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EXITitis in the UK: Gravity Estimates in the Aftermath of Brexit

Abstract

The withdrawal of the United Kingdom from the European Union has had disruptive effects on international trade. As part of its 'Global Britain' strategy, in the wake of Brexit, the UK is pursuing a series of Free Trade Agreements with countries around the world, including Canada, Japan, Korea, Mexico, Norway, Switzerland, Turkey and possibly the United States. Closer to home, the UK is under mounting pressure to dissuade Scotland, Northern Ireland and Wales from seeking independence to regain the severed ties with the EU. We analyze the economic consequences of these scenarios with a state-of-the-art structural gravity model for major economies around the world. We find that 'Global Britain' yields insufficient trade creation to compensate for Brexit-induced trade losses. Our results also reveal that independence from the UK in itself would inflict greater post-Brexit economic harm on the devolved nations of Great Britain. Nevertheless, these effects could be entirely removed for each of these devolved nations conditional on a renewed trade deal with the EU.

JEL-Codes: F130, F140.

Keywords: Brexit, gravity model.

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1. Introduction

As predicted by many trade studies that were published between the Brexit referendum in June 2016 and the departure by UK from the EU in January 2020 (for an overview, see Brakman, Garretsen and Kohl, 2018), the actual withdrawal of the United Kingdom from the European Union has indeed had disruptive effects on international trade. Leaving the impact of the COVID19-crisis on international trade aside, Brexit has in particular harmed international trade for the UK itself; the UK government notes that trade with the EU fell by 21% and with the rest of the world 0.8% (see section 2 below).[2] As part of its 'Global Britain' strategy and as a reaction to its own Brexit decision, the UK government is pursuing a series of Free Trade Agreements with countries around the world, including Canada, Japan, Korea, Mexico, Norway, Switzerland, Turkey and possibly the United States. Yet, closer to home, the UK is under mounting pressure to dissuade Scotland, Northern Ireland and Wales from seeking independence to regain their severed ties with the EU.

We analyze the economic consequences of these scenarios with a state-of-the-art structural gravity model for major economies around the world. We find, and update similar earlier findings, that 'Global Britain' yields insufficient trade creation to compensate for Brexit-induced trade losses. Our results also reveal that independence from the UK in itself would inflict greater post-Brexit economic harm on the devolved nations. However, these effects would be more than compensated, conditional on a renewed trade deal with the EU. Note that Huang et al. (2021) also find that the costs of Scottish independence would be negative, but that it cannot be compensated by rejoining the EU. In this sense our results differ. It is often said that economists hardly agree on anything, but when it comes to predictions on the impact of Brexit on international trade and in particular on UK-EU trade, there was and continues to be an overwhelming consensus that Brexit has detrimental trade effects.

To date the most comprehensive study of the possible (trade) impact of Brexit on the UK economy is Dhingra et al. (2017), whereas Brakman et al. (2018) provides gravity-based estimations of the impact of Brexit on international trade more generally, but also for alternative trade agreements that may arise in the wake of Brexit. The actual numbers differ but the vast majority of studies conclude that the impact of Brexit on the UK economy, both in terms of trade and GDP, will be a very negative one and that alternative future trade agreements cannot make up for this. In the present paper we will not survey this literature (again), but focus instead on new estimations by employing a state-of-the-art gravity model and by using the most recent data to investigate in more detail the trade impact for alternative trade arrangements and focus on the trade consequences for *intra*-national trade for the UK

[2] For detailed data see: https://www.ons.gov.uk/businessindustryandtrade/internationaltrade/articles/theimpactsofeuexitandthecoronavirusonuktradeingoods/2021-05-25#main-points

economy.[3] The latter is novel in the Brexit literature and has been under-researched until now. Partly inspired by Brexit itself, the UK faces the prospect of a break-up given the discussion of devolution or even outright independence in notably Scotland but also Wales and (Northern) Ireland. The discussion about devolution in the UK does not only relate to the economics literature because of Brexit, but it also speaks to the 'optimum size of nations' literature following the seminal study by Alessina and Spolaore (2003). In addition, studying the intra-UK consequences of Brexit and of alternative internal UK 'break up' scenarios is inspired by a growing literature linking the (the regional dispersion in the) Brexit vote or preferences to regional differences in economic, political or even psychological make-up of UK regions, see for instance Los et al (2016), De Ruyter et al (2021) and Garretsen et al (2018) respectively.

The remainder of this paper is structured as follows. Section 2 first illustrates what happened to actual UK trade now that Brexit has come into effect. A key difference with previous Brexit studies (including our own 2018 study) is that Brexit has materialized and we can do a first check what happened to UK trade from 2020 onwards, allowing for the fact that to date the COVID-19 crisis complicates a pre- and post-Brexit comparison. Section 3 subsequently discusses the gravity model methodology employed as well as the five trade scenarios that we will consider. In section 4 we introduce and review the dataset. Section 5 presents our main estimation results, followed by an overall summary and conclusion in section 6.

2. Actual UK trade after Brexit in times of COVID-19

The UK's EU membership formally expired on February 1, 2020 – just weeks before the COVID-19 pandemic induced an unprecedented decline in world trade as of March 2020. Unfortunately, these two simultaneous trade shocks complicate the matter of empirically estimating the ex-post effects of Brexit on international trade. Yet, a comparison between the UK's trade developments and those of similar (advanced, industrialized) nations may be insightful to obtain a ballpark estimate how Brexit, as a country-specific trade shock, has affected UK trade above and beyond the *global* trade shock induced by the COVID-19 pandemic. Assuming that the 2020 decline in observed world trade for various advanced, industrialized nations is largely related to the pandemic, we propose that any differences in the UK trends with those of other countries is a measure of Brexit-induced trade effects.

Figure 1a plots the development of aggregate monthly imports (top panel) and exports (bottom panel) of goods for the United Kingdom, the G7 (i.e., Canada, Germany, France, Italy, Japan, United States, excluding the UK), the G20 (excluding the UK) and the EU27.[4] Given that

[3] Huang et al. (2021) provide detailed trade estimates for Scottish independence. Besides Scotland we also study independence of Wales and Northern-Ireland.

[4] While Brexit naturally affects EU27 members – as our ex-ante trade effects for a "Hard Brexit" in section 5 also show – the Withdrawal Agreement contains a transition period for February 1 to December 31, 2020, ensuring continued frictionless trade between the UK and EU while the EU-UK Trade and Cooperation Agreement were being negotiated (https://ec.europa.eu/info/relations-united-kingdom/eu-uk-withdrawal-agreement_en). As

the pandemic was already underway during the late 2019 and early 2020, we set the base month in January 2019. We can gradually see imports and export declining for all selected units of observation, with a sudden, significant decline in trade around March-April 2020 following several lockdown policies enforced in many countries around the world. Figure 1b shows the EU27s imports dropping to a low of only 68% of the base month's trade in April 2020; for the G7 and G20 this was around 72% in the same month. The UK's lowest point was around the same time at just shy of 60% of its January 2019 imports, and 63% of its exports. For the EU27 and G20 exports were down, at most, to around 68% of their baseline levels.

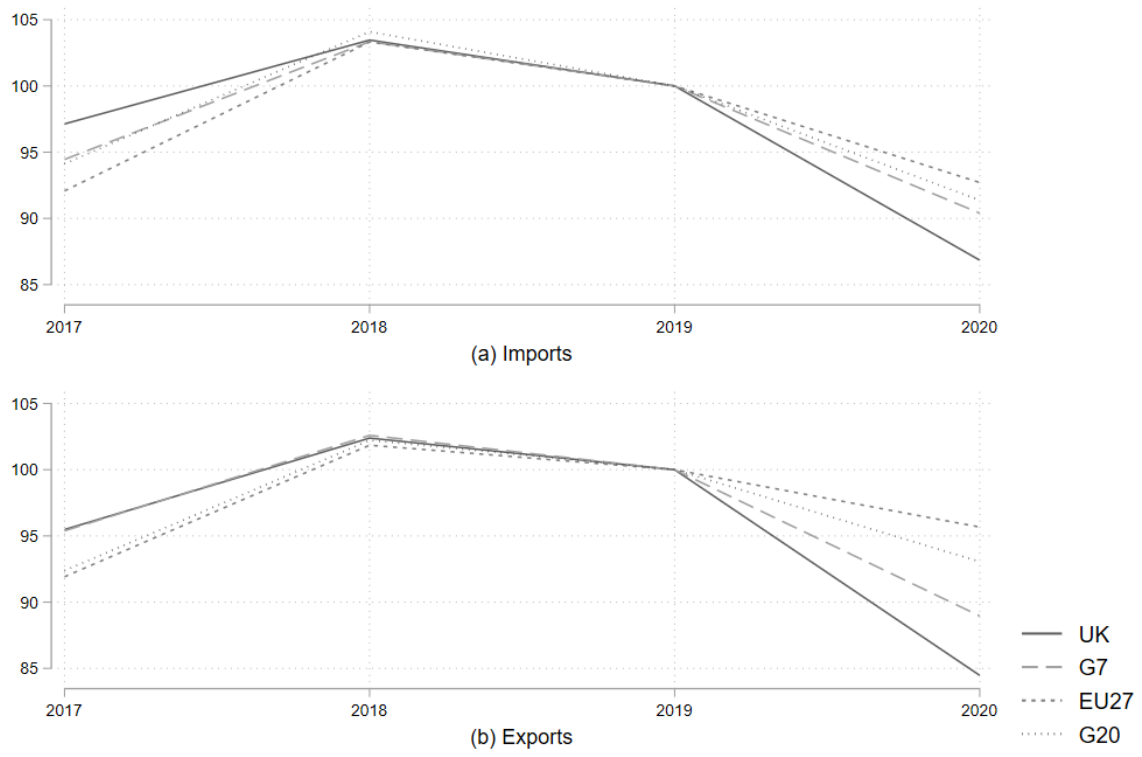

Figure 1a. Annual aggregate trade in goods (2019=100). Source: Authors' calculations based on OECD (2021).

such, we propose that it is reasonable to assume that the observed declines in EU27 trade in 2020 are largely, if not entirely, related to the pandemic, rather than the UK's withdrawal from the EU.

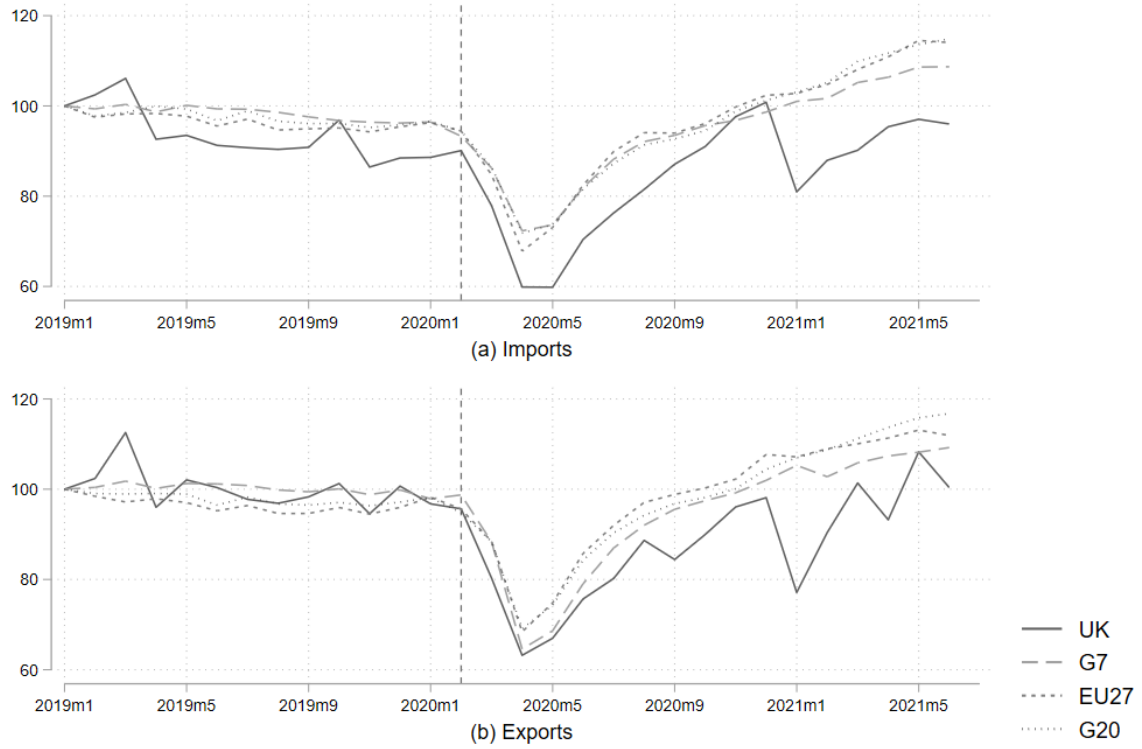

Figure 1b. Monthly aggregate trade in goods (2019m1=100). Dashed vertical line reflects the beginning of the Withdrawal Agreement. Source: Authors' calculations based on OECD (2021).

Interestingly, aside from this example of when the pandemic seemed to have had its worst effect on international trade, the longer time horizon reflects a lower trend line for the UK in general. This observation suggests that the UK's trade performance lags behind that of its peers – even before the official UK withdrawal from the EU – and gives us a simple proxy to distinguish pandemic-induced and Brexit-induced trade effects.

For every month after January 2019 until June 2021, we calculate the difference between the UK's level of imports (exports) vis a vis those of the EU27, G7 and G20 (with all values to 100 in January 2019). We interpret this difference as the Brexit-induced trade effect. We then calculate the average of these monthly differences between the UK and EU27, G7 and G20 respectively, to arrive at the values presented in Table 1.

Table 1. Average difference between UK and selected groups of countries' trade in goods (values in percentage points).

Frequency	**EU27**		**G7 excl. UK**		**G20 excl. UK**	
	Imports	Exports	Imports	Exports	Imports	Exports
Annual	-5,9	-11,2	-3,5	-4,5	-4,5	-8,6
Monthly	-8,0	-4,8	-7,8	-4,2	-8,3	-5,2

Notes: Calculations with annual data based on 2019-2020 (2019=100). Calculations with monthly data based on 2019m1-2021m6 (2019m1=100). Values are the post-2019 averages of the differences between the plotted lines for the UK and selected country groups in Figure 1.

Table 1 shows that in terms of *annual* trade, the UK saw its imports decrease in excess of the EU27's by 5.9 percentage points (pp) and exports by 11.2 pp. Compared to the G7, UK imports were lower with an additional 3.5 pp and exports by 4.5 pp, respectively. Compared to the G20, these differences were 4.5 and 8.6 percentage points. Taken together, our stylized statistics suggest that the UK experienced a sizeable negative Brexit-induced trade shock in addition to the worldwide decline in trade caused by the COVID-19 pandemic!

3. Methodology: the gravity model approach

We use a structural gravity trade framework to measure the effects of Brexit on international trade flows. The calculations are based on the procedure outlined by Anderson et al. (2016) and Yotov et al. (2016) and follows earlier applications in Brakman et al. (2016) and Kohl (2019).

The objective is to estimate the general equilibrium impact on international trade resulting from a counterfactual scenario, and compare this counterfactual outcome to the results of a baseline situation before such a counterfactual scenario is introduced. In order to do so, we first estimate the baseline,

$$X_{odt}^{BSL} = \mathbf{exp}[\beta_1 lnDST_{od} + \beta_2 CTG_{od} + \beta_3 INT_{od} + \beta_4 FTA_{odt} + \gamma_{ot} + \delta_{dt} + \zeta_{od}] \times \epsilon_{odt}, \quad (1)$$

where *X* represents aggregate trade between origin (exporter) *o* and destination (importer) *d* in year *t*; *lnDST* is the log geographic distance in kilometers between the origin and destination, *CTG* a binary variable indicating if the country-pair shares a common border, *INT* is a binary variable accounting for intra-national vs. international trade and *FTA* is 1 for country-pairs that share a Free Trade Agreement (FTA) and 0 otherwise. Origin-year and destination-year fixed effects account for time-varying multilateral resistance terms, while pair fixed effects control for unobserved time-invariant phenomena and potential concerns with respect to endogeneity bias in the parameter estimate of the FTA variable (see Baier and Bergstrand 2007).

In the second step, baseline trade costs for a country-pair-year and the related trade cost elasticities for our key variable of interest, i.e. *FTA*, is calculated assuming a constant elasticity of substitution among varieties with $\sigma > 1$,

$$(\hat{\tau}_{od}^{BSL})^{(1-\sigma)} = \mathbf{exp}[\hat{\tau}_1 lnDST_{od} + \hat{\tau}_2 CTG_{od} + \hat{\tau}_3 INT_{od} + \hat{\tau}_4 FTA_{odt}]. \quad (2)$$

The third step is to implement the change in trade policy for a given counterfactual scenario. Effectively, this involves a "switching on or off" of the binary FTA variable for the relevant country-pairs under consideration. Details on the various scenarios are introduced below.

In step four, the counterfactual trade costs stemming from each counterfactual scenario in step three are estimated as

$$(\hat{t}_{od}^{CFL})^{(1-\sigma)} = \mathbf{exp}[\hat{\tau}_1 lnDST_{od}^{CFL} + \hat{\tau}_2 CTG_{od}^{CFL} + \hat{\tau}_3 INT_{od}^{CFL} + \hat{\tau}_4 FTA_{od}^{CFL}]. \quad (3)$$

As a fifth and final step, the partial, conditional and general (full endowment) equilibrium results are calculated, as explained in detail in Yotov et al. (2016). The partial equilibrium trade volumes are a result of changes in counterfactual trade costs, while the general equilibrium results also incorporate subsequent changes in multilateral resistance terms, output and expenditure stemming from the counterfactual trade costs.

We calculate **the general equilibrium trade effects** of the following **five scenarios**:

I. **Brexit**. Here, the baseline situation reflects the pre-Brexit situation in which case the FTA variable equals 1 for all country-pairs in which the United Kingdom is importer (exporter) and other EU members are exporters (importers). Brexit – specifically, a "hard Brexit" in which there is no subsequent trade arrangement between the UK and EU, is then implemented by switching the FTA variable from 1 to 0 for all country-pairs involving the United Kingdom as importer (exporter) and other EU members as exporter (importer).

II. **Current FTAs between the United Kingdom and non-EU countries**. Before Brexit, all the United Kingdom's trade agreements with non-EU countries were arranged through agreements that applied at an EU level. This means that in a post-Brexit situation, the UK would not have a single trade deal with any country in the world other than its membership of the World Trade Organization. Signing trade deals with non-EU countries has therefore been of particular importance to the UK government to ensure a certain degree of continuity of trade relations with foreign partners. At the time of writing, the UK has reproduced several of the trade deals that formerly applied at an EU level with various countries around the world; these agreements have either already been fully ratified or are being applied provisionally.[5] We will analyze the impact of Brexit (see above) in conjunction with the new major FTAs that the UK has successfully implemented with the economies in our dataset: Canada, Japan, Korea, Mexico, Norway, Switzerland, and Turkey.

III. **An Anglo-American FTA**. Proponents of Brexit have long argued that a priority of a regained independent British trade policy would be to sign a trade deal with the United States, reflecting their most special relationship. We therefore estimate the potential trade impact of a post-Brexit Anglo-American trade deal on the UK, US and the U''s current non-EU FTA partners, while noting that the prospects of such an agreement materializing in the near future are not favorable given the July 1, 2021 expiration of

[5] For an up-to-date list of the UK's non-EU trade deals, see https://www.gov.uk/guidance/uk-trade-agreements-with-non-eu-countries.

the Trade Promotion Authority which the Biden administration has not yet sought to renew.[6]

IV. **Global Britain**. In this scenario, we consider a situation in which the UK has implemented FTAs with all countries other than EU members, arguably reflecting trade (policy) independence from the EU in its ultimate form. In a post-Brexit world, all non-EU countries trading with the United Kingdom do so under an FTA.

V. **A Kingdom Divided**. While the British government has vigorously pursued a 'Global Britain' strategy, domestic concerns arise about the unity of the United Kingdom. In our fifth and final scenario, we therefore ask how a decision by one of the devolved nations – Northern Ireland, Scotland, and Wales – to leave the United Kingdom and sign an FTA with the European Union might impact trade in the United Kingdom and beyond. We examine the cases of a Scottish (Scoxit), Northern-Irish (Nirexit) and Welsh exit (Welxit) from the United Kingdom in turn. In these respective situations, the FTA variable for all inter-regional UK pairs is switched from 1 to 0.[7] We also analyze the consequences of independence followed by an FTA between the newly independent nation and the EU. In these cases, the FTA variables for the relevant devolved nation as importer (exporter) and EU members as exporters (importers) are recoded from 0 to 1.

4. Data

Our main datasets are the United States International Trade Commission (USITC)'s Gravity Portal, with bilateral (aggregated) trade data from the ITPD-E dataset (Borchert et al. 2020) and relevant country-pair information such as bilateral distance, contiguity and FTA membership coming from the DGD (Gurevich and Herman 2018). Following the recommendation in Yotov et al. (2016), we use 4-year intervals when estimating our parameters for the years 2002, 2006, 2010 and 2014, thereby also steering clear of the 2008-09 Great Trade Collapse.[8] We focus on 43 countries together accounting for about 90% of world trade; this helps ensure convergence of the Poisson pseudo-maximum likelihood (PPML) estimator and facilitates mapping to regional input-output data, explained below. A full list of countries is provided in Appendix Table A1.

In order to conduct our analyses for England, Northern Ireland, Scotland and Wales (scenario V, described above), one would ideally use high-quality interregional trade data. While these data are not available at the required level of detail for the United Kingdom, regional input-output tables can be used to estimate interregional trade for the UK (Greig et al. 2020) or European Union (Thissen et al. 2018). We obtain measures of final consumption expenditure

[6] See, for example, https://www.politico.com/newsletters/weekly-trade/2021/06/28/say-goodbye-to-trade-promotion-authority-796173.

[7] Note that intraregional and intranational trade, i.e., "trade with self", is never subject to an FTA so that the FTA variable is always zero in cases when the importer is identical to the exporter.

[8] The baseline year in the counterfactual analyses is 2014.

by household, non-profit organizations and governments at the NUTS2 regional level for the full sample of 43 countries and aggregate these back up to the national level for all nations except the United Kingdom, for which we aggregate up to England, Northern Ireland, Scotland and Wales.[9] While these input-output based trade measures are not entirely consistent with more advanced value-added trade metrics that have been widely adopted to study global supply-chain trade at a *national* level (e.g. Costinot and Rodriguez-Claire 2014, Koopman et al. 2014), we propose that our measures can at least serve as a proxy for regional trade data when transaction-based official trade records are not available.

We expand the country-level gravity dataset to include England, Northern Ireland, Scotland and Wales (henceforth referred to as the "UK regions") as follows. First, all observations involving the United Kingdom as importer, exporter, or both importer and exporter simultaneously, are linked to one of the four UK regions. Second, we adjust the national-level trade flows by weighting these with relevant regional weights derived from the input-output metrics described above. A UK region's exports to non-UK countries are calculated as the level of UK exports to the importer, weighted by the importer's final demand for imports from that UK region as a share of the importer's final demand for imports from the UK overall. Similarly, a country's exports to a UK region are calculated as the country's exports to the UK, weighted by the UK region's share of final demand for UK imports from the exporter. For inter- and intraregional trade flows, we weight the UK intranational trade flow by the importing UK region's final demand from the exporting UK region over total UK final demand for imports from all UK regions. Third, the distance matrix is accordingly adjusted by updating the UK regions' geographic coordinates in terms of latitude and longitude and recalculating the great-circle distances for all importer-exporter pairs (Picard 2010).[10] Fourth, the contiguity variable is updated to reflect that the UK regions do not share a common border with any other region or country, with the exception of the borders between Northern Ireland and Ireland, England and Scotland, and England and Wales, respectively. Finally, the FTAs of the UK are assumed to uniformly apply to England and the three devolved nations in the baseline situation.

[9] This so-called PBL EUREGIO database (2000-2010) is available at https://data.overheid.nl/dataset/pbl-euregio-database-2000-2010. Values for 2010 are assumed to be constant for 2014.

[10] Latitudes and longitudes were obtained from OpenStreeMap.org. Intraregional distances remain unaffected and consistent with those provided by Gurevich and Herman (2018); for the four UK regions, the new intraregional distance value is the UK intraregional distance weighted by the devolved nation's share of the UK's geographic area (Office for National Statistics 2016).

5. Results

5.1. Brexit, alternative FTAs and international trade

We first consider how Brexit will affect international trade in general equilibrium. In line with our earlier results (Brakman et al. 2018) and consistent with the broader literature (see Dhingra et al, 2017), Figure 2 shows that the UK's withdrawal from the EU brings about a significant decline in international trade for the UK (around -29%), as well as substantial decreases in trade across the EU members. For a complete set of results for all countries and scenarios, see Appendix Table A1. While the average EU member sees its trade fall by 1.85%, Ireland, Cyprus and Malta face the strongest decline of around 4%. These results are generally in line with our prior expectations; interestingly, Brakman et al. (2018) find that when supply-chain trade is taken into account, Ireland, Belgium, The Netherlands, Germany and France will be most severely affected by Brexit. The difference in these results stems from the fact that the present paper relies on gross exports as a measure of international trade, rather than trade in value-added.

Once the UK has withdrawn from the EU, Figure 2 also shows how the signing of new FTAs by the UK government will affect international trade for the UK and its former EU members. For the latter set of countries, UK FTAs with third countries will have very limited trade diverting effects; Brexit induces the most significant decline in EU trade. Turning to the UK, more dramatic effects of additional FTAs are found. With a general equilibrium decline of international trade of around 23%, the UK manages to soften the blow of leaving the European Union by about 6 percentage points. In addition, establishing an FTA with the United States would be of significant economic importance to the UK, further limiting the Brexit-induced trade loss to about 12%. Yet, "the world is not enough" for the United Kingdom to fully undo the trade loss inflicted by its withdrawal from the EU: even if the UK were to succeed in implementing trade deals with all countries in our dataset except EU members, the decline in trade still amount to an impressive 5.2%. Together, these findings reflect the paradoxical outcome that the United Kingdom relies entirely on the members of the European Union on implementing a trade deal that can offset the self-inflicted economic wounds of Brexit (also see Brakman et al. 2018).

How will non-EU countries be affected by Brexit and the introduction of new FTAs with the UK? Figure 3 shows the general equilibrium changes in trade for all countries in our dataset, with the exception of the UK and EU members. Four results stand out. First, Brexit itself induces relatively small amounts of trade creation of about 0.25% on average, with countries geographically close to the UK (i.e. Norway, Switzerland and Turkey) gaining the most. Second, we confirm positive effects of the current non-EU FTAs that the UK has signed with Canada (1.5%), Japan (2.1%, and Turkey (3.6%), while the gains from the deals with Korea, Mexico, Norway and Switzerland are much less pronounced, if not negligible. Third, our results suggest

that an Anglo-American FTA would indeed be beneficial from a trade perspective, not only for the United Kingdom as already discussed above, but also for the United States with an increase in trade of 3.6%. Finally, while a Global Britain strategy would not help the United Kingdom to entirely compensate for the loss in Brexit-induced trade, potential UK partners which could stand to gain from an FTA with the UK include India (3%), followed by Australia, Brazil and Russia (all about 2% each). The economic gains from an FTA with China and other countries are more limited.

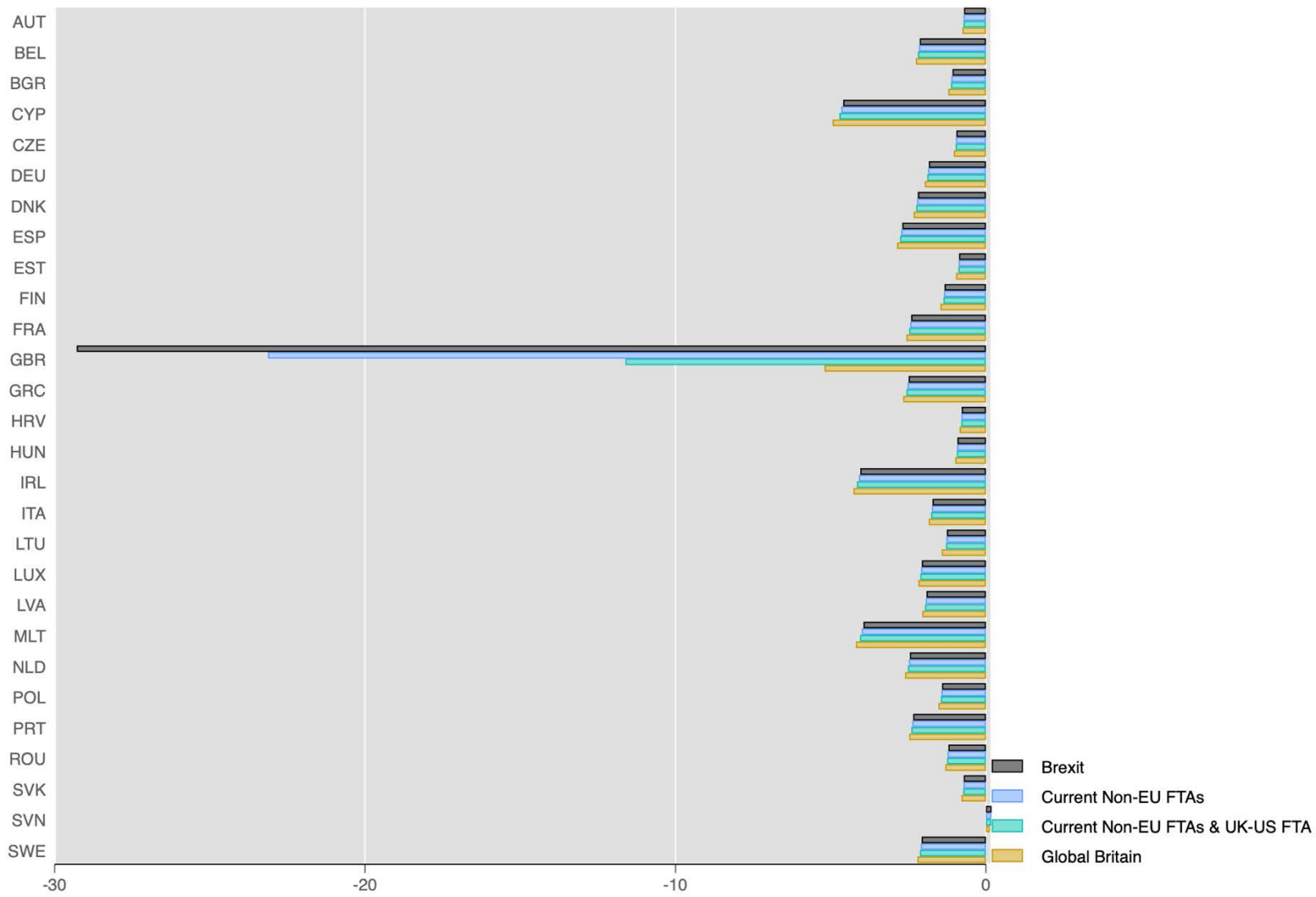

Figure 2. General equilibrium trade effects of Brexit, current non-EU FTAs, a UK-US FTA, and "Global Britain" FTAs for EU27 and UK (in %).

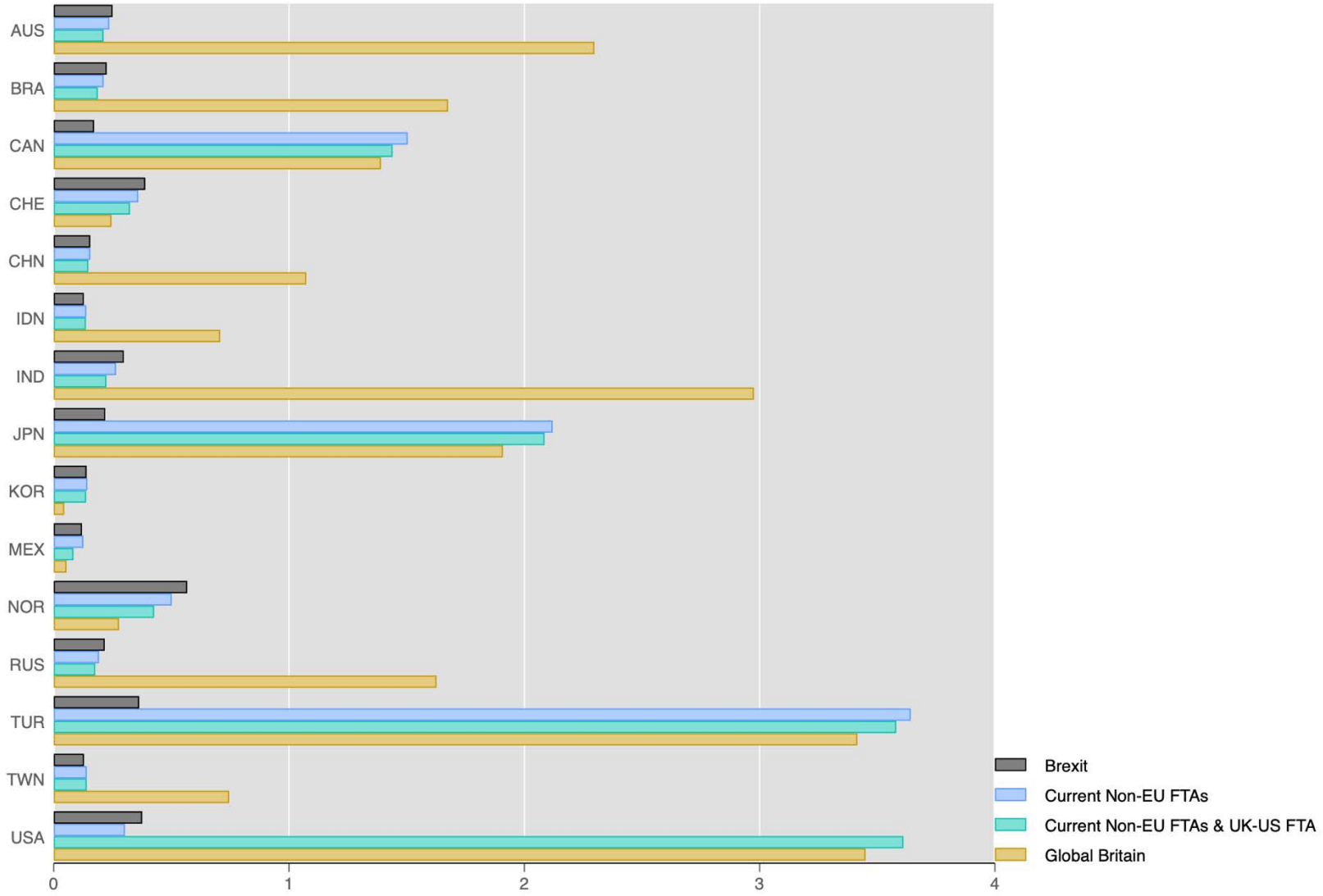

Figure 3. General equilibrium trade effects of Brexit, current non-EU FTAs, a UK-US FTA, and "Global Britain" FTAs for UK partners (in %).

5.2. Brexit, a break-up of the UK and international trade

We now turn to the question of how Scottish, Northern-Irish or Welsh independence from the United Kingdom – possibly combined with an EU FTA – will affect international trade. Figure 4 presents our findings for England, the three devolved nations, and Ireland, given its geographic location in the British Isles. A complete set of results for all regional scenarios is presented in Appendix Table A2. We first note that our results suggest that the brunt of Brexit's negative trade impact is borne by England with a decline of about 19%, followed by Scotland (-10.8%), Wales (-10.2%) and Northern Ireland (-6.6%). We then consider how independence of each of the three devolved nations changes these results in turn.

Our results suggest that independence in itself is not an appealing business from a trade perspective, as disrupting a devolved nation's FTA with the remainder of its former UK counterparts puts it in further isolation in terms of trade policy. Overall, independence in itself puts England, Northern Ireland, Scotland and Wales in an even worse perspective in terms of trade compared to the predicament achieved by Brexit. A Scoxit would have the most severe trade effect on England (-23.5%) followed by a relatively similar effect by either a Nirexit or Welxit (both around -22%). Qualitatively our results for Scotland are consistent with those of Huang et al.(2021) who also find that Scotland stands out in trade terms. Given interregional dependences, notably a Scottish exit from the UK would also negatively affect Northern Ireland and vice-versa; for Wales the negative regional spillovers seem less of a concern.

While our results do not suggest promising trade outcomes from independence itself, the prospects change once we independence conditional on regained economic integration with the European Union. Figure 4 compares our previously discussed results for independence to those when independence is regained together with an FTA with the EU. In all cases, we find that independence together with an FTA with the EU would undo the trade damage imposed by Brexit, but the potential to generate additional trade creation beyond the "break-even point" is limited to 0.5-1 percentage point. Our results also suggest that England would in all cases suffer an additional loss in trade of about 2 percentage points, while Ireland would see its trade increase to a similar extent.

The necessary caution is advised when interpreting our results. Even if a devolved nation succeeds in gaining independence and signing a trade deal with the EU – the geopolitical feasibility of such an outcome is not set in stone – the extent to which an FTA would result in gains from trade depends on the depth of the agreement and the extent to which acceding nations seek to re-integrate their markets for goods, services, labor and capital with the European Single Market. The gains from full-fledged re-accession to the EU would likely exceed the current estimates of an "average" FTA, which therefore serves as a lower-bound estimate.

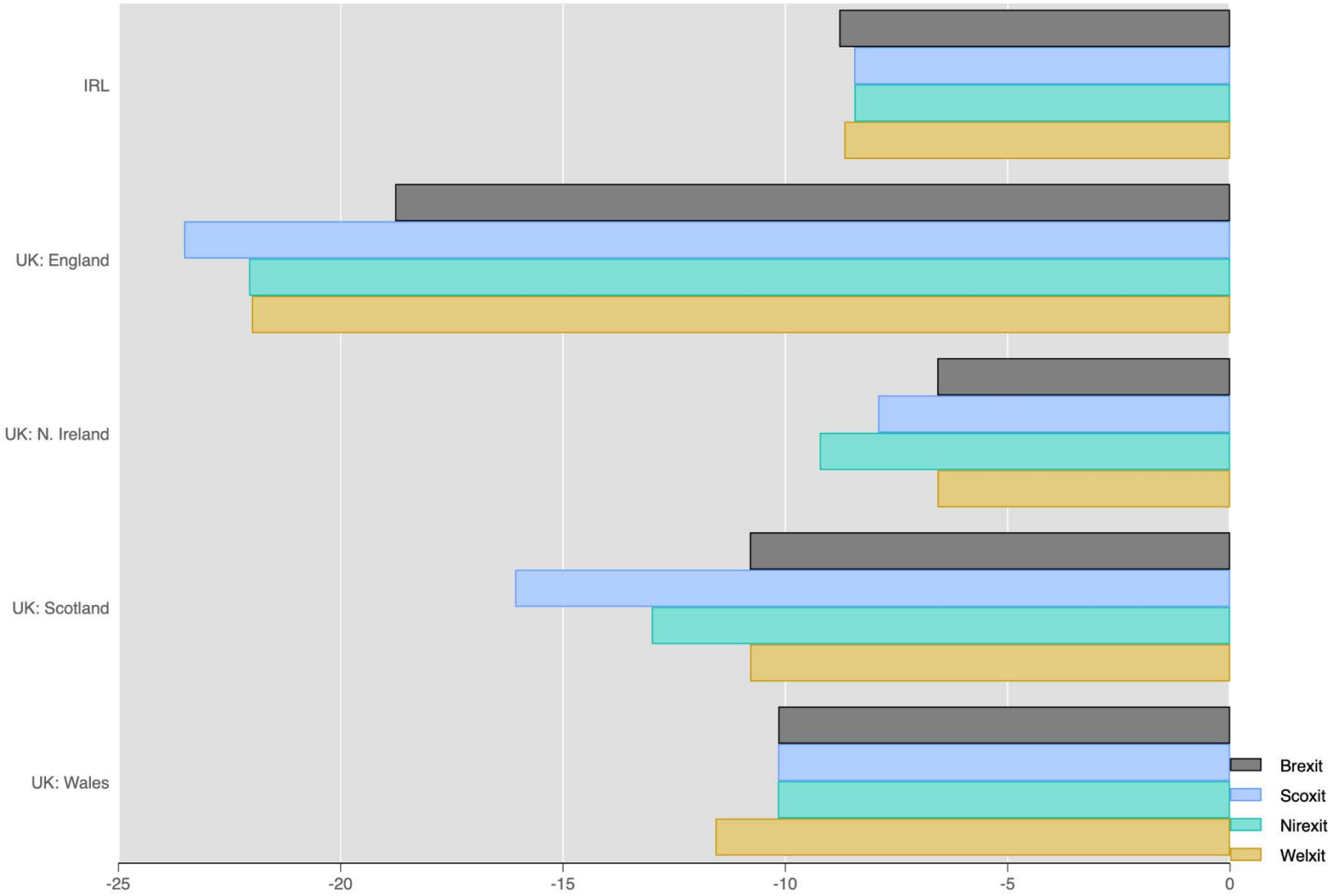

Figure 4. General equilibrium trade effects of Brexit and devolved nations' independence from the United Kingdom (in %).

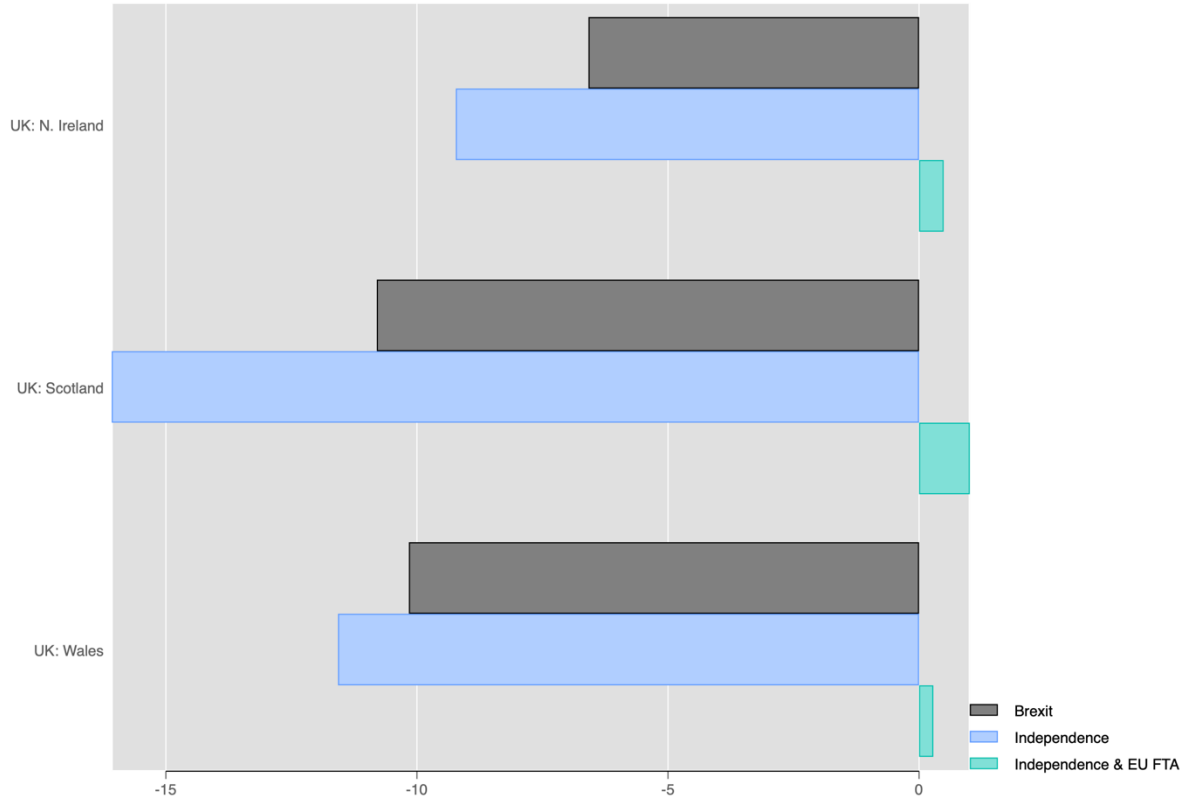

Figure 5. General equilibrium trade effects of Brexit, UK exits, and regained EU FTAs (in %).

5.3. Mapping the distance equivalents of the trade impact: the UK becomes Greenland

To visualize the importance of trade barriers and the role these barriers play in changing the global trade landscape, we now consider a complementary approach to modelling the impact of Brexit and independence of the devolved nations. In the following simulations, we consider how counterfactual changes in *bilateral distance* impacts trade, rather than changes in FTAs induced by various EXIT scenarios. This is done by taking equation (1) and replacing the time-varying multilateral resistance terms with an origin-specific and destination-specific fixed effect; the dyadic fixed effect is dropped. These modifications are motivated by the fact that we are now no longer interested in changes in the time-variant independent variable of interest (i.e., FTA), but only in a counterfactual change in the time-invariant DIST variable.

In the scenarios that follow, we change the bilateral distance by a multiple of 1 or more and calculate the associated change in that country or region's trade. To be precise, in the case of Brexit, only the distance between the UK and its EU counterparts is changed; all other distances remain fixed. It is as if one would geographically move the UK farther away from the EU for all UK-EU trade, but not for all other trading relationships. Figure 6, panel (a) shows how the general-equilibrium trade effects of Brexit (-29.3 percent, see Appendix Table A1) are approximated by a 3-fold increase of the geographic (great-circle) distance between the UK and EU; the equivalence of shifting, for example, the UK all the way to Greenland, or keeping the position of the UK fixed and shifting the Netherlands to the position of Spain, Belgium to Portugal, Germany to Greece, Italy to Russia and Romania to Canada.

Next, we calculate by how much geographic distance between Scotland and the remainder of the UK and EU member states would have to increase to approximate our FTA-based trade effects of Scoxit (-16.1 percent, see Appendix Table A2). Figure 6, panel (b) shows that this would require increasing the relative distance by a magnitude of 14.7, putting Scotland somewhere between India and China relative to the UK and EU. Panel (c) shows that a Nirexit would require shifting Northern Ireland close to Romania and Malta to approximate the 9.2 percent loss in trade, reflecting an increase in the relative distance by a magnitude of 4.8. Finally, the trade effects of a Welxit (-11.6 per cent per Appendix Table 2) could also be obtained by shifting Wales to somewhere between Hungary and Lithuania, indicative of the required increase in distance by a factor 8.6.

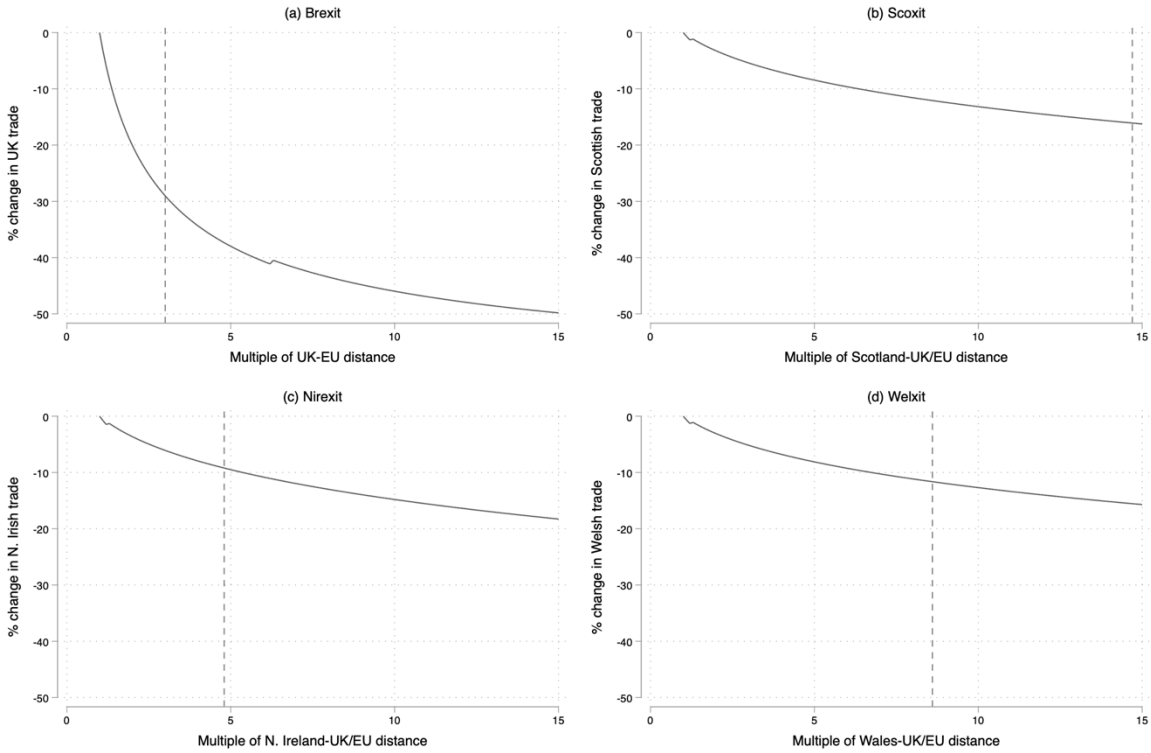

Figure 6. General equilibrium trade effect equivalents in terms of geographic distance.

6. Summary & Conclusion

As a follow-up and extension to Brakman, Garretsen and Kohl (2018), we have estimated the trade effects of Brexit and various free-trade arrangements (FTAs) for not only the UK but also for its main trading partners in- and outside the EU. In addition, we have used our gravity model approach to estimate the trade impact of a break-up of the UK where we allow for the possibility the newly 'independent' nations that exit the UK sign up to an FTA with the EU. To visualize our results, we also presented the (bilateral) distance equivalent effects of the FTA changes in the trade scenarios that we consider in our paper. Our analysis takes place against the background that Brexit has actually materialized and that at least for now international trade for the UK seems markedly lower than it would have been without Brexit. Our findings confirm the main conclusions from related studies to the effect that the UK cannot make up for the trade and hence welfare loss caused by Brexit by signing alternative FTAs.[11] Also, grand schemes like 'Global Britain' will not succeed in doing so. In addition, independence from the UK by Scotland or Wales would further increase economic damage for these devolved nations, but a renewed FTA with the EU by the newly 'independent nations' could compensate for their break-up with the UK. To put our findings in (visual) perspective we derived the distance equivalent effects of both Brexit and the break-up of the UK: in distance terms our gravity estimations imply for instance (or most notably) that the UK would become Greenland so as to get perspective on the size of the negative impact of Brexit in trade terms.

There are a number of ways as to how our analysis could be extended. First of all, one could use more refined trade data. We stick to gross trade data in the present paper so as to be able to do the intra-UK analysis. The use of for instance value-added trade data, like in Brakman et al (2018), would allow research to be more specific on the trade impact and to take the relevance of value chains into account. Secondly, a more in-depth analysis of trade barriers would be useful. Certainly, in the case of Brexit, the real trade impact for firms and hence customers comes from non-tariff, regulatory trade barriers. Finally, a sectoral breakdown of the analysis would enable more precise predictions where the impact of Brexit or alternative FTAs will be felt most in a positive or negative way. Despite these avenues for future research and consequently limitations of the present paper, and also taking into account that Brexit has come into effect since early 2020, it remains a fair conclusion to state that Brexit did and will not make much economic sense for the UK from the perspective of international trade. On the contrary, alternative FTAs clearly cannot make up for the trade and welfare losses for the UK as a whole caused by Brexit. A 'devolved nation' scenario might ultimately enable parts of the UK to undo the negative Brexit impact by signing up a new FTA with the EU, but only at the cost of leaving the UK.

[11] Detailed welfare calculations are available upon request.

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Appendix

Table A1. General equilibrium effects on trade for national analyses (in %).

COUNTRY	BREXIT	CURRENT FTAS	CURRENT FTAS & UK-US FTA	GLOBAL BRITAIN
AUS	0.2	0.2	0.2	2.3
AUT	-0.7	-0.7	-0.7	-0.8
BEL	-2.1	-2.2	-2.2	-2.3
BGR	-1.1	-1.1	-1.1	-1.2
BRA	0.2	0.2	0.2	1.7
CAN	0.2	1.5	1.4	1.4
CHE	0.4	0.4	0.3	0.2
CHN	0.2	0.2	0.1	1.1
CYP	-4.6	-4.7	-4.7	-4.9
CZE	-1.0	-1.0	-1.0	-1.0
DEU	-1.8	-1.9	-1.9	-2.0
DNK	-2.2	-2.2	-2.2	-2.3
ESP	-2.7	-2.7	-2.8	-2.9
EST	-0.9	-0.9	-0.9	-1.0
FIN	-1.3	-1.3	-1.4	-1.5
FRA	-2.4	-2.4	-2.5	-2.6
GBR	-29.3	-23.1	-11.6	-5.2
GRC	-2.5	-2.5	-2.6	-2.7
HRV	-0.8	-0.8	-0.8	-0.8
HUN	-0.9	-0.9	-0.9	-1.0
IDN	0.1	0.1	0.1	0.7
IND	0.3	0.3	0.2	3.0
IRL	-4.0	-4.1	-4.2	-4.3
ITA	-1.7	-1.7	-1.8	-1.8
JPN	0.2	2.1	2.1	1.9
KOR	0.1	0.1	0.1	0.0
LTU	-1.3	-1.3	-1.3	-1.4
LUX	-2.1	-2.1	-2.1	-2.2
LVA	-1.9	-1.9	-2.0	-2.0
MEX	0.1	0.1	0.1	0.1
MLT	-3.9	-4.0	-4.1	-4.2
NLD	-2.5	-2.5	-2.5	-2.6
NOR	0.6	0.5	0.4	0.3
POL	-1.4	-1.4	-1.5	-1.5
PRT	-2.3	-2.4	-2.4	-2.5
ROU	-1.2	-1.2	-1.3	-1.3
RUS	0.2	0.2	0.2	1.6
SVK	-0.7	-0.7	-0.7	-0.8
SVN	0.2	0.2	0.2	0.1
SWE	-2.1	-2.1	-2.1	-2.2
TUR	0.4	3.6	3.6	3.4
TWN	0.1	0.1	0.1	0.7
USA	0.4	0.3	3.6	3.4

Table A2. General equilibrium effects on trade for regional analyses (in %).

COUNTRY	BREXIT	SCOXIT ONLY	NIREXIT ONLY	WELXIT ONLY	SCOXIT & EU FTA	NIREXIT & EU FTA	WELXIT & EU FTA
AUS	2.0	2.2	2.2	2.1	1.5	1.4	1.3
AUT	-2.4	-2.3	-2.3	-2.3	-1.8	-1.9	-1.8
BEL	-5.8	-5.6	-5.6	-5.7	-4.3	-4.5	-4.4
BGR	-3.4	-3.3	-3.3	-3.4	-2.6	-2.7	-2.6
BRA	1.7	1.9	1.9	1.8	1.3	1.2	1.1
CAN	1.3	1.4	1.4	1.3	1.0	0.9	0.8
CHE	2.9	3.2	3.2	3.0	2.3	2.1	1.9
CHN	1.0	1.1	1.1	1.0	0.8	0.7	0.6
CYP	-10.0	-9.6	-9.6	-9.9	-7.3	-7.6	-7.4
CZE	-3.0	-2.9	-2.9	-3.0	-2.3	-2.3	-2.3
DEU	-5.4	-5.2	-5.2	-5.3	-4.0	-4.2	-4.1
DNK	-6.3	-6.0	-6.0	-6.2	-4.7	-4.8	-4.7
ESP	-7.3	-7.0	-7.0	-7.2	-5.4	-5.7	-5.5
EST	-2.9	-2.8	-2.8	-2.8	-2.1	-2.2	-2.2
FIN	-4.1	-4.0	-4.0	-4.1	-3.1	-3.2	-3.1
FRA	-6.7	-6.4	-6.4	-6.6	-5.0	-5.2	-5.1
GRC	-6.6	-6.4	-6.4	-6.5	-4.9	-5.1	-5.0
HRV	-2.5	-2.4	-2.4	-2.5	-1.9	-2.0	-1.9
HUN	-2.9	-2.8	-2.8	-2.9	-2.2	-2.3	-2.2
IDN	0.7	0.8	0.8	0.7	0.6	0.5	0.5
IND	2.5	2.8	2.8	2.6	1.9	1.7	1.6
IRL	-8.8	-8.5	-8.4	-8.7	-6.4	-6.7	-6.5
ITA	-5.1	-5.0	-4.9	-5.1	-3.8	-4.0	-3.9
JPN	1.8	2.0	2.0	1.9	1.4	1.3	1.2
KOR	0.9	1.0	1.0	0.9	0.7	0.6	0.6
LTU	-3.8	-3.7	-3.7	-3.8	-2.9	-3.0	-2.9
LUX	-5.9	-5.6	-5.6	-5.8	-4.3	-4.5	-4.4
LVA	-5.3	-5.1	-5.1	-5.2	-3.9	-4.1	-4.0
MEX	0.5	0.5	0.5	0.5	0.4	0.3	0.3
MLT	-10.3	-9.9	-9.9	-10.2	-7.6	-7.9	-7.7
NLD	-6.6	-6.4	-6.4	-6.5	-4.9	-5.1	-5.0
NOR	3.6	3.9	3.9	3.7	2.8	2.5	2.3
POL	-4.2	-4.1	-4.1	-4.2	-3.2	-3.3	-3.2
PRT	-6.4	-6.2	-6.2	-6.4	-4.8	-5.0	-4.9
ROU	-3.8	-3.6	-3.6	-3.7	-2.8	-2.9	-2.9
RUS	1.5	1.7	1.7	1.6	1.2	1.1	1.0
SVK	-2.3	-2.2	-2.2	-2.3	-1.7	-1.8	-1.8
SVN	1.3	1.4	1.4	1.3	1.0	0.9	0.9
SWE	-6.3	-6.0	-6.0	-6.2	-4.7	-4.9	-4.7
TUR	2.9	3.2	3.2	3.0	2.3	2.0	1.9
TWN	0.7	0.8	0.8	0.7	0.5	0.5	0.5
UK: England	-18.8	-23.5	-22.1	-22.0	-20.5	-20.4	-20.4
UK: Scotland	-10.8	-16.1	-13.0	-10.8	1.0	-11.8	-10.9
UK: N. Ireland	-6.6	-7.9	-9.2	-6.6	-7.1	0.5	-6.6
UK: Wales	-10.2	-10.2	-10.2	-11.6	-10.2	-10.2	0.3
USA	1.8	2.0	2.0	1.9	1.3	1.3	1.3