to Ex Ante Using Structural Gravity

C.1 The Model in Changes

We solve for counterfactual changes in all variables of interest using the following system of equations:[1]

$$\hat{c}_n^j = \hat{w}_n^{\beta_n^j} \left(\prod_{i=1}^{N} [\hat{p}_n^j]^{\gamma_n^{k,j}} \right)^{1-\beta_n^j}, \tag{C.1}$$

$$\hat{p}_n^j = \left(\sum_{i=1}^{N} \pi_{in}^j [\hat{\kappa}_{in}^j \hat{c}_i^j]^{-1/\theta^j} \right)^{-\theta^j}, \tag{C.2}$$

$$\hat{\pi}_{in}^j = \left(\frac{\hat{c}_i^j}{\hat{p}_n^j} \hat{\kappa}_{in}^j \right)^{-1/\theta^j}, \tag{C.3}$$

$$X_n^{j'} = \sum_{j=1}^{J} \gamma_n^{j,k} (1 - \beta_n^k) \left(\sum_{i=1}^{N} \frac{\pi_{ni}^{k'}}{1 + t_{ni}^{k'}} X_i^{k'} \right) + \alpha_n^j I_n', \tag{C.4}$$

$$\frac{1}{B} \sum_{j=1}^{J} F_n^{j'} X_n^{j'} + s_n = \frac{1}{B} \sum_{j=1}^{J} \sum_{i=1}^{N} \frac{\pi_{ni}^{j'}}{1 + t_{ni}^{j'}} X_i^{j'}, \tag{C.5}$$

[1] See also Caliendo and Parro (2015). Solving for counterfactual changes rather than levels strongly reduces the set of parameters and moments that have to be estimated or calibrated. In particular, no information on price levels, iceberg trade costs, or productivity levels is needed.

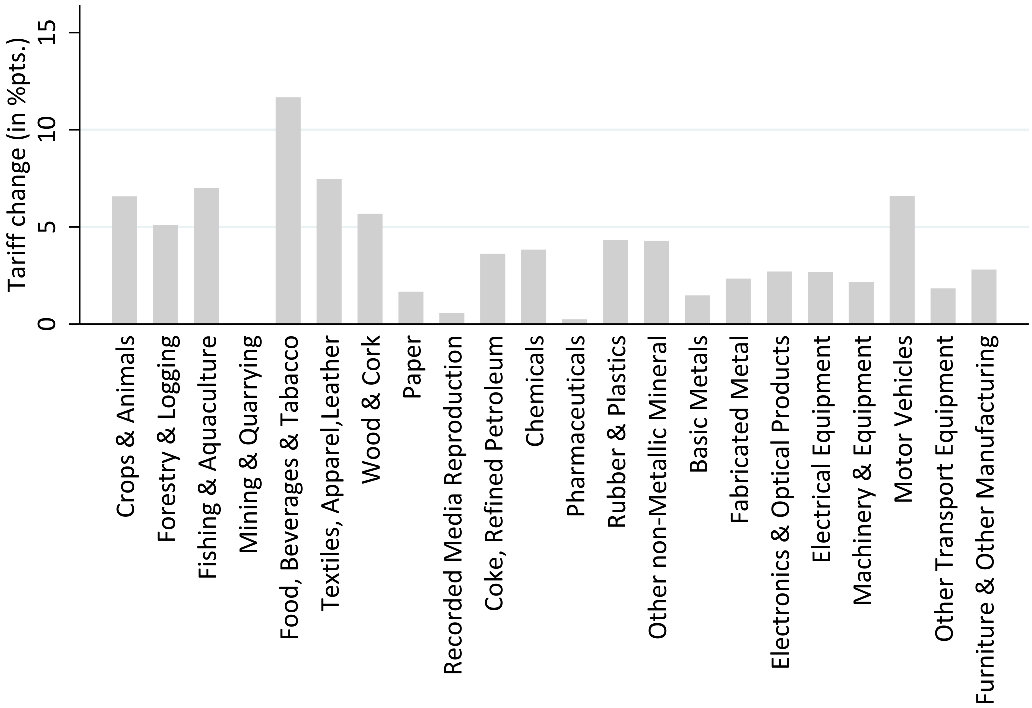
where $\hat{w}_n$ are wage changes, X_n^j are sectoral expenditure levels, $F_n^j \equiv \sum_{i=1}^N \frac{\pi_j^{in}}{(1+t_{in}^j)}$, $I_n' = \hat{w}_n w_n L_n + \sum_{j=1}^J X_n^{j\prime}(1 - F_n^{j\prime}) - S_n$, L_n denotes country n's labor force, and S_n is the (exogenously given) trade surplus. We fix $s_n \equiv S_n/B$, where $B \equiv \sum_n w_n L_n$ is global labor income, to make sure that the system is homogenous of degree zero in prices.

The shift in unit costs due to changes in input prices (i.e., wage and intermediate price changes) is laid out in equation (D.3). Trade cost changes directly affect the sectoral price index p_n^j, while changes in unit costs have an indirect effect (see equation (D.4)). Trade shares change as a reaction to changes in trade costs, unit costs, and prices. The productivity dispersion θ^j indicates the intensity of the reaction. Higher θ^j's imply bigger trade changes. Equation (D.6) ensures goods market clearing in the new equilibrium and the counterfactual income-equals-expenditure or balanced trade condition is given by equation (D.7).

To solve the system for multiple sectors, we again relate to Caliendo and Parro (2015), who extend the single-sector solution algorithm proposed by Alvarez and Lucas (2007). We start with an initial guess about a vector of wage changes. Using (D.3) and (D.4), it computes changes in prices, trade shares, expenditure levels, evaluates the trade balance condition (D.7), and updates the change in wages based on deviations in the trade balance.

C.2 Details on Data and Results

Figure C.1: Average MFN Tariffs on Intra-EU Trade, 2014



Note: Averages of sectoral bilateral tariffs across intra-EU country-pairs. Sectoral bilateral tariffs are trade-weighted MFN averages of the product-level MFN tariffs imposed by the EU in 2014.

Table C.1: List of WIOD Manufacturing Sectors

Sector ID	Sector Name	ISIC Rev. 4
1	Crops & Animals	A01
2	Forestry & Logging	A02
3	Fishing & Aquaculture	A03
4	Mining & Quarrying	B
5	Food, Beverages & Tobacco	C10-C12
6	Textiles, Apparel,Leather	C13-C15
7	Wood & Cork	C16
8	Paper	C17
9	Recorded Media Reproduction	C18
10	Coke, Refined Petroleum	C19
11	Chemicals	C20
12	Pharmaceuticals	C21
13	Rubber & Plastics	C22
14	Other non-Metallic Mineral	C23
15	Basic Metals	C24
16	Fabricated Metal	C25
17	Electronics & Optical Products	C26
18	Electrical Equipment	C27
19	Machinery & Equipment	C28,C33
20	Motor Vehicles	C29
21	Other Transport Equipment	C30
22	Furniture & Other Manufacturing	C31_C32
23	Electricity & Gas	D35
24	Water Supply	E36
25	Sewerage & Waste	E37-E39
26	Construction	F
27	Trade & Repair of Motor Vehicles	G45
28	Wholesale Trade	G46
29	Retail Trade	G47
30	Land Transport	H49
31	Water Transport	H50
32	Air Transport	H51
33	Aux. Transportation Services	H52
34	Postal and Courier	H53
35	Accommodation and Food	I
36	Publishing	J58
37	Media Services	J59_J60
38	Telecommunications	J61
39	Computer & Information Services	J62_J63
40	Financial Services	K64
41	Insurance	K65_K66
42	Real Estate	L68
43	Legal and Accounting	M69_M70
44	Business Services	M71,M73-M75
45	Research and Development	M72
46	Admin. & Support Services	N
47	Public & Social Services	O84
48	Education	P85
49	Human Health and Social Work	Q
50	Other Services, Households	R-U

Table C.2: Gross National Income and Transfer Redistribution

	Gross National Income in mn Euro	Fiscal Transfers in mn Euro
Austria	328,897	183
Belgium	402,665	224
Bulgaria	40973	23
Cyprus	16,583	9
Czech Republic	144473	81
Germany	2,972,188	1657
Denmark	264,873	148
Spain	1,052,245	587
Estonia	19,049	11
Finland	203,977	114
France	2,179,155	1215
United Kingdom	2,174,280	-6549
Greece	178,381	99
Croatia	41,773	23
Hungary	100,695	56
Ireland	159,732	89
Italy	1,613,795	900
Lithuania	35,203	20
Luxembourg	29,477	16
Latvia	23,868	13
Malta	7,629	4
Netherlands	662,465	369
Poland	396,058	221
Portugal	171,108	95
Romania	146,462	82
Slovak Republic	73,854	41
Slovenia	36,676	20
Sweden	445,168	248
EU27	11,747,422	6549

Note: Redistribution calculated based on the operating budgetary balance as stated by the European Commission for the 2010-2014 UK average, relative to each country's gross national income. The value of fiscal transfers that get redistributed make up 0.06% of EU27 member states' GNI and 0.30% of UK's GNI.

Table C.3: EU Integration Steps and Bilateral Imports, Goods (2000 - 2014)

Dep. var.:	Bilateral Imports									
Sector Description	Both EU27	exp: EU27 imp: UK	exp: UK imp: EU27	Euro	Schengen	EU27-KOR	UK-KOR	Other FTAs	Tariffs	Obs.
1 Crops & Animals°	1.154***	1.254***	0.733***	0.236***	0.184***	0.327	-0.212	0.144	-3.471***	27,735
2 Forestry & Logging°	0.075	0.194	0.267	0.414***	0.179***	0.091	-0.919***	-0.204	-3.471***	26,490
3 Fishing & Aquaculture°	0.711***	0.003	1.057	0.097	0.053	-0.174	0.605	-0.213	-3.471***	25,755
4 Mining & Quarrying°	0.013	-0.797***	-0.192	0.936***	0.016	1.136***	2.792***	-0.519***	-3.471***	27,705
5 Food, Beverages & Tobacco	0.706***	0.736***	0.555***	0.061	0.216***	0.18	-0.611***	0.106	-1.066	27,735
6 Textiles, Apparel, Leather°	0.440***	0.117	0.295	-0.035	0.032	0.345***	-0.414*	0.173	-3.471***	27,735
7 Wood & Cork°	0.298**	0.076	-0.109	0.131**	0.013	0.410***	0.479***	0.054	-3.471***	27,735
8 Paper°	0.438***	0.369	0.307**	0.037	0.041***	0.341***	-0.167	-0.003	-3.471***	27,735
9 Recorded Media Reproduction	-0.040	-0.111	-0.011	-0.175	0.052	0.879***	0.174	-0.203	-1.254	26,520
10 Coke, Refined Petroleum	-0.067	-0.294	-0.031	0.198*	0.217***	0.512*	0.372***	-0.108	-6.021***	26,795
11 Chemicals	0.459***	0.778***	0.254**	0.128**	0.106***	0.318***	0.166**	0.032	-3.530***	27,735
12 Pharmaceuticals	1.003***	1.099***	0.829***	0.008	0.178***	-0.061	-0.088	0.336**	-11.388***	26,310
13 Rubber & Plastics	0.609***	0.698***	0.448***	0.069*	0.154***	0.307***	0.116*	0.289***	-2.258**	27,735
14 Other non-Metallic Mineral	0.389***	0.265	0.223*	0.176***	0.069***	0.029	0.033	0.188*	-1.365*	27,735
15 Basic Metals	0.574***	0.681**	0.641***	0.154	0.130***	0.308***	0.075	0.280***	-3.191***	27,735
16 Fabricated Metal	0.457***	0.551***	0.254	0.121***	0.065***	0.275***	0.135	0.217***	-1.543***	27,090
17 Electronics & Optical Products	0.130	0.694***	-0.208	-0.176	-0.028	-0.150	-0.809***	-0.044	-7.780***	27,735
18 Electrical Equipment	0.554***	0.601***	0.151	0.053	0.092***	0.370***	-0.003	0.207***	-6.001***	27,090
19 Machinery & Equipment	0.264***	0.570***	0.214*	0.040	0.065***	0.119*	0.180***	0.053	-7.870***	27,735
20 Motor Vehicles	0.525***	0.731***	0.364	-0.088	0.117**	0.311***	0.144	0.249***	-4.610***	27,735
21 Other Transport Equipment	-0.041	0.187	-0.303	0.270**	-0.043	0.315	0.169	0.026	-2.948	27,090
22 Furniture & Other Manufacturing	0.008	-0.086	-0.149	0.076	0.130***	-0.571***	-1.110***	-0.164	-3.727***	27,735

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use Poisson Pseudo Maximum Likelihood (PPML) methods. Robust standard errors (not reported) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Sectors marked with ° report estimates based on tariff adjusted imports, applying overall trade elasticities for goods trade from Table (3.1) column (5).

Table C.4: EU Integration Steps and Bilateral Imports, Services (2000 - 2014)

Dep. var.:	Bilateral Imports								
Sector Description	Both EU27	exp: EU27 imp: UK	exp: UK imp: EU27	Euro	Schengen	EU27-KOR	UK-KOR	Other FTAs	Obs.
23 Electricity & Gas	0.903**	0.895**	1.068**	-0.169	0.065	0.356	-1.653***	0.605*	27,225
24 Water Supply	-0.098	-0.336	-0.000	0.105	0.117**	0.628***	0.623***	-0.530***	23,085
25 Sewerage & Waste	1.183***	1.314***	0.893***	0.080	0.016	-0.015	-0.015	0.716***	24,435
26 Construction	1.269***	1.239***	2.154***	0.000	0.102	0.137	0.234	0.763***	27,210
27 Trade & Repair of Motor Vehicles	0.705**	1.501**	2.251***	-0.030	0.518***	0.735***	1.096***	-0.051	25,770
28 Wholesale Trade	0.753***	1.515***	2.611***	0.105	0.215***	0.471***	1.299***	0.198**	27,285
29 Retail Trade	0.710***	1.373***	1.571***	-0.063	0.198***	0.425*	0.847***	0.105	25,740
30 Land Transport	0.617***	0.333*	1.047***	0.291**	-0.039	0.327*	0.384	-0.199**	27,630
31 Water Transport	0.782***	0.679**	0.759**	0.050	-0.015	0.302	-1.020**	0.141	27,480
32 Air Transport	0.344**	0.198	0.700***	-0.097	0.054	0.108	-0.859**	-0.289**	27,735
33 Aux. Transportation Services	0.246*	0.240	0.638***	-0.194**	0.082***	0.040	-0.025	-0.260**	27,525
34 Postal and Courier	0.620***	1.266***	0.245	-0.343**	0.445***	0.680**	-0.163	0.638***	23,475
35 Accommodation and Food	-0.315*	0.002	-0.018	0.382***	-0.305***	-0.457***	-1.576***	-0.450***	25,455
36 Publishing	0.200	0.230	0.542*	-0.487***	-0.010	-0.191	-0.096	-0.286**	24,270
37 Media Services	0.347*	0.027	0.565**	0.246*	-0.084	0.071	0.063	-0.144	24,165
38 Telecommunications	0.166	0.466	0.323	0.281***	0.103***	0.604***	-0.060	-0.067	27,720
39 Computer & Information Services	0.825***	1.067***	0.532**	0.207**	0.154***	0.848**	-0.221	-0.084	26,955
40 Financial Services	0.616**	1.809***	0.484	0.558***	-0.067	0.899***	-0.366*	-0.055	27,015
41 Insurance	-0.103	-0.121	-0.609	0.471***	-0.143	0.058	-0.147	-0.246	26,370
42 Real Estate	0.336	0.832**	1.104***	0.208	-0.008	0.040	0.544	-0.095	23,565
43 Legal and Accounting	0.451***	0.520**	0.599**	-0.011	0.143***	0.160	0.018	0.243*	24,960
44 Business Services	1.116***	0.999***	0.993***	-0.028	0.063	0.809***	0.413***	0.632***	25,635
45 Research and Development	0.163**	-0.134	-0.049	0.097	0.035	-0.138	-1.095***	-0.024	24,647
46 Admin. & Support Services	0.450***	0.229	-0.097	0.176	0.133***	0.046	-0.509***	-0.140	26,910
47 Public & Social Services	0.533***	0.438	0.656	0.027	0.084**	0.095	1.085***	0.272*	25,785
48 Education	0.427***	1.062***	1.503***	0.289**	0.292***	0.555	1.065***	0.021	25,950
49 Human Health and Social Work	0.377*	0.271	0.959**	0.317**	0.456***	0.971***	1.058***	0.036	26,160
50 Other Services, Households	0.963	0.824	0.397	-0.243**	-0.089	0.023	0.919***	0.078	27,495

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use Poisson Pseudo Maximum Likelihood (PPML) methods. Robust standard errors (not reported) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. For services sectors, we calculate the trade elasticity for services according to Egger et al. (2012).

Table C.5: Counterfactual Change in Real Consumption of Welfare Decomposition in Scenario 1, in %

	All Sub-Scenarios	Transfers Only	Agri.	Manuf.	Agri.	Manuf	Serv.
			Tariffs Only		NTBs Only		
UK	**-2.61**	**0.29**	**0.01**	**0.05**	0.03	**-0.73**	**-2.31**
	[-3.21, -2.00]	[0.29, 0.29]	[0.00, 0.01]	[0.04, 0.06]	[-0.04, 0.11]	[-1.11, -0.36]	[-2.79, -1.83]
Austria	**-0.33**	**-0.06**	0.00	**-0.01**	0.00	**-0.03**	**-0.23**
	[-0.38, -0.27]	[-0.06, -0.06]	[-0.00, 0.00]	[-0.02, -0.01]	[-0.00, 0.01]	[-0.05, -0.02]	[-0.28, -0.18]
Belgium	**-1.36**	**-0.06**	**-0.00**	**-0.07**	0.02	**-0.20**	**-1.04**
	[-1.60, -1.12]	[-0.07, -0.06]	[-0.00, -0.00]	[-0.09, -0.06]	[-0.01, 0.04]	[-0.27, -0.13]	[-1.26, -0.82]
Bulgaria	**-0.46**	**-0.04**	0.00	**-0.00**	0.00	**-0.07**	**-0.35**
	[-0.54, -0.38]	[-0.04, -0.04]	[-0.00, 0.00]	[-0.01, -0.00]	[-0.00, 0.01]	[-0.11, -0.03]	[-0.42, -0.28]
Croatia	**-0.37**	**-0.05**	0.00	-0.00	-0.00	**-0.03**	**-0.28**
	[-0.44, -0.29]	[-0.05, -0.05]	[-0.00, 0.00]	[-0.00, 0.00]	[-0.00, 0.00]	[-0.05, -0.02]	[-0.35, -0.21]
Cyprus	**-1.45**	**-0.05**	**-0.01**	0.00	-0.00	**-0.19**	**-1.21**
	[-1.80, -1.09]	[-0.05, -0.05]	[-0.01, -0.00]	[-0.00, 0.01]	[-0.01, 0.01]	[-0.33, -0.05]	[-1.55, -0.88]
Czech R.	**-0.54**	**-0.07**	-0.00	**-0.04**	**0.01**	**-0.06**	**-0.37**
	[-0.65, -0.44]	[-0.07, -0.07]	[-0.00, 0.00]	[-0.05, -0.04]	[0.00, 0.02]	[-0.11, -0.00]	[-0.46, -0.28]
Denmark	**-0.93**	**-0.07**	**-0.00**	**-0.03**	-0.00	**-0.12**	**-0.72**
	[-1.10, -0.77]	[-0.07, -0.07]	[-0.00, -0.00]	[-0.03, -0.02]	[-0.03, 0.03]	[-0.16, -0.08]	[-0.87, -0.57]
Estonia	**-0.64**	**-0.06**	**-0.00**	**-0.02**	0.00	**-0.11**	**-0.46**
	[-0.79, -0.50]	[-0.06, -0.06]	[-0.00, -0.00]	[-0.03, -0.01]	[-0.01, 0.01]	[-0.21, -0.01]	[-0.57, -0.35]
Finland	**-0.49**	**-0.06**	-0.00	-0.01	0.01	**-0.05**	**-0.39**
	[-0.58, -0.41]	[-0.06, -0.06]	[-0.01, 0.01]	[-0.01, 0.00]	[-0.00, 0.03]	[-0.08, -0.01]	[-0.46, -0.31]
France	**-0.52**	**-0.06**	-0.00	**-0.02**	0.01	**-0.07**	**-0.38**
	[-0.63, -0.40]	[-0.06, -0.06]	[-0.00, 0.00]	[-0.02, -0.02]	[-0.00, 0.02]	[-0.10, -0.04]	[-0.50, -0.27]
Germany	**-0.60**	**-0.07**	-0.00	**-0.05**	0.02	**-0.09**	**-0.41**
	[-0.69, -0.50]	[-0.07, -0.07]	[-0.01, 0.00]	[-0.05, -0.04]	[-0.00, 0.05]	[-0.13, -0.05]	[-0.49, -0.33]
Greece	**-0.38**	**-0.04**	**0.00**	0.00	0.00	**-0.04**	**-0.31**
	[-0.46, -0.31]	[-0.04, -0.04]	[0.00, 0.00]	[-0.00, 0.00]	[-0.00, 0.01]	[-0.07, -0.02]	[-0.38, -0.23]
Hungary	**-0.68**	**-0.06**	0.00	**-0.04**	**0.01**	**-0.05**	**-0.52**
	[-0.78, -0.58]	[-0.07, -0.06]	[-0.00, 0.00]	[-0.05, -0.04]	[0.00, 0.02]	[-0.09, -0.01]	[-0.60, -0.43]
Ireland	**-7.25**	**-0.09**	**-0.16**	**-0.25**	**-0.21**	**-1.48**	**-5.14**
	[-8.36, -6.14]	[-0.10, -0.09]	[-0.21, -0.12]	[-0.40, -0.09]	[-0.38, -0.03]	[-1.81, -1.14]	[-5.92, -4.36]
Italy	**-0.40**	**-0.06**	-0.00	**-0.02**	0.00	**-0.04**	**-0.28**
	[-0.47, -0.32]	[-0.06, -0.06]	[-0.00, 0.00]	[-0.02, -0.02]	[-0.00, 0.01]	[-0.06, -0.02]	[-0.34, -0.21]
Latvia	**-0.58**	**-0.05**	-0.00	**-0.03**	0.00	-0.10	**-0.41**
	[-0.72, -0.43]	[-0.05, -0.05]	[-0.00, 0.00]	[-0.04, -0.02]	[-0.00, 0.01]	[-0.21, 0.01]	[-0.51, -0.30]
Lithuania	**-0.47**	**-0.06**	0.00	**-0.07**	**-0.01**	-0.07	**-0.27**
	[-0.60, -0.33]	[-0.06, -0.06]	[-0.00, 0.00]	[-0.08, -0.06]	[-0.01, -0.00]	[-0.17, 0.03]	[-0.34, -0.19]
Luxembourg	**-6.36**	**-0.12**	**-0.01**	**-0.06**	-0.02	**-0.09**	**-6.05**
	[-8.79, -3.93]	[-0.12, -0.12]	[-0.01, -0.00]	[-0.07, -0.06]	[-0.05, 0.00]	[-0.16, -0.02]	[-7.69, -4.40]
Malta	**-4.63**	**-0.03**	**0.00**	**0.02**	0.01	**-0.32**	**-4.32**
	[-5.78, -3.47]	[-0.03, -0.03]	[0.00, 0.00]	[0.02, 0.03]	[-0.01, 0.03]	[-0.48, -0.15]	[-5.50, -3.14]
Netherlands	**-1.63**	**-0.09**	**-0.01**	**-0.10**	-0.05	**-0.24**	**-1.15**
	[-1.85, -1.41]	[-0.09, -0.09]	[-0.02, -0.01]	[-0.11, -0.09]	[-0.11, 0.02]	[-0.32, -0.16]	[-1.31, -0.99]
Poland	**-0.63**	**-0.06**	**0.00**	**-0.04**	0.01	**-0.08**	**-0.45**
	[-0.71, -0.54]	[-0.06, -0.06]	[0.00, 0.00]	[-0.05, -0.04]	[-0.01, 0.02]	[-0.12, -0.04]	[-0.52, -0.37]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets.

Table C.6: Counterfactual Change in Real Consumption of Welfare Decomposition in scenario 1, in %, continued

	All Sub-Scenarios	Transfers Only	Agri.	Manuf.	Agri.	Manuf	Serv.
			Tariffs Only		NTBs Only		
Portugal	**-0.45**	**-0.05**	**0.00**	**-0.02**	-0.00	**-0.05**	**-0.34**
	[-0.56, -0.35]	[-0.05, -0.05]	[0.00, 0.00]	[-0.02, -0.02]	[-0.01, 0.01]	[-0.08, -0.03]	[-0.44, -0.23]
Romania	**-0.37**	**-0.05**	**0.00**	**-0.01**	**-0.00**	**-0.05**	**-0.26**
	[-0.45, -0.29]	[-0.05, -0.05]	[0.00, 0.00]	[-0.01, -0.00]	[-0.00, -0.00]	[-0.07, -0.03]	[-0.33, -0.18]
Slovakia	**-0.73**	**-0.06**	**-0.00**	**-0.04**	0.00	**-0.16**	**-0.48**
	[-0.86, -0.60]	[-0.06, -0.06]	[-0.00, -0.00]	[-0.05, -0.04]	[-0.01, 0.01]	[-0.19, -0.12]	[-0.62, -0.35]
Slovenia	**-0.42**	**-0.06**	**-0.00**	**-0.01**	-0.00	**-0.07**	**-0.28**
	[-0.50, -0.35]	[-0.07, -0.06]	[-0.00, -0.00]	[-0.01, -0.01]	[-0.01, 0.00]	[-0.09, -0.05]	[-0.36, -0.20]
Spain	**-0.39**	**-0.06**	**-0.00**	**-0.01**	-0.00	**-0.07**	**-0.23**
	[-0.48, -0.30]	[-0.06, -0.06]	[-0.00, -0.00]	[-0.02, -0.01]	[-0.02, 0.01]	[-0.09, -0.05]	[-0.31, -0.14]
Sweden	**-0.75**	**-0.07**	**-0.00**	**-0.02**	0.00	**-0.09**	**-0.58**
	[-0.91, -0.58]	[-0.07, -0.07]	[-0.00, -0.00]	[-0.02, -0.02]	[-0.03, 0.04]	[-0.14, -0.04]	[-0.75, -0.42]
Australia	-0.00	**0.00**	0.00	**0.00**	**0.00**	0.00	-0.00
	[-0.01, 0.00]	[0.00, 0.00]	[-0.00, 0.00]	[0.00, 0.00]	[0.00, 0.01]	[-0.00, 0.01]	[-0.00, 0.00]
Brazil	**-0.01**	**-0.00**	0.00	**-0.00**	**0.00**	-0.00	**-0.00**
	[-0.01, -0.01]	[-0.00, -0.00]	[-0.00, 0.00]	[-0.00, -0.00]	[0.00, 0.00]	[-0.00, 0.00]	[-0.01, -0.00]
Canada	0.00	0.00	0.00	**-0.00**	**-0.01**	**0.01**	-0.01
	[-0.00, 0.01]	[-0.00, 0.00]	[-0.00, 0.00]	[-0.00, -0.00]	[-0.01, -0.00]	[0.00, 0.02]	[-0.01, 0.00]
China	**0.05**	**-0.00**	0.00	**0.01**	-0.00	**0.02**	**0.02**
	[0.04, 0.05]	[-0.00, -0.00]	[-0.00, 0.00]	[0.01, 0.01]	[-0.00, 0.00]	[0.01, 0.03]	[0.01, 0.03]
India	**0.02**	**0.00**	0.00	**0.00**	**0.00**	**0.00**	**0.01**
	[0.01, 0.02]	[0.00, 0.00]	[-0.00, 0.00]	[0.00, 0.01]	[0.00, 0.00]	[0.00, 0.01]	[0.00, 0.01]
Indonesia	**0.01**	**-0.00**	0.00	0.00	-0.00	**0.00**	**0.00**
	[0.01, 0.01]	[-0.00, -0.00]	[-0.00, 0.00]	[-0.00, 0.00]	[-0.00, 0.00]	[0.00, 0.00]	[0.00, 0.01]
Japan	-0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	**-0.01**
	[-0.00, 0.00]	[0.00, 0.00]	[-0.00, 0.00]	[0.00, 0.00]	[-0.00, 0.00]	[0.00, 0.00]	[-0.01, -0.00]
Korea	-0.03	**0.00**	0.00	-0.00	**0.00**	**0.04**	**0.04**
	[-0.08, 0.02]	[0.00, 0.00]	[-0.00, 0.00]	[-0.00, 0.00]	[0.00, 0.00]	[0.02, 0.05]	[0.03, 0.06]
Mexico	-0.01	**0.00**	**0.00**	**0.00**	**-0.00**	**0.01**	0.00
	[-0.01, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[-0.00, -0.00]	[0.01, 0.01]	[-0.00, 0.00]
Norway	**0.52**	**0.01**	0.00	**0.01**	-0.09	0.02	-0.05
	[0.10, 0.94]	[0.01, 0.01]	[-0.00, 0.00]	[0.01, 0.01]	[-0.19, 0.01]	[-0.05, 0.08]	[-0.17, 0.06]
Russia	0.01	**-0.00**	0.00	0.00	-0.01	0.00	0.01
	[-0.02, 0.03]	[-0.00, -0.00]	[-0.00, 0.00]	[-0.00, 0.00]	[-0.03, 0.01]	[-0.01, 0.02]	[-0.01, 0.03]
Switzerland	-0.01	**-0.00**	**-0.00**	**0.01**	0.00	**0.10**	0.06
	[-0.16, 0.14]	[-0.00, -0.00]	[-0.00, -0.00]	[0.01, 0.01]	[-0.00, 0.00]	[0.06, 0.14]	[-0.01, 0.14]
Taiwan	**0.13**	**-0.00**	0.00	**0.02**	-0.00	**0.05**	**0.07**
	[0.11, 0.16]	[-0.00, -0.00]	[-0.00, 0.00]	[0.02, 0.02]	[-0.00, 0.00]	[0.03, 0.08]	[0.04, 0.09]
Turkey	**-0.04**	**0.00**	**0.00**	**0.03**	**0.00**	**0.03**	-0.01
	[-0.07, -0.01]	[0.00, 0.00]	[0.00, 0.00]	[0.02, 0.03]	[0.00, 0.00]	[0.02, 0.04]	[-0.02, 0.00]
USA	**-0.01**	**0.00**	**0.00**	**0.00**	**0.00**	-0.00	**-0.01**
	[-0.02, -0.01]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.00]	[-0.00, 0.00]	[-0.02, -0.01]
ROW	-0.02	**0.00**	0.00	**0.00**	**-0.00**	**0.01**	-0.02
	[-0.05, 0.01]	[0.00, 0.00]	[-0.00, 0.00]	[0.00, 0.01]	[-0.01, -0.00]	[0.00, 0.01]	[-0.05, 0.01]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets.

Table C.7: Counterfactual Changes of Bilateral Exports of EU27, in %

	Exports to EU27		Exports to UK		Exports to ROW	
	Initial mn USD	Δ in %	Initial mn USD	Δ in %	Initial mn USD	Δ in %
Panel A: S1						
Agriculture	126230.6	-0.24	13150.26	**-22.74**	55078.38	**0.85**
		[-0.72, 0.25]		[-41.40, -4.09]		[0.50, 1.19]
Manufacturing	2185370	-0.14	266238	**-30.63**	1726202	**1.15**
		[-0.34, 0.07]		[-34.45, -26.81]		[0.86, 1.44]
Services	839322.2	**-0.30**	127694	**-21.21**	1097312	**0.44**
		[-0.53, -0.06]		[-24.98, -17.43]		[0.25, 0.63]
Total	3150923	**-0.18**	407082.2	**-27.42**	2878593	**0.87**
		[-0.36, -0.01]		[-30.14, -24.71]		[0.67, 1.08]
Panel B: S2						
Agriculture	126230.6	-1.34	13150.26	40.06	55078.38	-0.13
		[-2.97, 0.30]		[-15.79, 95.91]		[-0.50, 0.23]
Manufacturing	2185370	-0.31	266238	-4.71	1726202	**0.35**
		[-0.62, 0.00]		[-10.75, 1.34]		[0.00, 0.69]
Services	839322.2	0.25	127694	**-7.55**	1097312	**0.32**
		[-0.02, 0.51]		[-13.07, -2.03]		[0.05, 0.59]
Total	3150923	-0.20	407082.2	-4.15	2878593	**0.33**
		[-0.45, 0.04]		[-9.03, 0.72]		[0.07, 0.58]
Panel C: S3						
Agriculture	126230.6	-0.34	13150.26	**-19.87**	55078.38	**0.95**
		[-0.84, 0.15]		[-39.10, -0.64]		[0.54, 1.35]
Manufacturing	2185370	**-0.35**	266238	**-34.35**	1726202	**1.14**
		[-0.56, -0.15]		[-38.42, -30.29]		[0.82, 1.47]
Services	839322.2	**-0.48**	127694	**-19.76**	1097312	**0.37**
		[-0.72, -0.24]		[-23.72, -15.81]		[0.18, 0.56]
Total	3150923	**-0.39**	407082.2	**-29.31**	2878593	**0.84**
		[-0.56, -0.21]		[-32.21, -26.41]		[0.62, 1.07]
Panel D: S4						
Agriculture	126230.6	-0.28	13150.26	**-10.90**	55078.38	-0.12
		[-0.75, 0.19]		[-14.53, -7.27]		[-0.39, 0.14]
Manufacturing	2185370	**-0.22**	266238	**-11.52**	1726202	**-0.51**
		[-0.44, -0.00]		[-12.98, -10.06]		[-0.70, -0.33]
Services	839322.2	**0.28**	127694	**-4.29**	1097312	**0.21**
		[0.03, 0.52]		[-5.12, -3.46]		[0.02, 0.40]
Total	3150923	-0.09	407082.2	**-9.23**	2878593	**-0.23**
		[-0.28, 0.09]		[-10.37, -8.09]		[-0.36, -0.09]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets. Domestic trade is not taken into account.

Table C.8: Counterfactual Changes of Bilateral Exports of UK, in %

	Exports to EU27		Exports to ROW	
	Initial mn USD	Δ in %	Initial in mn USD	Δ in %
Panel A: S1				
Agriculture	12761.92	-4.46	17163.94	**-6.31**
		[-37.27, 28.35]		[-8.11, -4.52]
Manufacturing	116610.8	**-32.19**	187800.8	**-10.00**
		[-38.09, -26.28]		[-11.98, -8.02]
Services	160391.2	**-20.85**	253204.4	**-0.43**
		[-26.24, -15.45]		[-0.80, -0.06]
Total	289763.9	**-24.69**	458169.1	**-4.57**
		[-28.29, -21.08]		[-5.49, -3.65]
Panel B: S2				
Agriculture	12761.92	96.05	17163.94	**-7.20**
		[-14.14, 206.25]		[-9.57, -4.82]
Manufacturing	116610.8	7.16	187800.8	**-7.58**
		[-6.68, 21.00]		[-10.24, -4.93]
Services	160391.2	**-7.16**	253204.4	**-0.76**
		[-14.19, -0.13]		[-1.33, -0.20]
Total	289763.9	3.15	458169.1	**-3.80**
		[-4.83, 11.12]		[-5.15, -2.45]
Panel C: S3				
Agriculture	12761.92	-6.70	17163.94	7.11
		[-38.26, 24.86]		[-5.83, 20.04]
Manufacturing	116610.8	**-32.33**	187800.8	**14.80**
		[-38.11, -26.55]		[8.30, 21.31]
Services	160391.2	**-21.33**	253204.4	**4.49**
		[-26.50, -16.16]		[2.94, 6.03]
Total	289763.9	**-25.11**	458169.1	**8.81**
		[-28.70, -21.53]		[6.07, 11.56]
Panel D: S4				
Agriculture	12761.92	2.50	17163.94	**7.61**
		[-32.46, 37.46]		[3.75, 11.46]
Manufacturing	116610.8	**-17.84**	187800.8	**9.93**
		[-24.12, -11.56]		[7.92, 11.94]
Services	160391.2	**-18.79**	253204.4	**1.44**
		[-24.25, -13.33]		[1.10, 1.77]
Total	289763.9	**-17.47**	458169.1	**5.15**
		[-21.12, -13.82]		[4.20, 6.10]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets. Domestic trade is not taken into account.

Table C.9: Counterfactual Changes of Bilateral Exports of RoW, in %

	Exports to EU27		Exports to UK		Exports to ROW	
	Initial mn USD	Δ in %	Initial mn USD	Δ in %	Initial mn USD	Δ in %
Panel A: S1						
Agriculture	323832.4	**-1.19**	37293.41	**10.05**	1678540	**0.25**
		[-2.13, -0.25]		[1.73, 18.37]		[0.17, 0.33]
Manufacturing	1172862	**-0.91**	223334.2	**9.80**	6719728	**0.24**
		[-1.18, -0.65]		[7.46, 12.14]		[0.19, 0.29]
Services	721619.4	**-0.96**	98251.83	0.07	2389414	**0.20**
		[-1.27, -0.65]		[-0.89, 1.03]		[0.16, 0.23]
Total	2218314	**-0.97**	358879.5	**7.16**	1.08e+07	**0.23**
		[-1.23, -0.71]		[5.24, 9.08]		[0.19, 0.28]
Panel B: S2						
Agriculture	323832.4	-1.96	37293.41	9.62	1678540	-0.04
		[-4.55, 0.62]		[-3.23, 22.47]		[-0.20, 0.12]
Manufacturing	1172862	**-0.68**	223334.2	1.80	6719728	0.06
		[-1.12, -0.24]		[-1.35, 4.94]		[-0.02, 0.14]
Services	721619.4	-0.33	98251.83	1.04	2389414	0.01
		[-0.67, 0.02]		[-0.37, 2.46]		[-0.05, 0.07]
Total	2218314	**-0.75**	358879.5	2.40	1.08e+07	0.03
		[-1.22, -0.28]		[-0.29, 5.09]		[-0.05, 0.11]
Panel C: S3						
Agriculture	323832.4	**-1.49**	37293.41	**22.05**	1678540	**0.27**
		[-2.42, -0.55]		[11.28, 32.81]		[0.14, 0.39]
Manufacturing	1172862	**-1.35**	223334.2	**34.19**	6719728	0.03
		[-1.64, -1.06]		[28.66, 39.73]		[-0.05, 0.10]
Services	721619.4	**-1.13**	98251.83	**9.04**	2389414	**0.11**
		[-1.42, -0.83]		[6.21, 11.87]		[0.07, 0.14]
Total	2218314	**-1.30**	358879.5	**26.05**	1.08e+07	**0.08**
		[-1.58, -1.02]		[21.96, 30.13]		[0.02, 0.15]
Panel D: S4						
Agriculture	323832.4	-0.57	37293.41	-2.51	1678540	**0.25**
		[-1.38, 0.23]		[-5.76, 0.74]		[0.21, 0.29]
Manufacturing	1172862	0.19	223334.2	**9.96**	6719728	**0.16**
		[-0.10, 0.48]		[8.06, 11.87]		[0.12, 0.20]
Services	721619.4	-0.07	98251.83	**-4.28**	2389414	**0.19**
		[-0.40, 0.26]		[-5.07, -3.50]		[0.16, 0.21]
Total	2218314	-0.01	358879.5	**4.77**	1.08e+07	**0.18**
		[-0.25, 0.24]		[3.35, 6.18]		[0.15, 0.21]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets. Domestic trade is not taken into account.

Table C.10: Counterfactual Changes of Gross Trade Flows, in %

	Initial Exports	Changes in Exports in %				Initial Imports	Changes in Imports in %			
	bn USD	S1	S2	S3	S4	bn USD	S1	S2	S3	S4
Panel A: UK										
Agriculture	29.93	-5.52	36.83	1.22	5.43	50.44	1.50	**17.56**	**11.12**	**-4.70**
		[-19.64, 8.59]	[-9.66, 83.33]	[-14.70, 17.13]	[-9.96, 20.81]		[-7.01, 10.02]	[0.76, 34.35]	[1.00, 21.24]	[-7.32, -2.08]
Manufacturing	304.41	**-18.50**	-1.94	-3.25	-0.71	489.57	**-12.19**	-1.74	**-3.08**	**-1.72**
		[-21.23, -15.76]	[-7.27, 3.40]	[-7.57, 1.06]	[-3.11, 1.70]		[-13.65, -10.72]	[-4.25, 0.77]	[-5.17, -1.00]	[-2.70, -0.74]
Services	413.60	**-8.35**	**-3.24**	**-5.52**	**-6.41**	225.95	**-11.96**	**-3.81**	**-7.24**	**-4.29**
		[-10.44, -6.26]	[-5.93, -0.56]	[-7.62, -3.43]	[-8.39, -4.42]		[-14.09, -9.82]	[-7.05, -0.58]	[-9.64, -4.83]	[-5.09, -3.48]
Total	747.93	-12.36	-1.11	-4.33	-3.61	765.96	-11.22	-1.08	-3.37	-2.67
		[-24.80, 0.07]	[-42.83, 40.62]	[-15.28, 6.63]	[-15.91, 8.69]		[-22.82, 0.38]	[-20.09, 17.93]	[-17.67, 10.93]	[-5.37, 0.02]
Panel B: EU27										
Agriculture	194.46	**-1.45**	1.80	-1.30	**-0.96**	462.82	**-1.02**	0.91	**-1.32**	**-0.41**
		[-2.80, -0.11]	[-1.23, 4.84]	[-2.67, 0.07]	[-1.40, -0.51]		[-1.49, -0.54]	[-0.30, 2.12]	[-1.77, -0.86]	[-0.81, -0.01]
Manufacturing	4177.81	**-1.55**	-0.32	**-1.90**	**-1.06**	3474.84	**-1.48**	-0.18	**-1.76**	**-0.67**
		[-1.80, -1.30]	[-0.70, 0.06]	[-2.16, -1.64]	[-1.26, -0.87]		[-1.63, -1.32]	[-0.46, 0.09]	[-1.92, -1.60]	[-0.80, -0.55]
Services	2064.33	**-1.20**	-0.20	**-1.22**	-0.04	1721.33	**-2.49**	**-0.68**	**-2.69**	**-1.64**
		[-1.46, -0.94]	[-0.60, 0.20]	[-1.49, -0.95]	[-0.22, 0.13]		[-2.91, -2.07]	[-1.30, -0.06]	[-3.11, -2.28]	[-2.07, -1.22]
Total	6,436.60	**-1.43**	-0.22	**-1.67**	-0.73	5,659.00	**-1.75**	-0.25	**-2.01**	**-0.95**
		[-2.27, -0.59]	[-2.66, 2.22]	[-2.62, -0.71]	[-1.54, 0.07]		[-2.79, -0.71]	[-1.59, 1.10]	[-2.99, -1.03]	[-1.85, -0.05]
Panel C: RoW										
Agriculture	2039.67	**0.20**	-0.17	**0.39**	0.07	1750.78	**0.21**	-0.11	**0.35**	**0.31**
		[0.11, 0.29]	[-0.58, 0.24]	[0.29, 0.49]	[-0.05, 0.19]		[0.12, 0.29]	[-0.27, 0.04]	[0.20, 0.51]	[0.25, 0.37]
Manufacturing	8115.92	**0.34**	0.00	**0.77**	**0.43**	8633.73	**0.20**	-0.05	**0.57**	**0.24**
		[0.27, 0.41]	[-0.12, 0.12]	[0.66, 0.88]	[0.38, 0.49]		[0.17, 0.23]	[-0.13, 0.03]	[0.47, 0.67]	[0.20, 0.27]
Services	3209.29	**-0.07**	-0.03	**0.10**	-0.01	3739.93	**0.23**	0.05	**0.48**	**0.28**
		[-0.12, -0.01]	[-0.10, 0.03]	[0.01, 0.19]	[-0.06, 0.05]		[0.17, 0.28]	[-0.05, 0.15]	[0.37, 0.59]	[0.23, 0.33]
Total	13,364.88	0.22	-0.03	**0.55**	0.27	14,124.44	**0.21**	-0.03	**0.52**	**0.26**
		[-0.06, 0.50]	[-0.32, 0.25]	[0.10, 1.00]	[-0.06, 0.60]		[0.14, 0.27]	[-0.20, 0.14]	[0.33, 0.71]	[0.19, 0.33]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution.

Table C.11: Counterfactual Changes of Real Wages, in %

	Change of Real Wages, in %					Change of Real Wages, in %			
	S1	**S2**	**S3**	**S4**		**S1**	**S2**	**S3**	**S4**
UK	**-3.37**	**-0.95**	**-1.78**	**-0.36**	Portugal	**-0.45**	**-0.13**	**-0.47**	**-0.38**
	[-3.38, -3.37]	[-0.96, -0.94]	[-1.79, -1.77]	[-0.37, -0.36]		[-0.46, -0.45]	[-0.13, -0.13]	[-0.47, -0.47]	[-0.38, -0.38]
Austria	**-0.28**	**-0.08**	**-0.29**	**-0.25**	Romania	**-0.33**	**-0.16**	**-0.35**	**-0.29**
	[-0.28, -0.28]	[-0.08, -0.08]	[-0.29, -0.29]	[-0.25, -0.25]		[-0.33, -0.33]	[-0.16, -0.16]	[-0.35, -0.35]	[-0.29, -0.29]
Belgium	**-1.27**	**-0.27**	**-1.31**	**-0.94**	Slovakia	**-0.58**	**-0.28**	**-0.59**	**-0.35**
	[-1.28, -1.27]	[-0.27, -0.27]	[-1.31, -1.30]	[-0.94, -0.94]		[-0.58, -0.58]	[-0.28, -0.28]	[-0.60, -0.59]	[-0.35, -0.34]
Bulgaria	**-0.51**	**-0.25**	**-0.51**	**-0.44**	Slovenia	**-0.35**	**-0.15**	**-0.35**	**-0.30**
	[-0.51, -0.51]	[-0.25, -0.24]	[-0.52, -0.51]	[-0.44, -0.44]		[-0.35, -0.34]	[-0.15, -0.15]	[-0.36, -0.35]	[-0.30, -0.30]
Croatia	**-0.30**	**-0.04**	**-0.30**	**-0.26**	Spain	**-0.35**	**-0.13**	**-0.37**	**-0.26**
	[-0.30, -0.30]	[-0.04, -0.04]	[-0.30, -0.30]	[-0.26, -0.26]		[-0.35, -0.35]	[-0.14, -0.13]	[-0.37, -0.37]	[-0.27, -0.26]
Cyprus	**-1.49**	**-0.37**	**-1.48**	**-1.09**	Sweden	**-0.68**	**-0.14**	**-0.69**	**-0.60**
	[-1.49, -1.48]	[-0.37, -0.36]	[-1.49, -1.48]	[-1.10, -1.09]		[-0.68, -0.67]	[-0.15, -0.14]	[-0.70, -0.69]	[-0.60, -0.60]
Czech R.	**-0.57**	**-0.28**	**-0.61**	**-0.45**	Australia	**-0.00**	**-0.00**	**0.14**	**0.01**
	[-0.57, -0.57]	[-0.28, -0.28]	[-0.61, -0.60]	[-0.46, -0.45]		[-0.00, -0.00]	[-0.00, -0.00]	[0.14, 0.14]	[0.01, 0.01]
Denmark	**-0.75**	**-0.15**	**-0.75**	**-0.65**	Brasil	**-0.00**	**-0.00**	**-0.00**	**0.01**
	[-0.75, -0.75]	[-0.15, -0.14]	[-0.76, -0.75]	[-0.65, -0.65]		[-0.00, -0.00]	[-0.00, -0.00]	[-0.00, -0.00]	[0.01, 0.01]
Estonia	**-0.67**	**-0.26**	**-0.67**	**-0.60**	Canada	**-0.00**	**-0.01**	**0.28**	**0.01**
	[-0.67, -0.66]	[-0.27, -0.26]	[-0.67, -0.67]	[-0.60, -0.60]		[-0.00, -0.00]	[-0.01, -0.01]	[0.28, 0.28]	[0.01, 0.01]
Finland	**-0.46**	**-0.08**	**-0.47**	**-0.42**	China	**0.00**	**0.00**	**0.08**	**0.02**
	[-0.46, -0.46]	[-0.08, -0.08]	[-0.47, -0.47]	[-0.42, -0.42]		[0.00, 0.00]	[0.00, 0.00]	[0.08, 0.08]	[0.02, 0.02]
France	**-0.50**	**-0.10**	**-0.52**	**-0.38**	India	**0.00**	0.00	**0.18**	**0.05**
	[-0.50, -0.50]	[-0.10, -0.10]	[-0.52, -0.52]	[-0.38, -0.37]		[0.00, 0.00]	[-0.00, 0.00]	[0.18, 0.18]	[0.05, 0.05]
Germany	**-0.53**	**-0.14**	**-0.55**	**-0.42**	Indonesia	**0.00**	-0.00	-0.00	**0.01**
	[-0.53, -0.53]	[-0.14, -0.14]	[-0.55, -0.55]	[-0.42, -0.42]		[0.00, 0.00]	[-0.00, 0.00]	[-0.00, 0.00]	[0.01, 0.01]
Greece	**-0.40**	**-0.13**	**-0.40**	**-0.35**	Japan	**0.00**	**0.01**	**0.07**	**0.01**
	[-0.40, -0.39]	[-0.13, -0.13]	[-0.40, -0.40]	[-0.35, -0.35]		[0.00, 0.01]	[0.01, 0.01]	[0.07, 0.07]	[0.01, 0.01]
Hungary	**-0.69**	**-0.27**	**-0.71**	**-0.54**	Korea	**-0.08**	**-0.09**	**0.09**	**0.01**
	[-0.69, -0.69]	[-0.27, -0.27]	[-0.71, -0.71]	[-0.54, -0.54]		[-0.08, -0.08]	[-0.09, -0.09]	[0.09, 0.09]	[0.01, 0.01]
Ireland	**-5.13**	**-1.59**	**-5.13**	**-4.01**	Mexico	**-0.01**	**-0.02**	**0.04**	**-0.00**
	[-5.13, -5.12]	[-1.60, -1.59]	[-5.14, -5.12]	[-4.02, -4.01]		[-0.01, -0.01]	[-0.02, -0.02]	[0.04, 0.04]	[-0.00, -0.00]
Italy	**-0.34**	**-0.08**	**-0.36**	**-0.28**	Norway	**0.04**	**-0.03**	**0.08**	**-0.08**
	[-0.34, -0.34]	[-0.08, -0.08]	[-0.36, -0.36]	[-0.28, -0.28]		[0.03, 0.04]	[-0.04, -0.02]	[0.08, 0.09]	[-0.08, -0.08]
Latvia	**-0.58**	**-0.16**	**-0.58**	**-0.50**	Russia	**-0.02**	**-0.06**	**-0.02**	**0.01**
	[-0.58, -0.58]	[-0.16, -0.16]	[-0.59, -0.58]	[-0.50, -0.50]		[-0.02, -0.02]	[-0.06, -0.05]	[-0.02, -0.02]	[0.01, 0.01]
Lithuania	**-0.42**	**-0.10**	**-0.44**	**-0.38**	Switzerland	**-0.05**	**0.00**	**-0.05**	**0.04**
	[-0.43, -0.42]	[-0.10, -0.10]	[-0.44, -0.44]	[-0.38, -0.38]		[-0.05, -0.05]	[0.00, 0.00]	[-0.05, -0.05]	[0.04, 0.04]
Luxembourg	**-3.61**	**0.70**	**-3.66**	**-2.85**	Taiwan	**0.02**	**0.02**	**0.02**	**0.02**
	[-3.62, -3.60]	[0.69, 0.71]	[-3.67, -3.66]	[-2.85, -2.84]		[0.02, 0.03]	[0.02, 0.02]	[0.02, 0.02]	[0.02, 0.02]
Malta	**-5.54**	**-0.81**	**-5.51**	**-3.48**	Turkey	**-0.06**	**-0.08**	**-0.09**	**0.01**
	[-5.55, -5.53]	[-0.83, -0.80]	[-5.52, -5.50]	[-3.49, -3.48]		[-0.06, -0.06]	[-0.08, -0.08]	[-0.10, -0.09]	[0.01, 0.01]
Netherlands	**-1.14**	**-0.33**	**-1.15**	**-0.89**	USA	**-0.00**	**-0.00**	**0.12**	**0.01**
	[-1.14, -1.14]	[-0.34, -0.33]	[-1.15, -1.15]	[-0.89, -0.89]		[-0.00, -0.00]	[-0.00, -0.00]	[0.12, 0.12]	[0.01, 0.01]
Poland	**-0.61**	**-0.23**	**-0.63**	**-0.45**	ROW	**-0.00**	**0.01**	**-0.01**	**0.04**
	[-0.61, -0.60]	[-0.23, -0.23]	[-0.63, -0.63]	[-0.45, -0.44]		[-0.00, -0.00]	[0.01, 0.01]	[-0.01, -0.01]	[0.04, 0.04]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets.

Table C.12: Counterfactual Changes of Sectoral Value Added of Agricultural and Manufacturing Goods in UK, in %

	initial VA	Change of Sectoral Value Added in %			
	in mn USD	**S1**	**S2**	**S3**	**S4**
Crops & Animals	18168	**7.87**	**6.71**	**8.30**	**-2.22**
		[3.63, 12.11]	[0.91, 12.50]	[4.14, 12.46]	[-3.24, -1.20]
Forestry & Logging	300	-1.96	-1.28	-1.22	-0.10
		[-7.28, 3.35]	[-7.47, 4.90]	[-6.59, 4.15]	[-1.87, 1.67]
Fishing & Aquaculture	1099	**-15.83**	-7.68	-10.36	**-15.11**
		[-27.09, -4.56]	[-27.12, 11.76]	[-22.42, 1.71]	[-26.85, -3.36]
Mining & Quarrying	43315	**-7.93**	8.22	-3.60	6.77
		[-14.07, -1.79]	[-9.03, 25.48]	[-10.54, 3.33]	[-0.59, 14.12]
Food, Beverages & Tobacco	47220	1.86	**2.39**	**3.50**	**-3.06**
		[-0.84, 4.55]	[0.21, 4.57]	[0.95, 6.04]	[-4.35, -1.77]
Textiles, Apparel,Leather	10096	**-6.82**	-2.97	**-10.62**	**-4.02**
		[-10.17, -3.47]	[-7.70, 1.76]	[-15.84, -5.39]	[-7.70, -0.33]
Wood & Cork	4056	0.43	-3.86	-1.78	0.45
		[-5.22, 6.08]	[-12.01, 4.29]	[-7.91, 4.34]	[-0.46, 1.37]
Paper	7484	0.81	0.36	1.00	0.46
		[-5.49, 7.12]	[-6.77, 7.48]	[-5.37, 7.36]	[-1.25, 2.18]
Recorded Media Reproduction	8128	**-1.13**	1.10	0.55	0.40
		[-1.94, -0.31]	[-0.38, 2.59]	[-0.37, 1.47]	[-0.48, 1.28]
Coke, Refined Petroleum	7602	4.13	18.84	**19.89**	0.75
		[-10.10, 18.35]	[-14.06, 51.75]	[0.11, 39.66]	[-8.71, 10.20]
Chemicals	16774	**-5.71**	0.34	**-4.12**	**-3.74**
		[-8.85, -2.58]	[-4.15, 4.84]	[-7.67, -0.58]	[-6.65, -0.83]
Pharmaceuticals	22050	-3.08	-5.82	**-11.94**	8.75
		[-10.73, 4.57]	[-14.87, 3.23]	[-21.46, -2.41]	[-2.04, 19.53]
Rubber & Plastics	16810	-0.68	0.93	0.66	**-3.25**
		[-2.26, 0.90]	[-1.03, 2.89]	[-1.28, 2.61]	[-4.68, -1.82]
Other non-Metallic Mineral	8577	-1.01	0.94	0.71	**-0.93**
		[-2.24, 0.22]	[-0.51, 2.40]	[-0.53, 1.96]	[-1.55, -0.30]
Basic Metals	7651	**-16.95**	**-9.73**	-6.11	-2.13
		[-23.43, -10.47]	[-16.10, -3.36]	[-13.20, 0.98]	[-5.85, 1.59]
Fabricated Metal	28099	-0.49	1.44	**2.63**	**1.21**
		[-2.14, 1.17]	[-0.28, 3.17]	[0.83, 4.43]	[0.35, 2.06]
Electronics & Optical Products	19366	-3.05	-2.15	-6.60	**13.07**
		[-10.83, 4.72]	[-11.46, 7.17]	[-15.11, 1.92]	[2.23, 23.90]
Electrical Equipment	8910	**-8.48**	-0.35	**-8.93**	3.67
		[-12.88, -4.07]	[-6.79, 6.09]	[-13.93, -3.93]	[-0.40, 7.73]
Machinery & Equipment	32117	**-6.86**	-3.93	-4.11	**8.38**
		[-11.18, -2.54]	[-8.87, 1.01]	[-8.63, 0.41]	[4.42, 12.34]
Motor Vehicles	20517	-2.52	-1.49	**5.13**	-3.33
		[-7.15, 2.11]	[-8.46, 5.49]	[0.17, 10.10]	[-6.94, 0.28]
Other Transport Equipment	17066	-2.80	11.80	**23.45**	**10.01**
		[-7.70, 2.11]	[-0.21, 23.81]	[4.48, 42.43]	[2.53, 17.48]
Furniture & Other Manufacturing	16106	-3.10	-1.29	-2.29	4.39
		[-6.72, 0.53]	[-4.46, 1.87]	[-6.45, 1.87]	[-0.54, 9.31]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets.

Table C.13: Changes of UK's Sectoral Value Added of Services, in %

	initial VA	Change of Sectoral Value Added in %			
	in mn USD	**S1**	**S2**	**S3**	**S4**
Electricity & Gas	43740	**-1.08**	0.67	**0.99**	**-0.53**
		[-1.74, -0.42]	[-0.49, 1.84]	[0.14, 1.85]	[-1.03, -0.03]
Water Supply	8828	**-0.67**	0.46	**0.91**	-0.35
		[-1.29, -0.05]	[-0.63, 1.54]	[0.14, 1.68]	[-0.87, 0.18]
Sewerage & Waste	21167	**-1.72**	-0.79	-0.84	**-2.45**
		[-3.15, -0.30]	[-2.70, 1.11]	[-3.24, 1.56]	[-4.11, -0.79]
Construction	179017	-0.46	0.87	**1.15**	**-0.70**
		[-1.10, 0.19]	[-0.24, 1.98]	[0.34, 1.95]	[-1.27, -0.12]
Trade & Repair of Motor Vehicles	52638	**-2.14**	-0.74	0.38	**-2.62**
		[-3.23, -1.04]	[-2.25, 0.78]	[-0.79, 1.56]	[-3.64, -1.61]
Wholesale Trade	87853	**-7.91**	**-6.50**	**-5.40**	**-9.32**
		[-11.18, -4.65]	[-10.11, -2.89]	[-8.60, -2.20]	[-12.92, -5.71]
Retail Trade	151457	-0.60	0.49	**1.01**	**-1.02**
		[-1.23, 0.03]	[-0.52, 1.51]	[0.25, 1.77]	[-1.60, -0.43]
Land Transport	52683	**-1.86**	-0.58	-0.30	**-1.87**
		[-2.68, -1.04]	[-1.77, 0.62]	[-1.24, 0.64]	[-2.68, -1.06]
Water Transport	11472	0.78	-1.00	0.97	**1.45**
		[-0.63, 2.20]	[-3.90, 1.90]	[-0.47, 2.40]	[0.99, 1.91]
Air Transport	14985	-0.84	-0.25	0.49	-0.18
		[-2.59, 0.90]	[-2.37, 1.87]	[-1.35, 2.33]	[-0.81, 0.45]
Aux. Transportation Services	30772	**-3.28**	**-2.08**	**-1.76**	**-3.15**
		[-4.45, -2.12]	[-3.45, -0.70]	[-2.99, -0.52]	[-4.40, -1.90]
Postal and Courier	19150	0.03	**1.71**	**1.41**	-0.31
		[-0.93, 1.00]	[0.41, 3.02]	[0.40, 2.41]	[-1.22, 0.61]
Accommodation & Food	85664	**-0.76**	0.47	0.53	0.16
		[-1.37, -0.16]	[-0.42, 1.35]	[-0.18, 1.24]	[-0.33, 0.66]
Publishing	17750	**-1.59**	-0.73	-0.64	-0.18
		[-2.58, -0.60]	[-2.02, 0.56]	[-1.66, 0.39]	[-1.13, 0.77]
Media Services	23527	**-1.77**	-0.54	-0.67	-0.78
		[-2.77, -0.76]	[-2.14, 1.06]	[-1.76, 0.43]	[-1.70, 0.14]
Telecommunications	46927	-0.65	0.62	0.64	-0.83
		[-2.46, 1.15]	[-1.58, 2.82]	[-1.20, 2.47]	[-1.88, 0.23]
Computer & Information Services	78127	**-0.64**	**1.02**	**0.89**	-0.22
		[-1.27, -0.01]	[0.00, 2.04]	[0.14, 1.64]	[-0.82, 0.38]
Financial Services	125534	0.38	**1.78**	**1.43**	0.16
		[-0.51, 1.27]	[0.39, 3.17]	[0.50, 2.35]	[-0.52, 0.85]
Insurance	109604	1.17	**3.17**	2.29	**2.73**
		[-1.15, 3.49]	[0.07, 6.27]	[-0.07, 4.65]	[0.33, 5.13]
Real Estate	303820	-0.35	0.73	**1.09**	**-0.58**
		[-0.97, 0.28]	[-0.33, 1.78]	[0.32, 1.87]	[-1.14, -0.02]
Legal and Accounting	96495	**-1.51**	0.66	0.74	-0.87
		[-2.57, -0.44]	[-0.86, 2.18]	[-0.44, 1.92]	[-1.85, 0.11]
Business Services	87560	**-2.57**	0.51	0.78	**-2.05**
		[-3.69, -1.45]	[-0.92, 1.95]	[-0.50, 2.06]	[-3.17, -0.93]
Research and Development	15230	-0.68	0.41	0.52	0.38
		[-1.66, 0.30]	[-0.77, 1.60]	[-0.55, 1.60]	[-0.38, 1.13]
Admin. & Support Services	128914	-0.17	1.47	1.16	0.90
		[-2.35, 2.00]	[-1.10, 4.04]	[-1.10, 3.41]	[-0.77, 2.56]
Public & Social Services	154785	**-0.59**	0.61	**0.93**	**-0.56**
		[-1.18, -0.01]	[-0.39, 1.62]	[0.19, 1.66]	[-1.10, -0.03]
Education	171370	**-0.66**	0.49	**0.84**	**-0.56**
		[-1.23, -0.10]	[-0.47, 1.45]	[0.12, 1.56]	[-1.08, -0.04]
Human Health and Social Work	199282	-0.52	0.60	**0.94**	-0.51
		[-1.11, 0.06]	[-0.41, 1.61]	[0.21, 1.67]	[-1.05, 0.03]
Other Services, Households	120406	-0.22	0.89	0.80	-0.37
		[-1.19, 0.74]	[-0.42, 2.20]	[-0.33, 1.94]	[-1.10, 0.37]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets.

Table C.14: Changes of EU27's Sectoral Value Added of Agricultural and Manufacturing Goods, in %

	initial VA	Change of Sectoral Value Added in %			
	in mn USD	**S1**	**S2**	**S3**	**S4**
Crops & Animals	221514	**-1.36**	**-0.70**	**-1.46**	**-0.54**
		[-1.65, -1.08]	[-1.14, -0.25]	[-1.75, -1.18]	[-0.68, -0.41]
Forestry & Logging	29863	**-0.52**	0.04	**-0.63**	**-0.70**
		[-0.85, -0.20]	[-0.38, 0.47]	[-0.97, -0.29]	[-0.80, -0.60]
Fishing & Aquaculture	7486	1.08	0.91	1.00	0.71
		[-0.29, 2.45]	[-1.21, 3.04]	[-0.35, 2.36]	[-0.59, 2.01]
Mining & Quarrying	78597	**2.51**	**5.86**	**2.75**	**-1.07**
		[0.46, 4.56]	[1.48, 10.24]	[0.60, 4.89]	[-1.94, -0.20]
Food, Beverages & Tobacco	311327	**-1.55**	**-0.53**	**-1.67**	**-0.63**
		[-1.94, -1.15]	[-0.90, -0.16]	[-2.07, -1.28]	[-0.81, -0.45]
Textiles, Apparel,Leather	83953	-0.38	0.93	**-0.83**	**-1.15**
		[-1.05, 0.29]	[-0.22, 2.08]	[-1.53, -0.14]	[-1.61, -0.69]
Wood & Cork	44213	**-0.72**	0.16	**-0.88**	**-0.84**
		[-1.19, -0.26]	[-0.54, 0.87]	[-1.36, -0.41]	[-1.03, -0.65]
Paper	55968	**-0.83**	-0.29	**-0.88**	**-0.85**
		[-1.57, -0.08]	[-1.15, 0.56]	[-1.64, -0.12]	[-1.11, -0.59]
Recorded Media Reproduction	40974	**-0.47**	**-0.23**	**-0.62**	**-0.49**
		[-0.61, -0.33]	[-0.46, -0.01]	[-0.77, -0.47]	[-0.64, -0.33]
Coke, Refined Petroleum	60143	-0.44	2.02	-0.82	**-1.02**
		[-1.52, 0.64]	[-0.25, 4.29]	[-1.87, 0.23]	[-1.74, -0.29]
Chemicals	178271	**-1.10**	**-0.64**	**-1.33**	**-0.80**
		[-1.42, -0.79]	[-1.05, -0.24]	[-1.66, -1.01]	[-1.06, -0.54]
Pharmaceuticals	121944	-0.67	**-2.16**	-0.02	**-1.92**
		[-2.38, 1.04]	[-3.70, -0.61]	[-1.93, 1.89]	[-3.06, -0.77]
Rubber & Plastics	113713	**-1.16**	**-0.49**	**-1.37**	**-0.51**
		[-1.39, -0.93]	[-0.81, -0.17]	[-1.62, -1.12]	[-0.68, -0.34]
Other non-Metallic Mineral	84895	**-0.70**	**-0.23**	**-0.84**	**-0.54**
		[-0.85, -0.54]	[-0.42, -0.04]	[-0.99, -0.69]	[-0.64, -0.44]
Basic Metals	91464	**-0.43**	-0.14	**-0.74**	**-0.43**
		[-0.79, -0.07]	[-0.60, 0.32]	[-1.12, -0.37]	[-0.69, -0.16]
Fabricated Metal	220110	**-0.79**	**-0.26**	**-1.00**	**-0.61**
		[-0.97, -0.61]	[-0.47, -0.05]	[-1.20, -0.81]	[-0.71, -0.52]
Electronics & Optical Products	126896	**-1.73**	**-2.69**	**-1.48**	**-2.43**
		[-2.54, -0.92]	[-3.58, -1.80]	[-2.33, -0.63]	[-3.29, -1.58]
Electrical Equipment	124261	**-0.60**	-0.25	**-1.18**	**-1.10**
		[-1.09, -0.10]	[-0.88, 0.38]	[-1.66, -0.71]	[-1.42, -0.78]
Machinery & Equipment	381086	-0.12	-0.24	-0.16	**-1.04**
		[-0.55, 0.30]	[-0.67, 0.19]	[-0.61, 0.28]	[-1.36, -0.72]
Motor Vehicles	249064	**-1.57**	-0.21	**-2.24**	**-0.81**
		[-2.03, -1.10]	[-0.84, 0.42]	[-2.74, -1.73]	[-1.23, -0.38]
Other Transport Equipment	68303	-0.77	1.22	**-3.86**	**-1.40**
		[-1.87, 0.33]	[-0.69, 3.14]	[-5.85, -1.87]	[-2.32, -0.49]
Furniture & Other Manufacturing	103874	-0.27	**-0.58**	-0.05	**-1.34**
		[-0.88, 0.34]	[-1.14, -0.01]	[-0.76, 0.67]	[-1.96, -0.72]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets.

Table C.15: Changes of EU27's Sectoral Value Added of Services, in %

	initial VA	Change of Sectoral Value Added in %			
	in mn USD	**S1**	**S2**	**S3**	**S4**
Electricity & Gas	284959	**-0.67**	-0.12	**-0.86**	**-0.52**
		[-0.77, -0.57]	[-0.27, 0.02]	[-0.96, -0.75]	[-0.62, -0.43]
Water Supply	37499	**-0.61**	-0.07	**-0.80**	**-0.48**
		[-0.71, -0.51]	[-0.21, 0.08]	[-0.90, -0.70]	[-0.57, -0.39]
Sewerage & Waste	99891	**-0.62**	-0.14	**-0.79**	-0.16
		[-0.84, -0.41]	[-0.38, 0.10]	[-1.00, -0.58]	[-0.41, 0.09]
Construction	751630	**-0.70**	**-0.18**	**-0.89**	**-0.50**
		[-0.80, -0.60]	[-0.31, -0.04]	[-1.00, -0.79]	[-0.59, -0.40]
Trade & Repair of Motor Vehicles	209725	**-0.45**	0.09	**-0.69**	-0.07
		[-0.70, -0.20]	[-0.22, 0.41]	[-0.94, -0.44]	[-0.31, 0.17]
Wholesale Trade	762831	0.05	**0.51**	-0.10	**0.52**
		[-0.31, 0.42]	[0.11, 0.90]	[-0.46, 0.26]	[0.09, 0.95]
Retail Trade	600221	**-0.65**	-0.14	**-0.83**	**-0.39**
		[-0.77, -0.53]	[-0.29, 0.01]	[-0.96, -0.71]	[-0.51, -0.27]
Land Transport	357195	**-0.51**	-0.01	**-0.68**	**-0.40**
		[-0.61, -0.41]	[-0.15, 0.13]	[-0.78, -0.57]	[-0.49, -0.31]
Water Transport	42166	**-0.41**	0.33	**-0.52**	**-0.37**
		[-0.71, -0.12]	[-0.37, 1.03]	[-0.83, -0.21]	[-0.42, -0.31]
Air Transport	43027	**-0.62**	0.06	**-0.68**	**-0.76**
		[-1.20, -0.04]	[-0.67, 0.78]	[-1.28, -0.08]	[-0.87, -0.65]
Aux. Transportation Services	266620	**-0.39**	0.06	**-0.55**	**-0.29**
		[-0.49, -0.28]	[-0.07, 0.19]	[-0.66, -0.43]	[-0.40, -0.19]
Postal and Courier	60266	**-0.86**	**-0.48**	**-1.01**	**-0.43**
		[-1.09, -0.64]	[-0.77, -0.19]	[-1.23, -0.78]	[-0.63, -0.23]
Accommodation & Food	407634	**-0.57**	**-0.15**	**-0.75**	**-0.46**
		[-0.67, -0.47]	[-0.28, -0.03]	[-0.86, -0.64]	[-0.56, -0.37]
Publishing	79566	**-0.82**	-0.18	**-0.96**	**-0.77**
		[-1.02, -0.63]	[-0.42, 0.06]	[-1.16, -0.76]	[-0.95, -0.59]
Media Services	73756	-0.17	0.15	**-0.34**	-0.08
		[-0.44, 0.09]	[-0.26, 0.55]	[-0.60, -0.09]	[-0.33, 0.17]
Telecommunications	185217	**-0.68**	-0.17	**-0.82**	**-0.45**
		[-1.09, -0.27]	[-0.68, 0.34]	[-1.23, -0.40]	[-0.66, -0.23]
Computer & Information Services	315976	**-0.43**	**-0.23**	**-0.56**	**-0.35**
		[-0.53, -0.32]	[-0.38, -0.07]	[-0.67, -0.45]	[-0.46, -0.24]
Financial Services	498840	**-0.78**	**-0.43**	**-0.94**	**-0.48**
		[-0.95, -0.60]	[-0.69, -0.16]	[-1.11, -0.76]	[-0.63, -0.33]
Insurance	249245	**-0.94**	**-0.61**	**-1.09**	**-0.94**
		[-1.35, -0.52]	[-1.17, -0.06]	[-1.50, -0.69]	[-1.39, -0.49]
Real Estate	1574061	**-0.67**	**-0.17**	**-0.85**	**-0.45**
		[-0.77, -0.57]	[-0.30, -0.04]	[-0.96, -0.75]	[-0.55, -0.35]
Legal and Accounting	439618	**-0.46**	-0.05	**-0.62**	**-0.34**
		[-0.63, -0.28]	[-0.27, 0.17]	[-0.79, -0.44]	[-0.50, -0.19]
Business Services	328994	**-0.39**	-0.12	**-0.58**	-0.06
		[-0.60, -0.18]	[-0.36, 0.12]	[-0.79, -0.38]	[-0.29, 0.16]
Research and Development	121236	**-0.56**	-0.12	**-0.73**	**-0.52**
		[-0.69, -0.43]	[-0.28, 0.05]	[-0.87, -0.60]	[-0.62, -0.42]
Admin. & Support Services	581599	**-0.77**	-0.37	**-0.90**	**-0.69**
		[-1.19, -0.35]	[-0.84, 0.11]	[-1.33, -0.47]	[-0.97, -0.41]
Public & Social Services	993571	**-0.67**	**-0.15**	**-0.87**	**-0.50**
		[-0.78, -0.57]	[-0.28, -0.02]	[-0.97, -0.76]	[-0.60, -0.40]
Education	731363	**-0.68**	-0.14	**-0.87**	**-0.50**
		[-0.79, -0.58]	[-0.27, 0.00]	[-0.98, -0.76]	[-0.61, -0.39]
Human Health and Social Work	1096971	**-0.71**	-0.14	**-0.91**	**-0.54**
		[-0.82, -0.61]	[-0.28, 0.00]	[-1.02, -0.80]	[-0.64, -0.43]
Other Services, Households	504146	**-0.70**	-0.21	**-0.89**	**-0.45**
		[-0.88, -0.52]	[-0.43, 0.00]	[-1.07, -0.70]	[-0.60, -0.30]

Note: The baseline year is 2014. Bold characters indicate significance at the 10%-level based on 1,000 replications and an approximate normal distribution. Confidence intervals in square brackets.

Table C.16: Sectoral Trade Cost Elasticities from Caliendo & Parro (2015)

Sector id	Sector Name	Trade Cost Elasticity
1	Crops & Animals	8.11
2	Forestry & Logging	8.11
3	Fishing & Aquaculture	8.11
4	Mining & Quarrying	15.72
5	Food, Beverages & Tobacco	2.55
6	Textiles, Apparel,Leather	5.56
7	Wood & Cork	10.83
8	Paper	9.07
9	Recorded Media Reproduction	9.07
10	Coke, Refined Petroleum	51.08
11	Chemicals	4.75
12	Pharmaceuticals	4.75
13	Rubber & Plastics	1.66
14	Other Non-Metallic Mineral	2.76
15	Basic Metals	7.99
16	Fabricated Metal	4.3
17	Electronics & Optical Products	10.60
18	Electrical Equipment	10.60
19	Machinery & Equipment	1.52
20	Motor Vehicles	1.01
21	Other Transport Equipment	0.37
22	Furniture & Other Manufacturing	5.00
23	Electricity & Gas	5.00
24	Water Supply	5.00
25	Sewerage & Waste	5.00
26	Construction	5.00
27	Trade & Repair of Motor Vehicles	5.00
28	Wholesale Trade	5.00
29	Retail Trade	5.00
30	Land Transport	5.00
31	Water Transport	5.00
32	Air Transport	5.00
33	Aux. Transportation Services	5.00
34	Postal and Courier	5.00
35	Accommodation & Food	5.00
36	Publishing	5.00
37	Media Services	5.00
38	Telecommunications	5.00
39	Computer & Information Services	5.00
40	Financial Services	5.00
41	Insurance	5.00
42	Real Estate	5.00
43	Legal and Accounting	5.00
44	Business Services	5.00
45	Research and Development	5.00
46	Admin. & Support Services	5.00
47	Public & Social Services	5.00
48	Education	5.00
49	Human Health and Social Work	5.00
50	Other Services, Households	5.00

Table C.17: Change in Real Consumption, in %

Elasticities:	Services = 5	Caliendo & Parro (2015)		Services = 5	Caliendo & Parro (2015)
UK	**-1.17**	**-3.27**	Portugal	**-0.16**	**-0.24**
	[-1.65, -0.68]	[-3.95, -2.59]		[-0.18, -0.13]	[-0.27, -0.20]
Austria	**-0.15**	**-0.20**	Romania	**-0.14**	**-0.19**
	[-0.16, -0.13]	[-0.24, -0.17]		[-0.16, -0.12]	[-0.22, -0.17]
Belgium	**-0.49**	**-0.72**	Slovakia	**-0.48**	**-0.46**
	[-0.55, -0.42]	[-0.82, -0.62]		[-0.58, -0.39]	[-0.54, -0.39]
Bulgaria	**-0.17**	**-0.25**	Slovenia	**-0.17**	**-0.22**
	[-0.21, -0.14]	[-0.28, -0.22]		[-0.19, -0.15]	[-0.25, -0.19]
Croatia	**-0.13**	**-0.15**	Spain	**-0.17**	**-0.22**
	[-0.16, -0.10]	[-0.21, -0.09]		[-0.19, -0.14]	[-0.27, -0.18]
Cyprus	**-0.48**	**-0.82**	Sweden	**-0.23**	**-0.40**
	[-0.63, -0.34]	[-1.01, -0.63]		[-0.28, -0.19]	[-0.47, -0.34]
Czech R.	**-0.33**	**-0.40**	Australia	**-0.01**	**-0.02**
	[-0.37, -0.30]	[-0.44, -0.36]		[-0.01, -0.00]	[-0.02, -0.01]
Denmark	**-0.30**	**-0.40**	Brazil	**-0.00**	**-0.01**
	[-0.35, -0.26]	[-0.45, -0.35]		[-0.00, -0.00]	[-0.01, -0.00]
Estonia	**-0.25**	**-0.39**	Canada	0.00	**-0.02**
	[-0.34, -0.17]	[-0.47, -0.32]		[-0.00, 0.01]	[-0.03, -0.01]
Finland	**-0.16**	**-0.29**	China	**0.03**	**0.02**
	[-0.19, -0.13]	[-0.35, -0.23]		[0.02, 0.03]	[0.02, 0.03]
France	**-0.21**	**-0.27**	India	**0.01**	-0.00
	[-0.24, -0.18]	[-0.31, -0.22]		[0.01, 0.01]	[-0.01, 0.01]
Germany	**-0.32**	**-0.36**	Indonesia	**0.01**	**0.00**
	[-0.35, -0.29]	[-0.44, -0.28]		[0.00, 0.01]	[0.00, 0.01]
Greece	**-0.13**	**-0.19**	Japan	**0.00**	**-0.00**
	[-0.16, -0.10]	[-0.23, -0.16]		[0.00, 0.01]	[-0.01, -0.00]
Hungary	**-0.35**	**-0.42**	Korea	0.00	-0.06
	[-0.38, -0.32]	[-0.46, -0.38]		[-0.03, 0.04]	[-0.29, 0.16]
Ireland	**-2.94**	**-4.40**	Mexico	0.00	**-0.01**
	[-3.22, -2.66]	[-4.70, -4.10]		[-0.00, 0.00]	[-0.02, -0.01]
Italy	**-0.17**	**-0.22**	Norway	**0.47**	0.08
	[-0.19, -0.15]	[-0.26, -0.18]		[0.27, 0.67]	[-0.06, 0.23]
Latvia	**-0.23**	**-0.30**	Russia	0.00	**-0.03**
	[-0.32, -0.13]	[-0.37, -0.23]		[-0.01, 0.02]	[-0.05, -0.02]
Lithuania	**-0.17**	**-0.36**	Switzerland	0.03	**-0.08**
	[-0.22, -0.12]	[-0.42, -0.29]		[-0.01, 0.07]	[-0.15, -0.00]
Luxembourg	-0.97	-0.96	Taiwan	**0.07**	**0.08**
	[-2.64, 0.70]	[-2.60, 0.68]		[0.06, 0.08]	[0.08, 0.09]
Malta	**-2.55**	**-2.77**	Turkey	0.01	**-0.08**
	[-3.52, -1.58]	[-3.65, -1.89]		[-0.01, 0.03]	[-0.10, -0.05]
Netherlands	**-0.67**	**-0.86**	USA	**-0.01**	**-0.02**
	[-0.74, -0.60]	[-0.94, -0.77]		[-0.01, -0.01]	[-0.02, -0.01]
Poland	**-0.31**	**-0.39**	ROW	-0.00	-0.01
	[-0.34, -0.28]	[-0.43, -0.35]		[-0.01, 0.00]	[-0.03, 0.00]
EU27	**-0.31**	**-0.41**			
	[-0.35, -0.28]	[-0.46, -0.35]			
ROW	**0.01**	**-0.01**			
	[0.00, 0.01]	[-0.02, -0.00]			

Note: The baseline year is 2014. Mean effects and [p5,p95] intervals. Bold characters indicate significance at the 10%-level based on 1,000 bootstrap replications. Confidence intervals in square brackets. The results for EU27 and ROW are calculated as GDP weighted averages. Caliendo & Parro (2015) results use elasticities from Table C.16 and tariff adjusted imports in all goods sectors in the underlying gravity estimations to back out NTB changes.

Appendix D

Appendix to Chapter 4 - Revisiting the Euro's trade cost and welfare effects

D.1 Model Closure

Let Y_n^j denote the value of gross production of varieties in each sector j. For each country n and sector j, Y_n^j has to equal the value of demand for sectoral varieties from all countries $i = 1, \ldots, N$. The goods market clearing condition is given by

$$Y_n^j = \sum_{i=1}^{N} \frac{\pi_{ni}^j}{(1 + t_{ni}^j)} X_i^j \qquad \text{with} \qquad X_i^j = \sum_{k=1}^{J} \gamma_i^{j,k} (1 - \beta_i^k) Y_i^k + \alpha_i^j I_i, \tag{D.1}$$

National income consists of labor income, tariff rebates R_i and the trade surplus, which is exogenous S_i, i.e. $I_i = w_i L_i + R_i - S_i$ and X_i^j is country i's expenditure on sector j goods.- [1] Demand of sectors k in all countries i for intermediate usage of sector j varieties produced in country n is given in the first term on the right hand side. The second term denotes the final demand. Tariff rebates are $R_i = \sum_{j=1}^{J} X_i^j \left(1 - \sum_{n=1}^{N} \frac{\pi_{ni}^j}{(1+t_{ni}^j)}\right)$.[2]

The second equilibrium condition requires that, for each country n, the value of total imports, domestic demand and the trade surplus has to equal the value of total exports

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[1] Aggregate trade deficits in each country are exogenous in the model, which follows the theoretical framework of Caliendo and Parro (2015). All counterfactuals are calculated by holding the countries' aggregate trade deficits constant, as a share of world GDP.

[2] Instead of the goods market clearing condition, one can also use the expenditure equation $X_i^j = \left(\sum_{k=1}^{J} \gamma_i^{j,k} (1 - \beta_i^k)(F_i^k X_i^k + S_i^k) + \alpha_i^j I_i\right)$ as in Caliendo and Parro (2015).

including domestic sales, which is equivalent to total output Y_n:

$$\sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{in}^{j}}{(1+t_{in}^{j})}X_n^j + S_n = \sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{ni}^{j}}{(1+t_{ni}^{j})}X_i^j = \sum_{j=1}^{J} Y_n^j \equiv Y_n \tag{D.2}$$

Conditions (D.1) and (D.2) close the model.

D.2 Comparative Statics in General Equilibrium

The following system of equations is required to solve the counterfactual changes. One advantage of solving the model in changes is that certain constant parameters such as the absolute advantage or the elasticity of substitution between input varieties ω drop out and need not be estimated.[3].

$$\hat{c}_n^j = \hat{w}_n^{\beta_n^j}\left(\prod_{i=1}^{N}[\hat{p}_n^j]^{\gamma_n^{k,j}}\right)^{1-\beta_n^j}, \tag{D.3}$$

$$\hat{p}_n^j = \left(\sum_{i=1}^{N}\pi_{in}^j[\hat{\kappa}_{in}^j\hat{c}_i^j]^{-1/\theta^j}\right)^{-\theta^j}, \tag{D.4}$$

$$\hat{\pi}_{in}^j = \left(\frac{\hat{c}_i^j}{\hat{p}_n^j}\hat{\kappa}_{in}^j\right)^{-1/\theta^j}, \tag{D.5}$$

$$X_n^{j'} = \sum_{j=1}^{J}\gamma_n^{j,k}(1-\beta_n^k)\left(\sum_{i=1}^{N}\frac{\pi_{ni}^{k'}}{1+t_{ni}^{k'}}X_i^{k'}\right) + \alpha_n^j I_n', \tag{D.6}$$

$$\frac{1}{B}\sum_{j=1}^{J}F_n^{j'}X_n^{j'} + s_n = \frac{1}{B}\sum_{j=1}^{J}\sum_{i=1}^{N}\frac{\pi_{ni}^{j'}}{1+t_{ni}^{j'}}X_i^{j'}, \tag{D.7}$$

with $\hat{w}_n$ depicting the wage changes. X_n^j are sectoral expenditure levels, $F_n^j \equiv \sum_{i=1}^{N}\frac{\pi_j^{in}}{(1+t_{in}^j)}$, $I_n' = \hat{w}_n w_n L_n + \sum_{j=1}^{J} X_n^{j'}(1-F_n^{j'}) - S_n$, L_n are a country n's labor force, and S_n is the trade surplus, which is exogenous. $s_n \equiv S_n/B$, is fixed, with $B \equiv \sum_n w_n L_n$ denoting the global labor income. This ensures that the system is homogeneous of degree zero in prices. Equation (D.3) shows the shift in unit costs, which arise due to changes in input prices (i.e., wage and intermediate price changes).

These changes in unit costs have an indirect effect on the sectoral price index p_n^j, while trade cost changes directly affect it (see equation (D.4)). Trade shares change as a

[3] See also Caliendo and Parro (2015)

reaction to changes in trade costs, unit costs, and prices. The productivity dispersion θ^j indicates the intensity of the reaction. The higher θ^j, the bigger trade changes. Goods market clearing is ensured in equation (D.6). Equation (D.7) provides the new equilibrium and the counterfactual income-equals-expenditure, thus balanced trade condition. The framework of Caliendo and Parro (2015) is exploited to solve the system for multiple sectors, which is an extension of the single-sector solution algorithm proposed by Alvarez and Lucas (2007). The initial guess is made about a vector of wage changes. Using (D.3) and (D.4), it then computes changes in prices, trade shares, expenditure levels, evaluates the trade balance condition (D.7), and updates the change in wages based on deviations in the trade balance.

D.3 Detailed Gravity Results

Table D.1: The Impact of EMU on Sectoral Bilateral Imports of Goods

Dep. var.: Bilateral Imports

	Broad Goods	Agriculture Fishing, etc. (1)	Mining and Quarrying (2)	Food, Beverages and Tobacco (3)	Textiles and Textile Products (4)	Leather, Leather and Footwear (5)
both Euro	**0.0753*** **	0.08516***	0.00194	0.16106***	-0.15815***	0.04468
	(0.03)	(0.03)	(0.07)	(0.03)	(0.04)	(0.06)
both EU	**0.4416*** **	0.45333***	0.35228***	0.45942***	0.35127***	0.35557***
	(0.02)	(0.03)	(0.08)	(0.03)	(0.04)	(0.05)
RTA	**0.2327*** **	0.11932	0.06353	0.13315**	-0.13970	-0.07319
	(0.06)	(0.08)	(0.09)	(0.06)	(0.16)	(0.12)
Schengen	**0.0336*** **	0.03247***	0.08363***	0.02642***	-0.04749***	0.01994
	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)
Tariffs	**-3.4673*** **	-2.18310***	-3.03081**	-0.89716**$^{\alpha}$	-2.50476***	-0.84339$^{\alpha}$
	(0.83)	(0.50)	(1.25)	(0.44)	(0.49)	(0.63)

	Wood and Products of Wood and Cork (6)	Pulp and Paper , etc. (7)	Coke, Refined Petroleum and Nuclear Fuel (8)	Chemicals and Chemical Products (9)	Rubber and Plastics (10)	Other Non-Metallic Mineral (11)
both Euro	0.22584***	0.07960**	0.85288***	0.08157**	0.00675	0.06857**
	(0.03)	(0.03)	(0.14)	(0.04)	(0.03)	(0.03)
both EU	0.23180***	0.29140***	0.43283***	0.38557***	0.39130***	0.27754***
	(0.03)	(0.03)	(0.10)	(0.03)	(0.02)	(0.03)
RTA	-0.05563	0.05293	-0.14462	0.18313**	0.18302***	0.18548**
	(0.10)	(0.09)	(0.16)	(0.07)	(0.06)	(0.08)
Schengen	-0.01980**	0.00285	-0.05153	0.02213**	0.01722**	-0.00853
	(0.01)	(0.01)	(0.06)	(0.01)	(0.01)	(0.01)
Tariffs	-1.67668**	-1.43138*	-1.19203	-2.04158**	-2.37919***	0.14617$^{\alpha}$
	(0.74)	(0.79)	(1.67)	(0.83)	(0.72)	(0.78)

	Basic Metals and Fabricated Metal (12)	Machinery, Nec (13)	Electrical and Optical Equipment (14)	Transport Equipment (15)	Manufacturing Nec; Recycling (16)
both Euro	0.04256	0.03305	0.00180	0.01186	0.03578
	(0.03)	(0.03)	(0.04)	(0.03)	(0.02)
both EU	0.37835***	0.46156***	0.51414***	0.36217***	0.31368***
	(0.03)	(0.03)	(0.06)	(0.04)	(0.02)
RTA	0.27069**	0.32786***	0.36537***	0.17377*	0.39739**
	(0.12)	(0.09)	(0.11)	(0.09)	(0.19)
Schengen	0.06006***	0.01149	0.01727	0.03751***	0.00203
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Tariffs	-1.39787*	-4.99101***	-4.67259***	-4.77642***	-2.2145
	(0.74)	(1.54)	(1.17)	(1.07)	(1.43)

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. $^{\alpha}$ Theory inconsistent trade cost elasticites get replaced by the trade cost elasticity of the broad goods sector (-3.4673***); Number of observations: 27,200.

Table D.2: The Impact of EMU on Sectoral Bilateral Imports of Services

Dep. var.: Bilateral Imports

	Broad Services (17)	Electricity, Gas and Water Supply (18)	Construction (19)	Sale, Repair of Vehicles (20)	Wholesale Trade Except of Vehicles (21)	Retail Trade, Except of Vehicles (22)	Hotels and Restaurants
both Euro	**0.0104**	0.26883***	0.00239	0.11129***	0.01043	0.02799	0.13393***
	(0.03)	(0.06)	(0.02)	(0.03)	(0.06)	(0.03)	(0.04)
both EU	**0.2241*** **	0.25402***	0.22359***	0.39919***	0.27699***	0.18707***	0.19428***
	(0.02)	(0.05)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
RTA	**0.1999*** **	0.07528	0.21308**	0.07640	0.12669	0.11608	0.19347***
	(0.07)	(0.13)	(0.09)	(0.05)	(0.09)	(0.09)	(0.07)
Schengen	**0.0195***	0.02360	-0.02957***	0.01203	0.01752	-0.00859	0.00790
	(0.01)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)

	Inland Transport (23)	Water Transport (24)	Air Transport (25)	Auxiliary Transport Activities (26)	Post and Telecom. (27)	Financial Intermediation (28)	Real Estate Activities (29)
both Euro	0.04196	-0.10906	0.02897	0.01410	-0.00197	-0.06000	0.00166
	(0.04)	(0.11)	(0.07)	(0.06)	(0.04)	(0.09)	(0.07)
both EU	0.28864***	0.08626	0.25163***	0.09940	0.29172***	0.04751	0.01792
	(0.05)	(0.09)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)
RTA	0.07877	0.36742**	0.01276	0.35035***	0.16693	0.02770	0.15499
	(0.07)	(0.18)	(0.10)	(0.11)	(0.11)	(0.09)	(0.11)
Schengen	0.06731***	0.00887	0.08209***	0.04689*	0.01641	-0.01054	0.07514***
	(0.02)	(0.04)	(0.02)	(0.02)	(0.01)	(0.03)	(0.03)

	Other Business Activities (30)	Public Admin and Defence (31)	Education (32)	Health and Social Work (33)	Community, Social and Personal Services (34)
both Euro	0.00839	0.11808**	0.03826	0.07489**	0.01217
	(0.04)	(0.05)	(0.05)	(0.03)	(0.04)
both EU	0.21323***	0.37947***	0.27733***	0.38639***	0.24880***
	(0.03)	(0.06)	(0.04)	(0.03)	(0.04)
RTA	0.20742***	0.08753	0.14450	0.21507***	0.16458
	(0.08)	(0.09)	(0.10)	(0.07)	(0.10)
Schengen	0.00568	0.01390	-0.01932*	0.02277**	0.01784
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Number of observations: 27,200.

Table D.3: The Impact of EMU on sectoral Bilateral Imports of Goods

Dep. var.: Bilateral Imports

	Broad Goods	Agriculture Fishing, etc. (1)	Mining and Quarrying (2)	Food, Beverages and Tobacco (3)	Textiles and Textile Products (4)	Leather, Leather and Footwear (5)
€$_{Deu,old}$	0.1922***	0.1775*	0.3782***	0.3172***	-0.3612***	-0.2373
	(0.07)	(0.10)	(0.13)	(0.09)	(0.10)	(0.16)
€$_{old,DEU}$	-0.1191*	0.0901	-0.2119	0.1923***	0.0389	0.1017
	(0.07)	(0.06)	(0.16)	(0.07)	(0.08)	(0.12)
€$_{Deu,new}$	-0.1191*	-0.3042***	-0.1306	0.0104	-0.0467	0.2037
	(0.07)	(0.09)	(0.10)	(0.19)	(0.10)	(0.15)
€$_{new,DEU}$	-0.1263**	0.0198	-0.1870	0.0652	-0.2175	-0.2390
	(0.06)	(0.05)	(0.12)	(0.07)	(0.13)	(0.15)
€$_{Rest}$	0.0212	0.0552**	-0.1081*	0.0863**	-0.1600***	0.1122
	(0.03)	(0.03)	(0.06)	(0.04)	(0.06)	(0.07)
both EU	0.4496***	0.4560***	0.3559***	0.4605***	0.3541***	0.3536***
	(0.02)	(0.03)	(0.08)	(0.03)	(0.04)	(0.05)
RTA	0.2325***	0.1192	0.0639	0.1329**	-0.1394	-0.0725
	(0.06)	(0.08)	(0.09)	(0.06)	(0.16)	(0.12)
Schengen	0.0336***	0.0333***	0.0857***	0.0291***	-0.0487***	0.0196
	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)
Tariffs	-3.4666***	-2.1784***	-3.0051**	-0.8911**	-2.5149***	-0.8413
	(0.83)	(0.50)	(1.24)	(0.44)	(0.49)	(0.64)
	Wood and Products of Wood and Cork (6)	Pulp and Paper , etc. (7)	Coke, Refined Petroleum and Nuclear Fuel (8)	Chemical Products (9)	Rubber and Plastics (10)	Other Non-Metallic Mineral (11)
€$_{Deu,old}$	0.3861***	0.2743**	1.0338***	0.1858*	0.0844	0.2446**
	(0.10)	(0.11)	(0.35)	(0.10)	(0.08)	(0.12)
€$_{old,DEU}$	0.3228***	0.0881	0.4842	0.1456**	0.0963	0.1065
	(0.08)	(0.08)	(0.36)	(0.07)	(0.06)	(0.10)
€$_{Deu,new}$	-0.1535	0.0731	0.0986	-0.2245**	-0.1444*	-0.0496
	(0.17)	(0.07)	(0.28)	(0.10)	(0.09)	(0.08)
€$_{new,DEU}$	-0.0450	0.0015	0.2097	-0.1022	-0.1156	-0.0250
	(0.10)	(0.06)	(0.29)	(0.09)	(0.09)	(0.07)
€$_{Rest}$	0.1245***	-0.0252	0.9409***	-0.0074	-0.0970***	-0.0323
	(0.03)	(0.04)	(0.17)	(0.04)	(0.03)	(0.04)
both EU	0.2427***	0.2944***	0.4415***	0.3925***	0.3973***	0.2819***
	(0.03)	(0.03)	(0.10)	(0.03)	(0.02)	(0.03)
RTA	-0.0556	0.0529	-0.1460	0.1832**	0.1831***	0.1855**
	(0.10)	(0.09)	(0.16)	(0.07)	(0.06)	(0.08)
Schengen	-0.0193**	0.0053	-0.0550	0.0251**	0.0193**	-0.0065
	(0.01)	(0.01)	(0.06)	(0.01)	(0.01)	(0.01)
Tariffs	-1.6800**	-1.4059*	-1.2981	-2.0410**	-2.3817***	0.1448
(0.73)	(0.78)	(1.67)	(0.83)	(0.72)	(0.78)	
	Basic Metals and Fabricated Metal (12)	Machinery, Nec (13)	Electrical and Optical Equipment (14)	Transport Equipment (15)	Manufacturing Nec; Recycling (16)	
€$_{Deu,old}$	0.2572***	0.1325*	0.1293	0.0626	0.0032	
	(0.08)	(0.07)	(0.09)	(0.06)	(0.07)	
€$_{old,DEU}$	0.0297	0.0325	0.0356	0.0566	0.1389**	
	(0.08)	(0.08)	(0.09)	(0.08)	(0.06)	
€$_{Deu,new}$	-0.2437***	-0.0178	-0.0475	-0.3067***	-0.1079	
	(0.07)	(0.07)	(0.10)	(0.09)	(0.10)	
€$_{new,DEU}$	-0.1669**	-0.1023*	-0.1838**	-0.2244**	-0.1679***	
	(0.08)	(0.06)	(0.07)	(0.09)	(0.04)	
€$_{Rest}$	-0.0628*	-0.0438	-0.0843*	-0.0127	0.0120	
	(0.03)	(0.03)	(0.05)	(0.04)	(0.03)	
both EU	0.3909***	0.4680***	0.5202***	0.3764***	0.3193***	
	(0.03)	(0.03)	(0.06)	(0.04)	(0.02)	
RTA	0.2709**	0.3279***	0.3652***	0.1738*	0.3978**	
	(0.12)	(0.09)	(0.11)	(0.09)	(0.19)	
Schengen	0.0608***	0.0122*	0.0175	0.0350***	0.0018	
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	
Tariffs	-1.3897*	-4.9916***	-4.6810***	-4.7859***	-2.2154	
	(0.73)	(1.54)	(1.17)	(1.07)	(1.43)	

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. The gravity specification further controls for EU membership, RTAs, FTA, Schengen and also tariffs to retrieve the trade cost elasticities, but are also not reported here. Number of observations: 27,200.

Table D.4: The Impact of EMU on German Sectoral Bilateral Trade of Services with Old and New EMU member states

Dep. var.: Bilateral Imports

	Broad Services (17)	Electricity, Gas and Water Supply (18)	Construction (19)	Sale, Repair of Vehicles (20)	Wholesale Trade Except of Vehicles (21)	Retail Trade, Except of Vehicles (22)	Hotels and Restaurants
$\text{€}_{Deu,old}$		0.5398***	0.1903**	0.1218	0.3898***	0.1761*	0.2570**
		(0.16)	(0.08)	(0.10)	(0.14)	(0.10)	(0.12)
$\text{€}_{old,DEU}$		0.2966**	-0.0125	0.1427	0.0085	-0.0377	0.1132
		(0.14)	(0.08)	(0.11)	(0.11)	(0.09)	(0.12)
$\text{€}_{Deu,new}$		-0.0388	-0.0224	-0.2197***	-0.1911	-0.0867	-0.1166
		(0.15)	(0.07)	(0.07)	(0.13)	(0.12)	(0.20)
$\text{€}_{new,DEU}$		0.1221	-0.0991*	-0.2171**	0.2126**	-0.1150	0.1267
		(0.20)	(0.06)	(0.10)	(0.09)	(0.11)	(0.09)
€_{Rest}		0.1798***	-0.0838***	0.1079***	-0.1029	0.0060	0.1010*
		(0.06)	(0.02)	(0.04)	(0.09)	(0.04)	(0.05)
both EU		0.2633***	0.2287***	0.4061***	0.2773***	0.1893***	0.1961***
		(0.05)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
RTA		0.0749	0.2129**	0.0768	0.1264	0.1157	0.1933***
		(0.13)	(0.09)	(0.05)	(0.09)	(0.09)	(0.07)
Schengen		0.0232	-0.0284***	0.0113	0.0200	-0.0082	0.0092

	Inland Transport (23)	Water Transport (24)	Air Transport (25)	Auxiliary Transport Activities (26)	Post and Telecom. (27)	Financial Intermediation (28)	Real Estate Activities (29)
$\text{€}_{Deu,old}$	0.2171**	0.4966**	0.3845**	-0.2000	0.0759	0.4427**	0.1223
	(0.11)	(0.22)	(0.15)	(0.18)	(0.13)	(0.17)	(0.20)
$\text{€}_{old,DEU}$	-0.0628	-0.5947***	-0.0456	0.1951**	-0.0883	-0.3384**	-0.0492
	(0.09)	(0.20)	(0.13)	(0.10)	(0.12)	(0.15)	(0.20)
$\text{€}_{Deu,new}$	-0.5063***	-0.2404	-0.6180***	-0.3187*	-0.0073	-0.3628**	-0.0900
	(0.16)	(0.26)	(0.13)	(0.18)	(0.15)	(0.17)	(0.12)
$\text{€}_{new,DEU}$	-0.2403	-0.0083	-0.0083	-0.1452	-0.2057	-0.1437	-0.0259
	(0.23)	(0.29)	(0.21)	(0.28)	(0.13)	(0.16)	(0.09)
€_{Rest}	0.0362	-0.0690	-0.0881	0.0417	0.0093	-0.0974	-0.0240
	(0.05)	(0.12)	(0.08)	(0.06)	(0.05)	(0.12)	(0.08)
both EU	0.2929***	0.0778	0.2600***	0.1043*	0.2923***	0.0478	0.0181
	(0.05)	(0.09)	(0.05)	(0.06)	(0.06)	(0.07)	(0.07)
RTA	0.0782	0.3671**	0.0123	0.3491***	0.1670	0.0263	0.1548
	(0.07)	(0.18)	(0.10)	(0.11)	(0.11)	(0.09)	(0.11)
Schengen	0.0673***	0.0124	0.0853***	0.0455*	0.0164	-0.0081	0.0759***

	Other Business Activities (30)	Public Admin and Defence (31)	Education (32)	Health and Social Work (33)	Community, Social and Personal Services (34)
$\text{€}_{Deu,old}$	0.1800	0.3648***	0.0611	0.2125**	0.0273
	(0.14)	(0.14)	(0.15)	(0.09)	(0.15)
$\text{€}_{old,DEU}$	-0.1078	0.0521	-0.0088	0.1420**	0.1128
	(0.11)	(0.10)	(0.14)	(0.07)	(0.13)
$\text{€}_{Deu,new}$	-0.1410	-0.1906	-0.2806*	-0.2594**	-0.1240
	(0.11)	(0.12)	(0.15)	(0.11)	(0.25)
$\text{€}_{new,DEU}$	-0.1905**	-0.1978***	-0.1118	-0.0596	0.0116
	(0.09)	(0.07)	(0.07)	(0.06)	(0.16)
€_{Rest}	0.0102	0.0372	0.0600	-0.0326	-0.0327
	(0.05)	(0.04)	(0.05)	(0.03)	(0.04)
both EU	0.2150***	0.3884***	0.2816***	0.3936***	0.2507***
	(0.03)	(0.05)	(0.04)	(0.03)	(0.04)
RTA	0.2070***	0.0877	0.1446	0.2151***	0.1646
	(0.08)	(0.09)	(0.10)	(0.07)	(0.10)
Schengen	0.0053	0.0151	-0.0198*	0.0253***	0.0184

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. All models estimated use PPML methods. Robust standard errors (in parentheses) allow for clustering at the country-pair level. Pair as well as year specific importer and exporter fixed effects included but not reported. Number of observations: 27,200.

Appendix E

Appendix to Chapter 5 - Quantifying the EU-Japan Economic Partnership Agreement

Table E.1: Sectoral Trade Creation Effects (%) of the EU-Korea FTA

GTAP-ID	Sector Description	EU (%)	p-value	KOR (%)	p-value
1	Crop and animal production	28.0**	0.002	33.8**	0.001
2	Forestry and logging	88.5**	0	55.0**	0.009
3	Fishing and aquaculture	102.4**	0	-6.3	0.718
4	Mining and quarrying	76.3**	0	44.8**	0.001
5	Manufacture of food beverages, tobacco	29.3*	0.04	18.4+	0.088
6	Manufacture of textiles, apparel, leather	8	0.643	16.8	0.109
7	Manufacture of wood and cork;	40.9*	0.02	35.7*	0.022
8	Manufacture of paper and paper products	9.3	0.299	31.1**	0.007
9	Printing and reproduction of recorded media	23.0*	0.022	26.0*	0.028
10	Manufacture of coke and refined petroleum	547**	0	130**	0
11	Manufacture of chemicals and chemical products	21.2+	0.074	39.4**	0
12	Manufacture of basic pharmaceutical products	73.8**	0	0.3	0.975
13	Manufacture of rubber and plastic products	23.7*	0.022	37.4**	0
14	Manufacture of other non-metallic minerals	53.6**	0.003	30.6*	0.021
15	Manufacture of basic metals	19.2+	0.054	32.4+	0.053
16	Manufacture of fabricated metal products	31.0**	0.001	24.2*	0.014
17	Manufacture of computer, electronic and optical	81.1**	0	-1.5	0.922
18	Manufacture of electrical equipment	60.5**	0	15.4	0.17
19	Manufacture of machinery and equipment nec.	50.4**	0	0.8	0.942
20	Manufacture of motor vehicles, trailers and semi-trailers	41.2**	0	47.0*	0.04
21	Manufacture of other transport equipment	79.3**	0	2.2	0.823
22	Manufacture of furniture; other manufacturing	10.3	0.265	-12.9	0.144
23	Repair and installation of machinery and equipment	-	-	-10	0.251
24	Electricity, gas, steam and air conditioning supply	238**	0.001	32.6*	0.035
25	Water collection, treatment and supply	385**	0.001	-54.5*	0.027
26	Sewerage; waste collection, disposal;	48.6**	0	3	0.882
27	Construction	39.4**	0	26.1**	0.002
28	Wholesale, repair of vehicles and motorcycles	72.5**	0	25.1	0.252
29	Wholesale trade, except of vehicles and motorcycles	59.5**	0	20.9+	0.092
30	Retail trade, except of motor vehicles and motorcycles	53.6**	0.001	26.7*	0.056
31	Land transport and transport via pipelines	73.0**	0	15.4	0.458
32	Water transport	22.5	0.261	28	0.112
33	Air transport	84.2*	0.033	32.6+	0.079
34	Warehousing and support activities for transportation	45.6**	0.001	1.9	0.862
35	Postal and courier activities	10.6	0.452	-5.2	0.835
36	Accommodation and food service activities	26.2*	0.013	17.9+	0.081
37	Publishing activities	31.4*	0.029	-9.3	0.646
38	Motion picture, video and television, sound	15.7	0.342	-17.6	0.295
39	Telecommunications	78.6**	0	-17.9	0.331
40	Computer programming, consultancy; information	74.9**	0.001	-5.2	0.841
41	Financial services, except insurance and pension	55.9+	0.082	10.4	0.537
42	Insurance, reinsurance and pension funding	106.3**	0	30.2+	0.083
43	Auxiliary to financial and insurance activities	13.2	0.744	-8.2	0.727
44	Real estate activities	-15.5	0.523	40.4*	0.032
45	Legal and accounting, management, consultancy	-27.7*	0.044	26.9*	0.022
46	Architectural, engineering, technical testing	53.3**	0.01	8.4	0.662
47	Scientific research and development	26.0*	0.029	5.2	0.594
48	Advertising and market research	-47.7+	0.061	-18.9	0.214
49	Other professional, scientific, veterinary activities	49.6**	0.024	9.2	0.271
50	Administrative and support service activities	30.9*	0.035	15.6	0.217
51	Public administration and defense	-0.2	0.988	-14.4+	0.054
52	Education	10.4	0.363	-3.3	0.772
53	Human health and social work activities	117**	0	6	0.658
54	Other service activities	42**	0.001	4.9	0.66
55	Undifferentiated goods- and services activities				0
56	Activities of extraterritorial organizations				

Note: Own estimates, based on WIOD (2014) data. The coefficients are translated into percentage trade creation effects. P-values below 0.10 denote statistical significance at least at the 10 percent level. If cell is blank it means that no sectoral estimate could be provided due to the lack of sufficient transactions in this area. + p < 0.10, * p < .05, ** p < .01.

Table E.2: Trade Cost Elasticities

GTAP ID	Description	Trade Elasticities
1	Paddy rice	-5.8230
2	Wheat	-1.3217
3	Cereal grains nec	-1.2893
4	Vegetables, fruit, nuts	-1.4956
5	Oil seeds	-1.3217
6	Sugar cane, sugar beet	-1.3217
7	Plant-based fibers	-14.4952
8	Crops nec	-1.8446
9	Cattle, sheep, goats, horses	-2.5031
10	Animal products nec	-3.5222
11	Raw milk	-2.5486
12	Wool, silk-worm cocoons	-2.5486
13	Forestry	-3.7834
14	Fishing	-3.6693
15	Coal	-10.3915
16	Oil	-26.6757
17	Gas	-26.6757
18	Minerals nec	-4.1475
19	Meat: cattle, sheep, goats, horses	-2.5486
20	Meat products nec	-2.5486
21	Vegetable oils and fats	-3.7847
22	Dairy products	-2.8907
23	Processed rice	-9.8984
24	Sugar	-2.5073
25	Food products nec	-3.2790
26	Beverages and tobacco products	-1.3169
27	Textiles	-5.2618
28	Wearing apparel	-2.1010
29	Leather products	-3.7073
30	Wood products	-3.3775
31	Paper products, publishing	-4.6448
32	Petroleum, coal products	-8.6460
33	Chemical, rubber, plastic prods	-4.4832
34	Mineral products nec	-3.3516
35	Ferrous metals	-1.5660
36	Metals nec	-4.8543
37	Metal products	-2.5564
38	Motor vehicles and parts	-4.0680
39	Transport equipment nec	-4.0118
40	Electronic equipment	-2.0006
41	Machinery and equipment nec	-3.3853
42	Manufactures nec	-2.5133
43-57	All Services	-5.9591

Note: The trade cost elasticities for the goods stem from Aichele et al. (2016). The trade cost elasticities for services stem from (Egger et al., 2015).

Table E.3: List of GTAP Sectors

GTAP sector ID	GTAP Sector	GTAP sector ID	GTAP Sector
	Agrifood		**Energy**
1	Paddy rice	15	Coal
2	Wheat	16	Oil
3	Cereal grains nec	17	Gas
4	Vegetables, fruit, nuts		
5	Oil seeds		**Metals**
6	Sugar cane, sugar beet	35	Ferrous metals
7	Plant-based fibers	36	Metals nec
8	Crops nec	37	Metal products
9	Cattle, sheep, goats, horses		
10	Animal products nec		**Raw Materials**
11	Raw milk	13	Forestry
14	Fishing	18	Minerals nec
19	Meat: cattle, sheep, goats, horses	30	Wood products
20	Meat products nec	31	Paper products, publishing
21	Vegetable oils and fats	32	Petroleum, coal products
22	Dairy products	34	Mineral products nec
23	Processed rice		
24	Sugar		**Other Services**
25	Food products nec	43	Electricity
26	Beverages and tobacco products	44	Gas manufacture, distribution
		45	Water
38	**Automotive**	46	Construction
		51	Communication
33	**Chemicals**	55	Recreation and other services
		56	Pub. Admin/Defense/Health/Education
40	**Electronic Equipment**	57	Dwellings
	Finance & Business Services		**Textiles & Apparel**
52	Financial services nec	12	Wool, silk-worm cocoons
53	Insurance	27	Textiles
54	Business services nec	28	Wearing apparel
		29	Leather products
	Machinery and Equipment		
39	Transport equipment nec		**Trade and Transportation**
41	Machinery and equipment nec	47	Trade
		48	Transport nec
42	**Other Manufacturing**	49	Sea transport
		50	Air transport

Note: The list depicts all sector,s available in the GTAP 9.0 data. The aggregated sectors used in the above analyses are underlined and bold. Individual underlined and bold sectors, such as the automotive industry are separately illustrated, which is why they are not categorized into another sector.

Table E.4: List of GTAP Regions and Countries

Africa	**Japan**	Israel	Ukraine
Ghana			Rest of EFTA
Mozambique	**Latin America**	**Oceania**	Croatia
Kenya	Brazil	New Zealand	Albania
Cameroon	Argentina	Australia	Norway
Uganda	Uruguay	Rest of Oceania	Switzerland
Rest of Eastern Africa	Puerto Rico		Turkey
South Central Africa	Rest of South America	**Philippines**	Rest of Europe
Namibia	Colombia		
Burkina Faso	Dominican Republic	**ASEAN, n.e.c.**	**Rest of World**
Rest of South African Customs Union	El Salvador	Rest of Southeast Asia	Kazakhstan
Nigeria	Chile	Brunei Darussalam	Belarus
South Africa	Panama	Cambodia	Sri Lanka
Benin	Trinidad and Tobago	Lao PDR	Rest of South Asia
Mauritius	Guatemala		Nepal
Ethiopia	Nicaragua	**Rest of European Union (RoEU)**	Rest of former Soviet Union
Zambia	Paraguay	Hungary	Mongolia
Zimbabwe	Venezuela, RB	Spain	Pakistan
Rwanda	Costa Rica	Sweden	Rest of East Asia
Senegal	Honduras	Lithuania	Bangladesh
Cote dIvoire	Ecuador	Slovak Republic	Georgia
Malawi	Mexico	Luxembourg	Azerbaijan
Central Africa	Peru	Finland	Armenia
Togo	Jamaica	Malta	Rest of World
Botswana	Belize	Netherlands	Russian Federation
Guinea	Bolivia	Belgium	Kyrgyz Republic
Rest of Western Africa		Latvia	
Tanzania	**Malaysia**	Poland	**Singapore**
Madagascar		Greece	
	Middle East	Cyprus	**South Korea**
China	Rest of North Africa	Austria	
Hong Kong SAR, China	Bahrain	Portugal	**Taiwan**
China	Qatar	Czech Republic	
	United Arab Emirates	Bulgaria	**Thailand**
France	Jordan	Denmark	
	Oman	Ireland	**USA& Canada**
Germany	Saudi Arabia	Romania	Rest of North America
	Morocco	Slovenia	Canada
India	Rest of Western Asia	Estonia	United States
	Tunisia		
Indonesia	Kuwait	**Europe, n.e.c.**	**United Kingdom (UK)**
	Iran, Islamic Rep.		
Italy	Egypt, Arab Rep.	Moldova	**Vietnam**

Note: The list depicts all countries available in the GTAP 9.0 data. The aggregated regions used in the above analyses are underlined and bold. Individual underlined and bold countries, such as Japan are separately illustrated, which is why they are not categorized into another region.

Table E.5: Change in Sectoral Value added, EU28 and Japan

	EU28 Value Added		Japan Value Added	
	Initital in bn USD	Change in %	Initital in bn USD	Change in %
Agri-Food	848	0.82	206	-1.50
Automotive	289	-1.59	93	6.55
Chemicals	602	-0.54	134	3.73
Electronic Equipment	143	1.07	98	-0.22
Energy	82	-1.41	0	-2.07
Financial & Business Services	3148	0.03	925	0.20
Machinery and Equipment	808	0.41	193	0.10
Metals	463	-0.22	146	1.64
Other Manufacturing	133	0.05	29	0.40
Other Services	6817	0.11	2478	0.26
Raw Materials	856	0.17	191	0.76
Textiles & Apparel	230	0.37	21	0.51
Trade and Transportation	1751	0.29	1139	0.08
Total	16172	0.11	5654	0.38

Note: The list depicts the aggregated sector categories. A detailed sector list can be found in the Appendix, table E.3.

Table E.6: Change of Sectoral Value Added of Agri-Food in EU28 and Japan, in bn USD & %

	EU28 Value Added		Japan Value Added	
	Change			
	in bn USD	in %	in bn USD	in %
Animal products nec	1.04	2.79	-0.30	-13.35
Beverages and tobacco products	1.01	0.63	-0.85	-1.22
Cattle, sheep, goats, horses	0.10	0.75	-0.01	-0.62
Cereal grains nec	0.17	0.80	-0.00	-0.79
Crops nec	0.20	0.39	-0.17	-1.36
Dairy products	1.00	1.48	-0.74	-11.92
Fishing	0.10	0.63	-0.05	-0.49
Food products nec.	1.13	0.49	-0.40	-0.68
Meat products nec.	1.00	1.81	-0.24	-17.70
Meat: cattle, sheep, goats, horses	0.04	0.16	-0.00	-0.05
Oil seeds	0.03	0.25	0.00	0.11
Paddy rice	0.00	0.05	-0.02	-0.15
Plant-based fibers	-0.01	-1.00	0.00	0.71
Processed rice	-0.00	-0.10	0.00	0.01
Raw milk	0.84	2.08	-0.27	-8.83
Sugar	0.05	0.29	-0.03	-1.95
Sugar cane, sugar beet	0.01	0.25	-0.00	-1.67
Vegetable oils and fats	0.03	0.19	-0.00	-0.00
Vegetables, fruit, nuts	0.10	0.18	-0.02	-0.10
Wheat	0.13	0.61	-0.00	-0.86
Agri-Food Total	6.98	0.82	-3.09	-1.50

Note: The list depicts the all sectors of the aggregated sector category Agrifood. A detailed sector list can be found in the Appendix, table E.3.

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