Online Appendix

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This Appendix contains further details of the analysis in the Briefing Paper 'Brexit and Global Value Chains: 'No-deal' is still costly'. It contains five sections:

1. Methodology
2. Trade in value added
3. The GTAP Data Base
4. The treatment of border formalities
5. Impacts on value added composition at the sector level

1. Methodology

This study is based on a counterfactual approach using the GTAP model, a perfectly competitive comparative static computable general equilibrium (CGE) model. It is built on general equilibrium theory and designed to assess the inter-regional, economy-wide incidence of economic policies (Hertel and Tsigas, 1997). The main advantages of the CGE approach are its solid micro-theoretical underpinning and its economy-wide scope, as well as its complete and consistent coverage of all bilateral trade flows.

The model underlying our analysis has a symmetric structure, with production and utility functions homogeneous across regions. The former differ by sector, however, and regions differ because the shares of different products in their outputs vary according to local characteristics. The model parameters are mostly drawn from the literature (Hertel, 2013).

The model assumes the presence of a representative regional household that receives the factor rewards and allocates regional income (through a Cobb-Douglas utility function) between private consumption, government consumption and saving to maximize its utility. The utility function is nested, with a first aggregation made over distinct goods or sectors and in the latter, a choice is made between domestic or imported quantities.

As for the production side, separable, constant returns-to-scale technologies are assumed. A common approach in CGE literature is to model the production side through a sequence of nested Constant Elasticity of Substitution (CES) functions that aims to re-produce the substitution possibilities across the full set of inputs. The firms' conditional demand for components of value added depends on the relative prices of factors of production whereas composite value added and intermediates are used in fixed proportions (a fixed coefficient function of the Leontief type). In the intermediate input side, imported intermediates are assumed to be separable from domestically produced intermediate inputs.

The import demand is modelled following the Armington aggregation structure, with an exogenous differentiation scheme given by the geographical origin of nationally homogeneous products. That is, under Armington trade, the output of each sector is assumed to be a region-specific variety. Consumer and intermediate goods are a CES composite of domestic and trade partner varieties. This specification explains the cross-hauling of similar products and makes it possible to track bilateral trade flows. Transaction costs are also accounted for in the model since transport services are explicitly considered among the activities in the economy.

For this application, the GTAP-VA module for the GTAP model (Antimiani et al., 2018) is used. In the GTAP-VA the gross trade flows are decomposed to reallocate the value added generated in the production of goods and services back to the countries in which that income is generated. This framework allows us to assess the effect of the policy change on the global structure of global value chains (GVCs), by comparing the baseline values and the updated values deriving from the shock that has been simulated.

2. Trade in value added

In this analysis, we define GVCs as an inter-country, inter-sector system of value-added sources and destinations (Koopman et al., 2014, p. 459). The value is added at each successive stage of the productive process, where the value added equals the value of payments to the primary factors of production in the country/sector in which the particular stage of production occurs. (This equality is why we talk about value added equaling income.) The trade in value added (VA) metric allows gross outputs and trade flows to be disaggregated into the segments of value created in different countries.

When intermediate goods (e.g., parts and components or any other item used as an input for further processing) cross more than one border, traditional trade statistics are not representative of the production patterns underlying global trade.

In the main paper we use four important concepts of value added (VA) in an exported good or service.

i) Domestic value added (DVA)

This is the value originating in all sectors of the UK economy that is embedded in a given UK sector's exports. It includes the value originating in the domestic exporting sector (direct DVA) plus that originating in the UK sectors providing its inputs. (We refer to such inputs as intermediate goods or intermediates.)

From the individual sector's perspective, we also need to recognize indirect DVA, i.e., the DVA from that sector that is embodied in other sectors' exports.

ii) Foreign value added (FVA)

This is the value of imported intermediate inputs embodied in UK exports, and represents the import content of exports. It is sometimes referred to as the backward linkage in global production networks because it reflects linkages back up the value chain towards its origin. The foreign value added in exports includes some that is exported back to its country of origin.

iii) Double counting (DDC)

Sometimes the foreign intermediates will include value originating in the UK, but we need to count this only the first time it is exported and not the second time when it is embodied in another UK export.

iv) Multilateral domestic value added (DVAM)

This is defined as UK value added contained in intermediate goods and services that is exported to one country which then re-exports it, embodied in other goods or services, to another. DVAM provides a measure of the UK's forward linkages from selling in global value chains (GVCs).

To illustrate them, figure A1 provides a numerical example and shows traditional trade flows as well as value added (VA) decompositions. Let's suppose that country A exports in a first round an intermediate input worth $1 to country B. The receiving country B then processes that input, adds $2 in value added, and then exports the good back to country A as an intermediate with value $3. In country A, this intermediate good is combined with other intermediate inputs imported from country C worth $3, and $4 of country A's domestic value added. The $10 intermediate input is sent to country C which performs the last stage of production adding $5 of value to satisfy the demand for imports in country B. To provide an example, we focus here on country A's exports.

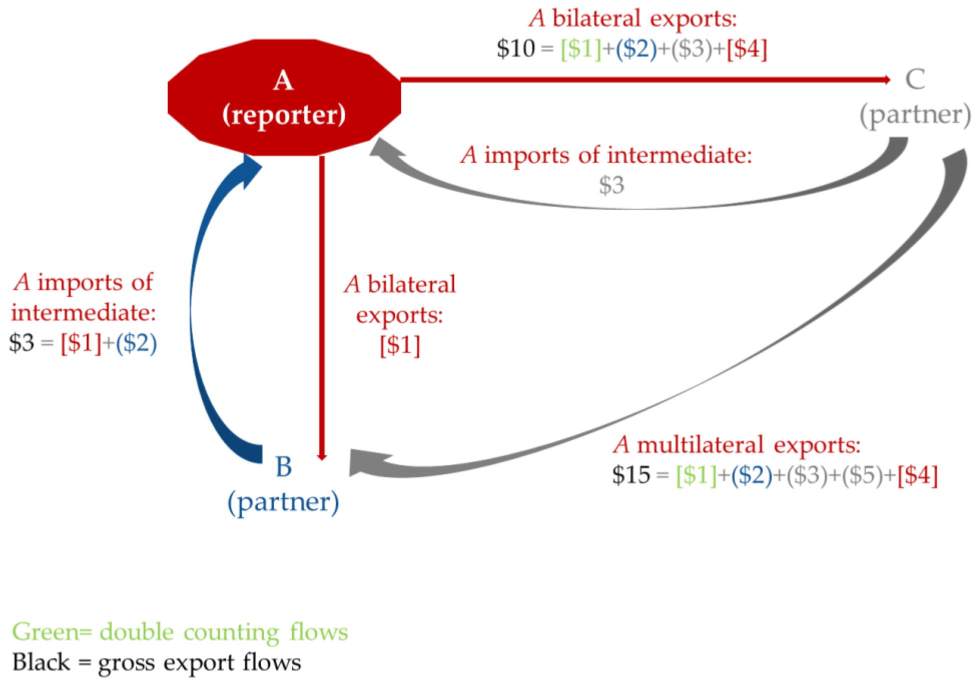
Traditional trade statistics tally the gross value of goods at each border crossing. Then, in a gross accounting, country A exports total $11 ($1 to country B and $10 to C). However, the value which has been effectively produced in A accounts for only $5 of exports. The difference between gross and value-added exports arises from two sources. First, in order to export, A needs some intermediate inputs from abroad ($2 from B and $3 from C), representing the foreign value added in its exports. Second, A's intermediate export to B returns home as an intermediate import and is used for the production of its exports to C, meaning that there is a double counting of $1 in A's domestic value added in exports. The foreign content of exports and the double-counting implies that gross statistics overstate the domestic value added in a country's exports.

There are two approaches to conducting these decompositions of trade into parts allocated to different partners – so-called source and sink approaches. Both the source and sink methods provide trade in VA accounting that distinguishes between domestic and foreign content of trade and removes the double-counting inflating traditional accounts. However, the two approaches provide two different reallocations of value-added flows to specific bilateral trade links.

The source-based approach – which we adopt here - counts the value added at its first border crossing. In this case, country A exports $1 of domestic value added to country B. Since, by assumption, it uses only domestic inputs which have never left the country, gross and value-added exports coincide. Conversely, country A's gross exports to country C do not reflect the value added created in country A. The composition of country A's exports to country C would be the following: $4 of domestic value added ($DVA_{A,C} = 4$) + $5 of foreign value added ($2 from country B and $3 from country C which are reflected to the source country) ($FVA_{A,C} = 5$) + $1 of double-counting ($DDC_{A,C} = 1$) (country A's domestic value added already accounted for in its exports to country B). That is to say, under the source method, the value added of country A is allocated to the first country that imports the value added to, in this case, both countries B and C.

Conversely, the sink-based approach would attribute $5 to the domestic value added in the exporting country A to the final importer (C): the original $1 it exported to country B plus the additional $4 added before exporting the good to country C. That is, under the sink method, the value added of country A is allocated to the last country that absorbs the value added, in this case, country C.

Figure A1. Trade and value-added flows under different accounting approaches



Traditional

Exporter \ Importer	A	B	C
A		1	10
B	3		
C	3	15	

Source

Exporter \ Importer	A	B	C
A		1	4
B	2		
C	3	5	

Sink

Exporter \ Importer	A	B	C
A		5	
B		2	
C		8	

Source: based on Figure 1 in Antiamiani et al. (2018).

In this work, we adopt a source-based approach and we assign the value-added exports to the gross trade flow in which it leaves the producing country for the very first time; if the value-added crosses the international border a second or third time, it is considered double-counting. Besides properly allocating the domestic value-added exports within bilateral links, our framework also takes into account the multilateral production sharing relationships. In our example, country A's domestic value added reaches country B through bilateral exports ($1 of intermediate exports, DVA_{AB}) as well as through the value embedded in the exports of country C to that market ($4 exported through the multilateral link, $DVAM_{AB}$).

Summarizing, country A's exports can be expressed in value added terms as follows:

	Gross exports				Total exported VA
Importer:	DVA	DDC	FVA	DVAM	(DVA + DVAM)
Country B	1	0	0	4	5
Country C	4	1	5	0	4

3. The GTAP Data Base

To implement the GVC indicators used in this study, we need Inter-Country Input-Output (ICIO) data, harmonizing input-output tables for multiple regions and linking trade flows directly from producers in each region to importing firms and consumers in all other regions. In this study, we use version 9 of the Global Trade Analysis Project (GTAP) Data Base, a baseline of consistent data on consumption, production, and trade updated to 2014.

The GTAP Data Base has been extensively used to perform an economic analysis of trade in VA, mainly due to its consistency, full global coverage, and the large country and sectoral details it provides (Aguiar et al., 2016). The advantage of using the GTAP Data Base for GVC analysis is that it reconciles data from different sources and puts them into one consistent database with a broad sectoral and regional coverage. However, the database itself does not account for how imported intermediate products are used. Within the GTAP framework, imports of intermediates from all countries are aggregated at the product level at the border into a composite imported good. This composite good is then allocated across sectors and uses based on relative demands and shares. We cannot explicitly trace exports of intermediates from one country into the production processes of another, or following on from that, into their contributions to the other countries' exports. That is to say, we cannot directly identify the inter-country industry to industry trade required for the construction of an ICIO.

There are different methods in which supplementary information is used to distinguish between countries of origin on an industry-use basis. The approach used in this study as well as in others using the GTAP Data Base (for example, Daudin et al., 2011; Johnson and Noguera, 2012; Lejour et al., 2014; Greenville et al., 2017) applies the proportionality assumption to allocate the imports of products from any given country between final demand and intermediates, and then within intermediates, between the intermediate usage by individual production commodities. The key problem with this method is that it ignores differences in the types and quality of imports from different regions. For a given product, some country exports may target final demand, while others may target intermediate demand. A more complex method builds on the first method by using concordances that map between products and end uses to differentiate between sourcing of imports across agents (Liapis and Tsigas, 2014; Walmsley et al., 2014). The most advanced methods also incorporate tariff revenues in order to differentiate composite tariff rates across agents (Carrico, 2017).

For this study, 121 countries available in the full dataset are aggregated in 10 regions: the UK (United Kingdom), the EU27 (including France, Germany, Italy, and the remaining 24 members of the EU), FTA67 (comprising the 67 countries with which the EU has signed Free Trade Agreements), and the ROW (including, China, Japan, United States, and all the remaining countries in the rest of the world). The FTA67 includes: 'New Generation' FTAs (e.g., South Korea), 'Deep and Comprehensive Free Trade Areas FTAs (e.g., Ukraine), Economic Partnership Agreements (e.g., African Countries), 'First Generation' FTAs (e.g., Turkey). For the detailed list, please refer to the online Appendix to the Gasiorek, Serwicka and Smith (2018) - UKTPO Briefing Paper 16.

We use the most detailed sectoral aggregation available in GTAP (55 products), but we present the results for 10 aggregate sectors (see Table A1 for details of the aggregation procedure). The baseline refers to 2014.

Table A1. List of FTA67 countries in the GTAP Data Base and sectoral aggregation

FTA67 countries in the GTAP Data Base:
Korea (kor); Canada (can); Mexico (mex); Chile (chl); Colombia (col); Ecuador (ecu); Peru (per); Costa Rica (cri); Guatemala (gtm); Honduras (hnd); Nicaragua (nic); Panama (pan); El Salvador (slv); Rest of Central America (xca); Dominican Republic (dom); Jamaica (jam); Trinidad and Tobago (tto); Caribbean (xcb); Switzerland (che); Norway (nor); Rest of EFTA (xef); Albania (alb); Ukraine (ukr); Rest of Eastern Europe (xee); Georgia (geo); Israel (isr); Jordan (jor); Turkey (tur); Egypt (egy); Morocco (mar); Tunisia (tun); Cameroon (cmr); Cote d'Ivoire (civ); Ghana (gha); Madagascar (mdg); Mauritius (mus); Mozambique (moz); Zimbabwe (zwe); Botswana (bwa); Namibia (nam); South Africa (zaf); Rest of South African Customs (xsc)

Aggregated sector	**GTAP sector (code)**
Agriculture	Paddy Rice (pdr); Wheat (wht); Other Grains (gro); Veg & Fruit (v_f); Oil Seeds (osd); Cane & Beet (c_b); Plant Fibres (pfb); Other Crops (ocr); Cattle (ctl); Other Animal Prod (oap); Wool (wol); Forestry (frs); Fishing (fsh)
Food	Cattle Meat (cmt); Other Meat (omt); Vegetable Oils (vol); Dairy prod. (mil, rmk); Processed Rice (pcr); Sugar (sgr); Other Food (ofd); Beverages and Tobacco prod. (b_t)
Mining, petroleum and coke	Coal (coa); Oil (oil); Gas (gas); Other Mining (omn); Petroleum & Coke (p_c)
Textiles	Textiles (tex); Wearing Apparel (wap); Leather (lea)
Chemicals	Chemical Rubber Prod. (crp)
Iron, Steel and Metals	Iron & Steel (i_s); Non-Ferrous Metals (nfm); Fabricated Metal Prod. (fmp)
Motor Vehicles	Motor vehicles and parts (mvh); Other Transport Equipment (otn)
Electronic and Machinery	Electronic Equipment (ele); Other Machinery & Equipment (ome)
Other Manufactures	Lumber (lum); Paper & Paper Prod. (ppp); Non-Metallic Minerals (nmm); Other Manufacturing (omf)
Services	Electricity (ely); Gas Distribution (gdt); Water (wtr); Construction (cns); Trade (trd); Other Transport (otp); Water transport (wtp); Air transport (atp); Communications (cmn); Other Financial Intermediation (ofi); Insurance (isr); Other Business Services (obs); Recreation & Other Services (ros); Public Services (osg, dwe)

4. The treatment of border formalities

In the literature, the use of the technical coefficient AMS, set equal to one in initial equilibrium, has become a widely accepted method to model unobserved trade costs (for example, Hertel, Walmsley and Itakura, 2001; Fox, Francois and Londono-Kent, 2003; and Francois, Van Meij and van Tongeran, 2005). The modelling of border costs using Samuelson's iceberg approach (Samuelson, 1954), raises the cost of trade, lowering the quantity of imports consumed relative to the quantity sent or exported through an import-decreasing technological change.

Based on secondary literature, such as CEPR (2013), Francois et al. (2013), Carrère and de Melo (2004), Anson et al. (2005), Cadot et al. (2005) and Hayakawa (2011), and on and UKTPO's approach in Gasiorek, Serwicka and Smith (2019), we have assumed that border inspections would increase trade costs between the UK and the EU by 3.5%. This ad valorem equivalent has been used to simulate the impact of leaving the Single Market on trade flows. The new trade flows were then set exogenously, and the ad valorem equivalent was swapped with AMS in order to estimate the supply curve shifts, which could represent increasing trade costs due to the Brexit (-5.1 on UK exports and -4.1 on UK imports).

In our scenario we expect that Brexit is going to have three distinct effects. Firstly, a negative shock to AMS will raise the effective price of imports from the UK (EU) imported into the EU (UK), thereby inducing substitution away from the exporter and towards other exporters, as governed by the elasticity of substitution. However, there is a second effect which works in the opposite direction. Since the quantities of traded goods reaching the destination market has decreased, more is required to meet the needs of the importer. Finally, the shock to AMS will increase the average import price, thereby encouraging a contraction of imports at the expense of domestic purchases. While the total impact on imports is uncertain in theory, given the values of the trade elasticities in GTAP, we expect an increase in trade costs to reduce both observed expenditures on imports and the share of imports from the exporters to which this increase in trade costs is applied.

5. Impacts on value added composition at the sector level

Figure A2. UK DVA exports by sector: scenario MFN Brexit (percentage changes)

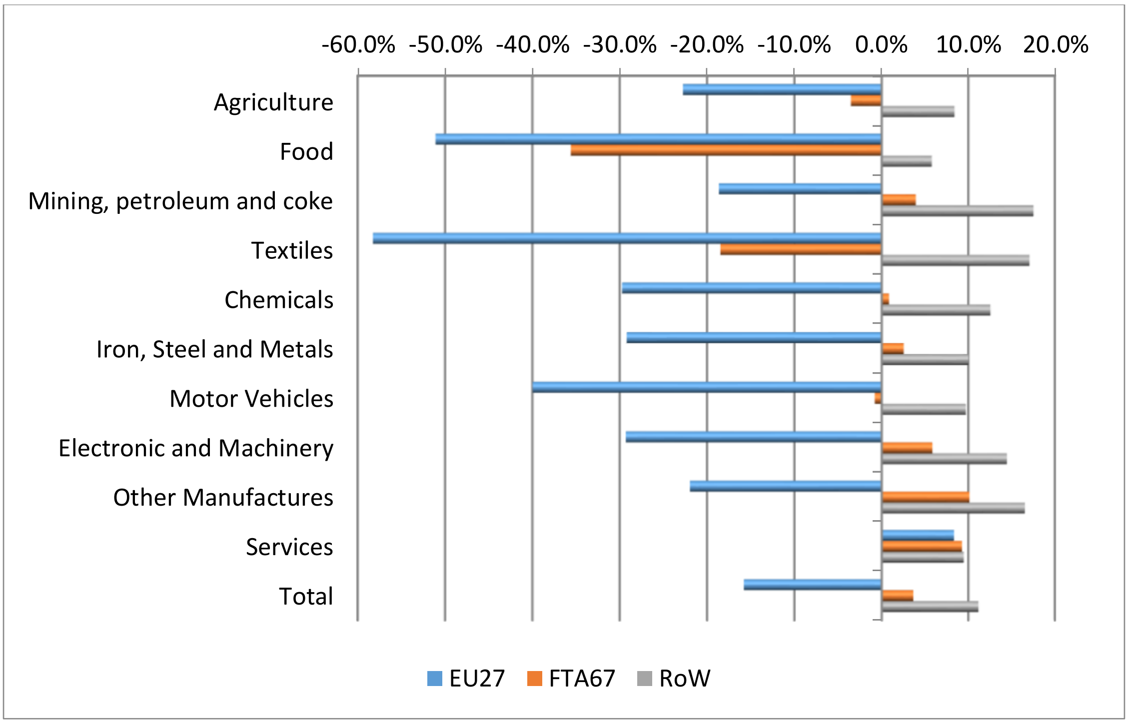
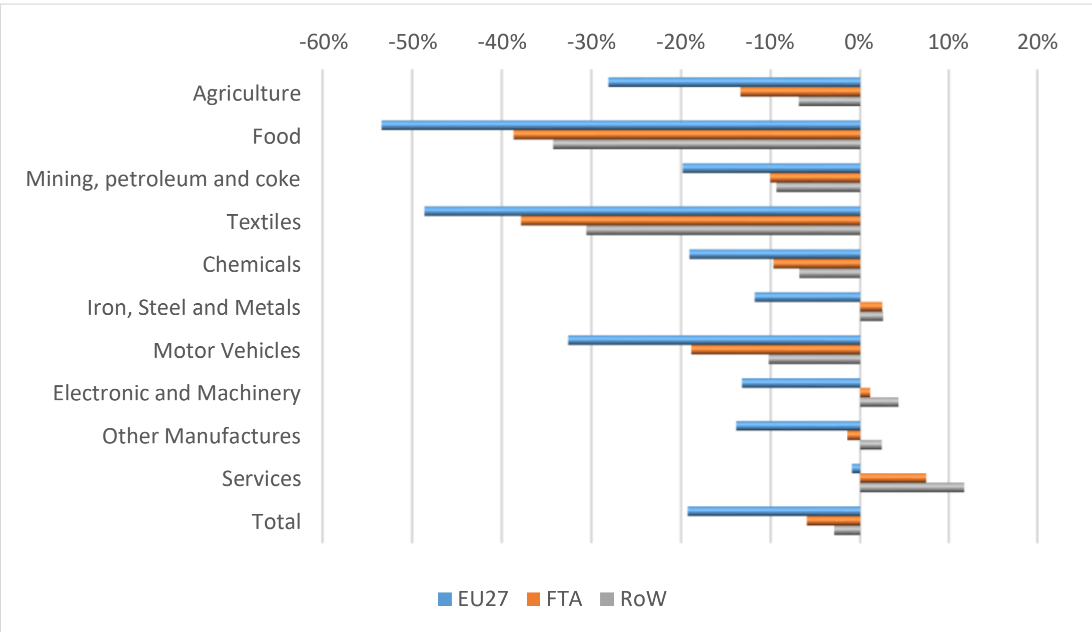


Figure A3. Providers of FVA in UK's exports: scenario MFN Brexit (percentage changes)



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