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The consequences of the Trade and Cooperation Agreement for the UK's international trade

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Appendix to The Consequences of the Trade and Cooperation Agreement for the UK's International Trade

Ilaria Fusacchia, Luca Salvatici and L Alan Winters

Section 1: Introduction

This Appendix provides more detail of the modelling that we have undertaken. The numbering of sections follows that of the main paper: section 2 discusses the GTAP model and section 4 the estimation of trade costs and how they are changed by the TCA.

Section 2: The Model

This study is based on a counterfactual approach using the GTAP model, a perfectly competitive 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. Our simulation is comparative static with a short-run closure: fixed (exogenous) factor endowments (labour and capital) while wage rates and rates of return are endogenous.

In keeping with its primary role as a trade model focusing on the international incidence of policies, the model underlying our analysis assumes the presence of a representative regional household that receives all gross factor payments net of capital depreciation, plus the receipts from all indirect taxes (generated in production, domestic demand, international trade). It allocates regional income through a Cobb-Douglas utility function between private consumption, government consumption and saving to maximize its utility. The Cobb-Douglas functional form implies that the average propensity to save is fixed and savings become a fixed proportion of income in each region.The utility function is nested, with a first aggregation made over distinct goods or sectors and in the second, a choice is made between domestic or imported quantities.

Private demand is non-homothetic and is modelled with the constant differences of elasticities (CDE) demand system (Hanoch, 1975), hence depending on income elasticities and own-price elasticities.In the GTAP model, there is not a government budget closure: government budget balances are slack implying that the deterioration in government budget balances caused by, say, the loss of tariff revenue is not offset by reduced government spending or by increases in other taxes. Revenue is a 'fixed' (according to the tax rates) share and the public spending rate (the percentage of income that is spent by the government) is assumed to be exogenous and constant, so that the quantity of public expenditure changes whenever income changes.

Modellers differ in the way that they treat the trade balance. The different options can be sketched using the following standard macro-identity:

$$S - I + T - G = X - M$$

In words, the trade balance (exports, X, minus imports, M) must be equal to the sum of the private and government surpluses, savings (S) minus investment (I), and taxes (T) minus government spending

(G) respectively.[1] It follows that, a current account (CA) surplus or deficit is linked to a capital flow. Countries that export more than they import generate revenues that are not expended domestically, but which are saved and flow abroad in order to finance the import surplus of their counterparts.

CGE models that consider current account imbalances follow two major alternatives (closure rules). Both have an impact on savings and investment. The first alternative is to set the current account exogenously, either following the historical trend based on econometric estimations or following projections from a linked macro-model. A second alternative, which is followed in our analysis, derives the current accounts endogenously given the propensities to save and other factors that drive trade flows (endowments, productivity differentials and trade policy).

There is one further constraint, however, that arises because ours is a multi-country model. The separately determined current account imbalances must sum to zero across countries. Thus a global reconciliation mechanism is required, and we adopt the the default closure in the standard GTAP model in which global investment is allocated across regions according to regional rates of return subject to the constraint that, across the world as a whole, aggregate investment equals aggregate savings (public and private).

The GTAP closure can be considered an (imperfect) alternative to modeling intertemporal optimization implementing an incentive-based approach in which international investment flows respond to economic incentives and move from slowly growing regions with low rates of return to strongly growing regions. This is in line with the direction of capital flows in the intertemporal macro-models, although the empirics of the last 20 years show that capital was flowing predominantly in the opposite direction from high-growth to low- growth regions (Bekkers et al. 2020). In this respect, it should be acknowledged that it would be desirable to have a more realistic model than the one used here to account for other items on current account, such as capital income and net transfers.

The real exchange rate in the model is captured by the factor returns ratio; that is, the price index of primary factors in a region evaluated relative to the global primary factor price index. A change in the real exchange rate is brought about by factor price adjustment: a decline (increase) in the factor returns ratio reflects cheaper (costlier) domestic factors relative to foreign factors and thus acts in the same manner as a real depreciation (appreciation).[2] Changes in the current account are driven by the changes in international trade, which in turn respond to factor prices and trade frictions.

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.

[1] We abstract in this exposition from other components of the current account such as capital and labor income crossing borders and remittances.

[2] As the model does not discuss absolute price levels (all prices are relative to a numeraire) and the demand functions are homogeneous of degree zero in prices, the model does not include a nominal exchange rate.

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 CES composites of domestic and trade partner varieties. This specification is consistent with 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.

The model 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's behavioral parameters are mostly drawn from the literature (Hertel, 2013). They include the source substitution (Armington) elasticities, the factor substitution elasticities, the factor transformation elasticities, and the consumer demand elasticities.

Table A1. Main parameters values in the GTAP model (median and interquartile range)

Parameter	Description	Median	IQR[a]
ESUBD	Armington elasticity of substitution between domestic and imported goods at region level	2.80	1.80
ESUBM	Armington elasticity of substitution of imports at region level	5.60	3.60
ESUBVA	Elasticity of substitution between primary factors in the production at region level	1.26	1.01
SUBPAR	The substitution parameter in the CDE minimum expenditure function	0.60	0.40
INCPAR	The expansion parameter in the CDE minimum expenditure function	0.98	0.54

Note a/ The IQR refer to variation over products in the first three rows and over products and regions in the last two.

Armington elasticities are obtained from econometric work done by Hertel, Hummels, Ivanic and Keeney (2004), exploiting cross-sectional variation in delivered prices (Hummels, 1999). The substitution elasticities between domestic and imported commodities are linked to the Armington elasticities by the "rule of two" (Jomini et al., 1991; Liu et al., 2004). The elasticities of substitution among primary factors are based on a review of the international cross-section studies, using data from a wide range of countries (Hertel and van der Mensbrugghe, 2019). As for the degree of primary factor mobility between the sectors, we use the default setting where all labor types and capital are treated as perfectly mobile across sectors, whereas natural resources and agricultural land are treated as sluggish factors of production. Finally, income elasticities are based on the work done by Reimer and Hertel (2004) who estimated an implicit, directly additive demand system (AIDADS) first using cross-country data on consumer expenditures from the International Comparison Project (ICP) and then using GTAP data. They are used to calibrate the CDE consumption equations as spelled out in Liu et al (1998).

George Box famously said "All models are wrong", but then added "but some are useful".[3] The model we use here is a standard Computable General Equilibrium (CGE) model. It focuses on trade flows, including of the value added embodied in them, and estimates of the effects of trade policy shocks by

[3] For an exegesis, see https://en.wikipedia.org/wiki/All_models_are_wrong.

sector and region taking into account in a consistent way the full set of markets from factors of production through to international trade and final purchase by consumers or users. It provides important information for policy-making, but detail in these dimensions comes at the expense of that in others.

Several extensions have been proposed to CGE models over the years, but we do not implement them in this exercise. This is not because they are implausible, but because economists have rather little idea of the appropriate functional forms or the crucial parameter values with which to model them. That is, in order to explore the trade effects of the TCA we have stuck, rather conservatively, with a model structure which is well understood and for which we have at least some basis for its parameterization. Thus among the extensions that we have foregone are:

- Deriving a time profile for our medium-term static results (6 to 10 years), so that we cannot comment on any path dependency of the final outcome on the dynamic profile.
- Allowing a feedback loop from trade into technology which could affect productivity beyond the adjustment of input shares that we do model.
- Allowing for increasing returns to scale or scope within sectors.
- Modelling the way in which investment responds to future prospects. and
- Allowing for agglomeration effects, a la Venables (2020).

A further consequence of the model structure is that we are not well set up to derive estimates of the effects of trade shocks on GDP, comparable with some of those in the literature. A CGE model describes only relative prices. As a consequence, one price serves as the model's numeraire, a benchmark of value against which the changes in all other prices can be measured: the numeraire in the GTAP model is an index of global wages and rents for labour, capital and other factors. Given the UK's small size (less than 3% of global GDP at market exchange rates), world factor rewards hardly change, so we are essentially valuing outputs at fixed international prices. However, as noted above UK factor prices do change relative to the numeraire in a way that is equivalent to a real exchange rate change, and since Brexit induces a reduction in the latter, it reduces the value of GDP in terms of international prices.

Table A2. List of TAC countries in the GTAP Data Base and sectoral aggregation

TAC 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)

Inter-country input-output linkages

GTAP rests on an input-output accounting framework that allows us to trace inter-sectoral linkages. The framework is complete, in that all sources and uses of each economic good are accounted for, as are all inputs into production. However, in the standard setting, firm-to-firm international exchanges are not explicitly taken into account and imports of a particular GTAP product from a particular country are captured by a single number, whether they are destined for final use by consumers or governments or for intermediate use by firms. Indeed, each GTAP product includes many different product headings measured at the Harmonized Commodity and Coding System (HS) 6-digit level (HS-6) and for many of these products it is clear from the nature of the product what the likely destination is. We follow Liapis and Tsigas (2014) and Walmsley et al. (2014) in exploiting this latter information to get a better estimate of the backward and forward linkages between firms in different countries.

The method relies on the use of a series of concordances from the United Nations Statistics Division (UNSD) (correspondence tables are retrieved from https://unstats.un.org/unsd/classifications/econ/). In particular, we use the Classification by Broad Economic Categories (BEC) to obtain derive shares that can attribute bilateral imports in the GTAP Data Base across different agents (i.e., firms, government, private households). Specifically, we start with UN COMTRADE import data at the six-digit level of the HS and apply the first concordance between HS and the BEC Rev.5. Each economic category is completely decomposable by end use. Accordingly, the mapping between BEC and the System of National Accounts (SNA) end-use dimension makes it possible to identify three different end use classes, namely, intermediate consumption, gross fixed capital formation and final consumption. Finally, the HS-GTAP concordance is applied to map each HS line to a GTAP commodity which gives the BEC-informed shares for each GTAP commodity.

Welfare decomposition

In the GTAP framework, total, equivalent variation welfare gains/losses can be decomposed into contributions from changes in allocative efficiency and the terms of trade (Huff and Hertel, 2000).

Allocative efficiency refers to the efficient industry-wise allocation of scarce resources to produce the optimal combination of outputs. Consequently, allocative efficiency effects arise when the allocation of resources changes relative to pre-existing distortions. They give a measure of the change in the deadweight loss 'triangle' associated with a distortion.

The terms of trade improve with a relative increase in the price of exports relative to that of imports and this increases welfare by allowing a given volume of output to purchase more goods for consumption/investment/government. The export and import price indices are current weighted and so changes in trade patterns can also affect the terms of trade a little.[4]

Trade in value added decomposition

For this application the GTAP-VA module developed by Antimiani et al. (2018) is used. In 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 one 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.

Value added is defined as the difference between the value of output and the total value of purchased intermediate inputs, and includes compensation for labour and capital and taxes. The main indicators related to the value added in an exported good or service which are used in this analysis are the following:

i) Bilateral domestic value added (DVA)

This corresponds to the value originated in all sectors of the exporting country which is embedded in a domestic sector's exports. The DVA in exports gives a measure of the real contribution a given export makes to an economy's income. Within the DVA, two components can be further distinguished: a) the value originating in the domestic exporting sector (direct); and b) the value that originated in other domestic sectors providing intermediate inputs to the domestic exporting sector (indirect).

ii) Multilateral domestic value added (DVAM)

This is defined as the domestic value added contained in intermediate goods and services that is exported to a partner country which then re-exports it to the final market, now embodied in other goods or services. DVAM, also referred to as a "triangular" production chain (Johnson and Noguera, 2012), provides a measure of the forward linkages a country has in selling in international VCs.

[4] In addition, in GTAP terms of trade changes also reflect changes in trading margins and in the relative prices of the savings and investment that a country contributes/draws from the global pool of capital. In our exercise neither plays a significant role.

Both the DVA and the DVAM indicators are adjusted for double-counting, meaning that the domestic value added embodied in an export that has previously crossed a region's international border, and hence has already been counted as domestic value added, is netted out.

iii) Foreign value added (FVA)

This is the value of imported intermediate inputs embodied in a country's exports. It is sometimes referred to as backward linkages in global production networks because it reflects linkages up the value chain towards its origin. Within FVA, a portion can refer to trade that is exported back to the country of origin of the value added (circular trade).

Updating the reference year in GTAP

For our analysis, we update the reference year of the current GTAP database (2014) including some more recent policy changes. We chose 2019 as the reference year since it is the latest year before the negative shocks due to the pandemic.

We construct the updated baseline using data from IMF and ILO on macro variables, such as population, labor force (by skill category), and GDP. Population and labor availability are exogenous variables in the CGE model. Thus these variables are shocked according to the data for 2019 from IMF and ILO. To target GDP, which is normally an endogenous variable in GTAP, the closure of the model is changed, with GDP growth made exogenous, and an economy-wide technology parameter allowed to adjust as needed.

As far as the trade policies are concerned, the baseline includes the EU agreements with Japan, Canada and Singapore. Accordingly, we set to zero tariffs on goods between the EU (including UK) and those countries.

The impacts these simultaneous shocks have on UK trade are shown in Table A3.

Table A.3 Changes in UK trade after updating to 2019 (world prices, % change from 2014)

	EU	**TAC**	**USA**	**Japan+China**	**RoW**
Exports	3.4	5.4	3.8	12.9	3.6
Imports	2.5	6.9	2.5	21.1	0.7

Section 4: Modelling Trade Policy

(A) Scenario definition

Table A.4 gives the full set of trade cost changes in our scenarios. For tariffs, we potentially have different rates on exports and imports, whereas for all other costs we assume either symmetry over directions of trade or no change from the base, in which case any asymmetries are built into the trade functions.

Table A4 Changes in Trade Costs from Base to TCA scenario

UK/EU Trade		
Trade cost	**Base (2019)**	**The Trade and Cooperation Agreement**
Tariffs: goods	zero	zero
Non-tariff measures: goods	zero	Cadot & Gourdon, non-RTA
Border costs: goods	zero	2% plus supplements in a few sectors
Rules of origin: goods	zero	3% plus supplements in some sectors
Non-tariff measures: services	unknown	Base + increments derived from gravity models

UK/MFN-partner Trade		
Trade cost	**Base (2019)**	**The Trade and Cooperation Agreement**
Tariffs: goods	UK= EU MFN, partner = MFN	UK= UKGT, partner = MFN

All other flows and barriers: no change

(B) Details on Trade Costs

Tariffs

We use the tariff estimates provided in the G-TAP database for most of the countries in this exercise. However, in the TCA scenario, we need to recognise that following Brexit the UK has introduced a new, slightly more liberal, regime for MFN trade. The UK's new Global Tariff (UKTP) was published at the 8-digit level on 19th May 2020 in https://www.gov.uk/government/news/uk-global-tariff-backs-uk-businesses-and-consumers. The changes, summarised by Magntorn Garett et al (2020), imply that the weighted average tariff on goods imported from countries paying the MFN tariff falls from 2.1% to 1.5% (excluding non ad-valorem tariffs). We converted the 8-digit tariffs to 6-digit level of the HS Classification by simple averaging within each HS-6 heading and then weighted these up to GTAP 57 industry level using trade weights. We also conducted the same exercise on the EU MFN tariff that applied in the base data (and which the UK is seeking to bind in the WTO), and calculated the difference between the two at GTAP industry level as a measure of the change implied.

For UK imports facing MFN rates – e.g. UK-USA - we used the GTAP base estimates of the tariff that was applicable when the UK was a mmber of the EU and added our calculated change in the UK tariff due to the UK moving from the EU-MFN to the UKGT. The reason for this approach is that tariffs in the GTAP base dataset have been subject to a certain amount of manipulation and balancing in constructing the GTAP database, and to drop an independent estimate into the middle of them runs the risk of disturbing the balance of the latter.

As noted in the text, we assume no change in the tariff applied by the UK to imports from the TAC countries and vice versa.

Non-Tariff Measures: Goods[5]

[5] We are grateful to Yohannes Ayele of UKTPO for providing these estimates and preparing this section.

Estimates of the ad-valorem equivalents of non-tariff measures (NTMs) for the GTAP's 43 agriculture and manufacturing sectors are taken from Cadot and Gourdon (2016). Using trade unit values from the CEPII database as price data, they applied the price-gap method to estimate the ad-valorem equivalents (AVEs) of the NTMs for 21 sections of the Harmonized System of product classification. They regress the log of the the unit value of imports of product *k* into market *d* from source *o* on various bilateral determinants of trade (e.g. distance), binary indicators of the presence or absence of an NTM distinguishing three types [A (SPS), B (TBT), and C(other)], and controls for importer characteristics. They do this at the HS-6-digit level and then aggregate the product-by-product estimates to the HS section averages.

Cadot and Gourdon (2016) also estimate whether 'deep' regional trade agreements (RTAs) dampen the effect of NTMs on prices by interacting their NTM dummies with dummies marking deep-integration clauses. However, they are explicit that the differences between the with and without-RTA estimates mainly arise from the mutual recognition of conformity-assessment procedures in many deep RTAs. Given that the TCA makes little progress on these – especially on SPS – we adopt in most cases, Cadot and Gourdon's non-RTA estimates.[6]

The exceptions arise from the Annexes to the TBT Chapter of the TCA and the rules pertaining to aircraft manufacture. Following the discussion in Ayele et al (2021) we assume that motor vehicles and aircraft and most of their parts do have the equivalent of mutual recognition and so use the -with-RTA' estimates for these sectors. We also assume that the recognition arrangements for the manufacture of pharmaceuticals would place the NTM for chemicals half way between the with and without estimates from Cadot and Gourdon. We reckon that the Annexes on wines and on recognising 'organic status' for vegetables do not reduce the without NTM-estimates.

Overall, unlike our previous work, in this exercise we use, with the exceptions noted, the 'without-RTA' results for the AVE of NTMs between the UK and the EU. This is arguably a little harsh on the TCA in general, although generous on the exceptions, but we believe it strikes roughly the right balance. In fact, however, the differences between Cadot and Gourdon's with and without RTA estimates are not generally very great.

Cadot and Gourdon's approach to NTMs very interesting and it seems to us among the most convincing approaches to NTMs. Nonetheless, there are some serious issues around them.

- First, given that the estimated equations regress the logarithm of the unit value on a series of variables, there is a problem where trade is zero and the unit value is undefined. So far as we can ascertain such observations are dropped from the estimation which may imply an under-estimation of trade cost effects. In addition, Cadot and Gourdon report their own concerns about the averaging of HS-6 results upto HS-section level: only coefficients that are statistically significant at 10% are kept (40% of the estimates).
- 15% of the observations provide negative AVE estimates. They consider these as aberrations and replace them with missing values.

[6] It is true that the EU permits 'self-certification' of exports of many non-sensitive products, but even here the UK firm must find an EU entity to make and take legal responsibility for the declaration, so it is not cost-free.

- as some of the AVE estimates are implausible (such as a 500% AVE), Cadot and Gourdon use a hyperbolic tangent function to transform the estimates before averaging.

Finally, we suggest three important caveats in interpreting the estimates: the first applies to any NTM estimation (including that for services) and the other two are specific to the price-gap method. First, NTMs are not only highly diverse in number and scope but also the mechanisms by which they affect international trade and the economy are complex and broad. Thus estimating and identifying a single AVE tariff equivalent of the NTMs is overly simple. Second, the estimates should be interpreted carefully considering that other factors than NTMs might contribute to the price-gap. Third, sometimes firms may choose to internalize the cost of NTMs to keep their market share by decreasing their mark-up, and thus the price-gap may be sensitive to extraneous shocks.

Converting Cadot and Gourdon’s estimates to GTAP sectors:

Cadot and Gourdon (2016) estimate of the tariff equivalents of NTMs for 21 sections of the Harmonized System of product classification. They now have to be matched to the GTAP 43 Agriculture and Manufacturing Sectors. To match the NTMs estimate of Cadot and Gourdon (2016) with GTAP’s 43 sectors. First, we use the HS6—GTAP many-to-many concordance provided by GTAP. Each HS6 headng was given the corresponding HS-section NTM estimate and the weighted average calculated, using UK imports as weights. (We also conducted the calculation using global HS6 import data and the results were generally not changed significantly.)

The final result is reported in Table A5 for all sectors. The weighted averages of NTMs on goods are 8.0% on UK exports and 8.4% on UK imports.

Table A5: Estimates of GTAP sectors AVE

GTAP Sector	**GTAP Sector Name**	**AVE without RTA**
PDR	Paddy rice	20.3
WHT	Wheat	20.3
GRO	Cereal grains, n.e.c.	20.3
V_F	Vegetables, fruit, nuts	20.3
OSD	Oil seeds	20.3
C_B	Sugar cane, sugar beet	20.3
PFB	Plant-based fibers	5.6
OCR	Crops n.e.c	20.1
CTL	Cattle, sheep, goats, horses	20.8
OAP	Animal products n.e.c.	19.3
WOL	Wool, silk-worm cocoons	5.6
FRS	Forestry	11.8
FSH	Fishing	20.5
COA	CoaL	9.4
OIL	Oil	9.4
GAS	Gas	9.4
OMN	Other minerals	7.8
CMT	Meat: cattle, sheep, goats, horse	20.8
OMT	Meat products n.e.c	18.9
VOL	Vegetable oils and fats	17.0
MIL	Dairy products	20.4
PCR	Processed rice	20.3
SGR	Sugar	16.5
OFD	Food products n.e.c.	17.4
B_T	Beverages and tobacco product	16.5
TEX	Textiles	5.6
WAP	Wearing apparel	5.6
LEA	Leather products	5.5
LUM	Wood products	6.5
PPP	Paper products, publishing	3.5
P_C	Petroleum, coal products	9.4
CRP	Chemical products	6.6
NMM	Mineral products n.e.c	6.5
I_S	Ferrous metals	5.8
NFM	Metals n.e.c.	5.4
FMP	Metal products	6.0
MVH	Motor vehicles and parts	7.7
OTN	Transport equipment n.e.c.	6.6
ELE	Computer, electronic and optical products	7.0
OME	Machinery and equipment n.e.c	6.7
OMF	Manufactures n.e.c	6.1
ELY	Electricity	9.4
GDT	Gas manufacture, distribution	9.4

Although the NTMs are estimated as tariff equivalents, they are not ‘regular’ tariffs. We model them using a “phantom tax” modelling approach whose main notion is that ‘home-biased’ import policies can be modelled through a subsidy accruing to domestic producers and a concurrent tax levied on imports. The exact match in terms of revenue flows ensures that there are no tax revenues gains/losses from AVEs (Aguiar et al., 2016). This captures their protective effect of switching demand towards domestic supplies, leads to the absorption of domestic factors of production, increases domestic output and slightly reduces UK production costs. If, however, NTMs are deadweight losses that absorb resources without producing outputs, while this approach captures the resource cost and the factor returns that it generates, it leads us to somewhat over-estimate aggregate domestic output.

We also treat the services NTMs and border and rules of origin costs below as “phantom taxes” which cost real resources.

Border Costs

Other than within the EU, all goods trade faces border formalities (customs forms the payment of local taxes, etc). We assume that after Brexit, all trade does. These costs are not related to the height of the tariff and are not avoided by an FTA except an extraordinarily deep one (i.e membership of the Single Market).

The cost of these formalities clearly varies between firms and even between transactions, and there appears to be little evidence on which to base an average estimate. The UK government did admit, however, that it believed that, for UK firms, the extra private border costs associated with Brexit would be £7 billion (implicitly per year, because forms will be required in perpetuity) – Parker et al (2020). UK exports and imports with the EU of goods summed to £435 billion in 2018, and so, allowing for some additional costs for the EU partners and for the costs of the official processing of these forms, we have set overall additional border costs on UK-EU goods trade, conservatively, at 2% of the transaction value on both imports and exports.

We do, however, make small additions to border costs where we believe that a significant share of pre-Brexit trade occurred via small packages and parcels. These are probably mainly retail transactions and so we make the following additions:

Table A6: Supplements to border costs

GTAP sector		Border cost: Total	‘Standard’	‘Retail’ addition
WAP	Wearing apparel	3.0%	2.0%	1.0%
LEA	Leather products	3.0%	2.0%	1.0%
FMP	Metal products	2.5%	2.0%	0.5%
ELE	Electronic equipment	2.5%	2.0%	0.5%
OME	Machinery and equipment nec	2.5%	2.0%	0.5%
OMF	Manufactures nec	2.5%	2.0%	0.5%

We assume no change in border costs between the base and the TCA simulation for all trade other than UK-EU trade.

Rules of Origin

Rules of origin are also highly variable across firms and transactions, but here there is a little evidence to work with. Based on gravity modelling, Cadestin et al (2016) estimate that RoOs in Latin American preferential agreements have an Ad Valorem Equivalent of the order of 8-9 per cent. This is rather higher than Francois, Hoekman and Manchin (2006) find by seeking the threshold at which it is no longer worth a developing country exporter seeking to take advantage of a preference. Their exercise identifies the total (additional) cost involved in using the preference (i.e. not only RoOs) and they suggest that it is 4 per cent for manufactures and 15 per cent for agricultural products.

Recognising that costs are probably lower in a developed country, we estimate that, on average, RoOs add 3.0% to the cost of a transaction. In addition, we make two adjustments to the costs of ROOs. First, given that ROOs impose a significant fixed cost on exporters, they impinge disproportionately on small firms. Unfortunately we do not have disaggregated data on the proportion of exports emanating from small firms but we do have production data. The ONS data on 'UK Business: Activity, Size and Location' reports the number of enterprises by Standard Industrial Classification (SIC) class and turnover size-band. From this we calculated the proportion of turn-over accounted for by firms with turnover below £250,000. The mean proportion in manufacturing (excluding repair activities) was 2.5%. SIC classes for which the observed figure was 10% or larger were flagged and where these accounted for a significant share of UK output in the GTAP sector, we added 0.5% or 0.25% to the ROO cost, as shown in table A7.

The second adjustment was to recognise that the 'insufficient processing' rule would disrupt sectors where repacking and resale were important. Many rules of origin require that at least a certain proportion of inputs into a good must be locally produced before that good can claim 'originating' status. The TCA allows for 'bilateral' cumulation, such that parts produced in either the UK or the EU can be counted towards either UK or EU origin, but with one exception. Article ORIG:4 (3) of the TCA states that bilateral cumulation shall not apply when the exporting country has not carried out 'sufficient processing' on the input, where sufficient processing requires more than things like just repackaging or simple painting and polishing. This means that whereas before Brexit it was possible for a manufacturer to produce a product in the EU, send it in bulk to the UK to be, say, repackaged, and then re-import it to the EU, the re-import will not be deemed to have UK origin and hence will now attract a tariff.[7]

On the basis of little more than press reports, we believe that processed foods, clothing and footwear face this problem to a material degree and we add 1.5% to the ROO cost to account for it. This supplement is quite large because disturbing a business model that focuses on having a distribution hub in just one EU member state seems to require major adjustment. On UK imports, any such adjustment is likely comprise creating a small hub in the UK, with a likely loss of economies of scale; for UK exports, it is likely to comprise the establishment of a continental hub to serve the remaining members of the EU and hence the loss of UK exports (and imports).

[7] These sorts clauses figure in many EU trade agreements and even in at least some of the UK's TAC agreements.

Table A7: Supplements to ROO costs

NTMS		ROO threshold			
GTAP Sector		total	standard	Small firms	Insufficient processing
OMT	Meat products nec	5.0%	3.0%	0.50%	1.50%
VOL	Vegetable oils and fats	5.0%	3.0%	0.50%	1.50%
MIL	Dairy products	5.0%	3.0%	0.50%	1.50%
PCR	Processed rice	5.0%	3.0%	0.50%	1.50%
SGR	Sugar	4.5%	3.0%		1.50%
OFD	Food products nec	5.0%	3.0%	0.50%	1.50%
B_T	Beverages and tobacco products	4.5%	3.0%		1.50%
TEX	Textiles	5.0%	3.0%	0.50%	1.50%
WAP	Wearing apparel	5.0%	3.0%	0.50%	1.50%
LEA	Leather products	5.0%	3.0%	0.50%	1.50%
OTN	Transport equipment nec	3.25%	3.0%	0.25%	
OMF	Manufactures nec	4.0%	3.0%	0.25%	0.75%

Imports that cannot prove they meet the ROO face the standard (MFN) tariff. HMRC evidence shows that in April 2021, about 70% of UK exports to the EU in trade headings with a non-zero EU MFN tariff paid the preferential rate of zero – Ayele (2021). (We do not know whether this is because they did not seek it or were denied it.) To incorporate this into our modelling, if, for any commodity, the EU MFN rate is below the cost-threshold, we apply the MFN rate to that flow, whereas if it is above we apply the threshold (i.e.the preferential tariff of zero plus the ROO-related cost of claiming it). We conduct this operation at the 6-digit level of the Harmonised System and then calculate the (weighted) average for each GTAP sector. The weighted average charge according to this approach is 1.8% for UK exports to the EU and 1.9% for UK imports from the EU.

Rules of Origin have the effect of diverting imports of intermediate inputs from third countries to the partners within an FTA. Precisely how much depends on the details of the production processes for every export product. We do not have such information and so we have not incorporated this aspect of ROOs into the modelling exercise.

We assume no change in the cost of RoOs for the TAC.

Summary for goods

Table A.8 pulls the new trading costs for UK-EU trade in goods together.

Table A.8 Costs on UK-EU goods trade resulting from Brexit with the TCA (tariff equivlaents, %)

	On UK exports to EU	On UK imports from EU
Non-tariff measures	8.0	8.4
Border costs	2.1	2.2
Rules of origin	1.8	1.9
Total	11.9	12.5

In terms of comparisons, Egger et al (2015) estimate that the ad valorem equivalent of intra-EU integration in goods trade is 12.9% (table 4) and Berden and Francois (2015) cite other studies which, while not offering averages, suggest that NTMs could easily be of this magnitude (their table 8). More recently Head and Mayer (2021) have estimated trade costs for the EU's intra- and extra-trade relative to 1960. Their figure 1 suggests that, since the advent of the Single Market (i.e. well after the creation of the Customs Union), intra-trade costs have fallen twice as much as extra-trade costs implying that moving outside the EU is equivalent to adding an ad valorem tariff of about 11%. Given that some non-tariff barriers had been eliminated before 1993, this seems very similar to our estimate.

One final comparison relevant to this paper is with Davenport et al (2022). They assume that new NTMs on goods average 5.5%.

Non-Tariff Measures: Services

Estimates of the barriers to services trade are notoriously difficult to undertake and offer widely different estimates of their effect – see, for example, Walsh (2008), Guillin (2013) and Ciuriak et al. (2020). As noted in the text, we sought initially to by-pass the full exercise by merely estimating the supposed benefits of the Single Market for services trade. One estimate of these is Fontagne, Mitaritonna and Signoret (2016), which offers estimates for the nine of the GTAP services sectors. (The full set of estimates comes from the website in the USITC version of the paper.)

Fontagne et al's estimates of country-specific services NTMs are based on importer fixed effects from gravity models for each of nine sectors estimated from cross-section data for 2011 for 117 countries. The data are from GTAP's bilateral trade database and hence contain a large number of imputed values. The estimates assume that the NTMs are importer-specific, applying equally to all exporters to that market. They are derived from the full set of importer fixed effects in the gravity model, and thus capture the extent to which an importer's services imports are, on average, higher or lower than other importers'. The average trade effects are converted into ad valorem tariff equivalents (AVEs) by asking what increments to trade costs over those faced by the most liberal importer would have produced the observed trade outcomes. The most liberal country is defined as the country with the largest estimated fixed effect, and this is set by definition as having 'barrier-free' trade. That is, Fontagne et al measure relative trade costs for imports of services from different sources, not the cost of imports relative to domestic sales.

Based on a structural gravity equation, the AVEs are the changes in iceberg trade costs that generate the best fit for the gravity model to the 2011 data. Fontagne et al assumed that the elasticity of trade wrt to prices, σ, was -5.6. This is basically the elasticity of substitution between sources. The key relationship is

$$\ln[\,(1+\,\tau_j)^{1-\,\sigma}] = \,\gamma_j -\,\gamma_0 \qquad (1)$$

where τ_j is the AVE and γ_j the fixed effect for importer *j*, with *0* denoting the country with the largest fixed effect, i.e. lowest NTMs.

The fixed effects clearly capture any country-specific feature, including, since this is a cross section, GDP and GDP pc, which clearly can affect trade in services. For this reason, we cannot take them very seriously as estimates of the absolute values of services trade barriers.

However, Fontagne et al's equations include the usual cross-section gravity variables for trading costs, including dummies for certain FTAs, including the EU (not the EEA, note). In principle, the EU variable captures the trade-increasing effects of the Single Market. It is the same for each member state and acts additively to the fixed effect for each member state's MFN policies. It is best thought of as a factor additive to γ_j for intra-EU trade, so that the appropriate AVE for intra-trade is

$$\ln[\,(1+\,\tau'_j)^{1-\,\sigma}] = \,\gamma_j + \mu -\,\gamma_0 \qquad (2)$$

where μ is the coefficient on the EU dummy.

Table A8 reports Fontagne's dummies, μ, for the GTAP sectors they estimated. In our exercise we have set the trade increment for Recreation & Other Services to the unweighted mean of the other sectors (0.315) and those for the utilities to zero. (There are only very low levels of trade in utilities.) In addition, when we come to convert these fixed effects to AVEs we have assumed an elasticity of -3.8, the elasticity of substitution used for services in our version of the GTAP model . It essentially gears the model up to reproduce the 'excess trade' that the fixed effects estimate if all the second and subsequent round effects are ignored.

Table A8 The effects of Single Market membership on services trade Dummy variable estimates from Fontagne et al (2016)

GTAP sector	acronym	EU effect
Construction	cns	0.334
Trade	trd	0.502
Other Transport	trn*	0.178
Air transport	trn*	0.178
Water transport	wtp*	0.317
Communications	Cmn	0.085
Other Financial Intermediation	ofi	0.501
Insurance	isr	0.208
Other Business Services	obs	0.325
Recreation & Other Services		n.a.
Public Services	osg	0.379

* Trn includes all three GTAP transport sectors, wtp is also estimated separately by Fontagne et al.

Although Fontagne's estimates do not come from a proper structural gravity model, because the equations do not include domestic sales as well as trade flows, the estimated EU dummy coefficients will probably be less distorted than the catch-all NTM estimates. Thus our approach is to work in terms of the changes in NTMs wrought by Brexit (rather than levels), i.e. to act as if NTMs were zero in the base year, and conduct all our estimates with the increments alone.

The reservations we have expressed above about Fontagne's estimates are not insignificant. We have therefore sought alternative measures from the one place which we know of where the UK government has associated itself with a view about what services NTMs might be - Developing Trade Consultants (DTC - 2019).[8] DTC estimate full structural gravity models on a series of services sectors, including as explanatory variables estimates of the OECD's Services Trade Restrictiveness Index. The coefficients on these variables plus the data themselves allow them to estimate the trade restricting effects of barriers and, using an elasticity of substitution of -3, derive tariff equivalents. The study is primarily oriented towards intra-UK NTMs – and includes STRI measures for each UK nation - but it reports barriers on UK imports from the European Economic Area (the Single Market) and also from non-preferred (MFN) sources. By comparing these we are able to infer the benefit of the Single Market.

For each of the MFN and EEA barriers we calculate a GDP-weighted average across the four UK nations and take the difference as a Single Market effect.[9] DTC's results map closely to GTAP sectors in seven cases; in the remaining four we scale up the Fontagne-based results by the (UK-trade- weighted) average ratio of DTC to Fontagne results. This results in significantly higher services trade barriers than we had previously from Fontagne alone. Table A9 gives the old and the new estimates.

[8] Of course, official standing gives no indication of scientific merit. However, given that the most significant disagreement concerning the costs of Brexit is between the UK government (which tries to maintain there are next to no costs) and the bulk of the economics profession, there is an argument for using government-sanctioned estimates of the new trade barriers.

[9] Strictly, we calculate $(1+\tau_{MFN})/(1+\tau_{EEA}) - 1$.

Table A9: Estimates of the barriers to UK-EU services trade introduced by Brexit

GTAP sector	Fontagne %	With the DTC adjustment %
Construction	7	9
Trade	11	8
Other Transport	4	16
Water transport	7	13
Air transport	4	21
Communications	2	5
Other Financial Intermediation	*11*	*26*
Insurance	*4*	*11*
Other Business Services	7	13
*Recreation & Other Services***	*7*	*16*
Public Services	*8*	*20*

Note: the sectors in italics are those where DTC do not offer direct estimates and we have scaled the Fontagne results – see text.

There are few AVEs in services to compare these estimates with, but one recent very useful source is by Benz and Jaax (2020) of the OECD. They conduct a thorough gravity-based estimation exercise using STRI data for 46 countries over 2015-19 on five sectors as defined in the International Balance of Payments data.

Their results for 2019 are summarised below for 25 members of the EEA in Table A10.

Table A10: Summary of the AVE of Single Market membership in services 2019, from Benz and Jaax (2020)

	Communications	Business services	Financial services	Insurance	Transport
EEA excluding the UK					
median	24.1%	39.8%	88.3%	52.6%	30.7%
mean	26.9%	41.0%	94.8%	59.2%	33.0%
UK	24.1%	39.2%	89.1%	49.0%	31.3%

Two conclusions shine out from table A10. First, Benz and Jaax have far higher Single Market effects than we have even after adjustment to the DTC estimates. Second the estimates for the UK are almost precisely the same as the median for the 24 EEA countries examined. We use the latter as justification for our decision to apply the numbers derived above to UK-EU trade in both directions.

In terms of weighted averages, our estimated ad valorem tariff equivalents for services NTMs are 15.7% for UK exports to the EU and 14.7% for UK imports from the EU. Egger et al (2015) suggest 12.8% while Head and Mayer suggest 11% in 2000 falling to about 8% in 2019 (p.34). However, they include only what they call ‘tradable services’ in this calculation, excluding sectors such as education and health which are certainly traded, and cite evidence based on Heiland et al (2020) that this reduces the estimated effect of the Single Market materially (footnote 6).

One final comparison relevant to this paper is with Davenport et al (2022). They assume that new NTMs on services average 7.3%.

Caveats

We would be the first to admit that the estimates of trade costs discussed in this Appendix and used in our paper are extremely crude. On the other hand, our estimates are more detailed than those elsewhere in the Brexit literature and for that reason may be more informative. For example, the influential study by Dhingra et al (2017) takes estimates for about a dozen sectors from Berden et al (2009, 2013), along with the latter’s estimate of the proportions of the barriers that are amenable to policy change. From these they calculate a single estimate of non-tariff trade costs for goods and services, and, making assumptions about how much of these would apply under a given Brexit scenario, ‘apply these increases uniformly to UK-EU trade in all sectors of the economy’. Davenport et al (2022) adopt these estimates.

It may be tempting to say that the estimates of barriers are so imprecise that it is not worth conducting modelling exercises at all. We disagree. For sure, one must take these and any other modelling results with a good dose of salt, but they are not plucked out of the air or based on wishful thinking. Given the inevitable level of aggregation in making models manageable, they represent our best estimates of the consequences of Brexit for the costs of doing international trade between the UK and the EU.

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