An examination of EU trade disintegration scenarios

Abstract

This paper demonstrates the welfare implications of the differential disintegration of the EU. Using a structural gravity approach, our estimates suggest that the rest of the EU countries have much more to lose from the disintegration of the EU compared to a disorderly Brexit. At the same time, neighboring high income and middle income countries, such as Bosnia and Herzegovina and Norway, are expected to benefit from EU disintegration under some scenarios because trade would be diverted from EU countries.

Key words: Gravity model, trade policy, Brexit, EU

JEL codes: F13, F14

1 Introduction

Understanding the costs of Brexit is important not only for the ongoing negotiations of the future trade arrangements between the EU and UK, but also for EU members to evaluate the consequences of other countries leaving the EU. There is relatively less known about this process compared to integration. Historically, there are a few notable examples such as the dissolution of empires and the Soviet block collapse (Head et al., 2010; Suesse, 2018; Fidrmuc and Fidrmuc, 2003). However, the situation in the EU is somewhat different, where some countries have been able to negotiate opt-outs that have already created variability in integration across the EU. The recent Brexit negotiations have highlighted the potential to exacerbate this situation, with the UK seeking a special individual arrangement to disintegrate it further from the EU (Schimmelfennig, 2018). In the context of Brexit, the literature has tended to focus on the impact for the UK, and where it does consider the impact on the EU-27 it is typically used to provide a benchmark for the estimated UK welfare losses (Dhingra

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et al., 2017; Latorre et al., 2019). The work of Mayer et al. (2019) does take a broader look at the issue but only considers the impact on EU states, and does not model the possibility of the withdrawal of an additional sub-group of EU-27 countries. The impact of Brexit on the EU-27 member states, and neighboring middle income and high income countries, is less well researched and is the focus of our attention in this paper.

Our analysis is illustrative as we model a number of scenarios and examine the gains and losses across countries for different degrees of the EU disintegration. Firstly, there is the possibility of a hard Brexit, where the UK exits without a deal. This may occur because the UK negotiators do not put a credible proposition forward. Alternatively, EU negotiators may refuse to compromise with the UK, or some combination of the two positions. Secondly, it is also conceivable that EU negotiators soften their Brexit negotiation stance and concede to UK requests; in doing so they may create a domino effect of further exits, and potentially the disintegration of the EU (Baldwin, 1993). The impact of differentiated disintegration across the EU, due to Brexit, is something on which the modelling literature has been relatively silent (for a discussion of the political trilemma facing the EU project see Sampson (2017)). We construct a range of disintegration scenarios and examine the pattern of export and welfare changes in each case. This paper does not aim to predict the actual outcome of the Brexit negotiations, or the subsequent disintegration dynamics across the rest of the EU-27; instead, the aim is to illustrate the range of impacts in this uncertain trade policy environment.

Therefore, the contribution of the present paper is to explore the impact of nine EU disintegration scenarios, varying by degree of disintegration and number of countries exiting the EU, on the EU-27 and peripheral non-EU countries. We examine these cases by conducting a general equilibrium structural trade policy analysis developed by Anderson et al. (2015), where we calculate the price effects of changes in trade costs and trade block disintegration associated with each scenario. This approach is based on the general equilibrium global trade flows, where the relative merits of each scenario are examined from the standpoint of the welfare changes of a representative consumer. In the extreme benchmark case of a complete break-up of the EU, where all EU member states are left to trade on WTO-only rules, we assume that EU disintegration would result in only an increase in trade costs, while keeping the level of technology and factor inputs intact. Therefore, our results indicate a lower bound in the welfare losses. We compute changes in welfare for the conditional general equilibrium (CGE) and full general equilibrium (FGE). The former calculates welfare changes keeping output and expenditure constant, while the latter also accounts for the changes in output and expenditure due to global price adjustments. We consider three particular questions: To what extent do the costs of Brexit, and any further disintegration across the EU-27, vary across member and non-member states?; What is the trade diverting effect on third countries, including EU neighbouring countries?; Do the potential costs of EU-27 disintegration (even if partial) explain the opposition to giving in to UK Brexit demands?

Our estimates suggest that all EU-27 countries will lose out from a disorderly Brexit, but that losses are not distributed evenly between the EU-27. In the event of the UK alone exiting, the most significant losses will be felt by the UK's close EU-27 neighbours. However, if the UK exits with Portugal, Italy, Greece and Spain, then it is Portugal which is expected to experience the largest reduction in welfare. In the most extreme case of a complete disintegration of the EU, the largest negative effects will be felt by the eastern European countries and Luxembourg, where trade would be diverted to nearby non-EU members. Germany, France, Italy and Spain would be least negatively impacted by a complete collapse of the EU. Overall, EU countries have more to lose from the disintegration of the EU than from a hard Brexit since each member trades more with the rest of the EU than the UK. Therefore, the remaining member states will have more to lose if Brexit arrangements undermine the continuation of the EU. These results point to a dominant strategy for the EU to stand firm against UK demands, assuming that the EU negotiators believe this to be the most likely approach to avoid the complete disintegration of the EU.

The remainder of this paper is laid out as follows. Section 2 discusses the methodology, with Section 3 explaining the data. Section 4 describes the scenarios. The results for EU countries and their closest neighbors are discussed in Section 5. Section 6 presents the results by regions and income groups. Section 7 concludes.

2 Model and methodology

This paper uses a structural gravity approach that is consistent with a wide class of trade models. Based on the estimation of the structural parameters, we compute counterfactual changes in trade and welfare relative to the baseline scenario. This approach has been used to estimate the effect of the North America Free Trade Agreement (NAFTA) (Anderson et al., 2015), Transatlantic Trade and Investment Partnership (TTIP) (Felbermayr et al., 2015), and Brexit (Jackson and Shepotylo, 2018). In what follows, we explain the theoretical foundation and econometric specification.

2.1 Set up and assumptions

We consider N countries, indexed $i = 1, 2, ..., N$, each endowed with Q_i units of output. Furthermore, we adopt the Armington assumption (Armington, 1969) that consumers love variety. Each country produces a unique good, which is consumed in all other countries since imported goods are imperfect substitutes for the domestic variety. There is an elasticity of substitution across varieties of $\sigma > 1$. While our theoretical model is based on these Armington assumptions, it can be modified to fit other trade models, including monopolistic competition (Krugman, 1980), heterogeneous firms under monopolistic competition (Melitz, 2003), and heterogeneous firms under perfect competition (Bernard et al., 2003) models. It does not change the empirical approach, but modifies our interpretation of the estimated parameters, which differs under different models of trade (Costinot and Rodríguez-Clare, 2014).

Trade is costly – it takes $\tau_{ij} \geq 1$ units of good i to deliver one unit of this good from i to j, with $\tau_{ij} = 1$ if and only if $i = j$. [1] Aggregate output is defined as $Y_i = p_i Q_i$, where p_i is the factory gate price. We assume balanced trade, such that aggregate expenditures are equal to aggregate income $E_i = Y_i, \forall i \in 1, 2, \ldots, N$.

2.2 Equilibrium

Solving the model yields a structural gravity representation

$$X_{ij} = \frac{Y_i E_j}{Y_w} \left(\frac{\tau_{ij}}{\Omega_i P_j} \right)^{(1-\sigma)} \tag{1}$$

where X_{ij} is export from country i to country j, $Y_i = \sum_j X_{ij}$ is total income in country i, $Y_w = \sum Y_i$ is world output, and $E_j = \sum_i X_{ij}$ is total expenditure in country j. In addition, it has the following equilibrium relationships

[1] This is a standard assumption in the trade literature – domestic trade costs can be ignored when compared with international trade costs. However, the domestic trade costs can be substantial for some countries. The internal trade costs are higher for countries with a large area, rough terrain, and poor logistic and transport infrastructure. Therefore, $\tau_{ii} = 1$ introduces a measurement error which is likely to be correlated with some of our explanatory variables, which leads to attenuation bias. We deal with this issue by adding internal trade and internal fixed effects in the estimation of the structural gravity.

$$\Omega_i^{(1-\sigma)} = \sum_j \frac{E_j}{Y_w} \left(\frac{\tau_{ij}}{P_j} \right)^{(1-\sigma)} \tag{2}$$

is the outward multilateral resistance term and

$$P_j^{(1-\sigma)} = \sum_i \frac{Y_i}{Y_w} \left(\frac{\tau_{ij}}{\Omega_i} \right)^{(1-\sigma)} \tag{3}$$

is the inward multilateral resistance term.

The factory gate price in country i in the equilibrium is characterized as follows

$$p_i = (Y_i/Y_W)^{1/(1-\sigma)} \times 1/\Omega_i \tag{4}$$

2.3 Estimation

Our strategy follows Anderson et al. (2018) who developed an algorithm to evaluate welfare and export changes in an endowment economy. We evaluate changes in trade flows and consumer welfare before and after counterfactual trade policy changes, by estimating the structural gravity model (1)-(3) by Poisson Pseudo Maximum Likelihood (PPML) (Silva and Tenreyro, 2006) under the status quo and, after changing the trade policy assumptions, under counterfactual scenarios. Our estimated model is given by

$$X_{ij} = \exp(\gamma_{FTA} \times FTA + \gamma_{CU} \times CU + \gamma_{EU} \times EU + \gamma_Z Z_{ij} + \xi_i + \eta_j) + v_{ij} \tag{5}$$

where FTA is a binary variable that takes the value of 1 if trading pair of countries have a free trade agreement (FTA) and 0 otherwise; γ_{FTA} is the corresponding coefficient. CU is a binary variable that takes the value of 1 if the trading pair of countries are members of a customs union (CU) and 0 otherwise; γ_{CU} is the corresponding coefficient. EU is a binary variable that takes value of 1 if both countries are EU members and 0 othewise; γ_{EU} is the corresponding coefficient. γ_Z is a row vector of parameters and Z_{ij} is a column vector of bilateral trade cost variables, including distance, contiguity, colonial relationship, common legal system, common spoken language, common religion. ξ_i and η_j are inward and outward multilateral resistance terms. v_{ij} is an error term.

In the counterfactual scenarios, we apply changes in bilateral FTA, CU and EU such that FTA'_{ij}, CU'_{ij}, and EU'_{ij} reflect the changes in the policy scenarios. We then perform the constrained estimation of the multilateral resistance terms under the new set of policy variables, constraining the coefficients determining bilateral trade costs to be equal to our estimated coefficients from the previous stage:

$$X_{ij} = \exp(\hat{\gamma}_{FTA} \times FTA'_{ij} + \hat{\gamma}_{CU} \times CU'_{ij} + \hat{\gamma}_{EU} \times EU'_{ij} + \hat{\gamma}_Z Z_{ij} + \xi'_i + \eta'_j) + v'_{ij} \tag{6}$$

where ξ'_i and η'_j are new inward and outward multilateral resistance terms, consistent with the new policy variables, and v'_{ij} is an error term.

Using the result by Fally (2015), who has shown that under the PPML method the country fixed effects in equation 5 are consistent estimates of the inward and outward multilateral resistance terms, and a given the set of η_j and η'_j , estimated using PPML according to equations 5 and 6, we compute the inward multilateral resistance terms using the following expressions:

$$\hat{P}_j^{1-\sigma} = E_j \exp(-\hat{\eta}_j)/E_0 \tag{7}$$

$$\hat{P'}_j^{1-\sigma} = E_j \exp(-\hat{\eta}'_j)/E_0 \tag{8}$$

where σ is elasticity of substitution, E_0 is the level of expenditure in the country for which the inward multilateral resistance is normalized to $P_0 = 1$.[2]

2.4 Counterfactual export changes and welfare analysis

For the CGE (Head and Mayer, 2015; Anderson et al., 2018), we keep production and expenditure constant. The changes in bilateral exports in the CGE are computed as

$$E\hat{X}P_{ij} = 100\% \times \frac{\hat{X}'_{ij}}{\hat{X}_{ij}} \tag{9}$$

where $\hat{X}_{ij}$ and $\hat{X}'_{ij}$ are computed as linear predictions of equations 5 and 6 respectively.

The welfare changes in the CGE are evaluated as follows:

$$\hat{W}_i = 100\% \times (\hat{P}_i/\hat{P}'_i - 1) \tag{10}$$

[2]New Zealand is chosen as the reference country. The welfare gains of each country relative to the others do not depend on the choice of the reference country.

For the FGE results, we update the factory gate prices in equation 4, according to the following formula

$$\frac{p_i^{'}}{p_i} = \frac{\hat{\Omega}_i}{\hat{\Omega}_i^{'}} = \left(\frac{\exp\left(-\hat{\xi}_i\right)}{\exp\left(-\hat{\xi}_i^{'}\right)}\right)^{1/(1-\sigma)} \tag{11}$$

Then we compute new values of income, expenditure, and bilateral trade flows as follows:

$$Y_i^{'} = \frac{p_i^{'}}{p_i} Y_i \tag{12}$$

$$E_i^{'} = \frac{p_i^{'}}{p_i} E_i \tag{13}$$

and

$$X_{ij}^{'} = \frac{\tau_{ij}^{'(1-\sigma)}}{\tau_{ij}^{(1-\sigma)}} \frac{Y_i^{'} E_i^{'}}{Y_i E_i} \frac{\hat{\Omega}_i^{1-\sigma}}{\hat{\Omega}_i^{'1-\sigma}} \frac{\hat{P}_j^{1-\sigma}}{\hat{P}_j^{'1-\sigma}} X_{ij} \tag{14}$$

then re-estimate equation 6. The process continues until convergence is achieved.[3] The welfare changes in the FGE are computed as follows:

$$\hat{W}_i = 100\% \times \left(\frac{\frac{Y_i^{'}}{P_i^{'}}}{\frac{Y_i}{P_i}} - 1\right) \tag{15}$$

3 Data

The data used to estimate the trade policy elasticities covers 160 countries for the period 1967-2017. We look at 10 year intervals in order to capture long term trends and regularities as well as reducing the noise generated by short term fluctuations in trade flows. The bilateral export data is from the Directions of Trade Statistics (DOTS) of the International Monetary Fund (IMF). Data on different types of preferential trade agreements comes from Mario Larch's Regional Trade Agreements Database (Egger and Larch, 2008). Bilateral trade costs are from the CEPII gravity dataset (see Head et al. (2010)). The common spoken language and common religion dummy variables capture the effects of cultural similarities on trade (Melitz and Toubal, 2014). Finally, data on applied tariff

[3]For the detailed description of the iterative estimation of FGE, please see Anderson et al. (2018)

rates are from the UNCTAD Trade Analysis Information System (TRAINS).[4] When we estimate the regressions with tariffs, which are available only since the 1990's, our sample is bilateral trade in 5 year intervals from 1992 until 2017. Table 1 reports the summary statistics of all the variables in our dataset.

In our counterfactual analysis we aim to capture the fact that deeper trade integration is associated with more trade. Preferential trade agreements (PTAs) are heterogeneous in their effects on trade (Baier et al., 2019), while modern PTAs, as discussed in Limão (2016), differ from traditional FTAs by encompassing a wide range of policies. The common classification of PTAs is in terms of increasing degree of integration; this allows us to separate our sample into three mutually exclusive groups: free trade agreements (FTA), customs unions (CU), and common market (EU). Approximately 10% of country-pairs have preferential trade relationships in 1967-2017. Among those, 6% have tariff free trade and 3% are in a CU (excluding the EU). Finally, 1.5% of trade flows are within the EU. We also control for common border, cultural and political similarity, and distance when we report the cross-section results in 2017. Finally, the average applied tariff across our sample in 1992-2017 is 9.3%.

Table 1: Summary statistics

Variable	N	Mean	St. Dev.	Min	Max
Export, mln. USD	121,132	1.539	82.166	0	17948.6
PTA, Yes=1	121,173	0.118	0.322	0	1
FTA, Yes=1	121,173	0.060	0.237	0	1
CU, Yes=1	121,173	0.026	0.159	0	1
EU, Yes=1	121,173	0.015	0.121	0	1
Common border	121,173	0.018	0.135	0	1
Common spoken language	121,173	0.120	0.233	0	1
Former colony	121,173	0.014	0.118	0	1
Common legal system	121,171	0.349	0.477	0	1
Ln Distance	121,173	8.708	0.829	2.1	9.89
1+(Applied tariff, %)/100	111,086	1.093	0.109	1	13.1

The data sample is 160 countries for 1967-2017 in 10-year intervals. For the regression with tariffs we use 1992-2017 data with 5 year intervals. Theoretically, there are 25,600 observations of bilateral trade per year (25440 if internal trade is excluded). However, the 1967-2017 sample is not balanced, because the number of countries have changed substantially between 1967 and 2017. Our bilateral trade starts with 12,896 observations in 1967 and ends with 25600 observations in 2007 and 2017.

[4]We use bilateral MFN rates, which may differ across country-pairs due to different composition of trade, and adjust those for preferential rates.

4 Scenarios

We construct nine EU disintegration scenarios and consider their impact on the EU-27 and peripheral non-EU countries; while the central objective of the paper is to use this information to answer three questions: To what extent do the costs of Brexit, and any further disintegration across the EU-27, vary across member and non-member states?; What is the trade diverting effect on third countries, including the EU neighborhood countries and less developed countries?; Do the potential costs of EU-27 disintegration (even if partial) explain the opposition to giving in to UK Brexit demands?

We assume three different types of disintegration:

1. **No-deal or hard exit**

   The country exiting would not be able to maintain preferential tariffs with other EU member states, and will instead face the Most-Favoured Nation (MFN) rates. We also assume that the non-tariff barriers (NTBs) applied to the exiting country exporters would be similar to those applied to exporters from outside the EU free trade zone. [5]

2. **FTA**

   The country would leave the EU single market and sign a shallow FTA such that the preferential tariffs with EU member states are maintained but NTBs emerge (and would be similar to those applied to exporters outside the EU free trade zone).

3. **CU**

   The country would leave the EU single market and trade as part of a CU agreement with other EU member states.

Further, we construct scenarios where we have the following countries leaving the EU single market: a) UK b) UK + Portugal, Italy, Greece, and Spain (UK + PIGS) c) all EU member states. The PIGS countries were selected due to the economic instability derived from the accumulation of government debt. During 2018-19, Greece, Italy and Portugal have still been suffering from the highest levels of general government debt as a percentage of GDP out of all member states (Eurostat). While Spain is only the 7th most indebted, the concerns which emerged in 2009 have not gone away.

[5] The NTBs are not measured explicitly. We assume that under the hard brexit scenario, the EU applies the same types of NTBs to the UK as it applies to the other non-EU countries (ceteris paribus). In the regression analysis, the effect of NTBs on trade (among other things) is captured by the coefficient on the EU variable (which captures both the NTBs and tariff barriers).

Table 2: Counterfactual scenarios

Scenario #	Countries	Arrangement
1	UK	No deal (Hard)
2	UK	FTA
3	UK	CU
4	UK + PIGS	No deal (Hard)
5	UK + PIGS	FTA
6	UK + PIGS	CU
7	EU	No deal (Hard)
8	EU	FTA
9	EU	CU

The term PIIGS, including Ireland, was coined in 2009 due to concerns around the sustainability of public finances among this group of countries. In the case of Greece, there was a significant risk of Grexit during this period. We have not included Ireland since their departure is considered to be unlikely based on the attitude of citizens towards the EU: the November 2019 edition of the Standard Eurobarometer reports that 58% of respondents living in Ireland trust the EU, which is the fifth highest out of all member state respondents. The combination of the three types of disintegration with the three country groups creates a total of nine EU disintegration scenarios presented in Table 2. In all scenarios we assume that productivity and factor inputs of the EU economies will remain intact, which implies no changes in physical quantities of output. This assumption is made to identify the impact of trade policy changes on welfare, keeping all other things equal.

We are fully aware that such big shocks would result in changes in production capacities of the EU countries and political shocks that would further negatively impact welfare. Any productivity losses resulting from a lower variety of imports, implications for the monetary union and common currency, and political instability would further increase welfare losses. This would erode any positive effects due to increases in competitiveness for third countries. Therefore, our estimation present the lower bound of welfare losses. Nevertheless, it is instructive to highlight how changes in relative trade costs due to the differential disintegration of the EU would have regional and global implication for trade and welfare.

5 Analysis

5.1 Estimation of trade elasticities

In Table 3 we present the results of estimating PTA elasticities of trade using the Poisson Pseudo Maximum Likelihood estimator with exporter-time and importer-time fixed effects that control for multilateral resistance terms. In columns (3)-(8) we also have pair-wise fixed effects, accounting for pair specific, time invariant trade costs (Baier and Bergstrand, 2007).[6] We use the **ppmlhdfe** Stata program to deal with the high dimensionality of our fixed effects (Correia et al., 2019). The dependent variable is exports in millions of USD. Standard errors are clustered by country-pair. In column (1) we look at how any type of PTA influences exports and contrast it with extra exports generated within the EU using only the 2017 sample. In column (2) we break PTAs into different types. In column (3), the model is estimated by PPML using the 1967-2017 panel. Column (4) presents the estimation results for a panel with PTAs split into FTAs and CUs. In columns (5) and (6) we add internal trade. Finally, in columns (7) and (8) we also control for tariffs. The positive effect of FTAs on trade disappears when we control for tariffs, because tariffs capture the channel through which FTAs influence trade. The effect of CUs and the EU remains positive and significant, since these deeper types of PTAs work through the harmonization of NTMs, common regulatory framework, and the absense of customs for trade.

The column (6) is used as the baseline estimates, which accounts for directional time-varying fixed effects, bilateral pair effects, and internal trade. It allows us to estimate the trade policy effects using the best practices of estimating the structural gravity model (Piermartini and Yotov, 2016). Therefore, in further simulations we take 0.285 as the average impact of an FTA on exports; 0.675 as the average impact of a CU on exports; and 1.044 as the average impact of the EU on exports. To compute welfare changes we use the elasticity of substitution parameter of 5.13, which is the average elasticity reported by Head and Mayer (2015). Nevertheless, the welfare results are robust to changes in the trade elasticity values. There are slight changes in the magnitude of the welfare effects, without modifications to relative size across countries and country groups.

[6]In addition, the full set of exporter-time, importer-time, and bilateral fixed effects reduces concerns of the endogeneity of trade agreements and tariffs. As shown by Baier and Bergstrand (2007), this method effectively deals with endogeneity. Under this specification, only the time variant, bilateral unobserved factors may cause concerns. However, the remaining bias is likely to be negative, which means that the welfare effects are underestimated.

Table 3: Elasticity of export with respect to PTAs and EU

	(1) 2017	(2) +FTACU	(3) 1967-2017	(4) +FTACU	(5) Internal	(6) +FTACU	(7) Tariff	(8) +FTACU
PTA, Yes=1	.331*		.152*		.409*		.107*	
	(.066)		(.027)		(.048)		(.037)	
FTA, Yes=1		.420*		.090*		.285*		.044
		(.066)		(.029)		(.047)		(.040)
CU, Yes=1		.483*		.378*		.675*		.347*
		(.13)		(.083)		(.11)		(.084)
EU, Yes=1	.704*	.809*	.604*	.571*	1.142*	1.044*	.704*	.643*
	(.11)	(.11)	(.048)	(.049)	(.062)	(.060)	(.058)	(.060)
(1 + Applied tariff, %/100)							-3.873*	-3.999*
							(.27)	(.28)
$\ln(dist_{ij})$	-.744*	-.714*						
	(.043)	(.042)						
Common border	.371*	.388*						
	(.075)	(.072)						
Common language	.086	.060						
	(.13)	(.13)						
Colonial past	.178*	.201*						
	(.088)	(.081)						
Common legal	.203*	.213*						
	(.046)	(.044)						
Exporter-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pair FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R-Square	.86	.86	.89	.89	.99	.99	.99	.99
N	25440	25440	98757	98757	99541	99541	95485	95485

* $p < 0.05$ Standard errors are clustered at country pairs.

Notes: The dependent variable is exports. The data used for models (1) and (2) is from 2017, for models (3)-(6) is 1967-2017 in decades, for models (7) and (8) is 1992-2017 in five year intervals. All models have country-year fixed effects. Models (3)-(8) also have pair-wise fixed effects. All models are estmated by PPML using the Stata module **ppmlhdfe** developed by Correia et al. (2019), which absorbs multiple levels of fixed effects. To ensure convergence, ppmlhdfe eliminates singletons and observations separated by fixed effects, in a way that does not change the consistency of the estimation. As a result, 21591 observations are dropped when we estimate our structural gravity in columns (3) - (6).

5.2 Counterfactual scenarios for EU and neighboring countries

Table 4 and Table 8 (see Appendix), present welfare gains for each of the nine scenarios, for the FGE and CGE cases respectively; while our discussion in this section considers the main FGE results. The CGE results in Table 8 are included since they provide a useful overview of the welfare impact of the changes to trade costs, while holding output and expenditure constant.

We focus our attention on EU countries and non-EU neighbours. The results for other countries are available upon request. According to Table 4, all EU27 countries will lose out from both Brexit and any further disintegration across the rest of the EU-27. If only the UK exits (scenarios 1-3), unsurprisingly, the UK suffers the most significant losses. The extent of these losses range from 6.61%

Table 4: Changes in welfare as a percentage of GDP (FGE)

Country/Scenario	(1) Hard Brexit	(2) FTA Brexit	(3) CU Brexit	(4) Hard PIGS	(5) FTA PIGS	(6) CU PIGS	(7) Hard EU	(8) FTA EU	(9) CU EU
Austria	-0.75	-0.71	-0.33	-1.03	-0.94	-0.58	-7.92	-6.27	-3.19
Belgium	-1.55	-1.35	-0.61	-2.34	-1.99	-1.13	-6.68	-5.31	-2.72
Bulgaria	-0.71	-0.67	-0.32	-1.96	-1.66	-0.95	-7.98	-6.33	-3.19
Croatia	-0.82	-0.76	-0.36	-3.51	-2.89	-1.60	-14.72	-11.42	-5.56
Cyprus	-1.00	-0.89	-0.43	-2.33	-1.94	-1.08	-6.45	-5.10	-2.60
Czech Republic	-0.71	-0.67	-0.32	-1.37	-1.20	-0.71	-5.29	-4.28	-2.20
Denmark	-1.56	-1.34	-0.61	-1.89	-1.61	-0.93	-9.83	-7.71	-3.82
Estonia	-0.82	-0.76	-0.36	-1.19	-1.05	-0.63	-11.82	-9.24	-4.55
Finland	-0.97	-0.88	-0.41	-1.36	-1.19	-0.70	-5.76	-4.59	-2.34
France	-1.29	-1.13	-0.54	-2.04	-1.74	-0.99	-4.52	-3.56	-1.81
Germany	-0.93	-0.85	-0.38	-1.26	-1.13	-0.68	-2.48	-2.10	-1.12
Greece	-0.69	-0.66	-0.33	-6.35	-5.07	-2.71	-6.27	-4.96	-2.53
Hungary	-0.59	-0.58	-0.28	-1.38	-1.21	-0.72	-6.93	-5.58	-2.86
Ireland	-1.75	-1.49	-0.66	-2.36	-1.98	-1.11	-7.25	-5.79	-2.95
Italy	-0.65	-0.63	-0.31	-3.81	-3.15	-1.76	-3.79	-3.06	-1.59
Latvia	-0.77	-0.72	-0.34	-1.18	-1.04	-0.62	-10.96	-8.59	-4.26
Lithuania	-0.76	-0.70	-0.34	-1.26	-1.11	-0.66	-9.32	-7.35	-3.68
Luxembourg	-1.44	-1.25	-0.58	-3.05	-2.54	-1.41	-13.23	-10.16	-4.97
Netherlands	-2.01	-1.71	-0.75	-2.58	-2.17	-1.22	-8.11	-6.49	-3.31
Poland	-0.74	-0.70	-0.34	-1.30	-1.14	-0.68	-4.68	-3.74	-1.90
Portugal	-0.86	-0.79	-0.39	-6.57	-5.29	-2.86	-6.58	-5.22	-2.67
Romania	-0.70	-0.66	-0.32	-1.74	-1.49	-0.86	-6.70	-5.34	-2.71
Slovak Republic	-0.67	-0.64	-0.30	-1.50	-1.30	-0.77	-9.26	-7.34	-3.70
Slovenia	-0.82	-0.76	-0.35	-1.37	-1.21	-0.72	-11.26	-8.87	-4.43
Spain	-0.83	-0.76	-0.37	-4.31	-3.49	-1.90	-4.28	-3.41	-1.75
Sweden	-1.52	-1.31	-0.59	-1.92	-1.64	-0.94	-9.43	-7.47	-3.76
United Kingdom	-6.61	-5.27	-2.49	-6.47	-5.14	-2.74	-6.18	-4.85	-2.45
EU	**-1.90**	**-1.61**	**-0.75**	**-2.99**	**-2.47**	**-1.37**	**-5.14**	**-4.10**	**-2.10**
Albania	-0.45	-0.45	-0.24	-0.10	-0.17	-0.15	0.65	0.41	0.14
Algeria	-0.40	-0.42	-0.23	-0.02	-0.09	-0.10	0.28	0.15	0.02
Bosnia and Herzegovina	-0.29	-0.32	-0.19	0.29	0.14	0.01	1.74	1.23	0.53
Iceland	-0.35	-0.35	-0.20	-0.20	-0.22	-0.16	0.33	0.19	0.05
North Macedonia	-0.46	-0.46	-0.24	-0.14	-0.20	-0.17	0.91	0.59	0.20
Morocco	-0.46	-0.46	-0.24	-0.13	-0.17	-0.14	0.04	-0.03	-0.06
Norway	-0.26	-0.28	-0.19	-0.05	-0.11	-0.11	1.47	1.00	0.38
Switzerland	-0.43	-0.43	-0.24	-0.26	-0.29	-0.21	1.23	0.78	0.23
Tunisia	-0.39	-0.41	-0.22	0.08	-0.02	-0.07	0.56	0.36	0.11
Turkey	-0.51	-0.50	-0.26	-0.39	-0.39	-0.26	-0.16	-0.20	-0.15
Ukraine	-0.56	-0.53	-0.28	-0.49	-0.47	-0.31	0.68	0.40	0.08

Notes: Elasticity of trade with respect to FTA is 0.285, CU is 0.675, EU is 1.044. The data for simulations is from 2017. The EU average in bold is computed as the GDP-weighted average.

to 2.49% depending on whether it is a hard Brexit, or the UK and EU successfully negotiate a new CU arrangement. In terms of the EU-27, the losses are not distributed evenly. The most significant loss would be incurred by the Netherlands, followed by Ireland then Denmark and Belgium. All geographically proximate, and in the case of Ireland a common language and strong historical ties with the UK provides further explanation for the results. In scenarios 1-3, it is the southern and eastern EU states that are most shielded from the impact. While it is also noteworthy that in most cases the losses for the EU-27 drop sharply if a EU-UK CU is signed. For non-EU members, Norway is found to have the least to be concerned about in terms of welfare losses, despite its geographic proximity.

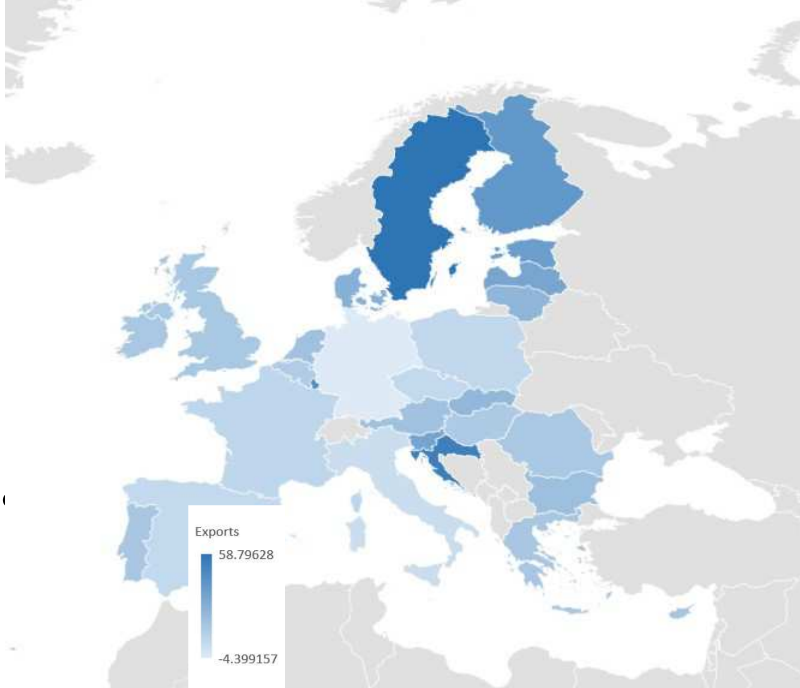
In scenarios 4-6, it is the PIGS and the UK that would suffer the largest welfare losses. Portugal is predicted to be particularly hard hit, alongside the UK and Greece. Signing an FTA with the EU only slightly reduces the impact of leaving the union. Similar to scenarios 1-3, the losses are much more moderate in the case that the UK and PIGS sign a new CU with the EU. It is interesting to note that in these three scenarios (4-6), Germany's losses are more in line with the eastern EU members. For non-EU neighbours such as Bosnia and Herzegovina the impact is expected to be positive.

In our final three scenarios (7-9), we illustrate the more extreme disintegration of the EU. In this case we find that the eastern European countries suffer the largest losses alongside Luxembourg; while, the lowest negative impact is expected for Germany, Italy, Spain and France. In other words the largest economies are most shielded from the negative effects of the disintegration of the EU. Among non-EU countries, the closest EU neighbors would gain due to the EU disintegration. This list includes high income countries – Iceland, Norway, and Switzerland – and middle income countries – Bosnia and Herzegovina, North Macedonia, Ukraine, Albania, Tunisia and Algeria. Despite already having preferential access to the EU markets, these countries would gain in competitiveness against the EU states. In other words, the disintegration of the EU would reduce trade across the EU countries and increase trade of the EU countries with their neighbours.

Therefore, we find that losses are very unevenly distributed across member states. If the disintegration stops at only the UK exiting, the losses are going to be mostly felt among the countries geographically proximate to the UK. However, a collapse of the EU would mean that the losses are most acute for the eastern European countries and Luxembourg; and in the most extreme case of a

Figure 1: Percentage change

Figure 2: Percentage



Note: Simulated on 2017 data

complete collapse of the EU with no deal, German losses are estimated at 2.48% while the largest losses are for Croatia, 14.72%. These results all point to a dominant strategy for the EU to stand firm against UK demands, assuming that negotiators believe that this is the most credible approach to avoid a collapse of the EU project.

One of our other observations from scenarios 7-9 is the suggestion of a trade diverting effect as a result of the disintegration of the EU as a whole. Therefore, Figure 1 and Figure 2 provide an illustration of the percentage change in exports from Bosnia and Herzegovina (Figure 1) and Norway (Figure 2) to the EU-28 for scenario 7, where there is no deal after the EU disintegration. The large changes in exports are towards EU neighbouring countries; for Norway the biggest shift is towards Sweden and for Bosnia and Herzegovina it is towards Croatia. However, in both cases we do not find evidence of sizable changes in (Norwegian and Bosnia and Herzegovinan) exports towards Germany, Italy or Spain. All of this points to a significant trade diverting effect underpinning the welfare changes we have identified.

6 Broader welfare effects

Table 5 presents GDP-weighted average welfare gains of the policy scenarios by region and income level for all countries in our sample under the FGE analysis. Panel A presents results for different regions, defined according to the World Bank classification. As expected, Europe & Central Asia would incur heavy losses on average from the collapse of the EU, while Brexit would bring smaller losses. Among other regions, North America would be the least impacted by the full scale collapse of the EU, while the East Asia & Pacific would be the most impacted. This finding can be explained by the growing economic importance of the East Asia & Pacific region in trade with the EU, including active trade liberalization between the EU and Japan, EU and Australia, and EU and New Zealand. Also, China has substantially increased its links with all regions in the world, including the EU.

Panel B presents welfare gains according to income level, which indicates that high income countries would experience more negative impact in all policy scenarios, while all other income groups would experience relatively small losses.

All regions and income groups are negatively impacted, due to the direct impact of disintegration as well as the indirect effect of the reduction of income and expenditure in EU countries on their trading partners. The evidence of the additional and loss-equalizing impact under the FGE analysis can be assessed by comparing the FGE and CGE results. The results under the CGE analysis are presented in Table 6. The Middle East & North Africa region would experience small gains after hard or FTA Brexit, but these gains are wiped out by the negative indirect effect. Likewise, low income countries would gain under Brexit and partial EU disintegration scenarios in the CGE, but lose compared to the other income groups once global trade adjusts to income and expenditure changes. Also, the overall losses are higher under the FGE analysis, as evident from comparison of the last rows in the tables.

Table 5: Changes in welfare as a percentage of GDP by region and income group (FGE).

Scenario	(1) Hard Brexit	(2) FTA Brexit	(3) CU Brexit	(4) Hard PIGS	(5) FTA PIGS	(6) CU PIGS	(7) Hard EU	(8) FTA EU	(9) CU EU
	A. Welfare gains by region								
East Asia & Pacific	-0.696	-0.634	-0.328	-0.807	-0.712	-0.424	-1.034	-0.859	-0.48
Europe & Central Asia	-1.638	-1.395	-0.658	-2.503	-2.08	-1.166	-4.113	-3.303	-1.706
Latin America & Caribbean	-0.643	-0.593	-0.301	-0.72	-0.64	-0.383	-0.613	-0.543	-0.333
Middle East & North Africa	-0.607	-0.568	-0.292	-0.644	-0.585	-0.359	-0.503	-0.462	-0.28
North America	-0.664	-0.6	-0.301	-0.675	-0.601	-0.362	-0.373	-0.364	-0.241
South Asia	-0.652	-0.6	-0.305	-0.704	-0.631	-0.382	-0.534	-0.489	-0.278
Sub-Saharan Africa	-0.617	-0.573	-0.294	-0.627	-0.569	-0.349	-0.552	-0.494	-0.294
	B. Welfare gains by income level								
Low income	-0.594	-0.556	-0.285	-0.561	-0.519	-0.323	-0.291	-0.303	-0.214
Lower middle income	-0.645	-0.594	-0.304	-0.687	-0.618	-0.375	-0.547	-0.496	-0.289
Uppre middle income	-0.669	-0.615	-0.317	-0.771	-0.685	-0.41	-0.95	-0.799	-0.457
High income	-1.094	-0.951	-0.46	-1.488	-1.259	-0.719	-2.067	-1.691	-0.899
Overall	-0.936	-0.826	-0.407	-1.218	-1.043	-0.603	-1.623	-1.338	-0.723

Note: Welfare gains are weighted by countries' GDPs. Regions and income groups are defined according to the World Bank classification.

Table 6: Changes in welfare as a percentage of GDP by region and income group (CGE).

Scenario	(1) Hard Brexit	(2) FTA Brexit	(3) CU Brexit	(4) Hard PIGS	(5) FTA PIGS	(6) CU PIGS	(7) Hard EU	(8) FTA EU	(9) CU EU
				A. Welfare gains by region					
East Asia & Pacific	-0.075	-0.064	-0.036	-0.223	-0.18	-0.096	-0.548	-0.421	-0.209
Europe & Central Asia	-0.842	-0.685	-0.371	-1.574	-1.271	-0.683	-3.128	-2.465	-1.277
Latin America & Caribbean	-0.005	-0.01	-0.009	-0.119	-0.093	-0.047	-0.26	-0.194	-0.092
Middle East & North Africa	0.034	0.015	0	-0.047	-0.044	-0.027	-0.235	-0.177	-0.086
North America	-0.04	-0.025	-0.009	-0.055	-0.038	-0.016	-0.043	-0.031	-0.014
South Asia	-0.017	-0.019	-0.013	-0.088	-0.074	-0.042	-0.241	-0.186	-0.093
Sub-Saharan Africa	0.017	0.006	-0.001	-0.028	-0.025	-0.015	-0.125	-0.094	-0.046
				B. Welfare gains by income level					
Low income	0.043	0.025	0.007	0.039	0.026	0.011	-0.034	-0.025	-0.012
Lower middle income	-0.01	-0.015	-0.012	-0.081	-0.069	-0.038	-0.239	-0.184	-0.092
Upper middle incomde	-0.041	-0.04	-0.025	-0.181	-0.148	-0.08	-0.511	-0.393	-0.196
High income	-0.396	-0.318	-0.17	-0.739	-0.593	-0.316	-1.429	-1.122	-0.579
Overall	-0.263	-0.214	-0.116	-0.526	-0.423	-0.226	-1.069	-0.837	-0.43

Note: Welfare gains are weighted by countries' GDPs. Regions and income groups are defined according to the World Bank classification.

7 Conclusions

Our results suggest that EU countries have much more to lose from the disintegration of the EU than from hard Brexit. These results can easily be understood when we consider the fact that each individual EU country trades more with the rest of the EU than with the UK. Consequently, each remaining EU country will have much more to lose in the event of the UK getting a deal that includes the benefits of EU membership without the costs, as this would undermine the future existence of the EU. We find that the welfare impact is unevenly spread among the EU27, with Germany, France, Italy and Spain most shielded from the negative impact of a complete collapse of the EU. On the other hand, middle income and developed countries that border the EU, would gain from EU disintegration due to trade diversion from EU countries. This result is more pronounced in the CGE analysis and in the full collapse of the EU scenario, while in the FGE analysis, the positive effects are neutralized by the indirect effects of disintegration due to adjustments of income and expenditure in the directly affected countries.

Aggregate trade policy analysis averages out the impact of policy on trade flows and welfare, while some products, such as medical supplies and car production, may be much more affected than others. Also, disintegration of trade links are likely to cause further political tensions and civil unrest, deterioration of productivity, out-migration and capital outflows. All these factors would further lower welfare. We keep these very important issues for further research.

References

Anderson, J. E., Larch, M., and Yotov, Y. V. (2015). Growth and trade with frictions: A structural estimation framework. Technical report, National Bureau of Economic Research.

Anderson, J. E., Larch, M., and Yotov, Y. V. (2018). GEPPML: General equilibrium analysis with PPML. *The World Economy*, 41(10):2750–2782.

Armington, P. S. (1969). A theory of demand for products distinguished by place of production. *IMF Staff Papers*, 16(1):159–178.

Baier, S. L. and Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics*, 71(1):72–95.

Baier, S. L., Yotov, Y. V., and Zylkin, T. (2019). On the widely differing effects of free trade agreements: Lessons from twenty years of trade integration. *Journal of International Economics*, 116:206–226.

Baldwin, R. (1993). A domino theory of regionalism.

Bernard, A. B., Jensen, J. B., and Schott, P. K. (2003). Falling trade costs, heterogeneous firms, and industry dynamics. Technical report, National Bureau of Economic Research.

Correia, S., Guimarães, P., and Zylkin, T. (2019). Ppmlhdfe: Fast poisson estimation with high-dimensional fixed effects. *arXiv preprint arXiv:1903.01690*.

Costinot, A. and Rodríguez-Clare, A. (2014). Trade theory with numbers: Quantifying the consequences of globalization. *Handbook of International Economics*, 4:197–261.

Dhingra, S., Huang, H., Ottaviano, G., Paulo Pessoa, J., Sampson, T., and Van Reenen, J. (2017). The costs and benefits of leaving the eu: trade effects. *Economic Policy*, 32(92):651–705.

Egger, P. and Larch, M. (2008). Interdependent preferential trade agreement memberships: An empirical analysis. *Journal of International Economics*, 76(2):384–399.

Fally, T. (2015). Structural gravity and fixed effects. *Journal of International Economics*, 97(1):76–85.

Felbermayr, G., Heid, B., Larch, M., and Yalcin, E. (2015). Macroeconomic potentials of transatlantic free trade: A high resolution perspective for europe and the world. *Economic Policy*, 30(83):491–537.

Fidrmuc, J. and Fidrmuc, J. (2003). Disintegration and trade. *Review of International Economics*, 11(5):811–829.

Head, K. and Mayer, T. (2015). Gravity Equations: Workhorse,Toolkit, and Cookbook. *Handbook of International Economics*, 4.

Head, K., Mayer, T., and Ries, J. (2010). The erosion of colonial trade linkages after independence. *Journal of International Economics*, 81(1):1–14.

Jackson, K. and Shepotylo, O. (2018). Post-brexit trade survival: looking beyond the european union. *Economic Modelling*, 73:317–328.

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *The American Economic Review*, 70(5):950–959.

Latorre, M. C., Olekseyuk, Z., Yonezawa, H., and Robinson, S. (2019). Brexit: Everyone loses, but britain loses the most. *Peterson Institute for International Economics Working Paper*, (19-5).

Limão, N. (2016). Preferential trade agreements. In *Handbook of commercial policy*, volume 1, pages 279–367. Elsevier.

Mayer, T., Vicard, V., and Zignago, S. (2019). The cost of non-europe, revisited. *Economic Policy*, 34(98):145–199.

Melitz, J. and Toubal, F. (2014). Native language, spoken language, translation and trade. *Journal of International Economics*, 93(2):351–363.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6):1695–1725.

Piermartini, R. and Yotov, Y. (2016). Estimating trade policy effects with structural gravity.

Sampson, T. (2017). Brexit: the economics of international disintegration. *Journal of Economic Perspectives*, 31(4):163–84.

Schimmelfennig, F. (2018). Brexit: differentiated disintegration in the european union. *Journal of European Public Policy*, 25(8):1154–1173.

Silva, J. S. and Tenreyro, S. (2006). The log of gravity. *The Review of Economics and Statistics*, 88(4):641–658.

Suesse, M. (2018). Breaking the Unbreakable Union: Nationalism, Disintegration and the Soviet Economic Collapse. *The Economic Journal*, 128(615):2933–2967.

8 Appendix

Table 7: Changes in welfare as a percentage of GDP (conditional equilibrium)

Country/Scenario	(1) Hard Brexit	(2) FTA Brexit	(3) CU Brexit	(4) Hard PIGS	(5) FTA PIGS	(6) CU PIGS	(7) Hard EU	(8) FTA EU	(9) CU EU
Austria	0.04	-0.02	-0.04	-0.13	-0.17	-0.14	-6.68	-5.26	-2.73
Belgium	-0.63	-0.55	-0.32	-1.24	-1.06	-0.6	-5.21	-4.20	-2.22
Bulgaria	0.02	-0.02	-0.03	-1	-0.84	-0.47	-6.12	-4.77	-2.44
Croatia	-0.05	-0.08	-0.07	-2.25	-1.84	-0.99	-11.68	-8.91	-4.40
Cyprus	-0.29	-0.25	-0.14	-1.5	-1.21	-0.65	-5.33	-4.12	-2.08
Czech Republic	0.05	0.00	-0.03	-0.43	-0.4	-0.25	-3.53	-2.90	-1.58
Denmark	-0.66	-0.57	-0.32	-0.9	-0.77	-0.44	-7.72	-5.98	-3.02
Estonia	-0.07	-0.09	-0.07	-0.34	-0.32	-0.2	-9.38	-7.20	-3.59
Finland	-0.18	-0.18	-0.12	-0.48	-0.43	-0.26	-4.46	-3.48	-1.78
France	-0.47	-0.42	-0.25	-1.11	-0.94	-0.53	-3.93	-3.01	-1.50
Germany	-0.07	-0.10	-0.08	-0.24	-0.27	-0.19	-1.07	-1.01	-0.62
Greece	0.02	-0.02	-0.03	-5.35	-4.15	-2.11	-5.28	-4.05	-2.03
Hungary	0.14	0.07	0.01	-0.44	-0.41	-0.25	-4.95	-3.96	-2.10
Ireland	-0.81	-0.67	-0.37	-1.26	-1.06	-0.58	-5.19	-4.16	-2.19
Italy	0.08	0.02	-0.01	-2.61	-2.12	-1.15	-2.64	-2.10	-1.11
Latvia	-0.02	-0.06	-0.05	-0.33	-0.31	-0.2	-9.03	-6.94	-3.46
Lithuania	-0.01	-0.04	-0.04	-0.39	-0.36	-0.22	-7.44	-5.78	-2.93
Luxembourg	-0.57	-0.50	-0.29	-1.93	-1.59	-0.87	-11.76	-8.94	-4.39
Malta	0.11	0.05	0.00	-6.48	-5.03	-2.54	-12.26	-9.10	-4.34
Netherlands	-1.00	-0.85	-0.47	-1.44	-1.21	-0.68	-6.27	-5.01	-2.63
Poland	0.00	-0.04	-0.04	-0.44	-0.4	-0.25	-3.60	-2.81	-1.44
Portugal	-0.13	-0.14	-0.10	-5.29	-4.16	-2.17	-5.35	-4.16	-2.13
Romania	0.03	-0.01	-0.03	-0.82	-0.7	-0.4	-5.10	-3.99	-2.05
Slovak Republic	0.09	0.03	-0.01	-0.54	-0.49	-0.3	-7.07	-5.57	-2.88
Slovenia	-0.03	-0.07	-0.06	-0.43	-0.41	-0.26	-8.76	-6.83	-3.47
Spain	-0.08	-0.11	-0.08	-3.29	-2.59	-1.35	-3.33	-2.59	-1.32
Sweden	-0.62	-0.53	-0.30	-0.91	-0.78	-0.45	-7.40	-5.76	-2.93
United Kingdom	-5.67	-4.37	-2.23	-5.53	-4.25	-2.15	-5.20	-3.94	-1.95
Albania	0.20	0.13	0.06	0.47	0.35	0.17	0.94	0.70	0.34
Algeria	0.23	0.16	0.07	0.48	0.37	0.18	0.49	0.39	0.20
Bosnia and Herzegovina	0.32	0.23	0.11	0.78	0.59	0.29	1.84	1.39	0.67
Iceland	0.17	0.15	0.09	0.3	0.25	0.14	0.77	0.59	0.29
North Macedonia	0.19	0.13	0.05	0.43	0.32	0.15	0.93	0.70	0.33
Morocco	0.18	0.12	0.05	0.38	0.3	0.16	0.33	0.27	0.15
Norway	0.23	0.20	0.11	0.43	0.34	0.17	1.22	0.92	0.44
Switzerland	0.15	0.11	0.05	0.31	0.22	0.1	0.70	0.50	0.23
Tunisia	0.24	0.17	0.07	0.59	0.45	0.22	0.66	0.52	0.26
Turkey	0.14	0.09	0.03	0.22	0.16	0.07	0.24	0.18	0.09
Ukraine	0.08	0.05	0.01	0.1	0.06	0.02	0.22	0.15	0.06

Notes: Elasticity of trade with respect to FTA is 0.285, CU is 0.675, EU is 1.044. The data for simulations is from 2017.

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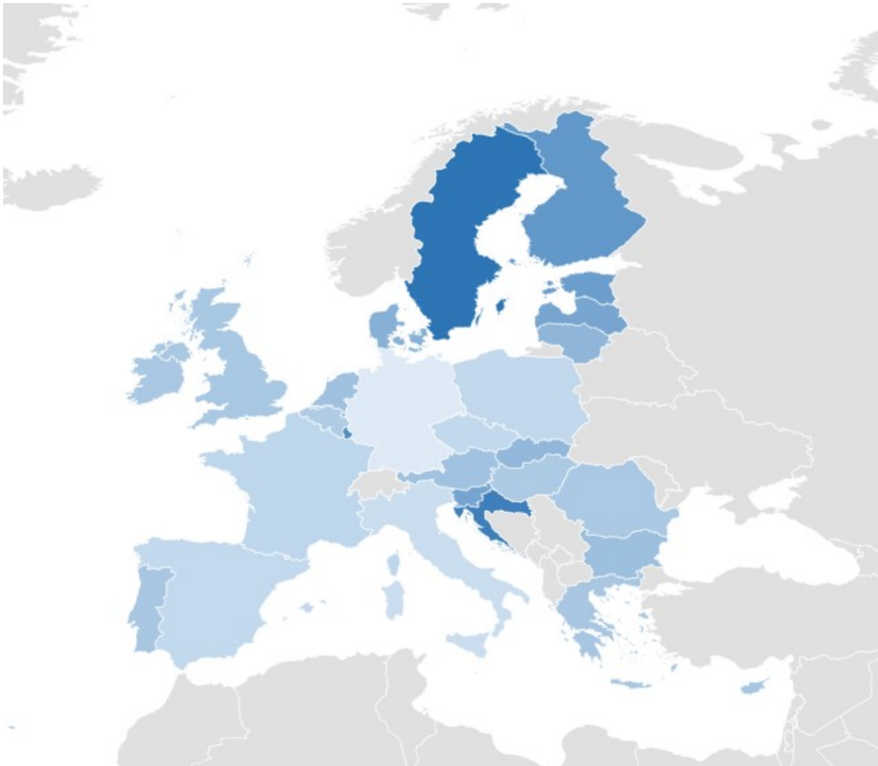

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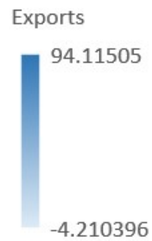

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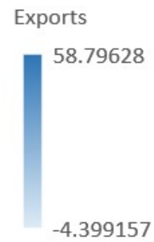

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