HM Government

EU Exit: Long-Term Economic Analysis

Technical Reference Paper

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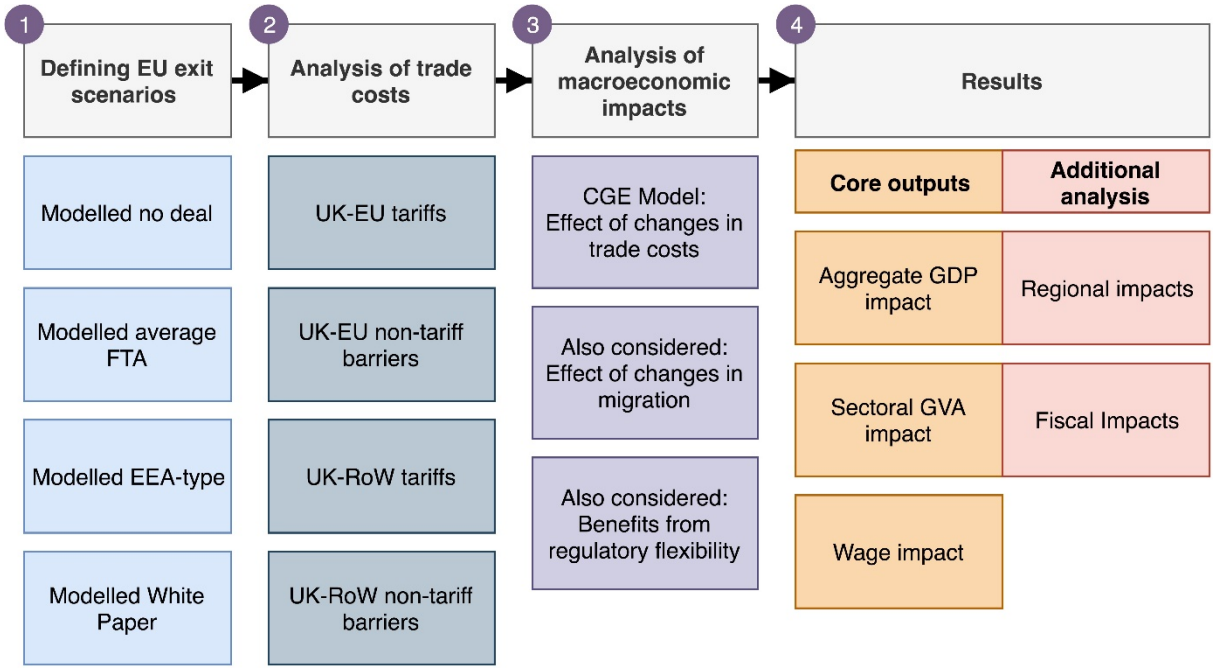
Contents

1. This technical reference paper sets out the methodology for estimating the long-term economic and fiscal impact of the UK's exit from the European Union used in the EU Exit: Long-term Economic Analysis (hereafter referred to as the 'analysis document').
2. This document is not intended as a standalone document. It is intended to accompany the analysis document, providing additional detail and aimed at a more technical audience.
3. Section 1 provides an overview of the Government's methodology. Sections 2 and 3 focus on the key inputs for the trade modelling, while section 4 describes the Computable General Equilibrium (CGE) trade model. Section 5 describes how the impact of different levels of migration are modelled. Section 6 provides the overall macroeconomic results of the analysis. Finally, sections 7 and 8 cover the regional and fiscal impacts derived from these aggregate results.

1. Overview of the analytical framework

4. EU exit will primarily impact the UK economy through changes in two main economic areas: trade (in goods and services) and migration. This analysis first estimates the economic impact of changes to trade costs, both with the EU and with the rest of the world (RoW). It then assesses the economic impact of potential changes to migration of EEA nationals and benefits that may arise from greater regulatory flexibility.
5. The analysis is in four stages. Figure 1.A provides an overview.

Figure 1.A: Overview of analytical framework



1.1 EU exit scenarios

6. The first stage in developing an economic assessment is defining a set of EU exit policy scenarios. As described in section 2.2 of the analysis document, the analysis considers four scenarios:
    a. “Modelled White Paper”
    b. “Modelled average FTA”
    c. “Modelled EEA-type”
    d. “Modelled no deal”
7. All scenarios are considered in comparison to today’s arrangements. An overview of the analytical assumptions in each scenario is set out in section 2.3.6 of the analysis document, with more detail on UK-EU trade costs, UK-RoW trade costs and migration assumptions in each scenario explained in sections 2, 3 and 5 of this technical reference paper.
8. As described in section 2.3.2 of the analysis document, in addition to results for the scenarios, an additional sensitivity point is modelled. Specifically, this represents the midpoint of the difference in NTBs between the modelled White Paper and the modelled average FTA scenarios. This NTB midpoint is illustrative only and does not represent an expected outcome.

1.2 Trade costs

9. In the second stage, potential long-term changes to EU and RoW trade costs are estimated for each EU exit scenario. Factors that restrict trade can take two main forms:
    a. **Tariffs** are import taxes, usually on an ad valorem or percentage basis. Tariffs are only levied on goods.[1]
    b. **Non-Tariff Barriers (NTBs)** can affect both goods and services. They are either “at the border”, such as customs delays, or “behind the border”, such as the costs from complying with overseas regulations in export destinations. Sections 2 and 3 define these more fully and explain in detail how these restrictions are estimated in EU exit scenarios.[2]
10. Details on the methodology and assumptions of changes to UK-EU trade costs are presented in section 2, while details on the methodology and assumptions of changes to UK-RoW trade costs are presented in section 3.

1 ‘Trade Topics - Tariffs’, World Trade Organisation, 2018.
2 Staiger, R., ‘Non tariff measures and the WTO’, WTO Economic Research and Statistics Division, January 2012.

1.3 Long-term economic impact of changes in trade costs, migration and regulatory flexibility

11. The third stage of the analysis estimates the long-term impact on the UK economy of these potential changes in trade costs, as detailed in section 4 of the analysis document. It then estimates the impact of migration and regulatory flexibility.

1.3.1 Trade costs

12. To estimate the impact of changes in trade costs on the UK economy, the analysis uses a CGE model. This is a standard method used to assess the impact of trade agreements. Working with experts in CGE modelling, the Government's model extends the standard GTAP model[3] to develop a CGE model referred to below as GETRADE. Model-based approaches permit more granular assessments of scenarios, including unprecedented arrangements, than purely econometric approaches.

13. In the long run, theory and evidence suggest that international trade increases output and raises living standards through four key channels:

    a. Domestic specialisation allows each country to put more resources into what it does best, leading to higher productivity and real wages.[4]

    b. Greater variety of inputs and products for businesses and consumers, with increased competition and lower prices leads to:

        i. More efficient production for businesses;
        ii. Increased consumer choice.[5]

    c. Access to new markets allows firms to scale their production up, leading to efficiency gains where there are increasing returns to scale.[6]

    d. Exposure to competition leads demand to shift away from the least competitive firms while the most competitive (and productive) firms gain opportunities to expand into new markets.[7]

14. Section 4 explains in detail how these channels are incorporated in the GETRADE CGE model.

15. In addition, increases in productivity may have an impact on the returns to capital, the level of investment and the overall size of the capital stock. Changes in the size of

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3 The GTAP model is one of the most widely used CGE models internationally for trade analysis. Corong, Hertel, McDougall, Tsigas, van der Mensbrugghe, 'The Standard GTAP Model, version 7' Journal of Global Economic Analysis 2(1), 2017.

4 Ricardo, D., 'On the Principles of Political Economy on Taxation', Kitchener, 1817 (re-printed in 2001)

5 Armington, P.S., 'A Theory of Demand for Products Distinguished by Place of Production', Staff Papers (International Monetary Fund), Volume 16, Number 1, p. 159-178, 1969.

6 Krugman, P., 'Increasing Returns, Monopolistic Competition, and International Trade', Journal of International Economics, p.469-479, 1979; Krugman, P., 'Scale Economies, Product Differentiation, and the Pattern of Trade', The American Economic Review, Vol.70, No.5, p.950-959, 1980.

7 Melitz, M., 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', Econometrica, Vol.71, No.6, p.1695-1725, 2003.

the capital stock can in turn have further impacts on productivity.[8] GETRADE includes an extension which can model such a capital accumulation channel. This extension is employed as a sensitivity to the core analysis.

16. As in other CGE models, the analysis using GETRADE holds labour supply fixed and assumes full employment. GETRADE does not make any assumptions about future levels of migration, and so with a fixed population, changes to GDP and per capita GDP are equivalent. The impact of changes in migration on the UK economy are therefore modelled separately and described below in section 5.

17. Model-based approaches like CGE also allow more granular assessments of scenarios, including of unprecedented arrangements. They provide a more detailed picture of the UK economy at a sectoral level while explicitly accounting for the interactions between sectors. Section 4 explains the approach to CGE modelling and the GETRADE model in more detail.

1.3.2 Migration

18. The migration analysis uses a separate model with greater detail about the labour market and demographic characteristics of EEA migrants, described in detail in section 5.

19. Specific migration policies have not been modelled. To estimate the impact of migration under the modelled White Paper, modelled average FTA and modelled no deal scenarios, the analysis considers an illustrative range of EEA net worker migration levels and their impacts on UK GDP.[9] Migration modelling and these illustrative ranges are both described in more detail in section 5.

20. Section 5 explains the approach to migration modelling in more detail.

1.3.3 Regulatory flexibility

21. The analysis uses an illustrative assumption based on external evidence to account for the potential impacts of greater regulatory flexibility when the UK is no longer subject to EU law. It is assumed that regulatory flexibility will add 0.1 per cent to GDP in the long run in all modelled scenarios apart from the modelled EEA-type scenario. This is set out in section 2.3.5 of the analysis document, alongside a summary of the external evidence.

1.4 Results and additional analysis

22. In the fourth stage, the total impact of EU exit on long-term UK GDP is obtained by combining the impacts of estimated changes to trade costs and changes in migration. The additional illustrative estimate of potential gains from new regulatory flexibility is also included. Core outputs from the model include changes to GDP and per capita GDP, real wages and sectoral output (measured as GVA) in each scenario.

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8 This channel was first described by Ricardo, D., 'Essay on the Influence of a Low price of Corn on the Profits of Stocks', 1812; See Baldwin, R. for a more recent and formal definition, and a first attempt at quantification, 'Measurable Dynamic Gains from Trade', Journal of Political Economy, Vol.100, Issue 1, p.162-74, 1992.

9 It is assumed that there is no change to migration arrangements in the modelled EEA-type scenario.

23. In addition, the GETRADE model estimates of long-term changes to output are used as the basis for estimating the regional and fiscal impacts of EU exit scenarios. These are explained in sections 7 and 8 respectively. Regional GVA impacts are generated by using the sectoral trade and output impacts, together with the sectoral structure of UK regions, e.g. the share of economic activity in each region which can be attributed to each sector. The analysis also takes into account regional levels of openness and GVA.

24. The long-term fiscal impact of each scenario is evaluated by considering both the indirect fiscal consequences of the exit-related change to the UK economy, and the direct fiscal impact of a new financial relationship with the EU. These effects are combined to calculate their total impact on Public Sector Net Borrowing (PSNB).

1.5 Sectors

25. Table 1.A shows how the sectors provided in the source data (GTAP 9) are grouped together for the purposes of the Government's analysis, and provides a mapping to 2-digit Standard Industrial Classification codes.

Table 1.A: Mapping of the five sector groups into the eleven modelled sectors, GTAP 9 codes and Standard Industrial Classification codes.[10]

5 Sector Groups	11 Sectors	GTAP 9 Codes	2 digit Standard Industrial Classification Codes
Manufactured Goods	Chemicals, pharmaceuticals, rubber and plastics	crp	20-22
	Machinery, electronics and aerospace	ome, otn, ele	26-28, 30, 33
	Motor vehicles and parts	mvh	29
	Other manufacturing	tex, lea, lum, nmm, i_s, nfm, fmp, wap, ppp, omf	13-18, 23-25, 31-32, 58
Agri-food	Agri-food	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh, cmt, omt, vol, mil, pcr, sgr, ofd, b_t	1-3, 10-12
Services	Business services	obs	62-63, 69-74, 77-78, 80-82
	Construction	cns	41-43
	Public administration, defence, education and health	osg	37-39, 75, 84-88, 94
	Other services	trd, ros, cmn	45-47, 53, 55-56, 59-61, 90-93, 95-97

[10] Where possible these sector definitions are used consistently across the technical reference paper for analytical results and statistics. Therefore statistics used within this paper may not always align with other statistical releases that may use different sector definitions.

5 Sector Groups	11 Sectors	GTAP 9 Codes	2 digit Standard Industrial Classification Codes
Financial services	Financial services	ofi, isr	64-66
Networks	Networks	coa, p_c, gas, ely, gdt, oil, omn, wtr, otp, wtp, atp	5-9, 19, 35-36, 49-52, 79
	Dwelling - Not Included[11]	*dwe*	68

[11] Dwellings is not a sector or sector group as defined in this publication. It is not a traded sector and as such is not included in any analysis of non-tariff barriers. It is included in the table for completeness.

2. Key input assumptions: UK-EU tariffs and non-tariff barriers (NTBs)

26. This section outlines the approach to estimating key model inputs for each EU exit scenario. Section 2.1 sets out the assumptions made on UK-EU tariffs and sections 2.2 to 2.6 set out the approach to estimating UK-EU NTBs. Section 2.7 draws comparisons with the external literature.

2.1 UK-EU tariffs

27. Under the modelled White Paper scenario, the analysis assumes there are no tariffs on UK-EU goods trade. This reflects the proposed customs arrangement with the EU. Under the modelled no deal scenario, the analysis assumes that the UK and EU levy EU-applied MFN tariffs on their bilateral goods trade.

28. Tariff rates for each sector have been estimated by trade-weighting EU applied MFN tariffs by UK-EU trade so that the tariff rates reflect the existing composition of products traded between the UK and the EU in each sector.

29. Specific tariffs, which are levied at a fixed amount per unit of a good and are prevalent in agri-food, are first converted into Ad Valorem Equivalents (AVEs)[12] before being trade-weighted in the same way as regular ad-valorem tariffs. Separate tariffs have been estimated for imports and exports for each sector.[13] The tariff estimates used in the modelled no deal scenario are presented in Table 2.A.

Table 2.A: Summary of UK-EU trade weighted tariffs, by sector, in the modelled no deal scenario, compared to today's arrangements.[14]

Compared to today's arrangements (per cent change)	Tariff on UK imports from the EU (per cent)	Tariff on EU imports from the UK (per cent)
Chemicals, pharmaceuticals, rubber and plastics	2	2
Machinery, electronics and aerospace	1	1
Motor vehicles and parts	9	8
Other manufacturing	3	3
Agri-food	20	20
Networks[15]	0	1

[12] Ad valorem equivalents are trade costs expressed as a percentage of the value of trade they affect.

[13] This reflects differences in the underlying composition of UK imports and EU imports within each sector. The UK-EU trade data used for the tariff estimation has been sourced from Trademap, and the EU applied MFN tariffs used have been sourced from MacMaps.

[14] EU-applied MFN tariffs were aggregated up to the 8-digit level by taking a simple average of the tariffs of the 10-digit products which relate to each HS-8 product. These 8 digit tariff rates were then aggregated up to the GTAP sector level, using UK-EU trade in each product as weights (separately for imports and exports).

[15] The networks sector includes both goods (2 digit Standard Industrial Classification codes 5-9, 19 and 35) and services (2 digit Standard Industrial Classification codes 36, 49-52 and 79): the weighted tariff presented in the table is taken across all trade in the sector, although services do not face tariffs. The weighted tariff on goods within networks is 1 per cent for both imports and exports.

30. As a sensitivity in the modelled no deal scenario, the analysis also considers a case where the UK unilaterally liberalises all of its tariffs to zero for both the EU and the rest of the world (RoW).

31. For the modelled average FTA and EEA-type scenarios, the analysis assumes the UK signs an agreement with the EU that eliminates all tariffs on UK-EU goods trade. In the modelled FTA and EEA-type scenarios firms must meet rules of origin (RoO), and the associated costs, to be able to pay zero tariffs. Firms may pay tariffs rather than face these costs. As a sensitivity for the modelled no deal, average FTA and EEA-type scenarios, the analysis also considers a case where EU applied MFN tariffs apply for the UK agri-food sector.

2.2 Framework for estimating UK-EU NTBs

32. Unlike tariffs, changes in NTBs cannot be directly observed. The analytical framework to estimate NTBs starts with assessing the modelled no deal scenario and then assesses changes in NTB drivers to enable estimates of the modelled white paper scenario. NTBs in the modelled average FTA and EEA-type scenarios are also estimated, as discussed in sections 2.3 to 2.5.

33. The framework is anchored to an econometric approach, known as gravity modelling, to estimate the impact of trading arrangements on trade flows. This approach is widely used to assess the impact of trade agreements on trade flows. Econometric methods are used to isolate the additional NTBs which apply on average between countries trading on WTO terms compared to intra-EU trade. This is considered to be a neutral proxy for the NTBs which would apply on UK-EU trade in the modelled no deal scenario. Econometric methods are also used to estimate the NTBs for the modelled average FTA scenario. See section 2.3 for further detail.

34. NTB estimates for the modelled White Paper and modelled EEA-type scenarios cannot be derived econometrically since there are either no direct precedents, or these are insufficient or partial. Drawing on a range of evidence, an analytical and policy assessment is made on whether the modelled White Paper scenario reduces or removes the NTBs considered in the modelled no deal estimates. NTB estimates for the modelled EEA-type scenario draw predominantly on the Government's evidence of customs and RoO costs.

2.2.1 NTB definition

35. In this analysis NTBs are defined as all barriers to trade that are not tariffs.[16] Examples include customs controls, differences between national regulatory regimes, and restrictions on the international movement of people insofar as this constitutes a barrier to trade. NTBs only capture barriers to trade, not barriers to investment or policy measures affecting domestic productivity unless they also constitute barriers to trade. Some organisations use a narrower definition, referring to NTBs as a subset of obstacles to trade brought about by policies with a protectionist or discriminatory intent.[17]

[16] 'The OECD glossary of statistical terms', OECD, 2014.
[17] 'Non-tariff measures to trade: Economic and Policy Issues for Developing Countries', UNCTAD, 2013.

2.3 Estimating sectoral NTBs in the modelled no deal and modelled average FTA scenarios

36. This section sets out the econometric gravity modelling approach used to estimate NTB changes in the modelled no deal and modelled average FTA scenarios. A gravity model[18] uses data to isolate the impact of existing trade agreements on trade, using statistical controls to account for other drivers of trade, such as distance, economic size and cultural factors[19].

2.3.1 Model specification and data

37. The central specification used to analyse bilateral trade between countries is summarised in Equation (1) and listed below:

$$(1) \qquad \log(trade)_{ijt} = \beta_1 EU_{ijt} + \beta_2 FTA_{ijt} + \gamma_1 X_{ij} + \gamma_2 Z_{ijt} + \mu_{it} + \upsilon_{jt} + \varepsilon_{ijt}$$

a. Whether the countries are both EU members or have a bilateral FTA in place. $\beta_1$and $\beta_2$in Equation (1) represent estimated differences in trade impacts compared to the WTO base group.[20] $\beta_1$is then used to generate modelled no deal NTBs. $\beta_2$and $\beta_1$are both used to generate modelled average FTA NTBs.

b. Whether the countries are both EEA members,[21] plus bilateral tariffs in the case of goods sectors. Denoted by $\boldsymbol{Z}$ in Equation (1).

c. All country-specific factors affecting the unilateral ability to import or export in each time period. This includes indicators such as overall economic size and sectoral output, but also all factors affecting the country's openness to imports or exports generally.[22] These are denoted by the fixed effects terms $\boldsymbol{u}$ and $\boldsymbol{v}$ in Equation (1).

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18 Referred to as 'the workhorse of empirical studies in the patterns of trade' in Baier, S.L. and Bergstrand, J.H. 'Do free trade agreements actually increase members' international trade?' Journal of International Economics, Volume 71, Issue 1, p. 72-95, 2007.

19 In the external EU exit literature, the OECD, LSE, World Bank and NIESR are some examples of institutions which have relied on gravity models to analyse trade impacts or the changes in NTBs associated with different trading arrangements.

20 The central specification is based on a sample of EU, OECD and BRICS countries. As a result, all country-pairs in the base group trade under WTO rules. One exception is Russia, which is included as a member of BRICS, but did not join the WTO until 2012. The WTO base group is made up of EU countries trading with third countries, but also third countries trading with third countries.

21 An EEA control variable is included equal to one if both countries are EEA members and are not both members of the EU. Trade data is not available for Iceland or Liechtenstein. As a result, the variable is based solely on Norway's relationship with the EU. This variable is not used to estimate the modelled EEA-type NTBs (see section 2.5).

22 These country-specific characteristics affecting importing or exporting with all partners are called 'multilateral resistance' factors. Intuitively they are important in that two countries will trade more when barriers to their trading with other countries are higher. See Anderson, J.E.and van Wincoop, E. 'Gravity with gravitas: a solution to the border puzzle', The American Economic Review, Volume 96, No.3 p.170-192, 2003 for more details. These factors are controlled for using time-varying importer/exporter fixed effects, which also capture all other country-specific variables such as country size, population and political stability.

d. Other observable country-pair specific factors affecting bilateral trade, such as distance between countries, and whether countries share a common language, historic link or land border. These are denoted by X in Equation (1).

e. Sector-specific factors affecting bilateral trade. Trade between global financial centres is accounted for when modelling business services and financial services. Bilateral visa waiver schemes are additionally accounted for when modelling business services. The United Nations Economic Commission for Europe (UNECE) 1958 Agreement is accounted for when modelling trade in motor vehicles.[23]

f. A simple regression error term is denoted by ε in Equation (1).

38. Bilateral trade, tariff data and sector-specific elasticities of substitution at a sectoral level are sourced from the latest complete GTAP database,[24] GTAP 9, which covers the whole economy and is consistent with the CGE modelling data and sectors. GTAP data has been used in recent gravity modelling analyses in the literature.[25] Equation (1) is estimated using pooled OLS on data for 2004, 2007 and 2011, the latest publicly available.[26] Bilateral control variables (distance, colony, language, border) are sourced from the CEPII gravity dataset.[27] The FTA dummy variable, is sourced from the Glick and Rose dataset.[28] The regression in Equation 1 is estimated separately for each sector, which are aggregates of the sectors from the GTAP database. The sample[29] used consists of all EU, OECD and BRICS countries

[23] For business services and financial services, the sample includes all countries with cities in the top 20 Global Financial Centres Index to account for trade between global financial centres. For business services, visa waiver agreements are accounted for as they can be negotiated independently of a wider trade agreement. An extended sample of countries is included to ensure sufficient variation. Similarly for motor vehicles trade, participation in the UNECE 1958 Agreement, which sets harmonised vehicle standards, is accounted for. The next top 5 motor vehicle trading countries are included to increase variation in this variable. Accounting for these additional controls allows the model to isolate EU specific effects.

[24] The GTAP data base is a fully documented, publicly available, global database which contains complete bilateral trade information along with transport and protection linkages. This is combined with data on production, consumption and intermediate use of goods and services to provide a representation of the world economy. Aguiar, A., Narayanan, B. and McDougall, R.,'An overview of the GTAP 9 data base', Journal of Global Economic Analysis, 1(1), pp.181-208, 2016.

[25] For example: Fally, T., 'Structural Gravity and Fixed Effects', Journal of International Economics, 2015; Fontagné, L. Mitaritonna, C. and Signoret, J., 'Estimated Tariff Equivalents of Services NTMs', CEPII, 2016; Engelbert, T., Bektasoglu, B., and Brockmeier, M., 'Moving toward the EU or the Middle East? An assessment of alternative Turkish Foreign Policies Utilizing the GTAP framework.' Food Policy, Volume 47, p.46-61, 2014.

[26] Trade flows under $10,000 are excluded from the sample.

[27] CEPII Gravity dataset from Head, K., Mayer, T., 'Gravity Equations: Toolkit, Cookbook, Workhorse', Handbook of International Economics, Vol. 4,eds. Gopinath, Helpman, and Rogoff, Elsevier, 2014.

[28] Glick, R. and Rose, A.K., 'Currency unions and trade: A post-EMU reassessment'. European Economic Review, 2016. The latest wave of trade data from the GTAP 9 database is the year 2011. Consequently, trade agreements signed and applied after 2011 would not be explicitly taken into account by the dataset, including the EU's EPA with Japan and CETA with Canada.

[29] Note that the central specification and sample is adjusted slightly when modelling business services, financial services and motor vehicles trade, to allow for the sector specific controls listed in section 2.3.1.

to ensure that analysis is based on trade between developed nations only. This is consistent with other studies.[30]

2.3.2 From trade impacts to NTB impacts

39. The gravity modelling provides estimates of the changes in trade associated with different trading relationships. The change in NTBs associated with precedent-based trading arrangements compared to today's arrangements is calculated as an AVE change, in a way that is comparable to imposing a tariff on trade.[31] This is the standard technique for estimating the change in NTBs.[32] The central estimate of the change in NTBs associated with the modelled no deal scenario is calculated according to Equation (2):

$$(2) \qquad Modelled\ no\ deal\ NTB\ change = \left(\exp\left(\frac{\beta_1}{\sigma - 1}\right) - 1\right)(0.85)$$

where β_1 refers to the estimated EU trade impact relative to the WTO base group. σ refers to the sector-specific elasticity of substitution taken from the GTAP 9 database. The 85 per cent adjustment is made to reflect the asymmetry of exiting a trade bloc. This is discussed in further detail in section 2.3.3.

Similarly, the change in NTBs associated with the modelled average FTA scenario compared to today's arrangements is calculated according to Equation (3):

$$(3) \qquad Modelled\ FTA\ NTB\ change = \left(\exp\left(\frac{\beta_1}{\sigma - 1}\right) - \exp\left(\frac{\beta_2}{\sigma - 1}\right)\right)(0.85)$$

40. The estimates capture the *change* in NTBs associated with different trading relationships. That is, the NTB associated with a scenario captures the change in NTBs when moving from current trading arrangements to that scenario. The *level* of NTBs among trading partners is not estimated. Econometric estimates for the modelled no deal NTBs have been compared with other sources of both quantitative and qualitative evidence. While there were some differences at a sub-sector level, they do not significantly affect the aggregate macroeconomic modelling results. The NTBs in the modelled no deal scenario are not intended to capture specific barriers that could arise between the UK and the EU under no deal.

2.3.3 Time horizons and asymmetry

41. The NTBs estimated econometrically are based on changes in trade which have occurred after the formation of trade agreements. In other words, the trade impacts associated with membership of a trade agreement. The academic evidence finds that these changes in trade tend to manifest themselves fully up to 15 years after

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30 Mulabdic, A., Osnago, A., and Ruta, M., 'Deep Integration and UK-EU Trade Relations', World Bank Policy Research Working Paper, 2017; Felbermayr, G., Gröschl, J. K., & Heiland, I. 'Undoing Europe in a new quantitative trade model', No. 250. Ifo Working Paper, 2018.

31 The estimated percentage change in trade from the econometric gravity model is converted into an AVE change by dividing it by the estimated elasticity of substitution by sector and taking the exponential as described in Equation [2].

32 Yotov, Y.V., Piermartini, R., Monteiro, J.A. and Larch, M., 'An advanced guide to trade policy analysis: The structural gravity model', World Trade Organization, 2016.

formation of the trade agreement.[33] For the present analysis, which aims to assess the trade impacts of exiting a trade agreement, it is the timing of the reversal of trade gains when exiting a trade agreement that is relevant.

42. Some trade impacts that arise when exiting a trade agreement may not fully materialise over the 15 year horizon considered in the modelling. Given the importance of pre-existing investments, supply chains and networks in determining trading patterns, it may take more than 15 years to 'wind down' these relationships such that NTBs realise their full impacts on trade. Furthermore, while some NTBs such as customs administration costs and the removal of financial services passporting rights might materialise immediately, other NTBs might only emerge gradually.

43. An adjustment to the NTBs is made to reflect the potential difference between joining and exiting a trade agreement and to reflect the UK's unique starting position. Between 70 and 100 per cent of the econometrically estimated changes in NTBs from joining a trade agreement are assumed to apply when leaving an agreement, with a central assumption of 85 per cent. This reflects the range of available evidence and the uncertainty around it.[34]

2.4 Approach to estimating NTBs for the modelled White Paper scenario

44. This section sets out the method used to estimate NTBs in the modelled White Paper scenario. The approach uses the modelled no deal NTBs as an 'anchor'. This ensures that all estimates are informed by the widely used econometric methodology described above. The approach draws on a variety of evidence sources, using consistent principles but also necessarily different tools and evidence depending on the sector.

45. A consistent set of drivers of NTBs across sectors is considered.[35] Evidence is gathered on the relative importance of these drivers of NTBs across sectors[36], and

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33 Baier, S. L., Bergstrand, J. H., Egger, P., & McLaughlin, P. A. 'Do economic integration agreements actually work? Issues in understanding the causes and consequences of the growth of regionalism' World Economy, Volume 31, No. 4 2008; Magee, C. S. 'New measures of trade creation and trade diversion.' Journal of International Economics, Volume 75, No. 2, 2008.

34 Most available evidence focuses on the reversal of higher levels of trade after decolonisation and the break-up of the Soviet Union and other ex-Soviet bloc states. Head, K., Mayer, T., & Ries, J. C. ('The erosion of colonial trade linkages after independence' Journal of International Economics, Elsevier, 2011) results on decolonisation and the breakdown of the Soviet Union are consistent with reversals of between 65 and 75 per cent of trade gains after 15 years. Fidrmuc, J., & Fidrmuc, J. ('Disintegration and trade.' Review of international economics 11, no. 5, 2003) results focus on post-Soviet, Eastern and Central European break-ups, and are consistent with reversals of 95 to 100 per cent of trade gains on a 15 year horizon. Other studies, for example, Ebell, M., and Warren, J. The long-term economic impact of leaving the EU', NIESR(2) and Mayer, T., Vicard, V., & Zignago, S., 'The Cost of Non-Europe, Revisited', CEPII, 2018 assume full symmetry of gravity model estimated trade impacts in the EU exit scenarios considered. Dhingra, S., Huang, H., Ottaviano, G., Pessoa, J.P, Sampson, T. and Van Reenen, J., "The costs and benefits of leaving the EU: trade effects", Centre for Economic Performance Discussion Paper No. 1478, 2017, assume that in a WTO scenario the UK would face 75 per cent of the reducible barriers faced by US exporters into the EU.

35 Drawing on more granular frameworks, including 'International Trade Centre's classification of Non-Tariff Measures', UNCTAD, 2012.

36 Noting that not all drivers may be relevant for all sectors.

an assessment is made of whether, relative to the modelled no deal scenario, these NTBs remain, are reduced, or are removed in the modelled White Paper scenario.

Table 2.B: Summary of NTB Drivers

NTB driver	Description
Customs and rules of origin	**Customs costs:** customs procedures generate costs at the border through the requirement to complete customs declarations, and indirect costs such as time spent waiting at the border for checks to be completed. **Rules of origin costs:** these include administrative costs and possible supply chain adaptation costs necessary to access preferential tariff rates in typical trade deals. Further possible costs arise from the loss of cumulation of UK content with EU content for exports to third countries.
Regulatory and market entry NTBs	**Regulatory NTBs:** these occur where there are variations in regulatory requirements (and no common regulatory system) between different countries where goods and services are sold. This can lead to "behind-the-border" costs from the businesses needing to understand different regulatory systems, adjust products to meet market requirements, and demonstrate compliance[37]. It can also lead to costs at the border, including additional checks. Costs can also arise from restrictions on cross-border market access from, for example, the loss of passporting in financial services or the lack of arrangements for 'regulatory equivalence' between different regulatory systems. Additionally, there may be restrictions on **entry into a market** such as limitations on foreign ownership and screening requirements.
Movement of people	**Temporary mobility NTBs:** restrictions on the movement of people across borders for business purposes or for providing services, including limits on duration of stay, restrictions on permitted activities, or other local labour market restrictions. **Long-term migration NTBs:** lower long-term migration might reduce the extent to which migrants' can help facilitate trade with their home country.[38] Wider economic impacts of migration, for example on labour supply, are considered through the macroeconomic modelling rather than as NTBs.
Cross-cutting and other NTBs	Trade costs affecting multiple sectors: examples include data protection regulations, government procurement, cross-border VAT and intellectual property rights.

46. The approach utilises structured decision-making tools to estimate NTBs for each sector drawing on evidence from a wide variety of sources, including:

    a. *Econometric evidence* - Gravity modelling (as outlined in section 2.3) in addition to analysis of the relative importance of different NTBs, including comparing the impact of individual trade agreement provisions on trade using further econometric approaches.

    b. *Direct cost estimation* - a range of analysis on the costs of particular NTBs.

[37] 'International Regulatory Co-operation and Trade: Understanding the Trade Costs of Regulatory Divergence and the Remedies', OECD, 2017.

[38] This analysis does not explicitly model small direct long-term migration trade impacts on NTBs arising from alternative migration policy scenarios. The modelled no deal NTB estimates reflect the NTB impact of long-term migration restrictions and migrant stocks in line with those observed between EU, OECD and BRICS countries trading on WTO terms – following the gravity modelling estimation of the modelled no deal scenario.

c. *Evidence from stakeholders* - insights provided by government sector leads, drawing on conversations with businesses regarding which NTBs are seen as most significant.

d. *External literature* - review of studies undertaken by academic authors or institutions such as the OECD, and other external research on NTBs.[39]

e. *Policy lead input* - insights from UK Government leads.

47. For some sectors and NTB drivers the quantitative evidence base to assess the modelled White Paper scenario was limited. Evidence gaps and challenges were dealt with through analytical judgement.

48. For other sectors a reduced form approach was followed, using estimates for comparable sectors, or econometric estimates for NTBs in comparable precedent scenarios. These sectors tended to have low trade flows or low NTBs in comparable precedent scenarios.

49. Table 2.C provides a summary of how individual NTB drivers are assessed in the modelled White Paper scenario, relative to today's arrangements.

Table 2.C: Summary of approach to estimating UK-EU NTBs in modelled White Paper scenario by driver of NTB, compared to today's arrangements.

	Modelled White Paper scenario (compared to today's arrangements)				
NTB Drivers	**Manufactured Goods**	**Agri-food**	**Services**	**Financial Services**	**Networks[40]**
Customs and Rules of Origin	*None*	*None*	*None*	*None*	*None*
Regulatory NTBs	*Minimal*	*Minimal*	*Some*	*Some*	*Some*
Movement of People	*Minimal*	*Minimal*	*Some*	*Some*	*Minimal*
Cross-cutting and Other	*None*	*None*	*None*	*Some*	*Some*

2.5 Approach to estimating NTBs for the modelled EEA-type scenario

50. The NTB costs associated with this scenario predominantly relate to customs and RoO. It is possible to estimate customs costs directly using UK-specific evidence, which is supplemented with other sources of evidence.

51. The evidence base on administrative burdens described in Box 2.A is used to estimate the cost of additional customs declarations required in each product group.

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39 Examples include 'Non-Tariff Measures in EU-US Trade and Investment – An Economic Analysis', Ecorys, 2009; Cadot, Gourdon & Tongeren, 'Estimating Ad Valorem Equivalents of Non-Tariff Measures: Combining Price-Based and Quantity-Based Approaches', OECD, 2018; 'The Impact of the UK's Exit from the EU on the UK-based Financial Services Sector', Oliver Wyman, 2016; 'Services Trade Restrictiveness index' OECD, 2014.

40 Networks considers both goods trade and services trade, which may face different barriers.

These costs are assigned to the goods and services sectors associated with the production of the relevant products[41].

52. RoO costs are based on external literature estimates of the costs of utilising tariff preferences in trade agreements.[42] These costs are converted into sectoral costs, based on evidence on firm sizes and EU-applied MFN tariff profiles in each sector. Estimated tariff costs from non-utilised preferences are also included when presenting central estimates of NTB changes associated with this scenario.

53. Goods trade barriers may impose some costs on the provision of cross-border services, where services trade follows the sale of goods. The barrier to services trade imposed is informed by evidence from the external literature on the relative importance of cross-border trade in goods and services for goods-producing firms.[43]

Box 2.A: Customs Administrative Burdens Evidence Base

Customs declarations would be required for UK-EU trade in goods under the modelled no deal, modelled average FTA and modelled EEA-type scenarios. This would result in additional recurring costs to business. HMRC analysis of the additional declarations required and cost per declaration gives a total estimated administrative burden of £13 billion annually for current UK-EU trade in goods[44]. Businesses are likely to respond to these increased costs by adjusting the size and frequency of their consignments and the analysis makes a subsequent adjustment for this[45]. Under the modelled White Paper scenario, there would be no additional customs declarations given these are already required for rest-of-world trade today, but there would be further informational requirements for these declarations to comply with two customs regimes on import. This additional administrative burden is estimated to be relatively small.[46]

41 Where the burden of customs declarations affects cross-border activity in services directly (for instance in e-commerce), the costs are assigned to the relevant services sector.

42 Cadot, O., Carrère, C., De Melo, J., & Tumurchudur, B., 'Product-specific rules of origin in EU and US preferential trading arrangements: an assessment.' World Trade Review 5, no., 2006; Francois, J., Hoekman, B., & Manchin, M, 'Preference erosion and multilateral trade liberalization'. The World Bank, 2005; Anson, J., Cadot, O., Estevadeordal, A., Melo, J. D., Suwa-Eisenmann, A., & Tumurchudur, B. 'Rules of origin in North–South preferential trading arrangements with an application to NAFTA' Review of International Economics, Volume 13, No. 3, 2005.

43 Szász, L, Demeter K., Boer H, Cheng Y.'Servitization of manufacturing: the effect of economic context,' Journal of Manufacturing Technology Management, 2017; elle, M., 'Crossing industry borders: German manufacturers as services exporters', World Economy, Vol. 36, 2013.

44 Details of HMRC's analysis on the additional estimated number of declarations and the administrative burden of these are set out in the letter from Jon Thompson, CEO of HMRC to Nicky Morgan, MP, 4 June 2018.

45 While the empirical literature is limited, it suggests that reduction in the number of consignments caused by the introduction of a customs border between two countries would usually be negligible since it only usually results in a small proportionate increase in shipping costs. However, the shipping costs of a 'typical' EU consignment are low because the average UK-EU consignment is relatively small in value and the distribution of UK-EU consignments are heavily skewed towards smaller consignments. Due to this, the introduction of a UK-EU customs border are expected to lead to greater aggregation of consignments by businesses than the literature suggests.

46 At most £0.7 billion. This cost is estimated on the basis of the additional fields on a customs declaration. The estimated total cost of these additional fields is then applied to current UK import declaration numbers from non-EU partners. As set out in letter from Jon Thompson, CEO of HMRC to Nicky Morgan, MP, 4 June 2018.

Businesses would incur additional recurring costs of time to queue and present declarations at the border. To estimate the cost of delays, academic literature is used to estimate of the costs to business of delays in trade and World Bank data of average customs delays between countries.[47]

2.6 UK-EU NTB estimates

54. This section presents for illustration the average goods and services UK-EU NTBs for all scenarios.

55. Estimates for changes in UK-EU NTBs by sector group are presented in section 3.2 of the analysis document.

56. NTB estimates show the change in trading costs expressed as a percentage of trade values relative to today. Estimates reflect long-term changes in individual sectors relative to today. They do not reflect macroeconomic impacts or short-run economic consequences.

57. For the modelled no deal, modelled average FTA and modelled White Paper scenarios, uncertainty around sectoral central NTB estimates is factored into the macroeconomic modelling (as explained in section 4.4) through statistical distributions, based on standard errors derived from the econometric modelling. For the modelled EEA-type scenario, uncertainty around central NTBs is based on estimates of uncertainty around the underlying cost estimates.

58. The analysis also considers a sensitivity to reflect the spectrum of outcomes from the Political Declaration. This illustrates the potential impact of higher non-tariff barriers, including checks at or behind the border and other regulatory costs, and specifically reflects 50 per cent of the difference in non-tariff barriers between the modelled White Paper scenario and modelled average FTA scenarios. This NTB midpoint is illustrative only and does not represent an expected outcome.

[47] Hummels, David L., and Georg Schaur. 'Time as a trade barrier.' American Economic Review 103.7 (2013): 2935-59; 'Doing Business - Trading across borders', World Bank, 2018.

Table 2.D: Summary of estimates of changes to UK-EU NTBs by sector compared to today's arrangements.

Compared to today's arrangements (per cent change)	Modelled no deal	Modelled average FTA	Modelled EEA-type[48]	Modelled White Paper	Modelled White Paper with 50 per cent NTB sensitivity[49]
All Goods[50]	+10 (+6 to +15)	+8 (+5 to +11)	+5 (+3 to +7)	+1 (0 to +1)	+4
All Services	+11 (+4 to +18)	+9 (+3 to +14)	+2 (+1 to +3)	+6 (+2 to +10)	+7

Central estimates and ranges in brackets.[51] *Note: estimates are rounded to the nearest per cent. Owing to rounding, narrow ranges (less than one per cent) are not distinguishable in the table.*

2.7 Comparisons with external literature

59. The Government's analysis of trade costs is within the range of trade cost estimates from external analyses. External studies deploy a range of approaches to estimating NTBs associated with the UK's potential future trading relationship with the EU. Most of these focus on precedent-based scenarios.

2.7.1 Estimates based only on gravity modelling

60. Many external analyses use econometric gravity modelling to isolate the total impact of trading on EU terms relative to trading on WTO terms. The results can then be transformed into estimates of trade costs, following a similar approach outlined in section 2.3. While there is variation in trade cost estimates across studies, it is worth noting that there is an inverse relationship between elasticities of substitution and implied trade impacts from gravity coefficients.

2.7.2 Other approaches taken to estimate NTB changes in a no deal scenario

61. A number of studies estimate UK-EU NTBs through applying assumptions and adjustments to NTBs estimated for other trading arrangements. For example assumptions about the share of the US-EU barriers suitable to approximate an EU

48 In the modelled EEA-type scenario, customs costs are primarily assigned to goods sectors. Where customs declarations affect cross-hyphen border activity in services (e.g. in e-commerce), the costs are assigned to the relevant services sector.

49 The sensitivity reflects 50 per cent of the difference in non-tariff barriers between the modelled White Paper and modelled average FTA scenarios. Implicitly, the modelled White Paper scenario represents zero per cent on this range, and the modelled average FTA scenario represents 100 per cent. This midpoint is illustrative only and does not represent an expected outcome.

50 The networks sector includes both goods (2-digit Standard Industrial Classification codes 5-9, 19 and 35) and services (2-digit Standard Industrial Classification codes 36, 49-52 and 79) and therefore is split across the weighted averages for 'all goods' and 'all services' used here.

51 Ranges reflect the 95 per cent confidence interval and are based on weighted statistical distributions for the sectors in the macroeconomic model. Ranges are not modelled for the 50 per cent NTB sensitivity.

exit scenario are applied in a range of studies using estimates of EU-US NTBs from Ecorys[52] and Egger et al[53]. These are presented in Table 2.E.

62. A UKTPO study[54] estimates the trade impacts of WTO relative to EU membership for the manufacturing sector only using literature estimates which include an econometric price gap approach. These estimates are equivalent to an AVE change of 11.7 per cent. Some studies estimate directly the costs of specific observable barriers to trade. For example, an Oliver Wyman study[55] estimates NTB increases based on evidence collected from corporate clients.

63. Rather than model NTBs with the EU, an Economists for Free Trade study[56] assumes no additional NTBs. They argue that given the UK's current regulatory alignment with the EU, any attempt to impose trade barriers would be illegal under WTO rules. The OBR notes that 'this appears to be based on Economists for Free Trade's interpretation of the WTO's MFN requirements. But most trade experts interpret these rules as meaning that the EU would be forced to impose the same NTBs that the rest of the world currently faces, unless the UK and EU sign a trade deal to lessen them'.[57]

2.7.3 Inputs for wider macroeconomic modelling on EU exit

64. Many studies on the economic impact of EU exit use NTBs as inputs to wider macroeconomic modelling, either estimating NTBs themselves or drawing on secondary literature. Table 2.E summarises the assumptions taken and corresponding NTB estimates[58]. Table 6.F lists the full references for these studies as well as explaining the labelling system.

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52 Berden, K.G. et al., 'Non-tariff measures in EU-US trade and investment - An economic analysis', Ecorys, 2009.

53 Egger, et al., 'Non-Tariff Barriers, Integration, and the Trans-Atlantic Economy', Economic Policy, Volume 30, Issue 83, Pages 539–584, July 2015.

54 Gasoriek et al., 'Which manufacturing sectors are most vulnerable to Brexit?', UK Trade Policy Observatory, February 2018.

55 Quest, L and Iyer, K., 'The "Red Tape" Cost of Brexit', Oliver Wyman, 2018.

56 'From Project Fear to Project Prosperity', Economists for Free Trade, August 2017.

57 'Brexit and the OBR's Forecasts,' OBR discussion paper, October 2018.

58 Trade costs are not always calculated or specified explicitly in AVE terms in the studies cited. In some cases, it is possible to calculate AVE trade costs which can be compared to the modelled no deal estimates in this analysis using the reported econometric regression coefficient on the joint EU membership variable, comparable to β1 in Equation [1]. The AVE trade costs implied by the external literature are then calculated as $\exp(\beta k / (\sigma-1)) - 1$ where βk is the external regression coefficient and σ is the elasticity of substitution. Where neither an AVE trade cost nor a σ is reported, AVE trade costs are calculated using a common σ of 7.2 for goods and 3.8 for services, in line with GETRADE assumptions.
[a] AVE trade costs calculated from coefficients given in the relevant study, but using elasticities in line with GETRADE assumptions.
[b] Denotes a study which estimates total trade costs, including tariffs.
[c] Denotes an estimate from a study which is about the effect of the deep trade agreements on trade, which include the EU and may also include some other trade agreements.

Table 2.E: Summary of trade cost assumptions for external studies that consider a WTO scenario

Label	Method	Source	WTO Trade Cost (per cent AVE)
Based on econometric estimates of WTO-EU NTBs			
HM Government (Autumn 2018)	As detailed in this section		Goods: 10 per cent Services: 11 per cent
CEPII	Gravity estimates[ab]	Within the study	Goods: 21 per cent Services: 6 per cent
CESifo (2017)	Gravity estimates	Within the study	Goods: 8 per cent Services: 20 per cent
CESifo (2018)	Gravity estimates	Within the study	Goods: 9 per cent Services: 34 per cent
IMF	Gravity estimates	CESifo (2018), average across all sectors	20 per cent for both goods and services
NIESR	Gravity estimates[abc]	Goods: Baier, et al. (2008) Services: Range of sources	Goods: 8 per cent to 14 per cent Services: specified in terms of changes to total trade
OECD	Gravity estimates[59]	Fournier, et al. (2015)	Specified in terms of changes to total trade
PWC	Gravity estimates, not presented	Within the study and other sources	Various specific AVE estimates
World Bank	Gravity estimates[a]	Within the study	Goods: 9 per cent Services: 7 per cent
Based on econometric estimates of US-EU NTBs			
CEPR	UK–EU NTBs increase to 75 per cent of the reducible US–EU NTBs	Berden et al. (2009)	8 per cent for both goods and services
CEP-LSE	UK–EU NTBs increase to 75 per cent of the reducible US–EU NTBs	Berden et al. (2009)	8 per cent for both goods and services
CPB NL	Gravity estimates for goods, range of sources for services.	Egger, et al. (2015)	13 per cent for both goods and services
Rabobank	UK-EU NTBs increase to 67 per cent of US-EU levels in WTO	Egger, et al. (2015)	9 per cent for both goods and services
RAND	UK–EU NTBs increase to 75 per cent of the reducible US–EU NTBs.	Berden et al. (2009)	8 per cent for both goods and services

[59] Gravity estimates in this study reflect EEA rather than EU membership.

Label	Method	Source	WTO Trade Cost (per cent AVE)
University of Bonn	UK-EU NTBs increase to 50 per cent of US-EU levels in WTO.	Egger, et al. (2015)	6 per cent for both goods and services
Based on other forms of evidence			
Ciuriak Consulting	Goods: Bottom-up evidence on specific trade costs Services: Econometric approach	Variety of sources	Goods border cost 3 per cent, and other costs
Open Europe	Based on Ciuriak, et al. 2017	Ciuriak, et al. 2017	Goods border cost 3 per cent, and other costs

3. Key input assumptions: UK-rest of world (RoW) tariffs and NTBs

65. This section outlines the method used to estimate key model inputs for barriers on RoW trade. The approach is similar to that used to estimate UK-EU NTB changes as set out in section 2, with methodological differences set out below. Section 3.1 details the assumed UK prospective trade partners. Section 3.2 details the tariffs assumptions and inputs, while section 3.3 explains the RoW NTB inputs and econometric modelling results.

3.1 Potential trade agreement partners

66. The Government has announced its intention to roll over all EU Free Trade Agreements (FTAs) to which the UK is currently a party. This includes those that have been implemented or provisionally applied (such as EU-Chile or EU-South Korea) and those agreed and yet to be ratified or implemented (such as the Japan Economic Partnership Agreement (EPA)).[60] It is assumed that all these countries agree to transition the agreements, and so there are no additional changes in the UK's relationship with these countries.

67. For the purposes of EU exit modelling, the UK is also assumed to make successful trade agreements with those countries listed in section 2.3.4 of the analysis document. This is illustrative and in keeping with the Government's ambitious free trade agenda.[61]

68. As in the UK-EU analysis, the approach to analysing the potential trade agreements involves considering changes to both tariffs and NTBs.

3.2 UK-RoW Tariffs

69. In the central ambition case, it is assumed that the UK's tariffs with prospective trade partners are eliminated, and tariffs faced by UK exporters to those same partners are also eliminated (i.e. set to zero for all sectors reciprocally). This occurs for all exit scenarios.

70. Additionally, the analysis models two sensitivities:

    a. A scenario where UK agri-food tariffs are not liberalised in the RoW future trade agreements and therefore remain at EU-applied Most Favoured Nation (MFN) levels;

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[60] The GTAP dataset is referenced to 2011 as a base year. Consequently, trade agreements the EU has signed and applied with third countries coming into force after 2011 would not be explicitly taken into account by the dataset, including the EPA with Japan and CETA with Canada. The analysis does not explicitly model these agreements in the baseline or exit scenarios on the assumption that there is no additionality from having these agreements either in the EU or outside of it.

[61] The Government has initiated public consultations on four negotiations: Australia, New Zealand, USA and The Comprehensive and Progressive Trans-Pacific Partnership (CPTPP).

b. Separately, a case where in addition to successfully negotiating new RoW future trade agreements, the UK unilaterally liberalises all its tariffs to zero for both the EU and the RoW as described in section 2.1.[62] This would also apply to all the partners in rolled over EU FTAs.[63] While this may be difficult to achieve in practice, this sensitivity is conducted for illustrative purposes.

71. Outside prospective trade partners, the UK is assumed to continue to levy MFN tariffs equivalent to the current EU-applied MFN tariffs on all imports in all the modelled scenarios.

72. Sensitivity tests on modelling parameters are also included in the analysis.

3.3 UK-RoW NTB Estimates

73. The approach taken to estimating RoW NTBs uses a similar dataset and analytical methodology to that taken to estimate changes in modelled no deal UK-EU NTBs.[64] The analysis draws on the literature estimating the level of NTBs which affect trade,[65] by using an econometric gravity approach to estimate the levels of NTBs faced by UK exporters when exporting to countries outside of the EU. The approach is identical for each EU exit scenario.

3.3.1 Assumptions and interpretation

74. The econometric modelling provides estimates of the levels of NTBs – in *ad valorem* equivalent (AVE) terms – affecting trade between the UK and the two groups of prospective trade partners detailed above. These capture the barriers to trade that prevent the free flow of goods and services across borders, including both trade policy-relevant barriers, and wider barriers that affect trade.

75. Due to the wide range of factors included in these estimates, only a portion of these levels are likely to be changed or 'actionable' through trade policy. There is limited evidence on this. A review of the literature suggests that a reasonable assumption tends to be around 50 per cent, but in general, barriers to services trade are found to be less actionable than barriers to goods trade.[66] It is therefore assumed that in all

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62 The analysis also assumes a reduction in NTBs on imports from preferential trading partners from the removal of Rules of Origin (RoO) requirements under unilateral liberalisation. The methodology for calculating cost reductions is in line with the approach taken in the modelled EEA-type scenario to calculate RoO costs.

63 The analysis makes no other assumption about how NTBs might change in rolled over FTAs as a result of unilateral tariff liberalisation.

64 Chen, C. and Novy, D., 'On the Measurement of Trade Costs: Direct vs. Indirect Approaches to Quantifying Standards and Technical Regulations', CEP Discussion Paper No 1164, Centre for Economic Performance, 2012.

65 Ferrantino, M., 'Quantifying the Trade and Economic Effects of Non-Tariff Measures', OECD Trade Policy Working Papers, 2006; Berden et al., 'Non-Tariff Measures in EU-US Trade and Investment - An Economic Analysis', Ecorys, 2009.

66 This assumption is often known as the "actionability" assumption – the proportion of total barrier that could be actioned upon to reduce in an FTA. See Berden et al., 'Non-Tariff Measures in EU-US Trade and Investment - An Economic Analysis', Ecorys, 2009; Ciuriak, D. and Xiao, Q., 'The trade related impact of a UK exit from the EU Single Market', Ciuriak Consulting, 2015.

goods sectors, 50 per cent of NTBs can be affected by trade policy and in services sectors, one third can be affected.[67]

76. The Government's approach to agreements between the UK and prospective trade partners is currently being developed. In this illustrative and indicative approach, representing ambitious agreements including but not limited to FTAs, it is estimated that under the central ambition case, 25 per cent of the actionable goods and services barriers might be reduced. These are applied in all the modelled EU exit scenarios. As set out in section 2.3.3 of the analysis document, the analysis does not model any constraints that the Government's policy could impose on future UK-RoW agreements.

3.3.2 Econometric approach used to estimate UK-RoW NTBs

77. The econometric methodology for estimating UK-RoW NTBs is based on a method employed by Fontagne *et al*. estimating the level of NTBs in service sectors.[68] This approach uses the characteristics of trading partners to explain the pattern of trade, accounting for a number of other drivers of trade. The approach here:

    a. Uses the same database, GTAP 9, as used to estimate UK-EU NTBs (section 2) and subsequent CGE modelling (section 4).

    b. Analyses trade flows on a pooled cross-section of 3 years' worth of data – 2004, 2007 and 2011 – for which GTAP has significant coverage. The full sample covers 120 countries.[69]

78. In a similar manner to the methodology outlined in section 2.3, the modelling uses a central specification to analyse bilateral trade between countries, accounting for a number of potential drivers. This helps to isolate the impact of individual factors. These are listed below and are summarised in equation (4) below:

    a. Bilateral dummy variables are included that control for both partners being members of the EU and for partners having an FTA with each other.

    b. Observable country-pair specific factors affecting bilateral trade, including the distance between countries, and whether countries share a common ethnic language, historic link or land border. A measure of time difference is also included.[70] These are denoted by X in equation (4) below.

    c. A dummy variable is included equal to one if both countries are EEA members.[71] Bilateral tariffs are also included in the regressions for goods and agri-food sector groups. These are denoted by $\boldsymbol{Z}$ in Equation (4) below.

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67 These assumptions are broadly in line with those used in Petri, P. A. and Plummer, M. G., 'The Economic Effects of the Trans-Pacific Partnership: New Estimates', Peterson Institute for International Economics Working Paper 16-2, 2017.

68 Fontagne et al., 'Estimates of tariff equivalents for the services sectors', CEPII, December 2011; Fontagne et al., 'Estimated tariff equivalents of Services NTMs', CEPII, August 2016.

69 Trade flows under $10,000 are excluded from the sample.

70 For sectors within the manufactured goods and agri-food sector groups, Common Official Language and Common Historical Links are also included.

71 An EEA control variable is included equal to one if both countries are EEA members and are not both members of the EU. Trade data is not available for Iceland and Liechtenstein. As a result, this variable is based on Norway's relationship with the EU.

d. Importer GDPs are included and its impact is constrained to 0.8 to avoid collinearity with the importer fixed-effects.[72]

e. All country-specific factors affecting the unilateral ability to import or export over time. This includes indicators such as overall economic size and sectoral output, but also all factors affecting the country's openness to imports or exports generally. These are denoted by the fixed effects terms $\boldsymbol{u_{it}}$ and $\boldsymbol{v_{it}}$ respectively in equation (4) below.

f. A simple regression error term is denoted by ε in Equation (4) below.

79. The final regression for goods, services and agri-food is:

$$(4) \quad \log(trade_{ijt}) = \beta_1 EU_{ijt} + \beta_2 FTA_{ijt} + \gamma_1 X_{ij} + \gamma_2 Z_{ijt} + 0.8GDP_{it} + u_{it} + v_{jt} + \varepsilon_{ijt}$$

80. The central specification is estimated separately for each sector.[73]

81. The importer-year fixed effects provide information as to how much trade was distorted by country specific characteristics, that are not explained by the other variables included in the regression. A portion of this trade distortion is attributed to NTBs that can be affected by trade policy. To estimate these barriers, each country's importer-year fixed effect needs to be compared to the benchmark of free trade. As free trade is unobservable, the country with the highest fixed effect coefficient (the country with the highest trade levels given its characteristics) is used as a proxy for a free trading nation.[74] The difference between countries' importer-time fixed effect and the free trade level is used to calculate an AVE on trade barriers, using the formula below:[75]

$$(5) \qquad \ln(1 + AVE)^{1-\sigma} = u_{it} - u_{free\ trade}$$

AVEs are calculated for each year, before an average is taken across the three years to give a single average AVE for each country and sector.

[72] 0.8 is chosen in line with Fontagné et al., 'Estimates of tariff equivalents for the services sectors', CEPII, December 2011, as it represents the most reliable estimate of GDP's impact.

[73] In two sectors, the specification is adjusted to account for other sector specific drivers of trade. For motor vehicles trade, an additional variable is included to account for participation in The United Nations Economic Commission for Europe (UNECE) 1958 Agreement, which regulates international standards in vehicles. Visa waiver programmes, which may facilitate services trade, are accounted for when modelling trade in business services.

[74] These estimates have been converted to AVEs using the same elasticities used in the Government's CGE model, which come from the GTAP database. This calculation is performed for each of the three years in the sample and a simple average of the tariff equivalent is used as the final level. Where the regional aggregation in the modelling is a group of countries, the GDP weighted tariff equivalent is used as the final level.

[75] See Fontagné et al., 'Estimates of tariff equivalents for the services sectors', CEPII, December 2011 for a full discussion of the method. By design, this is likely to understate the true level of trade distortions that are country specific, as it is expected that all countries to have some level of negative trade distortions when compared to free trade.

3.3.3 Rest of World NTB Estimates

82. Table 3.A below summarises the aggregated estimates for the UK and trade policy partners:

Table 3.A: Summary of estimates of changes to UK-Rest of World NTB compared to today's arrangements for all scenarios

Compared to today's arrangements (per cent change)	NTBs into the UK for ROW trade partners (per cent)	NTBs into ROW trade partners for the UK (per cent)
Manufactured Goods	-3.3	-2.3
Agri-food	-3.6	-3.8
Services	-2.6	-4.2
Financial Services	-5.0	-5.6
Networks	-3.8	-3.6

Negative figures reflect a reduction in NTB costs compared to today's arrangement.

83. The analysis captures additional customs costs which would apply under the modelled White Paper scenario. See section 2.5 for further information on customs costs.

3.3.4 Additional Sensitivity Scenario

84. As an additional sensitivity, inputs to model a "high ambition" trade agenda are estimated. In this sensitivity, the same levels of actionability are assumed, but ambition is assumed to be doubled to a 50 per cent reduction in NTBs for both goods and services. This sensitivity is not applied in the modelled White Paper or the modelled EEA-type scenarios, as elements of these could constrain the UK's ability to further reduce NTBs beyond the base scenario.

85. In this sensitivity, the reduction in NTBs with new trade deal partners would overall be larger than the difference in NTBs between modelled no deal and modelled FTA scenarios. In some sectors, particularly in services, the NTB reduction with new trade deal partners would be larger than the NTBs in the modelled no deal scenario.

4. CGE Model

86. The Government has developed a macroeconomic model of international trade (GETRADE) to provide a single coherent setting for the analysis of changes in trade costs as described in sections 2 and 3. GETRADE is a multi-country CGE model that captures trade linkages with countries around the world in order to understand the possible impacts of EU exit on trade flows and the overall economy in the long run.

87. Box 4.A below provides an overview of CGE modelling, while sections 4.1 and 4.2 describe the Government's model. Section 4.3 describes the data used. Section 4.4 sets out how uncertainty is treated throughout in the calculation and presentation of ranges around the results, and analysis of sensitivities around key policy parameters and modelling assumptions.

Box 4.A: CGE models

CGE models used in trade analysis focus on trade linkages in the global economy. They make it possible to quantify the impact of changes in trade policy on the economy in the long run.

These models represent various economic activities including production, consumption, investment and public provision by economic agents including firms, consumers and governments in a set of equations. They can allow for a large number of countries, and for a large number of sectors in each country, to give a stylised yet detailed representation of the economy.

They provide a coherent macroeconomic framework to estimate the economic impact of a trade policy change, taking into account the many interactions within the economy, including through supply chains.[76] Hence, output effects capture not only economic activity gained or lost by firms directly engaged in importing or exporting, but also those affected along the supply chain. They estimate a long-term equilibrium where supply and demand in all markets is in balance, and there is full employment of capital and labour.

4.1 Features of the HMG GETRADE CGE model

88. The GETRADE model used in this analysis is based on the GTAP model, which is one of the most widely used CGE models internationally for trade analysis. GETRADE extends the standard GTAP model to capture insights from modern trade theory, especially on the link between trade and productivity. GETRADE can also model how investment might respond to changes in trade and productivity.[77]

89. The GETRADE model is based on established trade theory. It incorporates key channels through which trade impacts on the economy. Like nearly all CGE models,

[76] While CGE models are well suited to capture supply chain responses, as with most structural models, they will not usually capture discontinuities or tipping points where whole markets become uneconomic to serve.

[77] GETRADE was built for the Government by Prof. Thomas Rutherford and Prof. Christoph Böhringer. More detail on its most important features is available in a forthcoming paper: Balistreri, Edward, Christoph Böhringer and Thomas F. Rutherford, Quantifying Disruptive Trade Policies (Working Paper), 2018.

GETRADE builds Ricardian comparative advantage and Armington benefits from variety into its foundations. It goes beyond this by incorporating more modern evidence-based benefits from trade motivated by Melitz-style increases in productivity due to enhanced competition. In addition, services firms can also access other markets by commercial presence, allowing the model to capture Mode 3 trade.[78]

Table 4.A: Drivers of trade effects on the economy

Driver of trade effect	How included in the Government's CGE modelling	Used widely in other trade analysis?
Ricardian comparative advantage (countries and firms specialise)	Country-specific costs of production for each sector gives rise to patterns of comparative advantage.	Central to all modern trade modelling, included in purely static CGE models.
Armington benefits to consumers and firms ('love of variety')	Firms use varieties of imported inputs, and using a greater variety of inputs reduces costs of production.	Central to all modern trade modelling, included in purely static CGE models.
Krugman scale effects	Changes in the number of firms in the economy affect aggregate productivity.	Central to modern trade modelling.
Melitz effects due to increased competition[79]	Lower trade costs are assumed to lead to changes in the numbers of firms active in each market, which affect productivity.	Central to modern trade modelling.
Capital accumulation channel	Changes in productivity (from changes in trade) affect returns on capital, the levels of investment and capital in the economy and a change into the capital to labour ratio. This channel is not 'turned on' for the Government's core GETRADE estimates, but is included in sensitivity analysis.	Less extensively utilised.

4.1.1 Gains from specialisation

90. Ricardian comparative advantage has long been seen as a principal motivation for trade, as well as a key source of trade's benefits to the economy. Trade allows each country to specialise in sectors where they have a comparative advantage, increasing whole economy productivity.

91. Ricardian comparative advantage is captured in GETRADE by allowing costs of production to vary across countries and sectors, according to their technologies, available resources and costs of labour and capital.

[78] Note: although Mode 3 trade is included in GETRADE, a full treatment of FDI is not included.
[79] Melitz, M., 'The impact of trade and aggregate industry productivity', NBER Working Paper 8881, 2002.

4.1.2 Gains from increased variety

92. Models based exclusively on Ricardian comparative advantage, however, predict a high degree of concentration in production, which sits uneasily with the phenomenon of cross-hauling (the simultaneous importing and exporting of the same good) that is observed. To address this gap in the theory Armington formalises a further channel through which trade benefits consumers and firms, a 'love of variety'. His model allows consumers to differentiate between domestically produced and imported goods and services (for example Swiss and French cheese). Even in the absence of comparative advantage, consumers may benefit from trade if they value variety. Firms, too, may benefit from increased variety if a greater variety of inputs makes their production more efficient.

93. Access to a wider variety of goods and services benefits consumers. Broda and Weinstein estimate these welfare gains to be either 2.6, 5.1 or 8.6 per cent over 30 years in the US depending on the methods and parameters used.[80]

94. Armington variety effects are captured in GETRADE by allowing firms to use varieties of inputs, where access to and use of a greater range of varieties leads to lower production costs.

4.1.3 Gains to productivity and increasing returns to scale

95. Modern trade theory emphasises additional channels by which trade can affect productivity. When firms have access to new markets, they are able to increase their scale of production. This can lead to efficiency gains where there are 'increasing returns to scale'. This channel was first described by Krugman.[81]

96. Melitz emphasises the importance of firm heterogeneity in driving productivity gains from trade.[82] Opening to trade exposes lower productivity firms to competition from higher productivity, lower cost firms. Domestic demand then shifts away from the lower productivity firms while access to foreign markets provides greater opportunity to the more productive firms. As a greater proportion of output is now produced with greater efficiency, average productivity in the economy increases.

97. In GETRADE, a change in the number of firms (varieties) influences productivity. In a Krugman model, the key simplifying assumption would be that all varieties are sold in all regions. However, GETRADE extends the standard Krugman structure to allow for a representation of independent firm entry, thus capturing firm-level productivity effects.[83] This approach is motivated by the bilateral selection margin key to trade responses in the Melitz model, but avoids the complexity associated with linking selected export firms to the pool of entered domestic firms with heterogeneous technologies. This complexity is difficult to model robustly and reliably in models with

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80 Broda, C. and Weinstein, D. E., 'Globalization and the Gains from Variety', The Quarterly Journal of Economics, 2006.

81 Krugman, P., 'Increasing Returns, Monopolistic Competition, and International Trade', Journal of International Economics, p.469-479, 1979; Krugman, P. 'Scale Economies, Product Differentiation, and the Pattern of Trade', The American Economic Review, Vol.70, No.5, p.950-959, 1980.

82 Melitz, M. J., 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', NBER Working Paper, 2003.

83 This "bilateral representative firm approach" is described in a forthcoming paper by Balistreri, Boehringer and Rutherford. Balistreri, Edward, Christoph Böhringer and Thomas F. Rutherford, Quantifying Disruptive Trade Policies (Working Paper) (2018)

high sectoral and regional dimensionality. Like the Krugman model, goods and services are differentiated by region of origin, but not all goods from region *r* are necessarily sold in all regions *s*.

98. Only those sectors which are imperfectly competitive have scope for these kinds of productivity gains, as numbers of varieties might be indeterminate otherwise. Some sectors are assumed to be perfectly competitive with constant returns to scale (CRTS) in GETRADE, and some are assumed to be imperfectly competitive with increasing returns to scale (IRTS). Some sectors are assumed to be mixed CRTS and IRTS.[84]

4.1.4 Gains from increased investment

99. When productivity increases, so too do the returns to capital. Increased returns to capital lead to increases in the capital stock. Though not included in the core GETRADE results, this channel is included as a sensitivity to understand the importance of accounting for capital accumulation effects. When GETRADE's investment channel is 'on', the capital stock adjusts downward to a reduction in productivity.[85] In dynamic models, there are also transition effects to adjusting the capital stock, as consumption adjusts over the transition to a lower capital stock. GETRADE does not account for such transition impacts, and so the GDP impacts from the investment channel should be treated as upper bounds.

4.1.5 Empirical evidence on the relative importance of different channels

100. Kehoe, Pujolas and Rossbach[86] examine the performance of purely static CGE models in predicting the impact of trade agreements. They compare the model predictions to the actual increases in trade and welfare that occurred after trade agreements are implemented. The authors conclude that purely static CGE models tend to underpredict the realised welfare and trade gains, and indicate that including extensive margin effects like those described by Melitz are likely to improve their performance.

101. The importance of Melitz-style effects is supported by the empirical evidence, which finds benefits from increased productivity due to greater competition[87] as well as impacts on firms' investment decisions.[88] Much of this literature decomposes the increases in trade into increases along the extensive and intensive margins. Growth in the extensive margin of trade is attributed to Melitz-style effects of firm entry, while

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84 CRTS sectors are: public administration, defence, education and health; energy; water and transport services. IRTS sectors are: chemical, rubber and plastic products; motor vehicles and parts; machinery and equipment; other manufacturing; business services; construction; financial services and insurance; recreation, communication and trade. "Agriculture, beverages, tobacco and food" is comprised of four sub-sectors: "agriculture" and "processed food" are classified as CRTS while "other food and drink" and "beverages and tobacco" are classified as IRTS.

85 This investment channel does not, however, distinguish between domestic and foreign investment, nor does it capture any spillover effects from foreign direct investment (FDI) on technology or productivity.

86 Kehoe, T., Pujolas, P., and Rossbach, J., 'Quantitative Trade Models: Developments and Challenges', Federal Reserve Bank of Minneapolis Staff Report 537, 2017;

87 Bernard et al., 'Plants and Productivity in International Trade', NBER Working Paper 7688, 2000.

88 Frésard, L. and Valta, P., 'Competitive pressure and corporate investment: evidence from trade liberalization', University of Maryland, 2013.

growth in the intensive margin of trade is attributed to Armington and Krugman-style effects.[89]

102. Kehoe and Ruhl and others[90] have found that the extensive margin is an important factor in explaining the growth in total trade following trade liberalisation, particularly on the varying impact on different sectors or products following a change in trade pattern. Baier, et al. find that the Melitz extensive margin accounts for about 30 per cent of the total increase in trade from entering into deep trade agreements over a ten-year horizon, compared to about 70 per cent for the intensive margin.[91,92] They also find that the extensive margin is more important at longer horizons, in line with the evidence in Bernard, et al.[93] Over a 10-year horizon, Bernard, et al. find that 24 per cent of increases in US trade were due to firm entry and exit, 42 per cent due to exporters entering new export markets, attributing only 35 per cent of the total increase in trade to the intensive margin.[94] Hummels and Klenow provide evidence that the extensive margin is also important in explaining the GDP impacts of greater trade. Using disaggregated trade data, they find that between 54 and 62 per cent of the GDP elasticity of exports was explained by the extensive margin.[95] This evidence implies that failing to include Melitz-style channels in general equilibrium models would significantly understate the impact of trade agreements on both trade and GDP.

4.1.6 Empirical evidence in support of investment channels

103. Baldwin provides an early attempt at quantifying the magnitude of welfare gains from the capital accumulation channel of trade liberalisation. Based on a range of estimates of the capital-output elasticity around a consensus value of about 0.30, Baldwin estimates that purely static CGE models underestimate the impact of trade liberalisations by between 24 and 93 per cent.[96] A recent paper by prominent trade economists Anderson, Larch and Yotov[97] provides the most up-to-date estimates of the importance of the capital accumulation channel. They find that accounting for capital accumulation effects increases the estimated welfare gains from trade liberalisation episodes by between 50 and 60 per cent. For example, the total welfare gains from NAFTA rise from 5.1 per cent in a purely static framework to 7.7 per cent

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89 Baier et al., 'Economic Integration Agreements and the Margins of International Trade', Journal of International Economics', 2014.

90 This literature builds on Hummels, D. and Klenow, P. J., 'The Variety and Quality of a Nation's Exports', American Economic Review, 2005, and includes Bernard et al., 'The Margins of US Trade', CEP, 2009; Arkolakis, C., 'Market Penetration Costs and the New Consumers Margin in International Trade', NBER Working Paper 14214, 2008; Kehoe, T. J. and Ruhl, K. J., 'How Important is the New Goods Margin in International Trade?', Journal of Political Economy, 2013; Baier et al., 'Economic Integration Agreements and the Margins of International Trade' Journal of International Economics, 2014.

91 Baier et al., 'Economic Integration Agreements and the Margins of International Trade' Journal of International Economics, 2014, defines deep trade agreements to be customs unions, common markets and economic unions including the EU.

92 30 per cent and 70 per cent represent the respective proportions of the extensive and intensive margin of the sum of both margins.

93 Bernard, et al.,The Margins of U.S. Trade', CEP, 2009.

94 Bernard, et al., 'The Margins of US Trade', CEP, 2009.

95 Hummels, D and Klenow, P. J., 'The Variety and Quality of a Nation's Exports', 2004.

96 Baldwin, R., 'Measurable Dynamic Gains from Trade', The Research Institute of Industrial Economics, 1992.

97 Anderson, J., Larch, M., and Yotov Y., 'Growth and Trade with Frictions: A Structural Dynamic Framework', NBER Working Paper 21377, 2015.

when capital accumulation effects are included.[98] In the sensitivity analysis of GETRADE with endogenous capital turned on, the output impact of moving to a no deal scenario increases by about 2.3 percentage points, in line with the lower end of Baldwin's estimates.

4.2 GETRADE model structure

104. The GETRADE model builds on a standard multi-regional, multi-sectoral CGE model of global trade (see Lanz and Rutherford for a detailed description of the basic model logic).[99] GETRADE is an extended version of this core GTAP model, which incorporates increasing returns to scale and Melitz-style effects for selected sectors. GETRADE also allows for Mode 3 services provision by commercial presence. GETRADE has an investment channel, which is switched off when generating the main results, but switched on as a sensitivity.

4.2.1 Overall model structure

105. Each region has a representative agent who supplies labour and capital and receives wages and returns on capital investments as income. Representative agents also receive government transfers from the redistribution of tax revenue. Their income can be used in three ways: private consumption of domestic and imported goods and services; government expenditure; or savings. Private and government consumption lead to demand for domestic and imported goods and services, while savings drive investment. When the 'investment channel' is turned on, investment and the amount of capital in the economy responds to the rate of return on capital, with each economy's capital stock rising in response to higher returns on capital and falling in response to lower returns. When the 'investment channel' is turned off, savings and investment are exogenously fixed.

106. On the production side of the economy, domestic output in each modelled region is created by using intermediate inputs, labour, capital, land and natural resources. Gross value-added is the output produced by labour and capital employed by the firm, while intermediate inputs are purchased from other industries and possibly regions. Production output of good or service *i* in each region *r* enters final demand of the representative agent, export demand and input demand for the production of other goods and services both domestically and in other regions. Production for each Armington good or service *i* in region *r* is based on a constant-elasticity-of-substitution (CES) technology that combines the domestically produced goods and services with imports from other regions *s*. Armington outputs serve as intermediate inputs to the production of all goods and services, including final demands.

107. A nested two-level CES cost function is used, which captures substitution possibilities between primary factor inputs and intermediate inputs. At the bottom level all primary factors (including labour and capital) enter a CES value-added composite whereas all intermediate inputs enter a CES material composite. At the

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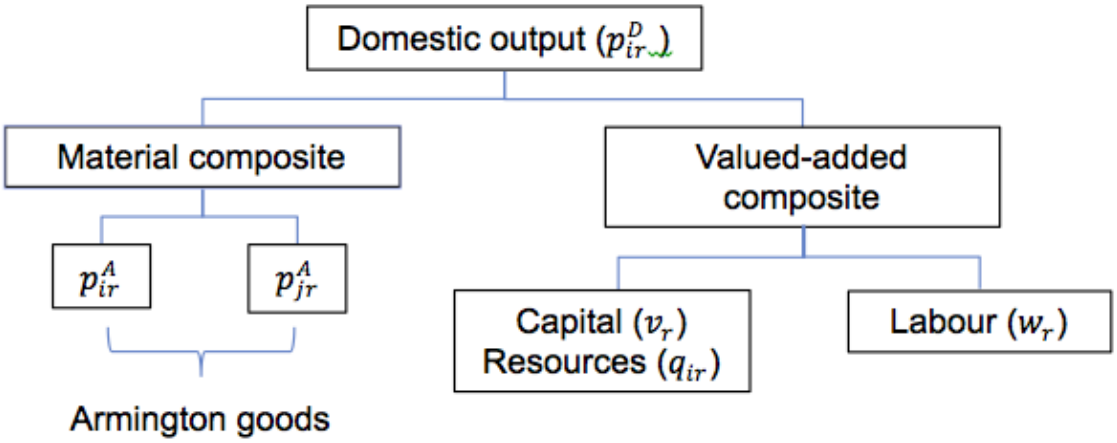
98 In both cases, the analysis refers to the welfare gains which include transition effects. That is, it cites the estimated welfare gains in Anderson et al 2015 which include both the increased welfare from a higher steady-state capital stock after trade liberalisation and the reduced welfare along the transition path as households reduce consumption to build up the higher capital stock.

99 Lanz, B., and Rutherford T. 'GTAPINGAMS: Multiregional and small open economy models' Journal of Global Economic Analysis, 1(2), pp. 1-77, 2016.

top level the value-added composite and the intermediate input composite trade off with a constant elasticity of substitution. The nesting structure in production is captured in Figure 4.A.

Figure 4.A: Generic production structure



Where:
P_{ir}^{D} is the price of domestically produced good *i* produced in region *r*;
P_{ir}^{A} is the price of Armington good *i* in region *r*;
w_r is the wage rate in region *r*;
v_r is the price of capital services in region *r*; and
q_{ir} is the rent to land and natural resources in region *r*.

108. Representative agents and firms are linked with foreign firms via international trade. Firms and representative agents demand both imported and domestic goods and services. Domestic and imported products are not perfect substitutes, and the rate at which imports can be substituted for domestic goods or services depends on the relative price of imports and consumers' preferences between foreign and domestic goods. Firms supply goods to both domestic and foreign markets. How much of firms' output goes to each market depends on the price at which the firm can sell its products at home and abroad.

109. There are several types of both labour and capital. Labour is broken down into five different skill levels. Each skill level earns a different wage. The model assumes that there is perfect labour mobility between sectors in the same country, but no mobility at all across skill levels or countries. Labour adjustment costs, for instance as a result of the need to retrain or relocate workers, are not taken into account. Also, consistent with the standard assumptions in long-term models, GETRADE assumes full employment of labour and capital, because in the long run the economy has had time to adjust to new trade policy, and any displaced workers have found new jobs in other industries. There are also two types of capital: sector-specific capital which cannot move between sectors, and general-purpose capital which can.

4.2.2 Production details in CRTS sectors

110. In the constant returns to scale (CRTS) sectors, the Armington goods and services are formed at the industry level as a CES composite of the domestic output and a

CES import composite of imports from all trading partners. The Armington composite in the CRTS trade model with regionally differentiated goods is represented as nested two-level CES function. At the bottom level, imports from different regions form a CES import composite. At the top level, the import composite trades off with the domestically produced good subject to a constant elasticity of substitution. The zero-profit condition for Armington good production in the CRTS model variant is:

$$p_{ir}^{A} = \left[\theta_{isr}^{A} p_{ir}^{D\,1-\sigma_{ir}^{DM}} + (1-\theta_{ir}^{A}) \left[\sum_{s} \theta_{isr}^{MM}\ p_{is}^{D\,1-\sigma_{ir}^{MM}} \right]^{\frac{1-\sigma_{ir}^{DM}}{1-\sigma_{ir}^{MM}}} \right]^{\frac{1}{1-\sigma_{ir}^{DM}}}$$

Where:

θ_{ir}^{A} is the cost share of domestic input to Armington composite in sector *i* and region *r*;

θ_{isr}^{MM} is the cost share of imports from region *s* in import composite of commodity (sector) *i* in region *r*;

σ_{ir}^{DM} is the substitution elasticity between domestic input and import composite for commodity (sector) *i* and region *r*;

σ_{ir}^{MM} is the substitution elasticity between imports from different regions.

4.2.3 Production details and including firm-specific productivity effects

111. Allowing for Melitz-style channels through the bilateral representative firms approach involves adapting the specification of the production function for Armington goods and services. In the increasing-returns to scale (IRTS) sectors, Armington supply is based on a Dixit-Stiglitz aggregation of bilateral trade at the firm level where changes in the number of firms (varieties) influence productivity. Bilateral firm-level supply is determined by a composite of domestic and imported inputs in fixed proportions together with firm-specific capital. The elasticity of substitution between specific capital and the composite trade inputs is calibrated to match an exogenous supply elasticity.

$$p_{isr}^{X} = \left[\theta_{isr}^{\kappa} \kappa_{isr}^{\ 1-\sigma_{isr}^{X}} + \left(1-\theta_{isr}^{\kappa}\right) \left(\sum_{s} \theta_{isr}^{X} p_{is}^{D} \right)^{1-\sigma_{isr}^{X}} \right]^{\frac{1}{1-\sigma_{isr}^{X}}}$$

Where:

p_{isr}^{x} is the bilateral supply price for commodity *i* shipped from region *s* to region *r,*

K_{isr} is the specific rent to firm delivering commodity *i* from region *s* to region *r,*

θ_{isr}^{K} is the cost share of specific rent in the total value of bilateral trade supply of commodity *i* from region *s* to region *r,*

θ_{isr}^{x} is the cost chare of bilateral trade supply from region *s* to region *r* in the composite of multilateral trade supply to region *r,*

σ_{isr}^{x} is the substitution elasticity between specific capital and the composite of bilateral trade flows.

112. With firm-level bilateral trade supply, the Armington composite in the IRTS model can be specified to capture productivity impacts from Dixit-Stiglitz aggregation across firms. In the Melitz-style variant a change in the number of firms (varieties) influences aggregate productivity. The model assumes that not all varieties from region *r* are necessarily sold in every region *s*, thus allowing for a representation of firm entry.

113. Given the assumption that fixed and variable cost indices are identical for each representative firm supplying good *i* from region *s* in region *r*, output per firm is constant. This implies that the number of firms is equal to the activity level of firm-level bilateral supply.

114. The zero-profit condition for Armington supply in the IRTS variant is:

$$p_{ir}^{A} = \left(\sum_{s} \left(\theta_{isr}^{XA} X_{isr} p_{isr}^{X} \right)^{1-\sigma_i^{XA}} \right)^{\frac{1}{1-\sigma_i^{XA}}}$$

Where:
$\theta_{isr}^{XA}$is the Dixit-Stiglitz cost share of firm-level export of commodity *i* from region *s* to region *r* in aggregate value of Armington supply of region *r*;
$X_{isr}$is the activity level of firm-level bilateral supply; and
$\sigma_i^{XA}$is the firm-level elasticity of substitution.

4.2.4 Cross-border provision of services through commercial presence

115. GETRADE allows for two types of firms: firms which trade exclusively via cross-border provision (Mode 1) and firms whose cross-border trade requires commercial presence (Mode 3).[100] The two types of firms are differentiated on the basis of domestic and import value shares. In commercial presence sectors with service, the supply by firms from region *r* to region *s* is portrayed by a Leontief aggregation of foreign and domestic inputs, so that service provision in these sectors requires both foreign and domestic inputs. Firm-level export supply of commodity *i* from region *r* into region *s* is hence given as:

$$X_{irs} = min\left[E_{irs,}, D_{irs}\right]$$

where E_{irs} denotes cross-border provision of sector i services from region r delivered in region s, e.g. commercial presence in region s and D_{irs} are domestic factors employed, e.g. domestic workers employed by a foreign-owned firm.

116. GETRADE makes it possible to assign each sector to different supply and production modes, either as CRTS sectors, or IRTS sectors with cross-border trade only, or IRTS with cross-border trade and commercial presence.

[100] According to the General Agreement on Trade in Services (GATS) there are four modes of supply which depend on presence of the supplier and the consumer at the time of a transaction. Mode 1 or cross-border provision involves a user in country A receiving services from another country. Mode 3 or commercial presence occurs when a service is provided in country A by a locally-established affiliate, subsidiary, or representative office of a foreign-owned and -controlled company.

4.3 Data

117. GETRADE assigns values to model parameters and underlying input-output linkages using real-world economic data. When these values are observable, such as GDP for all countries in the model, tariffs or trade volumes and input-output links, economic data from the GTAP 9 database is used. When these values are not directly observable, such as for elasticities which govern how consumers and firms react to changes in prices and costs, empirical estimates from the GTAP database are used.

118. The GTAP 9 database brings together Input-Output tables from 147 countries and is the key data input in GETRADE. The GTAP 9 database is widely used in CGE modelling, fully documented and publicly available.[101] The GTAP 9 database also provides a set of empirically estimated elasticities, which determine how consumers and firms respond to price changes. These elasticities differ between countries and industries.

4.4 Sensitivity analysis

119. There are a number of sources of uncertainty inherent to any modelling exercise. The main ones are uncertainty over the policy parameters such as non-tariff barriers (NTBs), and uncertainty over the other parameters in the model such as the behavioural responses of businesses and households.

120. This is dealt with in two main ways in the results that are presented. Firstly, uncertainty around key model and policy parameters is represented by ranges around central results derived through Structural Sensitivity Analysis (SSA). A Monte Carlo approach is followed, drawing policy parameters from a log-normal distribution around the central estimates in all scenarios excluding the modelled EEA-type, where a draw is taken from a normal distribution. Model parameters are drawn from a uniform distribution. These distributions are either based on the estimated statistical distributions in the econometrics (e.g. for NTBs) or the literature in the case of other parameters. Thousands of samples are taken and modelled and the ranges are chosen so that there is a 90 per cent probability that the true value lies within that range.

121. Table 4.B shows the model parameters and values which are varied in order to generate the range of results.

[101] 'Global Trade Analysis Project', (GTAP)

Table 4.B: Summary of model parameters and values varied in sensitivity analysis

Parameter	Definition	Distribution used	Range of values
UK-EU NTBs	Estimated NTBs on UK-EU trade (AVE)	Normal (modelled EEA-type) Log-normal (All other scenarios)	Statistical distributions estimated econometrically around central estimates (see Table 2.E)
NTB symmetry parameter	Scalar to reflect the fact that NTB increases on leaving an FTA may not be as high as reductions on joining one	Uniform	70 - 100 per cent (midpoint 85 per cent)
Technical and rent-generating NTB ratio	Ratio of NTBs assumed to be efficiency-reducing or rent-generating	Uniform	55:45 - 85:15 (midpoint 70:30)[102]
Sigma (σ_i^{XA})	Firm-level elasticity of substitution between varieties	Uniform	2 - 5 (midpoint 3)
eta_V	Scalar altering the magnitude of the bilateral export supply elasticity	Uniform	0.5 - 1.5 (midpoint 1)

122. Varying key model parameters leads to adjustments in the results.

- A higher value of the asymmetry parameter shifts the entire NTB distribution upwards, increasing the GDP losses from imposing trade barriers.
- A lower value of sigma increases the GDP gains from additional trade. This is because lower values of this elasticity imply that varieties are less similar and less substitutable, so additional varieties are worth more to firms and consumers.
- A higher value of eta_V increases the GDP gains from reductions in trade barriers. This is because larger values of this parameter makes bilateral firms more responsive to trade barriers, leading to a greater increase in the number of varieties from a given change in trade barriers.
- A higher proportion of technical NTBs will increase the GDP gains from lower trade barriers. This is because efficiency-reducing NTBs result in a pure loss of efficiency, whereas rent-generating NTBs include a redistribution of income.

123. A number of different variants have been run for the main policy scenarios to reflect either different assumptions about key policy parameters or different modelling assumptions. The results of these sensitivities are discussed in the analysis document.

[102] EEA-type NTBs are predominantly from customs administration, which imposes a real resource cost. Reflecting this, a 90:10 ratio is used in the EEA-type scenario, with a range of 80:20 to 100:0.

5. Migration

124. Section 5.1 provides an overview of the analytical approach for modelling the macroeconomic effects of changes in migration. Section 5.2 sets out the approach to projecting a EEA work-related immigration baseline. Section 5.3 sets out the migration scenarios and the data and assumptions on employment characteristics and dependants. Section 5.4 outlines how changes in EEA migration inflows affect the structure of the population, and in turn long-term employment projections. Finally, Section 5.5 explains how employment and GDP impacts are derived from migration changes.

5.1 Overview of analytical approach

125. Changes in EEA work-related migration flows are modelled and input into the EU exit scenarios in several steps:

    a. Estimate a baseline profile for net inflows of EEA workers driven by demographic and economic determinants.

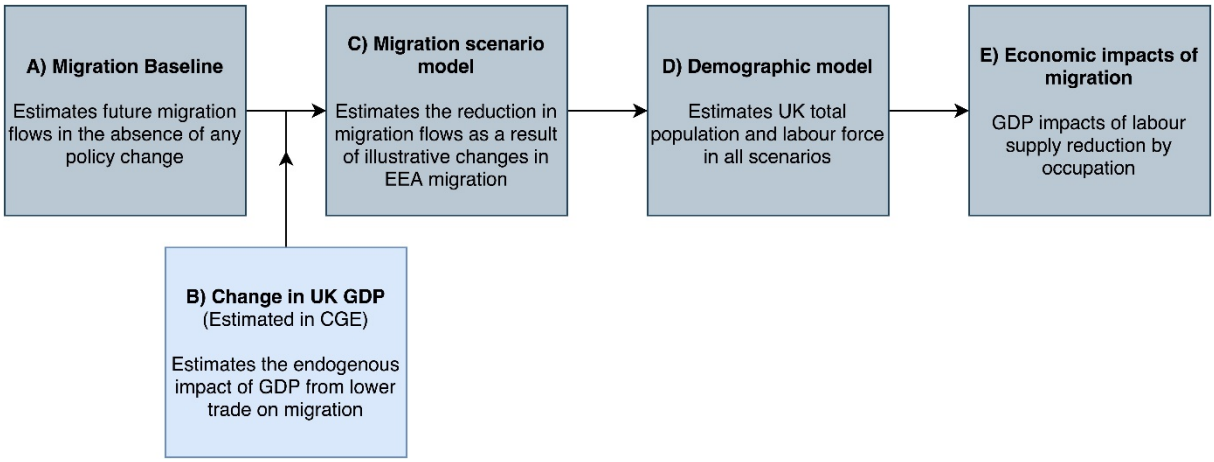
    b. These profiles are adjusted to reflect changes in GDP in the different trade scenarios that affect migrants' decisions to come to the UK.

    c. Then the impact of illustrative migration policy changes on EEA work-related immigration is assessed using a migration scenario model.

    d. The total impacts of (b) and (c) are then assessed relative to the baseline (a) to estimate the long-term changes in the UK's population and workforce.

    e. This effect is then modelled in terms of changes in GDP and GDP per capita effects.

Figure 5.A. Summary of migration scenario modelling



126. Two illustrative variants for migration effects are modelled: one in which there is no change to migration arrangements; and one in which there are zero net inflows of EEA workers. It should be noted that neither variant represents government policy.

127. Several important assumptions and caveats apply to the overall modelling. Migration is difficult to project due to the wide range of potential drivers which are themselves uncertain. Estimates are also sensitive to the chosen reference period and the estimated elasticities. The migration projections use the 3 year average inflows between 2013-15 as a starting point. Sensitivity analyses are used to show the impact of using alternative assumptions. In addition, due to limitations in the current migration statistics, short-term migration (<12 months) is not captured in the modelling. Implicitly this is assumed to continue in all scenarios.

5.2 Migration baseline

5.2.1 Inflow Modelling

128. To understand the impact of migration policy choices on economic outcomes, migration paths have to be compared against a common baseline.[103] The Office for National Statistics (ONS) produces a population projection, which includes an estimate of migration.[104] However, this is not split by nationality group or reason for migration. This makes it difficult to separate the work migration flows into/out of EU countries which are the focus of this analysis. For this reason, the analysis projects EEA work immigration taking into account the economic and demographic determinants of migration from the EU.[105]

5.2.2 Model specification, data and assumptions

129. The relationship between EEA work-related immigration and its economic and demographic determinants is estimated econometrically. This approach is consistent with previous empirical studies on migration and the recommendations of the Migration Advisory Committee.[106] The analysis implies:[107]

    a. A 1 per cent increase in relative GDP per capita between EU countries and UK results in a -1.8 per cent change in the EU work-related inflows.[108]

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[103] The CGE modelling analysis assumes fixed employment and population.

[104] National Population Projections: 2016-based statistical bulletin, ONS, October 2017

[105] Ireland is treated separately from the other EEA countries as it will not be subject to the same migration policy changes as the government is committed to the continuation of the Common Travel Area.

[106] Ortega, F and Peri, G, 'The causes and effects of international migrations: evidence from OECD countries 1980-2005', National Bureau of Economic Research, 2009;Portes, J and Forte, G, 'The economic impact of Brexit-induced reductions in migration', Oxford Review of Economic Policy, Volume 33, Number S1, 2017, pp. S31-S44; Disney, G et al. 'Evaluation of existing migration forecasting methods and models', Centre for Population Change, October 2015

[107] The dependent variable is the logarithm of inflows as a percentage of the population aged 20-39 in the EU country the migrants are coming from. Independent variables are defined as follows: Relative GDP per capita is the ratio of the log of GDP per capita between the relevant EU country and the UK; relative unemployment is the difference between the EU country and UK unemployment rate; and the change in relative unemployment is one-year change in the unemployment differential between the UK and the EU country. Coefficients for relative unemployment, change in relative unemployment and relative GDP per capita are statistically significant at 99 per cent level. Standard errors are: 0.03, 0.04 and 0.43, respectively. The effects shown in a) to d) are approximate due to the functional form.

[108] World Economic Outlook Database, IMF, 2018; the implied PPP conversion rate is expressed as national currency per current international dollar, projections for GDP in current prices (converted in PPS) are available.

b. A 1 percentage point change in the difference between unemployment rates results in an 8 per cent change in the EU work-related inflows.

c. A 1 percentage point change in the growth rate of the difference between unemployment rates results in a 10 per cent change in the EU work-related inflows.

d. A 1 per cent increase in population aged 20-39 in the origin country results in a 1 per cent increase in work-related inflows.

130. The model specification uses panel data modelling techniques. In this case, Random Effects (RE) estimation was chosen because the sample includes countries that have highly persistent differences in relative income levels, making it difficult to estimate the effect of relative income in regressions that have country fixed effects. Elasticities derived from other estimation methods used in the literature have been included in the sensitivity analyses.

131. The analysis uses International Passenger Survey (IPS)[109] data for annual inflows from 19 EU countries.[110] The data covers the period between 2005 and 2015.

132. Having derived an estimate for the economic and demographic impact on work-related inflows from the EEA, the estimates are then applied to forecast macroeconomic variables from the International Monetary Fund World Economic Outlook (IMF WEO) to project EEA migration inflows over time.

133. Projections for population, GDP and unemployment for EU countries are sourced from the IMF WEO October 2018 release.[111] For the UK, 2016-based economic projections are used[112].

134. From 2024 onwards, relative GDP per capita is assumed to remain at its 2023 level for the EU14[113], and the speed of convergence is assumed to decelerate for the EU8[114] and EU2[115] countries. All else equal, faster convergence would imply lower levels of immigration into the UK. Population projections, beyond 2023, by country and age are sourced from United Nations Population Projections.[116]

135. The projections use the 3-year average for the inflows between 2013 and 2015 as a starting point.

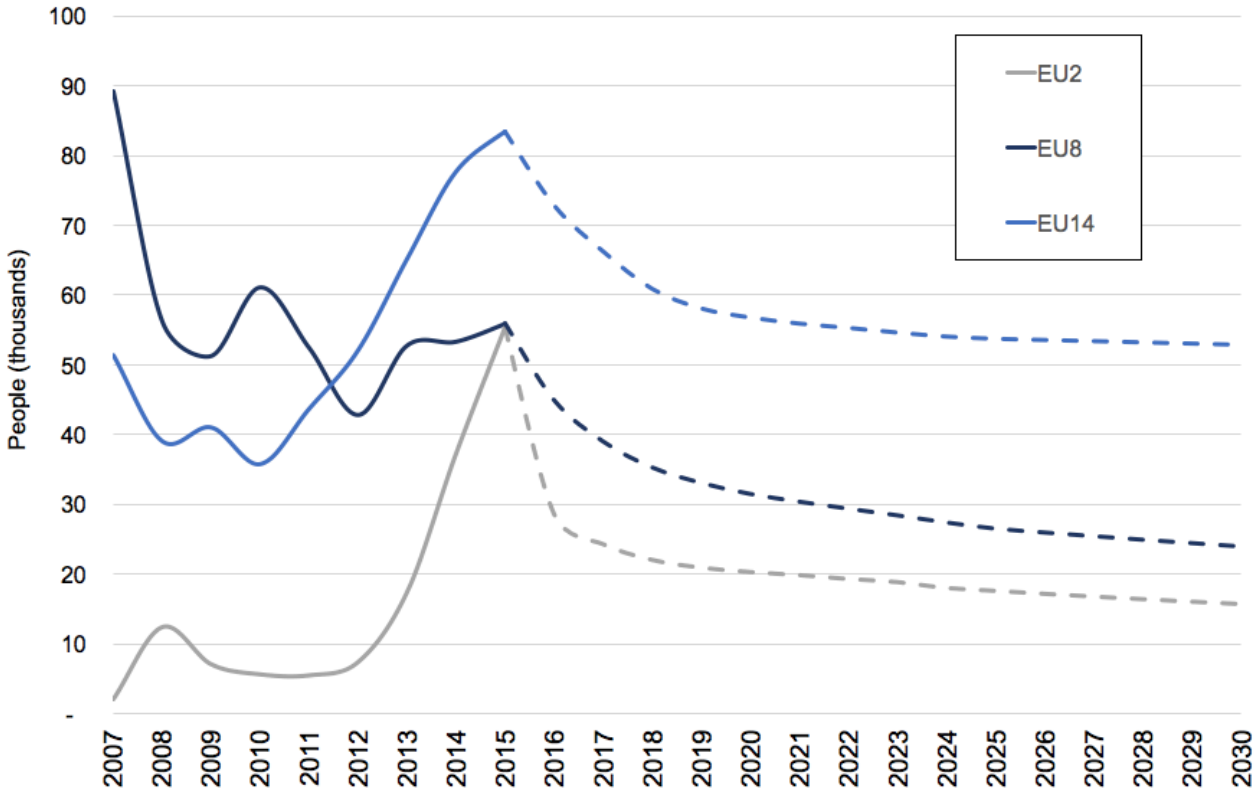
5.2.3 Treatment of uncertainty in the baseline projections

136. The central baseline projection for EEA work-related inflows is expected to fall over time – in the absence of any policy intervention or other outcomes driven by EU exit (Figure 5.B). This reflects the projected decline in the working age population in EU

[109] Analysis of International Passenger Survey' ONS, 2018.
[110] The EU countries not included in the sample are: Luxembourg, Cyprus, Malta, Slovenia, Romania, Bulgaria and Croatia, reflecting data availability. In addition, migration controls remained in place for Romania and Bulgaria until 2014. For these countries, the projections assume that migration flows respond to the demographic and economic determinants according to the estimated regression coefficients. Ireland is also excluded from the sample.
[111] 'World Economic Outlook Database', International Monetary Fund, October 2018
[112] 'World Economic Outlook Database', International Monetary Fund, April 2016
[113] EU14 countries are: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Republic of Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden.
[114] EU8 countries are: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia.
[115] EU2 countries are: Romania and Bulgaria.
[116] 'World Population Prospects 2017', United Nations Population Division, June 2017.

countries and the narrowing gap in the income levels between the UK and other EU countries.

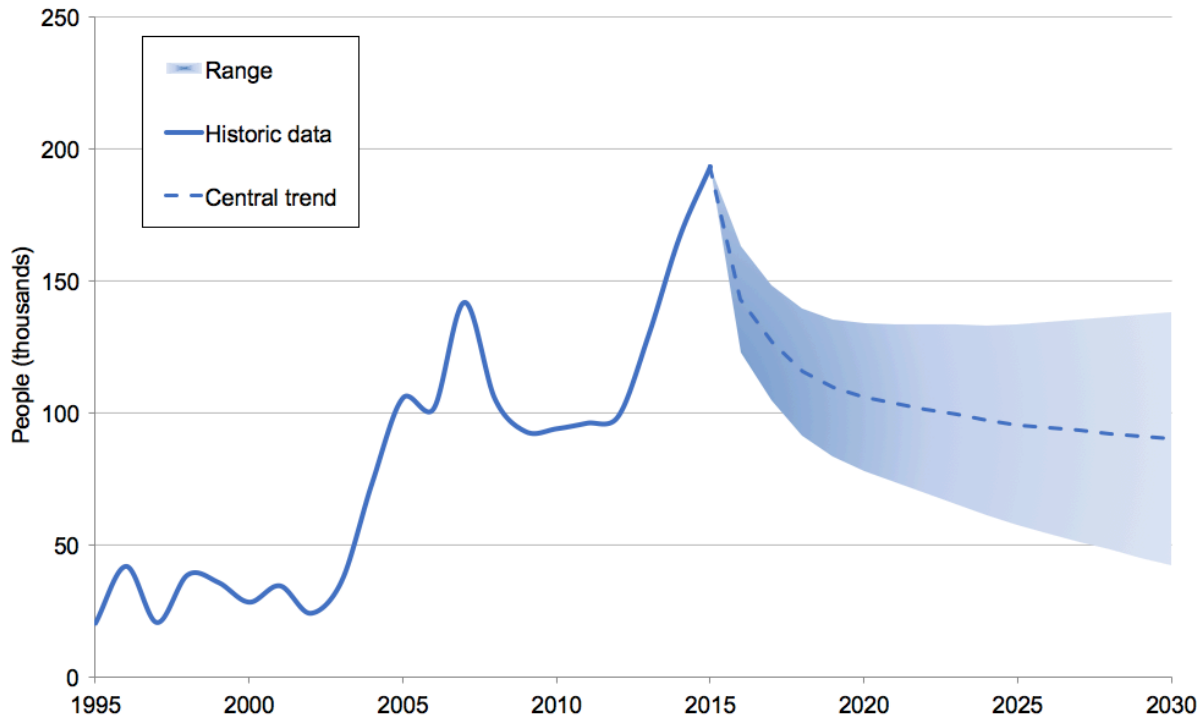
Figure 5.B: Historic work-related inflows from EU14, EU8 and EU2 and projections[117]



137. To illustrate the uncertainty around the central estimates, ranges have been estimated using the 'average' (root mean squared) prediction errors for EU inflows from the regression. The ranges are set at +/-20,000 initially and are assumed to widen over time at a rate of +/- 2,000 each year.

[117] IPS data is adjusted for other inflows such as asylum seekers and flows to and from Northern Ireland to estimate Long-Term International Migration (LTIM). As LTIM estimates are not provided by reason for migration and nationality, the analysis uses the unadjusted IPS estimates in the regression but makes a final adjustment to projections to account for the estimated work-related portion of the LTIM adjustment.

Figure 5.C: Range around central projection of total EEA work-related inflows



5.2.4 Comparison with other studies and sensitivity analyses

138. Studies of migration differ considerably in terms of the measures used, the range of the determinants considered, and the estimation techniques used. It is difficult to assess how each of these differences contribute to the variation in estimated coefficients on the variables of interest.[118] It is assumed that:

a. In the central estimate, gross EEA worker inflows fall to around 85,000 people a year after 2020 (from 191,000 outturn in 2015).

b. Using ranges reflecting the 95 per cent confidence interval for the coefficients found in this analysis suggests that a 1 per cent increase in relative GDP between EU countries and UK could reduce EU work-related inflows between -1 per cent and -2.7 per cent.[119] Applying this range of coefficient estimates suggests inflows of EEA work inflows could average between 95,000 and 80,000 a year after 2020.

c. The estimated ranges for relative unemployment suggests that for a 1 percentage point increase in the difference between the EU country and UK unemployment rates could change EU work-related inflows between 3 per cent

[118] i) Bertoli, S. and Fernández-Huertas Moraga, J., 'Multilateral resistance to migration', IZA Discussion Papers, 2011. ii) Ortega, F. and Peri, G., 'The causes and effects of international migrations: evidence from OECD countries 1980 - 2005', NBER Working Papers, 2009. Authors find a coefficient for the destination income variable of 0.75. iii) Portes and Forte (2017). The economic impact of Brexit-induced reductions in migration. Oxford Review of Economic Policy, Volume 33, Number S1, 2017, pp. S31–S44. iv) Forte, G and Portes, J (2017). Macroeconomic Determinants of International Migration to the UK, IZA DP No. 10802. Authors find that a 1 per cent increase in the unemployment rate in the origin country is associated with an increase in immigration of around 0.35 per cent, although the impact is only significant at the 10 per cent level.

[119] The estimated coefficients on relative incomes range from -0.99 to -2.66.

and 13 per cent. Applying this range of coefficient estimates suggests that inflows from EEA workers could average between 100,000 and 80,000 per annum from 2020.

d. A number of studies consider the impact of the exchange rate, but they do not provide a consistent picture.[120]

5.2.5 Outflow Modelling

139. There is less information available on how outflows respond to economic determinants. Therefore, outflows are modelled in a simpler manner. The ONS data on length of stay of EU migrants is used to make an assumption that outflows are a function of the EEA stock in the country. If outflows respond to economic conditions, outflows levels could be higher under the scenario of current migration arrangements due to changes in GDP.

140. In order to estimate the total net migration of EEA workers, outflows are related to cumulative inflows. The ONS provides estimates of long-term EU emigrants by year of previous arrival between 2005 and 2016.[121] This allows the estimation of a 9-year profile for length of stay of outflows (averaged over 2013-15). Due to lack of data by individual year of arrival prior to 2005, the outflows profile beyond 9 years cannot be estimated.

141. The 9-year outflow profile is applied to historic EEA inflows; these results are then compared to actual outflow data to infer the proportion of EEA inflows that eventually leaves the UK. Based on this, it is estimated that 40 per cent of EEA inflows leave the UK within 9 years. Given the data availability, all EU migrants who are estimated to leave the UK are assumed to do so within 9 years of arrival.

142. The approach assumes the behaviour of EEA migrants in terms of the proportion choosing to stay in the UK and length of time in the UK remains stable over time. It is also assumed that outflows have the same occupational distribution as the stock of EEA nationals.

5.2.6 Net migration of EEA workers

143. Estimated inflows and outflows are combined to create a baseline for net EEA work-related migration to the UK.

144. For the other nationality groups, the central estimate for Rest of World (RoW) and student net migration are assumed to stay flat at their 2013-15 average levels. The response of RoW inflows to economic and demographic factors is already restricted by migration policy, and student migration flows are driven by a range of factors including the policy environment.

145. For simplicity, the profile of native flows has also been held constant. IPS data on UK natives shows that gross flows are not large, which implies that a relatively large shock or behavioural change would be required to generate a material impact on the UK labour force.

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120 Portes and Forte (2017); Forte and Portes (2017) ibid

121 'International Passenger Survey estimates of long-term international emigration from the UK of former immigrants, by citizenship and year of previous arrival in the UK, 2005 to 2016', ONS, December 2017

5.3 Migration scenario modelling

5.3.1 Migration scenarios

146. The migration scenario model assesses the impact of illustrative changes in immigration policy, taking into account the employment and wage characteristics of the EEA worker migration flows.

147. Freedom of movement will end as the UK exits the EU. Future migration policy will be set out in a future White Paper. As such, specific migration policies are not modelled.

148. Under the modelled no deal, modelled White Paper and modelled average FTA scenarios, the analysis has modelled two illustrative variants for migration policy: one in which there is no change to migration arrangements; and one in which net inflow of EEA workers is assumed to be zero. These scenarios show a wide range of impacts and are not intended to indicate any future migration policy, nor should any midpoint be taken as the anticipated effect of any future policy. These migration impacts do not apply to the modelled EEA-type scenario.

5.3.2 Employment characteristics of flows: data and assumptions

149. The model uses a combination of data on flows and the current stock of EEA workers. Flow data from the IPS 2013-2015 is used to inform whether a migrant is a worker or dependant and their age profiles.

150. There is a lack of comprehensive data on the employment characteristics of flows; therefore, the employment and occupational profile of the EEA stock is taken as a proxy to inform where EEA workers may decide to work when they arrive and their salaries. A key caveat of this model is that it is assumed that the characteristics of the stock of EEA nationals are a reasonable proxy for the future flows, in the absence of any policy change.

151. The analysis uses the Annual Population Survey (APS) pooled dataset (2014-2016). APS indicates the current occupations at four-digit Standard Occupational Classification (SOC) level for EEA migrants.[122]

152. The models are static; they do not account for changes in migrant behaviour or labour market responses as a result of policy changes.

5.3.3 Dependants: data and assumptions

153. The number of dependants assumes a dependency ratio of 0.13 based on the data from the IPS. The dependency ratio is assumed to remain constant across the scenarios, implying that the number of dependants reduces proportionally with reductions in inflows.

154. Data on migrant flows does not further break down accompanying/joining migrants by economic activity, but to consider the total labour market impact, the total number of working dependants in any given scenario is estimated. The analysis uses APS (2016) data which implies an activity rate of 58 per cent for EEA adult dependants. Given 39 per cent of dependants are children, this implies 35 per cent of dependants are assumed to be workers.

[122] 'Annual Population Survey: 2014-16', ONS, 2018

5.4 Demographic model: Estimation of the size of UK's workforce

155. This section outlines how changes in net inflows of EEA workers affect the projected size and age structure of the population, which in turn affects long-term employment projections. Long-term employment projections are derived using population projections by age and nationality estimated through a demographic 'cohort' model and participation and employment rate projections that reflect the latest OBR forecast. This is similar to the approach that the OBR takes in its fiscal sustainability reports (FSR) to derive its long-term employment growth projections based on ONS population projections.[123]

5.4.1 Model specification

156. The net migration projections are input into a demographic model to estimate the potential size of the UK's workforce under the different scenarios.

157. The demographic model follows the ONS methodology and assumptions used in its population projections to produce population projections by age and nationality.

5.4.2 Data and assumptions

158. The population projections use data for 2015 as a starting point. The population is broken down by nationality, age and gender using APS analysis. Births and deaths are estimated using ONS mortality and fertility rates, which do not vary by nationality.[124]

159. The number of people active in the labour market is then estimated using Labour Force Survey (LFS) participation and employment rates specific to each gender, age and nationality group. Over time, the analysis assumes that these rates grow in line with the OBR's assumptions in the 2018 FSR[125] accounting for different growth rates by age group. The growth in the participation rate is not assumed to vary by nationality.

160. The age profile of migration flows is based on official statistics on long-term international migration.[126]

5.5 Employment and GDP impacts of migration changes

161. A production function is used to specify how labour employed by each occupation contributes to output. The GDP impact of lower migration is estimated using a constant elasticity of substitution (CES) function. This expresses GDP as a combination of the output produced by the workforce split into nine occupational groups.

162. For each scenario, an estimate of the effects of lower migration on the UK labour supply by 2035 is used to estimate the impact on GDP. The reduction in the

123 'Fiscal sustainability reports', OBR, July 2018.
124 Changing trends in mortality: an international comparison: 2000 to 2016', ONS, August 2018
125 Fiscal sustainability report, OBR, 2018
126 'Long-term International Migration 4.07', ONS, November 2016

workforce is wage-adjusted to take account of the wage shares of each occupation using wage data.[127] This allows the model to reflect the higher proportion of EEA migrants working in lower skilled/ lower wage occupations.

163. This framework can be expressed as:[128]

$$Y = Z^{\frac{1}{\gamma}}$$

Where:

$$Z = \sum_{j=1\ to\ 9} a_j\, L_j^{\gamma}$$

Y denotes aggregate output
γ is a function of the elasticity of substitution between the occupations σ: $\gamma = \frac{\sigma-1}{\sigma}$
L_j is the workforce in occupation *j*
a_j is the income share of occupation *j*

164. Using this method, an elasticity of between 0.7 and 0.9 is estimated for a labour supply shock on GDP. The elasticity depends on the skill mix of the EEA migrants and the specificities of the migration scenario modelled. In the scenarios used in the present analysis, which assume a proportionate reduction in EEA workers across the skills spectrum, the elasticity found is in the region of 0.9. Scenarios targeting lower skilled/lower paid EEA workers would have a lower GDP elasticity[129].

165. Changes to GDP per capita are also estimated. In the migration scenarios GDP per capita tends to change but by less than GDP as the change in the population offsets part of the change in GDP. Typically, GDP per capita is affected in the same direction as the effect on GDP because a higher proportion of EEA migrants are of working age and in employment than the population as a whole.

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[127] "This uses a dataset combining Annual Survey of Hours and Earnings with the Migrant Workers Scan through National Insurance Number data

[128] Hertel et al., Behavioural parameters, Centre for Global Trade analysis, 2016. A value of 1.3 has been chosen for σ . GTAP substitution of factors of production vary across sectors from 0.2 to 1.7, with a modal value of 1.3.
Karabarbounis, L. and Neiman, B., 'The global decline of labour share', NBER Working Papers, 2013 estimated it is also close to the value of 1.25 for the elasticity of substitution between labour and capital.

[129] Sensitivity analysis indicates that this ratio is not very sensitive to changes in the elasticity of substitution between each occupation in the production function.

5.5.1 Results

Table 5.A: Summary of labour supply and GDP impacts of changes in migration for the illustrative zero net inflows of EEA workers and no change to migration arrangements scenarios, compared to today's arrangements[130]

Compared to today's arrangements (per cent change)	Modelled no deal	Modelled average FTA	Modelled EEA-type	Modelled White Paper	Modelled White Paper with 50 per cent NTB sensitivity[131]
Zero net inflows of EEA workers					
Labour supply	-2.1	-2.1	n/a[132]	-2.1	-2.1
GDP	-1.8	-1.8	n/a	-1.8	-1.8
No change to migration arrangements					
Labour supply	-0.2	-0.1	0.0	0.0	-0.1
GDP	-0.2	-0.1	0.0	0.0	0.0

5.5.2 Comparison with the literature

166. Several studies have looked at the GDP impacts of changing net migration levels from the EU.[133] Most studies found that a percentage reduction in labour supply leads to a roughly similar percentage fall in GDP.

167. NIESR estimate a reduction in GDP of about 9 per cent by 2065 from a more restrictive migration policy. The migration scenario assumes 93,000 fewer EU migrants annually, which reduces labour supply by 9 per cent over the same period. The fall in GDP per capita over same period is much lower (0.8 per cent). An alternative scenario, which assumes that EU migrants are subject to a high skills threshold, leads to a slightly lower GDP impact of about 8.6 per cent.[134]

168. Portes and Forte[135] find that for a 0.15 per cent reduction in UK's population (as a result of a fall in annual net migration of 100,000 between 2017 and 2020), GDP

[130] Impacts of 0.04 per cent or smaller are rounded to 0.0 per cent.
[131] The sensitivity reflects 50 per cent of the difference in non-tariff barriers between the modelled White Paper and modelled average FTA scenarios. Implicitly, the modelled White Paper scenario represents zero per cent on this range, and the modelled average FTA scenario represents 100 per cent. This midpoint is illustrative only and does not represent an expected outcome.
[132] Analysis assumes no change to migration arrangements in a modelled EEA-type scenario.
[133] Lisenkova, K. and Sanchez, M.S., 'The long-term macroeconomic effects of lower migration to the UK' NIESR, May 2016; 'Leaving the EU: Implications for the UK economy', PwC, March 2016 found a ratio GDP-labour between 1.1 and 1.4 depending on scenario; 'Fiscal sustainability report', OBR, July 2018, where productivity growth is assumed constant in OBR's migration scenarios for baseline, high migration, low migration and 50 per cent EU migration scenarios, implying the percentage differences between the levels in real GDP in any given year between the scenarios are dependent solely on the percentage difference in employment size.
[134] Lisenkova, K. and Sanchez, M.S., 'The long-term macroeconomic effects of lower migration to the UK' NIESR, May 2016.
[135] Portes and Forte (2017). The economic impact of Brexit-induced reductions in migration. Oxford Review of Economic Policy, Volume 33, Number S1, 2017, pp. S31-S44

would fall by 0.3 to 0.55 per cent and GDP per capita by 0.1 to 0.4 per cent.[136] Wider productivity effects from changes in migration are not included in this analysis. If they were, the GDP and GDP per capita impacts of more restrictive migration policies could be higher. The productivity effects found in the literature range from near zero to up to two percentage points for each percentage point increase in migrants' share in the overall population.[137]

[136] The elasticities are taken from Boubtane, E., Dumont, J-C. and Roualt, C., 'Immigration and Economic Growth in the OECD Countries 1986-2006', CESifo Working Paper, 2014 and Jaumotte et al., 'Impact of migration on income levels in advanced economies', IMF, October 2016 respectively, which estimate the wider effects of migration on productivity and per capita growth.

[137] Ortega and Peri, 'The Causes and Effects of International Migrations: Evidence from OECD Countries 1980-2005', NBER, 2009; Openness and income: The roles of trade and migration, Journal of International Economics, 2013 & Boubtane et al., 'Immigration and Economic Growth in the' OECD Countries, 1986-2006, IZA, 2014. Note these studies estimate the indirect effects (longer-term) effects of migration associated with enhanced knowledge transfer, network effects, and/or complementarities between migrant and native workforce.

6. Comparisons with external literature on macroeconomic modelling of EU exit

169. To contextualise the estimated GDP impacts of EU exit scenarios presented in the analysis document, results from the Government's analysis are compared to results from the external literature. Most studies estimate a WTO-type scenario, while some also estimate the impact of FTA scenarios, and a small number of studies include an EEA scenario. However, the details of how scenarios are modelled differ, especially across FTA scenarios, and whether impacts are measured as GDP or consumption/welfare changes. There is also variation across the channels of impact with some studies focusing only on the trade impact of NTB and tariff changes with the EU, while others include FDI, migration, regulatory flexibility, fiscal or RoW trade agreements. A small number of studies also consider the impact of unilateral trade liberalisation. Tables 6.C, 6.D and 6.E list the relevant channels of impact in the results reported for each external study.

170. There are a number of approaches to modelling the impact of changes in trade and trade policy on the economy as a whole. Some approaches are purely econometric, while others are based on structural models such as NiGEM[138] or CGE models, supported by econometric evidence. Most take a two-stage approach:

    a. Estimate the impact of trade agreements and EU membership on trade flows and/or trade costs;

    b. Model the impact of estimated changes in trade flows and/or costs from the first stage on key macroeconomic variables such as GDP.

171. Most approaches have similar first stages, but vary more widely in the way they model macroeconomic impacts of changes in trade or trade costs. First-stage approaches usually estimate trade flows and/or trade costs based on the econometric analysis of real-world trade patterns. In the second stage, some approaches use econometric approaches, while others use different types of models. Table 6.A summarises the frameworks used in external literature for estimating the economic impact of EU exit scenarios.

[138] NiGEM is the National Institute Global Econometric Model, which is maintained by NIESR.

Table 6.A: Frameworks for EU exit analysis[139]

Framework	Impact of trade agreements on trade or trade costs	Estimation of GDP impact of trade costs	Includes dynamic productivity, investment effects	Examples
Structural econometric	Econometric	Structural econometric	Yes	NBER*
Reduced form econometric	Econometric	Econometric estimate of elasticity of GDP to trade	Yes	CEP-LSE (dynamic); World Bank
NiGEM	Econometric	Dynamic macroeconomic model	Investment — yes Productivity — can be added	NIESR(2); OECD; HMT
New Quantitative Trade Models	Econometric, estimated tariff elasticities	Stylised CGE	Generally no	CESifo
Static CGE	Econometric, estimated tariff elasticities	CGE	No	CEP-LSE (static)
Static CGE with dynamic elements	Econometric, estimated tariff elasticities	CGE	Yes	Government Analysis, RAND

** NBER studies the impact of NAFTA on welfare; it does not apply its analysis to the EU.*

6.1 Purely econometric approaches

172. Purely econometric approaches use statistical methods and real-world economic data to estimate not only the impact of trade policy changes on trade and/or trade costs, but also to estimate the partial or general equilibrium impact on welfare or other measures of overall economic activity such as GDP. The estimates of the Centre for Economic Performance (CEP)[140] and World Bank[141] convert first-stage estimates of changes in trade flows from EU membership into impacts on GDP using external estimates of the elasticity of GDP to changes in trade flows from Dartmouth College.[142]

173. The CEP[143] analyses an FTA scenario and finds GDP reductions of between 6.3 and 9.4 per cent. These estimates are based on econometric estimates of the decrease in total UK trade of 12.6 per cent, multiplied by the lower and upper bound estimates for the elasticity of GDP to changes in trade of 0.50 and 0.75 from Dartmouth College.[144] The World Bank[145] employs the same methodology, but uses data from

[139] See Table 6.F for a full list of references of the studies presented in this table.
[140] Dhingra et al., 'The costs and benefits of leaving the EU: trade effects', Centre for Economic Performance, April 2017.
[141] Mulabdic et al., 'Deep Integration and UK-EU Trade Relations', World Bank, 2017.
[142] Feyrer, J., 'Trade and income- exploiting time series in geography', Dartmouth College, 2009.
[143] Dhingra et al., 'The costs and benefits of leaving the EU: trade effects', Centre for Economic Performance, April 2017.
[144] Feyrer, J., 'Trade and income- exploiting time series in geography', Dartmouth College, 2009.
[145] Mulabdic et al., 'Deep Integration and UK-EU Trade Relations', World Bank, 2017.

2000 to 2014. It reports a 13 per cent decline in long-term GDP in a WTO scenario, and a 3 per cent decline in GDP for an EEA scenario. The different time periods also correspond to a different set of countries joining the EU, partly explaining the impacts. Also, the estimates used in the CEP study are best interpreted as the average changes in trade for an average EU country, while the World Bank uses estimates of the increases in UK trade with new joiners.

174. The NBER study[146] employs a fully econometric, structural general equilibrium estimation approach. This involves estimating a system of equations, including trade costs, trade, and a range of macroeconomic variables. However, the study applies this method to estimating the economic impact of NAFTA rather than EU membership.

175. Both types of econometric approaches are capable of capturing a broad range of channels by which trade agreements might impact on trade, without explicitly modelling them. As a result, econometric approaches tend to show among the largest estimated economic impacts of EU membership and hence of leaving the EU to trade on a WTO basis with the EU27 – as demonstrated in Table 6.B. However, econometric results rely on observing the impact of trade policy changes that have occurred in the past. The reliance on precedent means this approach cannot be used to model trade agreements or policies that do not have close historical precedents.

176. In contrast, CGE and other structural models can only capture impact channels which are explicitly modelled. Those models which include fewer channels tend to find smaller impacts of a given trade policy. As the number of channels included increases, the impact becomes larger. Model-based approaches have the advantage that they can assess trade policies with few or no precedents.

Table 6.B: Econometric-only estimates of different scenarios on UK GDP (per cent)[147]

Label	WTO	FTA	EEA
CEP-LSE dynamic		-9.4 to -6.3[148]	
World Bank	-13		-3

6.2 Static models

177. The models with the most restricted set of channels are often called ‘static CGE’ because they focus on comparative advantage and benefits from variety.[149] Static

[146] Anderson, J., Larch, M., and Yotov Y., ‘Growth and Trade with Frictions: A Structural Dynamic Framework’, NBER Working Paper 21377, 2015.

[147] Mulabdic, et al.,'Deep Integration and UK-EU Trade Relations', World Bank, January 2017; Dhingra et al., ‘The costs and benefits of leaving the EU: trade effects’, Centre for Economic Performance, April 2017.

[148] CEP-LSE analyses an FTA scenario, moving from EEA to EFTA membership, and finds GDP reductions of between 6.3 and 9.4 per cent.

[149] Studies included in the ‘static’ category are, broadly defined, static CGE models or based on a dynamic model such as NiGEM with the key dynamic effects turned off, such as Ebell, M., and Warren, J., ‘The long term impact of leaving the EU’, National Institute of Economic and Social Research, 2016. Studies include both fully structural CGE models and reduced form representations based on the work of Arkolakis, C., Costinot, A., and Rodriguez-Clare, A. ‘New trade models, same old gains?’, American Economic Association, 2012, as well as intermediate approaches.

studies find central GDP/welfare impacts of a no deal scenario ranging from -1.5[150] to -5.6[151] per cent. Some studies at the lower end assume relatively low increases in trade costs. For example, the static CGE results in CEP-LSE are based on an increase in NTBs of 8 percentage points,[152] relying on evidence on the reducible trade barriers between the US and EU. Some studies at the upper end of the static range incorporate additional features. For instance, CEPR[153] uses the same increase in NTBs of 8 percentage points as CEP-LSE, but includes supply chain effects. Its estimated impact of moving to a WTO scenario rises to -4.5 per cent compared to -2.7 per cent in the CEP-LSE study. Some static estimates are of welfare rather than GDP impacts.[154]

178. Results from static studies of GDP impacts in an FTA scenario tend to find a lower negative impact than those under a WTO scenario. GDP/welfare impacts of an FTA scenario range from -0.6 per cent[155] to -3.4 per cent.[156] These studies vary in the assumptions used. Some studies use existing FTAs as a baseline; for example, CES-ifo[157] base their FTA scenario on NTBs in the EU-Korea trade agreement, while Ciuriak Consulting[158] uses EFTA membership as a baseline. Other studies, such as IMF,[159] apply a proportion of NTB trade costs which have been eliminated as a result of EU membership.

179. A small number of studies consider an EEA scenario. Static results for these studies range from -1.3 per cent[160] to -1.8 per cent[161] GDP/welfare impact compared to a scenario where the UK remained a member of the EU. These studies apply non-tariff barriers on UK-EU trade to reflect this scenario. For example, NIESR(2)[162] applies NTBs calculated from US-UK trade and applies 25 per cent of the reducible NTBs calculated from other studies.

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150 'Costs and benefits of a United Kingdom exit from the European Union', Global Economic Developments report, 2015.
151 'Selected Issues: Britain', Arregui, N. and Chen, J., IMF, 2018.
152 'The costs and benefits of leaving the EU: trade effects', Dhingra, S., Huang, H., Ottaviano, G., Pessoa, J.P, Sampson, T. and Van Reenen, J, CEP Discussion Paper No. 1478, 2017. See Table 2.E for a summary of input assumptions for external studies.
153 'Global value chains, trade shocks and jobs: an application to Brexit', Vandenbussche, H., William Connell, W., and Simons, W., CEPR, 2017.
154 For example, 'The Cost of Non-Europe, Revisited', Mayer, T., Vicard, V., and Zignago, S., Banque de France Working Paper, 2018. and 'Brexit through the lens of new quantitative trade theory', Felbermayr, G., Gröschl, J., and Steininger, M., CESifo, 2018.
155 'Costs and benefits of a United Kingdom exit from the European Union', Global Economic Developments report, 2015.
156 'Trade effects of Brexit for the Netherlands', Romagosa, R, CPB Netherlands Bureau for Economic Analysis, 2016.
157 'Brexit through the lens of new quantitative trade theory', Felbermayr, G., Gröschl, J., and Steininger, M., CESifo, 2018.
158 'Brexit Trade Impacts: Alternative Scenarios' Ciuriak, D., Dadkhah, A., and Xiao, Q., Ciuriak Consulting, 2015.
159 'Selected Issues: Britain', Arregui, N. and Chen, J., IMF, 2018.
160 Dhingra et al., 'The costs and benefits of leaving the EU: trade effects', CEP, April 2017
161 'The long term impact of leaving the EU', Ebell, M and Warren, J. NIESR, 2016.
162 'The long term impact of leaving the EU', Ebell, M and Warren, J. NIESR, 2016.

Table 6.C: Static estimates of different scenarios on UK GDP (per cent)[163]

Label	WTO	FTA	EEA	Channels modelled
CEPII	-2.9	-2.4		Trade
CEPR[164]	-4.5	-1.2		Trade, supply chain effects
CESifo (2018)[165]	-3.2	-1.8[166]		Trade
CEP-LSE	-2.7[167]		-1.3	Trade
Ciuriak Consulting	-2.5	-1.0[168]		Trade, FDI
CPB NL	-4.1	-3.4[169]		Trade
GED	-2.8 to -1.5	-0.6		Trade
IMF[170]	-4.6 to -4.2	-2.0		Trade, FDI
IMF	-5.6 to -5.2	-2.6		Trade, FDI, migration
NIESR(2)	-3.2[171]	-2.1	-1.8	Trade, FDI, fiscal
Open Europe	-2.2			Trade and FDI
Oxford Economics	-3.9			Trade, migration and fiscal
PWC	-3.5	-1.2		Trade, FDI, migration, regulation and fiscal
RAND	-4.9	-1.9	-1.7	Trade and investment

6.3 Dynamic models

180. ‘Dynamic’ models additionally model a comprehensive range of possible impact channels, including at a minimum dynamic effects such as productivity and FDI or capital accumulation channels. These studies find central GDP impacts of a no deal

163 See Table 6.F for a full list of references of the studies presented in this table.
164 Results are presented as value added production as a percentage of GDP.
165 Results are presented as decrease in real consumption.
166 The CES-Ifo papers model a UK-EU FTA on the basis of EU-Korea.
167 The CEP-LSE study includes optimistic and pessimistic scenarios, with increases in NTBs of 2.8 per cent or 8.3 per cent respectively. The pessimistic scenario reported here is more in line with a WTO scenario. The optimistic scenario is more in line with the EEA-EU relationship.
168 This paper assumes a very ambitious FTA based on EFTA membership.
169 FTA scenario assumes 0 per cent tariffs and a 50 per cent reduction in WTO NTBs.
170 The IMF study reports results from three model variants: Armington, Krugman and Melitz. Armington and Krugman are reported here as ‘static’, while Melitz is reported here as dynamic.
171 Although the NIGEM model includes capital accumulation effects, they are only fully operative when productivity effects are turned on. The scenario included as static here has productivity effects turned off.

scenario ranging from -4.6[172] to -18[173] per cent, higher than the 'static models' cited in Table 6.C. Some studies in this group are based on NiGEM, a dynamic model including capital accumulation effects, which can also include productivity effects (for example OECD,[174] NIESR(2),[175] Rabobank;[176] see these studies for an explanation of NiGEM). Results among the NiGEM-based studies vary considerably, due both to differences in the changes in trade and the size of productivity effects related to trade included in each study. The CGE model used by RAND[177] is also included in the 'dynamic' category, as it integrates some dynamic elements related to FDI into an otherwise static CGE framework. The IMF[178] results, including a Melitz-style productivity channel, are also included as dynamic.

181. Modelled no deal scenario estimates (without the capital accumulation channel) are most directly comparable to the lower end of the 'dynamic' range, as the GETRADE model incorporates some dynamic elements into an otherwise static CGE framework. When the modelled no deal scenario includes the capital accumulation channel, it is more comparable to the upper end of the 'dynamic' range.

182. Modelled average FTA estimates range from -2.0 per cent[179] to -12.5 per cent[180] impact on GDP/welfare; as for the static estimates, dynamic FTA results show a reduced negative GDP/welfare impact than under a WTO scenario. For the reasons discussed above, impacts in the dynamic scenarios for FTA are generally higher than in static models. These models range from analysing trade-only channels (for example CPB NL)[181] to including other channels such as FDI or migration. For example, IMF's central trade-only GDP/welfare impact is -3.3 per cent, while its impact including trade, FDI and migration is 3.9 per cent[182]. Rabobank also include an EEA scenario; they find a change in GDP of -10 per cent[183].

[172] 'Brexit- an economy wide Impact assessment looking into trade, immigration and Foreign Direct Investment', Jafari, Y and Britz, W., University of Bonn, 2017
[173] Erken et al. 'Assessing the economic impact of Brexit: background report", Rabobank, 2018.
[174] Kierzenkowski, R., Pain, N., Rusticelli, E., and Zwart, S. "The economic consequences of Brexit: a taxing decision', OECD Economic Policy paper, No. 16, 2016.
[175] Ebell, M., and Warren, J., 'The long term impact of leaving the EU', NIESR, 2016.
[176] Erken et al., 'Assessing the economic impact of Brexit: background report', Rabobank, 2018.
[177] Ries et al., 'After Brexit: Alternative forms of brexit and their implications for the United Kingdom, Europe and the United States', RAND, 2017.
[178] Arregui, N. and Chen, J., 'Selected Issues: Britain', IMF, 2018.
[179] Global Economic Developments report,'Costs and benefits of a United Kingdom exit from the European Union' 2015.
[180] Erken et al. 'Assessing the economic impact of Brexit: background report", Rabobank, 2018.
[181] 'Trade effects of Brexit for the Netherlands', Rojas-Romagosa, H., CPB Netherlands Bureau for Economic Analysis, 2016.
[182] Arregui, N. and Chen, J., 'Selected Issues: Britain', IMF, 2018.
[183] Erken et al. 'Assessing the economic impact of Brexit: background report', Rabobank, 2018.

Table 6.D: Dynamic estimates of different scenarios on UK GDP (per cent)[184]

Label	WTO	FTA	EEA	Channels modelled
CPB NL	-8.7	-5.9[185]		Trade
GED[186]	-8.6	-2.0		Trade
IMF[187]	-6.4	-3.3		Trade
IMF[188]	-7.8	-3.9		Trade, FDI, migration
OECD	-7.7[189]	-5.1 to -2.7		Trade, migration
Rabobank	-18.0	-12.5	-10.0	Trade, FDI, migration, fiscal, regulation
RAND	-8.2	-4.2		Trade, investment
University of Bonn	-4.6			Trade, FDI, migration

6.4 External studies including unilateral tariff liberalisation

183. A number of studies model WTO scenarios which also include unilateral liberalisation of tariffs, as well as deregulation, lower taxes or changes to migration policy. These scenarios vary quite widely in their assumptions, which is reflected in the variation in the results presented in Table 6.E.

184. The Oxford Economics study considers a 'liberal MFN scenario' which consists of a WTO scenario including a broad set of policies such as unilateral tariff liberalisation, tax cuts, deregulation and some changes to migration policy, and estimates GDP would be 1.5 per cent lower than under today's arrangements. The Open Europe 2018 study includes unilateral tariff liberalisation and unilateral reductions in barriers to service market access and FDI in a WTO scenario, and estimates that GDP would be 0.5 per cent lower than under today's arrangements in the long run.[190]

185. Economists for Free Trade's analysis finds that an EU exit on WTO terms would result in GDP which is 6.8 per cent higher than under today's arrangements[191]. This is based on GDP which is higher by around 4 percentage points due to unilateral liberalisation, 2 percentage points higher from improved regulations, 0.6 percentage points higher from the net EU budget contributions and 0.2 percentage points higher from removing the 'subsidy to unskilled immigration'.

184 Please see table 6.F for a full list of references of the studies presented in this table.
185 Assumes 0 per cent tariffs and 50 per cent reduction in WTO NTBs. Assumes FTA would be agreed 10 years after EU exit, so WTO trade costs would apply for this period.
186 Scenarios are defined as 'soft exit' and 'deep cut', which are reported here as FTA and WTO scenarios respectively.
187 The results presented here use a 'Melitz assumption'. Unlike some other studies, it allows for monopolistic competition and differences in firms (heterogeneity).
188 The numbers presented are found by aggregating the effects of trade, investment and migration, which are presented separately in the paper.
189 The OECD study defines optimistic, central and pessimistic scenarios, but does not differentiate between WTO and FTA scenarios. The pessimistic (upper) estimate is most in line with a WTO scenario, and is included here.
190 "No Deal. The economic consequences and how they could be mitigated", Open Europe, October 2018
191 "From Project Fear to Project Prosperity", Economists for Free Trade, August 2017

186. The OBR has noted that Economists for Free Trade look at a wider definition of unilateral liberalisation as they assume that the UK would unilaterally abolish all tariffs and NTBs on imports. However, the OBR notes that "some non-tariff barriers would be impossible to eliminate, for example distance from trading partners and differences in language spoken."[192]

187. The OBR have also noted that "in the model that Economists for Free Trade use, output ... appears to be more responsive to trade barriers than in most other models. The removal of barriers to trade equivalent to a 10 per cent tariff on just the import of manufacturing and agricultural products from the rest of the world is estimated to boost GDP by 4 per cent in the long run. The OBR notes that "most models find a similar effect on GDP as a result of much more comprehensive changes in trade barriers".

Table 6.E: Estimates of WTO scenarios including unilateral tariff liberalisation on UK GDP (per cent)[193]

Label	WTO + UTL	Channels modelled
Economists for Free Trade	+4.0 to +6.8 per cent	Unilateral tariff liberalisation, unilateral reductions in NTBs, regulation, EU budget contributions
Open Europe	-0.5 per cent	Unilateral tariff liberalisation, unilateral reduction in services and FDI barriers
Oxford Economics	-1.5 per cent	Unilateral tariff liberalisation, 'aggressive' deregulation, tax cuts, modest restrictions on migration.[194]

6.5 Input assumptions of external studies

188. To help place the results of external studies into context, it is useful to note the variation in assumed NTBs. There are three main approaches to estimating the NTB inputs:

- Based on WTO-EU trade costs or flows
- Based on US-EU trade costs or flows
- Based on other forms of evidence

189. Section 2.7 summarises the different approaches taken and compares the Government's average NTB estimates to those found in the literature.

[192] "Brexit and the OBR's forecasts", OBR, October 2018
[193] Mulabdic, et al.,'Deep Integration and UK-EU Trade Relations', World Bank, January 2017; Dhingra et al., 'The costs and benefits of leaving the EU: trade effects', Centre for Economic Performance, April 2017.
[194] Liberal MFN scenario

Box 6.A: Agri-food modelling

As noted in section 4.4 of the analysis document, the agri-food sector has notably complicated tariff structures, with particularly high tariffs in some sub-sectors and other sub-sectors operating closer to the world market price. In these specific circumstances, models that operate at a high level of disaggregation, for example partial equilibrium models, may give greater definition to the sector-specific impacts. Unlike CGE models, partial equilibrium models do not tend to account for changes to demand and supply in the wider economy.

Some studies focusing on the agri-food sector show that rising producer prices, in response to higher tariffs, lead to higher values of economic activity in the sector while also increasing consumer prices. For example, a European Parliament report,[195] using a CGE model with very detailed treatment of the agri-food sector, shows that higher tariffs result in a fall in economic activity for the economy as a whole but growth in the agri-food sector. FAPRI-UK[196] uses a partial equilibrium model and also finds that higher tariffs lead to higher prices and domestic production but lower consumption in the sector.

Table 6.F: References to studies discussed in this section

Label	Reference
Baier, Bergstrand and Feng	'Economic Integration Agreements and the Margins of International Trade', Baier, S., Bergstrand J., and Feng, M., Journal of International Economics, 2014
Baier et al.	Baier et al. 'Do economic integration agreements actually work? Issues in understanding the causes and consequences of the growth of regionalism' World Economy, Volume 31, No. 4 2008.
CEPII	"The Cost of Non-Europe, Revisited", Mayer, T., Vicard, V., and Zignago, S., Banque de France Working Paper, 2018.
CEP-LSE	"The costs and benefits of leaving the EU: trade effects", Dhingra, S., Huang, H., Ottaviano, G., Pessoa, J.P, Sampson, T. and Van Reenen, J., Centre for Economic Performance Discussion Paper No. 1478, 2017.
CEPR	"Global value chains, trade shocks and jobs: an application to Brexit", Vandenbussche, H., William Connell, W., and Simons, W., CEPR, 2017.
CESifo (2017)	"Economic Effects of Brexit on the European Economy", Felbermayr et al., EconPol Policy Report
CESifo (2018)	"Brexit through the lens of new quantitative trade theory", Felbermayr, G., Gröschl, J., and Steininger, M., CESifo, 2018.
Ciuriak Consulting	"Brexit Trade Impacts: Alternative Scenarios" Ciuriak, D., Dadkhah, A., and Xiao, Q., Ciuriak Consulting, 2015.
CPB NL	"Trade effects of Brexit for the Netherlands", Rojas-Romagosa, H., CPB Netherlands Bureau for Economic Analysis, 2016.

[195] Bellora et al., EU – UK agricultural trade: state of play and possible impacts of Brexit', European Parliament, Policy Department for Structural and Cohesion Policies, Brussels, 2017.

[196] Davis et al., 'Impacts of Alternative Post-Brexit Trade Agreements on UK Agriculture: Sector Analyses using the FAPRI-UK Model', FAPRI-UK Project, 2017.

Label	Reference
Dartmouth	'Trade and income- exploiting time series in geography', Feyrer, J., Dartmouth College, 2009.
EFT	"From Project Fear to Project Prosperity", Economists for Free Trade, August 2017
GED	"Costs and benefits of a United Kingdom exit from the European Union", Global Economic Developments report, 2015.
Guillin	'Assessment of tariff equivalents for services considering the zero flows', Guillin A., World Trade Review, 2013.
HMT	'HM Treasury analysis: the long-term economic impact of EU membership and the alternatives', HM Treasury, 2016.
IMF	"Selected Issues: Britain", Arregui, N. and Chen, J., IMF, 2018.
NBER	"Growth and trade with frictions: a structural estimation framework", Anderson, J., Larch, M., and Yotov, Y., NBER, 2015.
NIESR(2)	"The long term impact of leaving the EU", Ebell, M. and Warren, J. National Institute of Economic and Social Research, 2016.
NIESR(3)	'Assessing the impact of trade agreements on trade', Ebell, M., National Institute Economic Review, 2016
OECD	"The economic consequences of Brexit: a taxing decision", Kierzenkowski, R., Pain, N., Rusticelli, E., and Zwart, S, OECD Economic Policy paper, No. 16, 2016.
Open Europe	"No deal: The economic consequences and how they could be mitigated", Booth, S. and Shankar, A., Open Europe, 2018.
Oxford Economics	"Assessing the Economic Implications of Brexit", Oxford Economics, 2016.
PwC	"Leaving the EU:Implications for the UK economy", PwC, 2016.
Rabobank	"Assessing the economic impact of Brexit: background report", Erken et al., Rabobank, 2018.
RAND	"After Brexit: Alternative forms of brexit and their implications for the United Kingdom, Europe and the United States", Ries, C., Hafner, M., Smith, T., Burwell, F., Egel, D., Han, E., Stepanek, M., and Shatz, H., RAND, 2017.
University of Bonn	"Brexit- an economy wide Impact assessment looking into trade, immigration and Foreign Direct Investment", Jafari, Y and Britz, W., University of Bonn, 2017.
World Bank	"Deep Integration and UK-EU Trade Relations", Mulabdic, A., Osnago, A., and Ruta, M., World Bank Policy Research Working Paper, 2017.

7. Regional impacts

190. The approach taken to estimate the long-term economic effect on the regions and nations of the UK of leaving the EU is based on apportioning the UK-wide estimates to these regions and nations.[197] This ensures consistency between regional results and UK-wide results. As with the CGE modelling discussed in Section 4, the regional analysis provides a long-term estimate and does not consider short-term impacts. Section 7.1 sets out the method for estimating regional impacts, 7.2 provides results, and section 7.3 provides a comparison with the external literature.[198]

7.1 Approach to apportioning national level results

191. The starting point for the methodology used is the observation from national accounts that the value added contained in the final demand for goods and services from a region in the UK must come from either that region, other regions in the UK or abroad. Final demand for goods and services in the UK consists of the total value of exports to the rest of the world and domestic demand. The CGE modelling results provide an estimate of the changes in the total value of exports and domestic demand by sector. The regional analysis then apportions these changes to regions to estimate their exposure to a particular scenario.

192. The model is built in three blocks explained below. The first block allocates UK-wide sectoral changes to regions in line with each region's relative sectoral specialisation. The second block models how impacts on one region can flow through to other areas of the UK as a result of integrated supply chains across regions in the UK. The third block ensures domestic demand adjusts to changes in income in the long run.

7.1.1 Reflecting regional specialisation

193. First, the model apportions UK-wide changes to regions using each region's current share in UK gross value added (GVA) by sector based on ONS data[199] and each region's share of UK exports by sector based on ONS[200] and HMRC data.[201] This implies a region which is specialised in a sector which experiences a large change in GVA or exports will also experience a large change in its GVA compared with other regions. Figure 7.A below shows each region's export specialisation.

194. For example, as the North East and the West Midlands are the regions most specialised in manufactured goods, the apportionment implies they would be more

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197 Regions are defined at the NUTS-1 level, which includes Northern Ireland, Scotland, Wales and 9 English regions. Further information on the NUTS-1 classification can be found at 'The establishment of a common classification of territorial units for statistics (NUTS)', Eurostat, 2018.

198 The regional results from the preliminary Cross-Whitehall Analysis published by the Exiting the EU Select Committee (March 2018) were provisional and reflected an early stage in the analysis. The modelling has been developed to better capture interregional linkages through supply chains, resulting in less variation between regions and nations than in March. However, the results in this publication no longer capture the impact of migration and are therefore not directly comparable with the preliminary estimates from March.

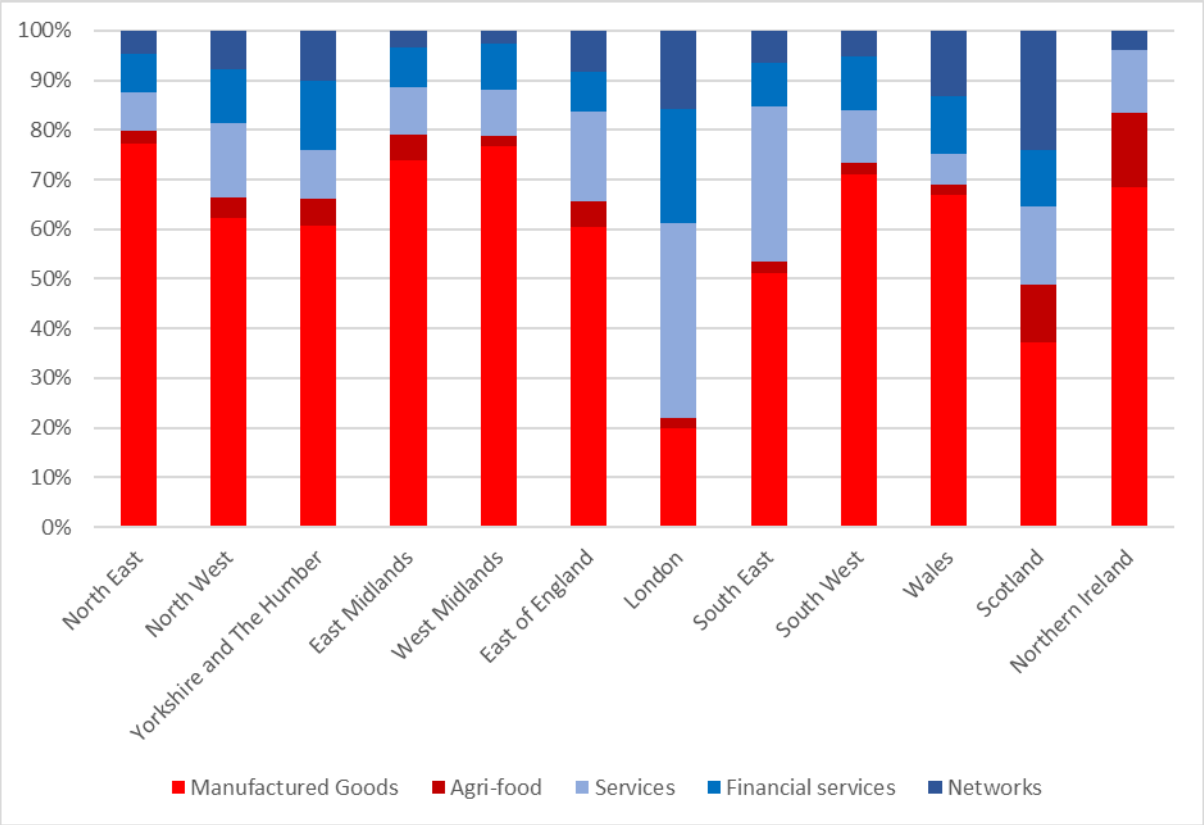
199 'Regional gross value added "UK 1998-2016', ONS, 2017

200 'Regionalised estimates of UK service exports', ONS, 2018

201 'Regional Trade Statistics', HMRC, October 2017

adversely affected by any reduction in manufactured goods exports than other regions[202].

Figure 7.A: Export composition by region, 2015 (Blue = sectors with mostly services exports; Red = sectors with mostly goods exports)[203]



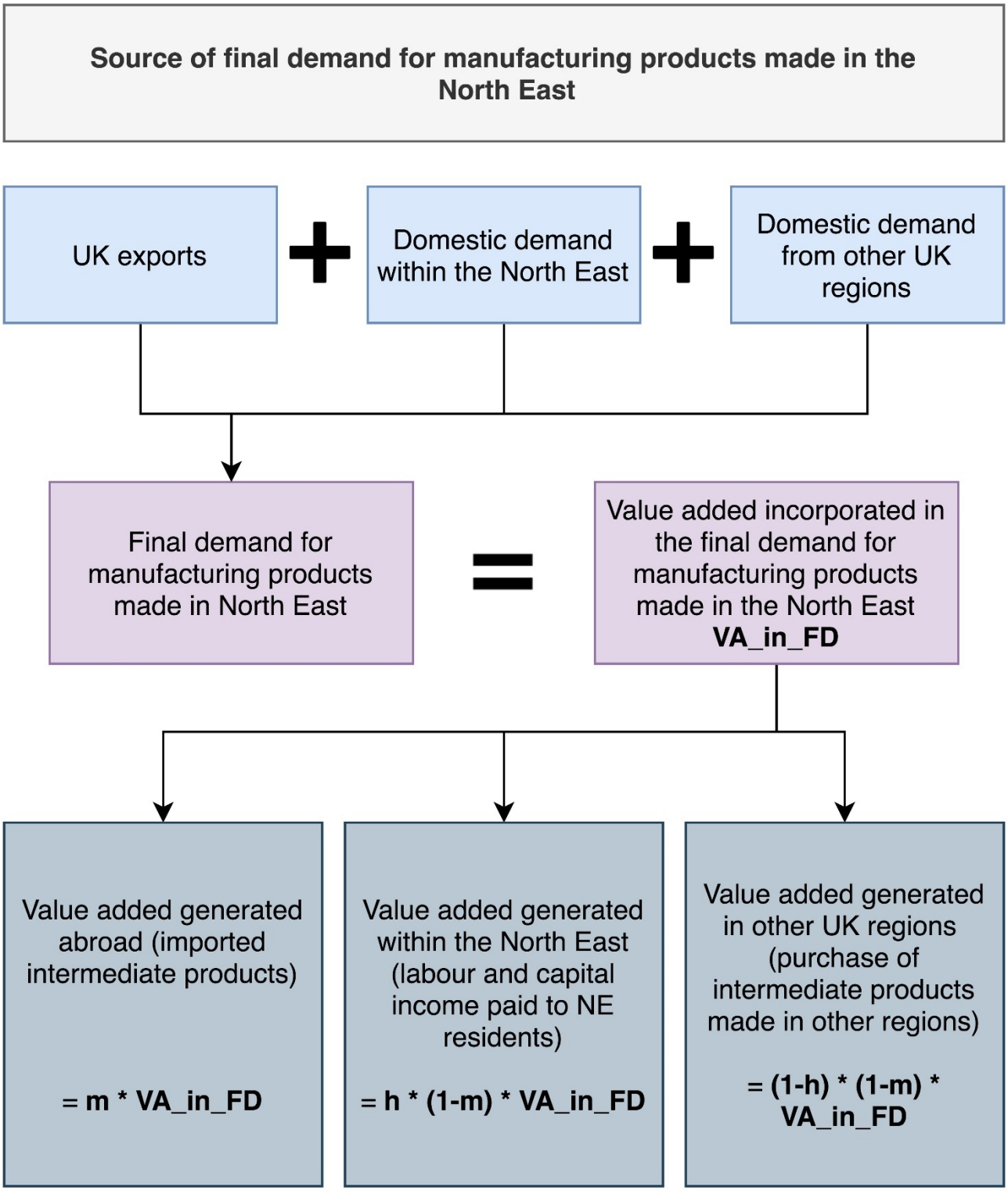
7.1.2 Inter-regional interconnectedness: reflecting supply chains

195. The next step is to consider how the trade shock in one region can flow through to other areas of the UK as a result of supply chains embedded across the UK. Supply chains within the UK arise when producers in one region use products produced in other regions. The approach taken here is informed by the academic literature on the role of Global Value Chains, which arise when supply chains extend across national borders.[204]

196. A feature of supply chains is that the final demand for a good or service produced in a given region is composed of value added by local residents, value added from other UK regions and value added from other countries (see Figure 7.B). Value-added from other UK regions or from other countries enters into the production process in the form of purchases of inputs from these regions or countries.

[202] 'Regionalised estimates of UK service exports', ONS, May 2017; 'Regional Trade Statistics', HMRC, October 2017;
[203] Regional Trade Statistics', HMRC, October 2017; ''Regionalised estimates of UK service exports', ONS, 2018
[204] Baldwin, R., 'The great convergence', Harvard University Press, 2016.

Figure 7.B: The relationship between final demand and value added: example for manufacturing products made in the North East



VA_in_FD denotes value added in final demand
m is the proportion of final demand for manufacturing products that compromises value added generated abroad
h denotes the distribution of value added between the home region (North East) and the rest of the United Kingdom

197. For each good or service, OECD trade in value added (TiVA)[205] data provides an estimate of the proportion of domestic demand derived from value added from abroad. The analysis applies this proportion to total final demand (i.e. exports plus domestic demand), assuming that the proportion of foreign value added in UK exports of each product is the same as the proportion in domestic demand for that product. This proportion is denoted by the parameter *m* in the flow chart.

198. The share of value added that is generated within the UK can be divided into:

    a. a proportion *h*, which comprises the value added in the final stage of production, and the value added contained in the inputs used in the final stage of production, that originate within that region.

    b. a share 1 – *h* that is associated with production that occurs in other regions. This comprises the value added contained in products used in the final stage of production that were produced in other UK regions. The analysis assumes that this proportion is allocated across UK regions in proportion to each region's share in total UK value added.

199. In this analysis the value of h depends on a parameter, β which can be interpreted as a measure of the "home bias" in each region's supply chains towards value added generated within the home region.[206] β would take the value 1 if producers did not use any intermediate products produced in other UK regions, and would take the value 0 if their consumption of intermediate products produced within their own region matched their region's share of UK GVA.

200. Data on the amount of trade between UK regions is not published, so it is not possible to derive direct estimates of β for each region and product[207]. Instead, β is calibrated using GTAP export data and ONS sectoral GVA for the period 2004-11. The results are compared to actual GVA change over that period. With β between 0.5 and 0.6, the model has an R^2 of over 90 per cent. The analysis assumes that the home bias parameter (β) is the same for all regions and sectors.

7.1.3 Long-term feedback loop between GVA and domestic demand

201. The final element of the model ensures that domestic demand within each region adjusts to changes in regional GVA. As GVA is a measure of the income generated within a region, domestic demand can be expected to change more or less proportionally to GVA in the long run. If changes to international trading relationships result in lower demand for goods and services in a region, then firms and individuals in the region will experience a drop in their incomes. As firms and individuals tend to consume more of their own region's goods and services, the change in income within a given region can be expected to have a greater impact on domestic demand within that region than elsewhere. This effect is stronger when producers have a greater tendency to use local intermediate products, which is captured by the β parameter in the analysis.

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[205] 'Trade in value added', OECD, 2018.

[206] Specifically h = β+ (1-β) * s, where s is the home region share in UK GVA. This means that h=1 when β=1, and h=s when β=0.

[207] Los et al. have estimated interregional trade using freight and business class train travel data as proxies for the underlying economic integration of each region. 'The mismatch between local voting and the local economic consequences of Brexit', Regional studies, 2017.

7.2 Results of analysis of regional impacts

7.2.1 Allowing for sources of uncertainty

202. The analysis tests the sensitivity of the regional results to CGE model outputs using the 80th and 20th percentiles from the distribution derived from the sensitivity analysis described in section 4.4. It also tests the sensitivity of the regional results to the value of the home bias parameter, β, that affects the allocation of national changes in sectoral GVA and exports to regional GVA. The central estimates are generated when this parameter takes the value 0.55,[208] and the range is generated using alternative values of 0.45 and 0.65, which respectively increase and reduce the diffusion of regional shocks to other UK regions and nations. The ranges in Table 7.A show the range generated by allowing for both sources of sensitivity taken together.

Table 7.A: Summary of trade only GVA impacts on UK nations and English regions compared to today's arrangements.

Compared to today's arrangements (per cent change)	**Modelled no deal**	**Modelled average FTA**	**Modelled EEA-type**	**Modelled White Paper**	**Modelled White Paper with NTB sensitivity: 50 per cent**[209]
North East	-10.5 (-13.1 to -8.1)	-6.5 (-9.2 to -3.8)	-1.5 (-2.9 to -0.8)	-0.4 (-1.1 to +0.1)	-2.1
North West	-9.4 (-11.7 to -7.2)	-5.8 (-8.3 to -3.4)	-1.4 (-2.6 to -0.7)	-0.5 (-1.3 to +0.1)	-2.2
Yorkshire and the Humber	-8.5 (-10.4 to -6.6)	-5.4 (-7.3 to -3.3)	-1.3 (-2.6 to -0.7)	-0.3 (-1.2 to +0.2)	-2.1
East Midlands	-8.5 (-10.2 to -6.7)	-5.1 (-6.9 to -3.2)	-1.4 (-2.8 to -0.8)	-0.4 (-1.2 to +0.1)	-1.9
West Midlands	-9.6 (-11.7 to -7.5)	-5.7 (-7.8 to -3.4)	-1.5 (-3.0 to -0.8)	-0.4 (-1.2 to +0.1)	-2.0
East of England	-8.4 (-10.2 to -6.6)	-5.3 (-7.3 to -3.3)	-1.3 (-2.5 to -0.6)	-0.4 (-1.3 to +0.2)	-2.0
London	-6.0 (-8.5 to -3.0)	-4.0 (-6.5 to -1.5)	-0.9 (-2.1 to -0.1)	-1.0 (-2.9 to +0.1)	-2.5
South East	-7.8 (-9.6 to -6.0)	-5.0 (-7.2 to -3.0)	-1.2 (-2.3 to -0.6)	-0.7 (-1.8 to +0.1)	-2.1
South West	-7.6 (-9.3 to -6.1)	-4.7 (-6.5 to -2.9)	-1.4 (-2.6 to -0.7)	-0.4 (-1.2 to +0.1)	-1.9
Wales	-8.1 (-9.8 to -6.4)	-4.9 (-6.8 to -3.0)	-1.2 (-2.5 to -0.5)	-0.1 (-0.9 to +0.5)	-1.8
Scotland	-8.0 (-9.8 to -6.2)	-4.8 (-6.9 to -2.8)	-1.0 (-2.4 to +0.1)	0.0 (-1.1 to +1.0)	-2.0

[208] This value is chosen as it is the midpoint of the range which gives the highest R^2 as discussed above.

[209] Sensitivity analysis highlights the impact on GVA if the non-tariff barriers are higher than estimated in the modelled White Paper scenario. A sensitivity point is measured reflecting 50 per cent of the difference in non-tariff barriers between the modelled White Paper scenario and modelled average FTA scenario. Implicitly, the modelled White Paper scenario represents zero per cent on this range, and the modelled average FTA scenario represents 100 per cent.

Compared to today's arrangements (per cent change)	Modelled no deal	Modelled average FTA	Modelled EEA-type	Modelled White Paper	Modelled White Paper with NTB sensitivity: 50 per cent[209]
Northern Ireland	-9.1 (-11.1 to -7.2)	-5.6 (-7.5 to -3.5)	-1.6 (-3.1 to -0.8)	-0.2 (-1.0 to +0.3)	-1.9

Central estimates and ranges.[210] This does not consider migration or regulation effects.

7.3 Comparisons with external studies

203. External studies show a range of regional impacts, driven by uncertainty both about aggregate and sectoral impacts and about the mechanisms through which these translate into local impacts. Most studies estimate regional shocks by allocating sector impacts based on a measure of local specialisation. More sophisticated approaches also account for spatial dispersion of shocks through supply chains. With the notable exception of the Centre for Economic Performance[211], most external studies assume goods sectors to be relatively worse hit than services sectors; this in turn drives regional impacts, with areas in northern England and the Midlands typically estimated to fare worse. In most studies, NUTS-1 regional results show less variation between regions than across sectors and across trading scenarios (e.g. WTO, FTA, EEA). Results presented for smaller areas (e.g. local authority) naturally show greater variation between places. Considering results at the NUTS-1 level, the Government's regional model implies a dispersion of regional impacts at the upper end of those found elsewhere.

204. CEP-LSE apportion sector results to local authorities based on the sectoral breakdown of employment by area.[212] The underlying assumption that services sectors are relatively harder hit on average is reflected in regional impacts, with areas in the South of England and urban areas predicted to be most negatively impacted. Under a no deal scenario, the percentage change in GVA at a local authority level varies between -4.3 per cent (City of London) and -0.5 per cent (Hounslow); the 10th and 90th percentiles are -2.6 per cent and -1.6 per cent respectively.

205. Los, et al.[213] estimate the share of local economic activity that is dependent on trade with the rest of the EU, including through intermediate demand[214]. The dependence of NUTS-2 regions on EU consumption and investment demand ranges from 7.2 per cent of local GDP (Inner London) to 13.2 per cent (Cumbria). London is relatively less exposed due to its specialisation in service exports, a relatively high share of which goes to non-EU countries. Conversely, regions outside London and the home counties are more specialised in manufacturing, agriculture and extraction industries,

[210] The central estimates are not necessarily the midpoint of the range. All ranges have been generated by a Monte Carlo statistical process, which draws several thousand input values from their full distributions. Ranges are not modelled for the 50 per cent NTB sensitivity.

[211] Dhingra et al., 'Local Economic Effects of Brexit', CEP-LSE, 2017.

[212] The Local Economic Effects of Brexit, CEP-LSE, 2017

[213] Los, et al., 'The mismatch between local voting and the local economic consequences of Brexit', Regional Studies, 2017

[214] 'The mismatch between local voting and the local economic consequences of Brexit', Regional studies, 2017

which are more oriented towards EU markets; local service sectors also tend to serve these EU-exporting industries. Many of the areas most dependent on EU demand are in the Midlands and North of England, whereas Scotland is relatively less exposed.

206. Kierzenkowski, et al.[215] use firm-level responses to historic export shocks to predict sector responses to modelled export shocks. Sector impacts are apportioned to NUTS-1 regions using employment data. Impacts are highest in the North East and Wales in the "tariffs and non-tariffs" (WTO) scenario, while London and the South East are least affected. The results are driven by the empirical observation that service sectors are more resilient to export shocks relative to goods sectors.

207. Levell and Keiller[216] account for the role of supply chains and intermediate inputs by considering changes in both output prices and input costs. Regional change in value added is calculated as the average change across local units, weighted by local unit employment. In the WTO scenario, the West Midlands suffers the most (-2.7 per cent change in employer value added), driven by a particularly large shock for the transport equipment sector. Next most affected are the East Midlands and the North West (both -2.5 per cent). Northern Ireland is least affected (-1.7 per cent) but the authors acknowledge that this is probably an underestimate, due to the assumption that a sector's share of exports to the EU does not vary by region.

208. The Scottish Government analysis is based on the National Institute's Global Econometric Model (NiGEM). The impact on Scottish GDP relative to EU membership is anticipated to be -8.5 per cent in 2030, in a WTO scenario[217]. The Scottish Government's analysis suggests that the whole UK would experience a relatively larger GDP impact by 2030 (-9.4 per cent). This approach cannot be replicated for each region of the UK due to data limitations.

[215] Kierzenkowski et al., 'Sectoral and Regional Distribution of Export Shocks', OECD Economics Department Working Paper 1501, 2018

[216] Levell, K. and Keiller, A. N.,'The exposure of different workers to potential trade barriers between the UK and the EU', The IFS Green Budget: October 2018, 2018

[217] 'Scotland's Place in Europe: People, Jobs and Investment', The Scottish Government, 2018

8. Fiscal impacts

209. The long-run fiscal impact of each EU exit scenario is evaluated by considering the indirect fiscal consequences of the exit-related change to the size and structure of the UK economy in section 8.1, as well as the direct fiscal consequences of the UK's new financial and trading relationship with the EU and the rest of the world, as set out in section 8.2. The methodology for estimating the debt interest consequences and other modelling assumptions is set out in sections 8.3 and 8.4. Effects are combined to calculate the total impact on Public Sector Net Borrowing (PSNB). For the fiscal analysis, the end state year is assumed to be 2035-36, 15 years after the end of the implementation period. Results are set out in section 8.5.

8.1 Indirect fiscal impacts

210. The Government's macroeconomic modelling provides an estimate of the long-run macroeconomic impact of each EU exit scenario relative to the status quo. Macroeconomic changes 'indirectly' affect the public finances through their impact on both tax receipts and welfare spending.

211. The long-term indirect fiscal impact of each EU exit scenario is estimated by applying fiscal ready-reckoners to the macroeconomic results in each scenario. Ready-reckoners use elasticities to quantify how a particular element of spending or taxation will change given a 1 per cent change in an underlying economic variable. The ready-reckoners used in the analysis are based on the fiscal ready-reckoners published by the OBR.[218] Consistent with the wider modelling, indirect fiscal impacts are disaggregated to estimate the relative impact of each component on the public finances (i.e. tariffs, NTBs, regulatory flexibilities, RoW trade and migration).

212. As the OBR's published ready-reckoners extend to 2021-22, to estimate indirect fiscal impacts in 2035-36, the elasticities for each component of tax and welfare are extrapolated based on their growth rate in the OBR's published series.

8.2 Direct fiscal impacts

213. Direct fiscal impacts capture the additional fiscal costs and savings associated with alternative financial and trading relationships with the EU and the rest of the world. The next section describes the direct fiscal impacts considered in the analysis.

8.2.1 EU budget savings

214. This represents the savings that will be realised as the UK discontinues budget payments to the EU. In all scenarios, the estimate of how much these savings will be worth in the long run is based on an extrapolation of the 'no-referendum' counterfactual payments included in the OBR's October 2018 Economic and Fiscal Outlook (EFO).[219] Beyond the forecast period this series is grown in line with nominal

[218] 'Fiscal risk report', OBR, July 2017.
[219] 'Economic and fiscal outlook', OBR, October 2018.

GDP. Although around £3 billion of the UK's annual contributions to the EU is in the form of customs revenue transferred directly to the EU (known as Traditional Own Resources), the 'EU Budget Savings' line does not include the savings from reduction in these transfers. Instead, the analysis assesses all customs revenue after exit separately, including the amount previously transferred to the EU (the method used to estimate customs revenue is outlined below).

8.2.2 EU programmes

215. This represents the costs of continuing to fund activities currently undertaken through EU-funded programmes in the UK, such as agricultural funding under the Common Agricultural Policy (CAP), regional investment through European Structural and Investment Funds and Horizon 2020 science funding. The UK will continue to receive receipts relating to 2014-2020 EU programmes from the EU as part of the financial settlement. Any domestic spending on replacements for post-2020 EU programmes will be decided at the next Spending Review in 2019. However, for the purposes of the analysis it is assumed that in the long run the UK either continues to participate in post-2020 EU programmes and pays the costs of receipts, or replaces the activity domestically at equivalent cost. The OBR's latest forecast for UK receipts from the EU is used to estimate the total cost of these programmes, including both receipts administered by the UK Government and devolved administrations and those paid directly to the private sector.[220] The share of the EU budget going to individual areas changes over time, but the total size of the EU budget is relatively stable as a share of GDP. Therefore, to estimate the long-run cost beyond the OBR's forecast period, the forecast is extrapolated in line with baseline nominal GDP growth.

8.2.3 UK-EU financial settlement

216. This represents a settlement of the UK's financial commitments to the EU and the EU's financial commitments to the UK, which result from the UK's participation in the EU budget, and other commitments relating to EU membership. This series represents the net cost of the financial settlement, and is based on the forecast provided by the OBR in the October 2018 EFO. The forecast annual financial cost of the financial settlement, net of receipts considered under 'EU programmes', falls gradually over time, from £9.9 billion in 2019-20 to £0.1 billion in 2035-36.[221]

8.2.4 Future financial contributions

217. This represents an estimate of the net cost of additional financial contributions that the UK might be required to make to the EU over and above the estimate of spending on EU programmes described above. As set out in the White Paper, where the UK and the EU agree terms for the UK's participation in post-2020 EU programmes, the UK would provide an appropriate financial contribution. Any future financial contributions to the EU remain subject to negotiation, are dependent on the UK's future relationship with the EU, and are therefore not modelled here. Future financial contributions are included in the modelled EEA-type scenario, where they are estimated based on Norway's existing precedent and relationship with the EU;

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220 'European Union Finances 2017', statement on the 2017 EU Budget and measures to counter fraud and financial mismanagement,HM Treasury, march 2018.

221 'Economic and fiscal outlook', OBR, October 2018.

Norway's overall net financial contribution to the EU is worth around 0.15 per cent of GDP.

8.2.5 Customs revenue

218. This represents the additional revenue to the UK government from domestic retention of customs receipts after exit. In the modelled White Paper, modelled average FTA and modelled EEA-type scenarios, it is assumed that all imported goods from the EU are tariff free. In the modelled no deal scenario, it is assumed all imports from the EU are subject to EU MFN tariffs. Customs revenue in 2035-36 is estimated by calculating implied tariffs for UK imports from two blocs, the EU and the RoW, and applying this to the volume of tariffed imports from each bloc. The average tariff for RoW, is calculated from current tariffed imports from RoW, whereas the EU implied tariff has been calculated by applying EU MFN tariffs to current UK imports from the EU. It is assumed that the current composition of goods from the EU and the RoW remains constant. The analysis captures changes in the overall value of imports from EU exit related impacts and the signing of new FTAs as well as the impact on revenue of changes to tariff rates on UK imports from different blocs.

8.2.6 Departmental spending on administration

219. This represents an estimate of the ongoing spending pressure that some government departments may experience to administer services and functions currently provided by the EU, after exit. At Autumn Budget 2017, £1.5 billion per year of additional departmental expenditure limit (DEL) funding for departments was announced to fund EU exit preparations in 2018-19 and 2019-20. At Autumn Budget 2018, a further £0.5 billion was announced to increase spending on EU exit preparations in 2019-20 to £2.0 billion[222]. No further funding has been announced in the years beyond 2019-20, where departmental budgets have not been set and are a matter for the Spending Review. However, it is likely that there will be some ongoing costs faced by departments beyond 2019-20. These costs include the administration of services and functions which are currently provided by the EU on behalf of the UK (for example; engaging with global standards, managing domestic regulations, proposing the domestic legislation to support these activities and other operational requirements). There is no baseline for the cost of providing these services in the UK therefore the assumption for spending in future years is based on funding allocated for EU Exit preparations in 2019-20. As the exact costs or profile of these costs are not known at this point, it is assumed that these are constant in cash terms over the period of the analysis.

8.2.7 Other direct fiscal impacts

220. In addition to the direct fiscal impacts described above, the fiscal analysis makes additional assumptions about smaller impacts relating to the future financial relationship with the EU:

    a. The UK has committed to spend 0.7 per cent of gross national income as Official Development Assistance (ODA)[223]. During membership, the UK's share of the EU budget's ODA-attributed spending has counted towards the UK's

[222] Autumn Budget, 2018.
[223] 'Net Official Development Assistance (Indicator)', OECD, 2017

commitment. The fiscal analysis assumes that ODA spending previously delivered through the EU budget is replaced by other types of ODA spending.[224]

b. After exiting the EU, the UK will explore options for a mutually beneficial future relationship with the European Investment Bank Group. The fiscal analysis does not assume any future financial contribution in exchange for this relationship; any contribution would hinge on the nature of the relationship agreed and be subject to the UK's withdrawal from the EIB Group in negotiation. Under the Withdrawal Agreement, the UK has secured the return of its c.€3.5 billion paid-in capital in the EIB. Payments will commence in December 2019 and will be made annually for a period of 12 years. In this analysis it is assumed there is no fiscal benefit as any capital savings will be offset by the costs associated with any future relationship or by increased government support for relevant sectors.

c. For the EU Emissions Trading System (ETS), in the modelled White Paper and modelled EEA-type scenario, the analysis assumes there is no loss of revenue from this source. For the modelled no deal and modelled average FTA scenarios, where the UK follows a domestic carbon pricing policy, it is assumed that this system recoups all lost revenue.

8.3 Debt interest

221. To provide a comprehensive estimate of the long-run fiscal impact in each EU exit scenario the analysis includes an estimate of the debt interest consequences of changes to borrowing relative to the status quo. For this aspect of the analysis, only considering the debt interest impact from changed borrowing in 2035-36 would underestimate the overall debt interest consequentials of each scenario as it would not be accounting for any of the EU exit-related additional (or reduced) borrowing in the preceding years. To estimate the total debt interest impact in each scenario a linear path for GDP is constructed that enables cumulative additional borrowing to be calculated from the end of the implementation period to the end state year.

222. To estimate the debt interest consequentials of additional borrowing the analysis uses a ready-reckoner based on the model that underpins the OBR's EFO forecast for debt interest. Beyond the final year of the OBR forecast period the elasticities capturing the relationship between additional borrowing and its debt interest consequentials are grown in line with the effective gilt rate series set out in the OBR's long-run economic determinants.[225]

8.4 Other modelling assumptions

223. In line with the wider modelling approach, the fiscal analysis does not incorporate or attempt to forecast any potential short-run disruption associated with leaving the EU. If there are short-term adjustment costs associated with moving to a new relationship, which lead to higher borrowing in the near-term, this will lead to higher debt interest payments in the end state due to a larger stock of debt.

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[224] This series includes only the additional ODA expenditure required as the UK's ODA contributions through the EU budget decline.

[225] 'Office for Budget Responsibility: Economic and fiscal outlook', OBR, March 2018.

224. The purpose of the long-run fiscal analysis is to isolate the long-run fiscal impacts related to each EU exit scenario. To do this the analysis assumes that there is no policy response to offset changes to public sector net borrowing as a result of exiting the EU.

225. Furthermore, the long-run fiscal analysis does not consider second order effects that might occur in practice if the changes in borrowing set out above have spillover effects on other sectors of the economy or financial markets.

226. The fiscal impact of long-run changes in migration are assessed via the impact of these changes on the macroeconomy (using the standard ready-reckoner approach described previously). The fiscal analysis does not assume any changes in departmental spending limits to reflect differences in the size and composition of the population.

8.5 Results of analysis of fiscal impacts

Table 8.A: Summary of impact on public sector net borrowing compared to today's arrangments, for the illustrative no change to migration arrangements and zero net inflows of EEA workers scenarios. Change as a percentage of GDP (£ billion in nominal terms)

Compared to today's arrangements (change as a percentage of GDP in 2035-36 (£ billion)	Modelled no deal	Modelled average FTA	Modelled EEA-type	Modelled White Paper
EU Programmes				
No change to migration arrangements	+0.3 (+£13.6bn)	+0.3 (+£13.6bn)	+0.3 (+£13.6bn)	+0.3 (+£13.6bn)
Zero net inflows of EEA workers	+0.4 (+£13.6bn)	+0.3 (+£13.6bn)	N/A	+0.3 (+£13.6bn)
Future Financial Contributions[226]				
No change to migration arrangements	0.0 (£0.0bn)	0.0 (£0.0bn)	+0.1 (+£6.2bn)	0.0 (£0.0bn)
Zero net inflows of EEA workers	0.0 (£0.0bn)	0.0 (£0.0bn)	N/A	0.0 (£0.0bn)
Departmental spending on administration				
No change to migration arrangements	+0.1 (+£2.0bn)	0.0 (+£2.0bn)	0.0 (+£2.0bn)	0.0 (+£2.0bn)
Zero net inflows of EEA workers	+0.1 (+£2.0bn)	+0.1 (+2.0bn)	N/A	0.0 (+£2.0bn)
Tariffs				
No change to migration arrangements	+0.5 (+£19.4bn)	0.0 (£0.0bn)	0.0 (£0.0bn)	0.0 (£0.0bn)
Zero net inflows of EEA workers	+0.5 (+£19.4bn)	0.0 (£0.0bn)	N/A	0.0 (£0.0bn)
NTBs				
No change to migration arrangements	+2.2 (+£87.4bn)	+1.7 (+£69.1bn)	+0.5 (+£20.7)	+0.3 (+£12.6bn)

[226] In the modelled EEA-type scenario there are future financial contributions based on Norway's existing precedent. There are no future financial contributions assumed in the other modelled scenarios. Future financial contributions in the modelled White Paper scenario remain subject to negotiation.

Compared to today's arrangements (change as a percentage of GDP in 2035-36 (£ billion)	Modelled no deal	Modelled average FTA	Modelled EEA-type	Modelled White Paper
Zero net inflows of EEA workers	+2.3 (+£87.4bn)	+1.8 (+£69.1bn)	N/A	+0.3 (+£12.6bn)
Migration				
No change to migration arrangements	0.0 (+£1.9bn)	0.0 (+£1.2bn)	0.0 (+£0.3bn)	0.0 (+£0.1bn)
Zero net inflows of EEA workers	+0.5 (+£21.0bn)	+0.5 (+£21.0bn)	N/A	+0.5 (+£21.0bn)
Debt interest				
No change to migration arrangements	+0.3 (+£12.8bn)	+0.3 (+£11.6bn)	+0.1 (+£3.8bn)	0.0 (-£0.5bn)
Zero net inflows of EEA workers	+0.4 (+£16.9bn)	+0.4 (+£15.7bn)	N/A	+0.1 (+£3.8bn)
Regulatory flexibility				
No change to migration arrangements	0.0 (-£1.4bn)	0.0 (-£1.4bn)	0.0 (£0.0bn)	0.0 (-£1.4bn)
Zero net inflows of EEA workers	0.0 (-£1.4bn)	0.0 (-£1.4bn)	N/A	0.0 (-£1.4bn)
Customs revenue				
No change to migration arrangements	-0.4 (-£15.9bn)	0.0 (-£1.0bn)	0.0 (-£1.0bn)	0.0 (-£1.0bn)
Zero net inflows of EEA workers	-0.4 (-£15.1bn)	0.0 (-£0.9bn)	N/A	0.0 (-£0.9bn)
EU budget saving				
No change to migration arrangements	-0.6 (-£22.8bn)	-0.6 (-£22.8bn)	-0.5 (-£22.8bn)	-0.5 (-£22.8bn)
Zero net inflows of EEA workers	-0.6 (-£22.8bn)	-0.6 (-£22.8bn)	N/A	-0.6 (-£22.8bn)
Rest of world trade				
No change to migration arrangements	-0.1 (-£3.0bn)	0.0 (-£1.6bn)	0.0 (-£1.5bn)	-0.1 (-£2.5bn)
Zero net inflows of EEA workers	-0.1 (-£3.0bn)	0.0 (-£1.6bn)	N/A	-0.1 (-£2.5bn)
UK/EU financial settlement				
No change to migration arrangements	0.0 (+£0.1bn)	0.0 (+£0.1bn)	0.0 (+£0.1bn)	0.0 (+£0.1bn)
Zero net inflows of EEA workers	0.0 (+£0.1bn)	0.0 (+£0.1bn)	N/A	0.0 (+£0.1bn)
ODA				
No change to migration arrangements	0.0 (+£1.0bn)	0.0 (+£1.0bn)	0.0 (+£1.0bn)	0.0 (+£1.0bn)
Zero net inflows of EEA workers	0.0 (+£1.0bn)	0.0 (+£1.0bn)	N/A	0.0 (+£1.0bn)

Compared to today's arrangements (change as a percentage of GDP in 2035-36 (£ billion)	Modelled no deal	Modelled average FTA	Modelled EEA-type	Modelled White Paper
Additional borrowing associated with EU exit [227]				
No change to migration arrangements	***+2.4 (+£95.1bn)***	***+1.8 (+£72.0bn)***	***+0.5 (+£22.5bn)***	***0.0 (+£1.3bn)***
Zero net inflows of EEA workers	***+3.1 (+£119.1bn)***	***+2.4 (+£95.9bn)***	***N/A***	***+0.6 (+£26.6bn)***

Effects shown as per cent of GDP reflect both changes to borrowing in nominal terms, and differences in GDP between scenarios.

[227] For the modelled White Paper scenario an additional sensitivity is run where NTBs are assumed to be 50 per cent of the difference between those in the modelled White Paper and modelled average FTA scenarios. Additional public sector borrowing relative to current arrangements where there is no change to migration arrangements is +0.6 per cent of GDP. In the zero net inflows of EEA workers scenario, the borrowing impact is +1.2 per cent of GDP.