Data Appendix for

"Disunited Kingdom? Brexit, Trade and Scottish Independence "

by

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A Calibration data

We use the World Input-Output Database[1] (WIOD) as the framework for our analysis, the latest available version contains data for 2014. The efforts outlined below essentially boil down to splitting the United Kingdom's entries in this database into Scotland and the rest of the UK's respective shares. To ensure consistency with WIOD, all other data we use is for 2014, and is measured in, or adjusted to, basic prices.

We supplement the WIOD with data describing the UK regions. For the UK as a whole, we use the Supply and Use Table[2] (WUK–SUT), and the Input—Output Analytical Tables[3] (WUK–IOT). For Scotland, we use data relating to both the onshore and offshore economies. The onshore data comes from the Scottish National Accounts Unit's Onshore Supply, Use and Input-Output Tables, 1998-2016 (SCN–SUT), supplemented by the Export Statistics Scotland (SCN–ESS) data on Scottish exports with ROW and RUK. The offshore data come from the offshore Supply and Use Satellite Account Tables[4] (SCF–SUT).

All our analysis is at the same level of industrial and regional aggregation; both are the most disaggregated, common grouping possible across our main data sources. Industries are aggregated to the 27 industry groups used by Export Statistics Scotland (see Table 1). Countries are aggregated into four regions: Scotland (SCO), the rest of the UK (RUK), the EU27 (EU) and, the remaining countries (NEU). Intermediate datasets are sometimes aggregated to other levels such as the whole United Kingdom (WUK), the whole world ex-UK (ROW), the onshore Scottish economy (SCN), and the offshore Scottish economy (SCF).

A.1 Targets

The ultimate goal is to calibrate three sets of parameters and the observed trade flows.

1. Intermediate expenditure shares: proportions of total intermediate use of source industry s output, by using industry k in using region j:

$$\alpha_{sk}^{j} = \frac{\text{Intermediate input}_{sk}^{j}}{\sum_{l=1}^{I} \text{Intermediate input}_{lk}^{j}}$$

   where I is the number of industries.

2. Final demand expenditure shares: proportions of final demand for source industry s output out of total final demand in using region j:

$$\alpha_{s,FD}^{j} = \frac{\text{Final demand}_{s}^{j}}{\sum_{l=1}^{I} \text{Final demand}_{l}^{j}}$$

[1] 2016 release, available from `http://www.wiod.org/release16`, accessed December 2019

[2] October 2019 release, 6 December 2019 vintage, available from `https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables/current`

[3] 2014 release, available from `https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed`, accessed February 2020.

[4] These are experimental statistics, produced by the Scottish National Accounts Programme: Whole of Scotland Economic Accounts Project. Available from `https://www.gov.scot/publications/scottish-national-accounts-programme-whole-of-scotland-economic-accounts-project/`

Table 1: Industry definitions

Index	ESS industry name (SIC07 Sections)	SIC07 Divisions
1	Agriculture, Forestry and Fishing (A)	01—03
2	Mining & Quarrying (B)	05—09
3	Food Prod., Beverages and Tobacco Prod. (CA)	10—12
4	Textiles, Wearing Apparel and Leather (CB)	13—15
5	Wood and Paper Prod., and Printing (CC)	16—18
6	Coke, Refined Petroleum Prod., Chemicals and Chemical Prod. (CD & CE)	19—20
7	Basic Pharmaceuticals and Their Prod. (CF)	21
8	Rubber, Plastic and Other Non-Metallic Mineral Prod. (CG)	22—23
9	Basic Metals and Fabricated Metal Prod., Except Machinery (CH)	24—25
10	Computer, Electronic and Optical Prod. (CI)	26
11	Electrical Equipment (CJ)	27
12	Machinery and Equipment N.E.C. (CK)	28
13	Transport Equipment (CL)	29—30
14	Furniture, Other Manufacturing; Repair and Installation of Machinery (CM)	31—33
15	Utilities (D & E)	35—39
16	Construction (F)	41—43
17	Wholesale, Retail and Repairs (G)	45—47
18	Transportation and Storage (H)	49—53
19	Accommodation and Food Services (I)	55—56
20	Information and Communication (J)	58—63
21	Financial and Insurance (K)	64—66
22	Real Estate Activities (L)	68
23	Professional, Scientific & Technical (M)	69—75
24	Administrative and Support Services (N)	77—82
25	Public Administration & Defense; Compulsory Social Security (O)	83
26	Education (P)	84
27	Other Services (Q & U)	85

3. Value-added shares: the proportion of value–added in the output of using industry k in region j.

$$\beta_k^j = \frac{\text{Value added}_k^j}{\text{Output}_k^j}$$

4. Trade: the value of output from source industry s and region i exported for use in using region j.

$$\text{Trade}_s^{ij} = \text{Domestic use}_s^{ij}$$

To calculate these parameters, we first collapse the WIOD to the appropriate level of industry aggregation and to three country groups—EU, non–EU, and WUK—and create two types of table:

– the Use table contains information on the use, by industry k, and Final Demand, in country j, of the outputs of industry s, and value–added, in the production of domestic output. We use this data to infer the intermediate input expenditure shares and the value-added shares.

– the Trade table contains information on the use by region j of outputs sourced from industry s in region i.

EU and non–EU parameters that do not involve WUK are calculated from these tables. Next, we split the WUK elements of these tables into shares for Scotland and RUK using SUT tables we construct from National Accounts data (Scotland and WUK are measured, RUK is the residual), and then calculate the remaining parameters as above.

A.2 Uniting Scotland's on– and offshore economies

To create Scotland's SUT, we would ideally just add the off– and onshore tables together, removing flows between them so we don't include intra–SCO trade. This is essentially what we do, after addressing a number of issues:

1. The offshore accounts data (SCF–SUT) is all in purchaser prices, and so the first step is to make a **basic price adjustment** to conform with our other data sources. We scale each row of the SCF–SUT by the same price adjustment, equal to the ratio of basic–to–purchaser price values in the WUK–SUT for the Mining and Quarrying industry.

$$\text{SCF Supply \& Use (bp)}_{sk} = \text{SCF Supply \& Use (pp)}_{sk} \times \frac{\text{WUK Mining \& Quarrying Use of } s \text{ (bp)}}{\text{WUK Mining \& Quarrying Use of } s \text{ (pp)}}$$

where s indexes the source industry, and k is the column of the SCF–SUT (including both supply[5] and use).

We calculate the adjustment from the WUK–SUT, rather than SCN–SUT, because the offshore accounts are only for the Mining & Quarrying industry. This industry is largely constituted by North Sea oil exploitation, which is explicitly excluded from the Scottish onshore economy's Mining & Quarrying data, but makes up the bulk of that industry for the whole UK.

2. The second issue is that the basic price onshore accounts data (SCN–SUT) is not disaggregated as we need. The basic price data are separated into two tables: use by industry k of domestically produced outputs of industry s, and total imports of the output of industry s. Hence, we need to to **allocate basic price imports to using industries**. To do this, we assume (a) full domestic absorption, i.e. no re–exporting imported goods; and (b) proportionality, i.e. using industries do not discriminate between imported and domestically produced inputs (o the allocation of industry s imports across using industries is the same as the allocation of locally produced output. Therefore, the formula for the total use of the outputs of industry s by the onshore industry k is

$$\text{SCN Use}_{sk} = \text{Use of local outputs}_{sk} + \text{Use of imported outputs}_{s} \times \frac{\text{Use of local outputs}_{sk}}{\sum_{l}^{I+1} \text{Use of local outputs}_{sl}}$$

Where we sum over industries up to $I + 1$ to include final demand.

3. The third issue is that the onshore and offshore trade flows are reported with RUK and ROW, but do not distinguish between EU and NEU destinations. Moreover flows between the onshore and offshore economies within Scotland are double counted. We therefore:

   (a) **Eliminate trade flows within SCO**: we remove the onshore purchases column from SCF–SUT, and subtract it from exports to RUK in SCN–SUT. Likewise, we remove the onshore sales column from SCF–SUT, and subtract it from imports from RUK in SCN–SUT. Remaining RUK trade flows are actually with England, Wales, and Northern Ireland.

   (b) **Apportion ROW trade flows between EU and NEU**: Onshore exports to ROW are apportioned between EU and non–EU using the shares, by exporting industry s, in the SCN–ESS data:

$$\text{Onshore exports to EU}_s = \text{Onshore exports to ROW}_s \times \frac{\text{ESS to EU}_s}{\text{ESS to EU}_s + \text{ESS to NEU}_s}$$

   Onshore exports to non–EU countries are the residual.

   For offshore exports, and imports off– and onshore, we have no such data. As such, we use equivalent proportions for the whole of the UK's trade with the EU and non–EU regions, from the WUK–SUT. That is, for industry s, the EU share is calculated as

$$p_s^x = \frac{\text{WUK exports to EU}_s}{\text{WUK exports to EU}_s + \text{WUK exports to NEU}_s}$$

   and offshore exports are apportioned to the EU and non–EU regions using this proportion. The import proportion from the EU region is calculated with an equivalent formula, and used to apportion both on– and offshore imports to EU and non–EU origins.

Having made these adjustments, the whole of Scotland Supply & Use tables are constructed by simply adding the on– and offshore tables together, element–wise, to get SCO–SUT. These tables are then used to populate the Scottish Use and Trade tables.

[5] We used the data for the 'low–specialisation' scenario.

A.3 Separating Scotland from the United Kingdom

To create the RUK–SUT tables, we subtract SCO–SUT from the WUK–SUT in basic prices. The latter is constructed from the basic price data in the WUK–IOAT, aggregated to the appropriate levels.

Extracting Scotland leaves some negative values in the RUK–SUT tables, when SCO's recorded use in basic prices exceeds that of the UK. We adjust for these cases by replacing the Scottish value with the lesser of its actual value and the WUK equivalent. Now, after subtracting the adjusted SCO-SUT from WUK–SUT, all RUK–SUT values are the greater of their unadjusted counterparts and zero.

We now have a basic price Supply and Use table for both SCO and RUK. Parameter values for intermediate expenditure and value–added shares are calculated from the Use tables.

A.4 Populating the trade table

Next, we split the WUK elements of the WIOD trade table into SCO and RUK shares. For Scottish exports to EU of the outputs of industry s, the formula is

$$\text{WIOD SCO exports to EU}_s = \text{WIOD WUK exports to EU}_s \times \frac{\text{SCO–SUT exports to EU}_s}{\text{WUK–SUT exports to EU}_s}$$

and the RUK equivalent is the residual. The formula for imports, and for flows with NEU, have equivalent structure.

For trade within the UK (flows between SCO and RUK, as well as self–trade in both regions), we need to split one WIOD trade table cell into four. Again, we use the RUK– and SCO–SUTs to do this—trade between the two regions is already measured, and the onshore and whole of UK National Accounts report self trade data. The only complication is self–trade in offshore Scotland. To estimate this, we impose the full-absorption of imports assumption[6], so that self–trade is found by subtracting imports from offshore intermediate and final use of the outputs of industry s. The resulting data on offshore self–trade is added to that from SCN to yield SCO's self–trade. And RUK self–trade is found by subtracting SCO from WUK self–trade (less flows with Scotland). Using these values, whole UK self–trade in the WIOD is split into relative shares. For example, the proportion for Scottish self–trade in s is

$$p_s = \frac{\text{SCO self–trade}_s}{\text{SCO self–trade}_s + \text{RUK self–trade}_s + \text{SCO export to RUK}_s + \text{RUK export to SCO}_s}$$

and the formula for its cell in the WIOD trade table is

$$\text{WIOD SCO self–trade}_s = \text{WIOD WUK self–trade}_s \times p_s$$

The other three flows are allocated with equivalent formulae. We now have the trade flow data.

A.5 Imputing final demand shares

Finally, we impute final demand expenditure shares from the information in the other parameters. First, note that total sale of an industry k from a region j must equal its domestic production. Hence, we can impute value–added

$$\text{Value added}_k^j = \beta_k^j \times \sum_l \text{Trade}_k^{jl}$$

and total intermediate use by industry k in region j

$$\text{Intermediate use}_k^j = (1 - \beta_k^j) \times \sum_l \text{Trade}_k^{jl}$$

Second, we can impute the intermediate use of product s from the intermediate expenditure shares

$$\text{Intermediate use}_{sk}^j = \alpha_{sk}^j \times \text{Intermediate use}_k^j$$

Third, final demand for industry s in region j is the difference between total expenditure, which equals the sum of imports from all regions, from the trade table, and total intermediate use

$$\text{Final demand}_s^j = \sum_l \text{Trade}_s^{lj} - \sum_k \text{Intermediate use}_{sk}^j$$

[6]This is why we opted for the 'low–specialisation' scenario in the offshore accounts' purchases measure. If we instead use the mid– or high–specialisation figures, self–trade is negative in some industries.

And this is used to calculate the final demand expenditure shares, the last remaining parameter values.

$$\alpha^j_{s,FD} = \frac{\text{Final demand}^j_s}{\sum_{l=1}^{I} \text{Final demand}^j_l}$$

Note: the dataset provided with this online appendix reports both parameters and the values they were calculated with (Value added, Intermediate use, Final use, and Trade). In all cases we report the imputed values as described above.

B Gravity data

B.1 Trade

The dependent variable is trade (T_{ij}), measured as bilateral exports from country i to country j. Our main data source is the WIOD 2014 data. Flows not involving Scotland or RUK are taken directly from WIOD.

Scotland's bilateral trade with WIOD countries is set equal to each partner's share of either the EU or non–EU total from the calibration dataset. The shares are measured from the HMRC Regional Trade Statistics (RTS) data[7]. The formulas for calculating Scottish trade with EU and non–EU partners are slightly different.

– For Scottish exports to a country j in the EU, the formula is

$$T_{SCO,j} = \frac{C_{SCO,j}}{\sum_{j \in EU} C_{SCO,j}} X_{SCO,EU}$$

where $X_{SCO,EU}$ is total exports by Scottish industries to the EU from the calibration dataset, and $C_{SCO,j}$ is Scottish exports to country j from the RTS data. Imports are found with an equivalent formula, swapping the subscripts.

– For Scottish exports to a country j not in the EU, the formula is

$$T_{SCO,j} = \frac{C_{SCO,j}}{\sum_{j \notin EU} C_{SCO,j}} \tilde{X}_{SCO,NEU}$$

Where $\tilde{X}_{SCO,NEU}$ is calibrated Scottish exports to NEU, scaled to account for our dropping ROW flows from the WIOD.

$$\tilde{X}_{SCO,NEU} = X_{SCO,NEU} \left(1 - \frac{T_{UK,ROW}}{\sum_{j \notin EU} T_{UK,j}} \right)$$

and $T_{UK,j}$ is WIOD exports from the UK to country j. Again, imports are calculated with an equivalent expression, swapping subscripts.

The rest of the UK's bilateral flows are simply the difference between the UK's flows in the WIOD data and Scotland's calculated flows. For example, exports are $T_{RUK,j} = T_{UK,j} - T_{SCO,j}$ and imports are equivalent, with subscripts swapped.

Finally, the two bilateral flows between Scotland and the rest of the UK are taken directly from the calibration dataset.

[7] RTS only measures goods trade, so using it to apportion total trade could skew results. The alternative is to use ESS trade which measures both goods and services, but is only available for exports. The export shares calculated on the two data sources are quite similar (89% correlation), implying that services exports are, roughly, distributed the same as goods exports. Because of this, and because it provides information about imports as well, we chose to use RTS.

B.2 Gravity variables

The control variables in the gravity model are: distance, common currency, common language, contiguity (i.e. sharing a land border), colonial history, existence of a free-trade agreement, and membership of the European Union. All but distance are binary variables and are taken from the CEPII Gravity dataset[8]. The values for distance are calculated as the ellipsoidal distance between capital cities, based on the coordinates in the CEPII dataset.

The values for Scotland's relationships are set equal to the UK's, except for distance, which we calculate between Scotland's partners' capitals and Edinburgh's position at $(55.9533, -3.1883)$. We switch off contiguity between Ireland and RUK (and Scotland), in order to let this variable capture a land border with the main bulk of the partner country.

We also calculate a measure of the population–weighted distance between countries. Following CEPII, we use the formula

$$d_{ij}^{w} = \sum_{k \in i} \sum_{l \in j} \frac{pop_k}{\sum_{k \in i} pop_k} \frac{pop_l}{\sum_{l \in j} pop_l} d_{kl}$$

where k and l index all the included cities in country i and j, respectively, and d_{kl} is the ellipsoidal distance between cities k and l.

To calculate this variable, we use 2015 population and coordinate data for 'urban agglomerations' of more than 300,000 people across the world, published in the *2018 Revision of World Urbanization Prospects* (United Nations, 2018)[9]. We include all cities in the dataset in our calculation i.e. there are *many* in China, and just two in Scotland (Glasgow and Edinburgh). For countries without any cities in the dataset (i.e. Luxembourg and Malta), we use the capital.

[8] Variable names: `comcur`, `comlang_off`, `contig`, `colony`, `fta_wto`, and `EU` is `eu_o` interacted with `eu_d`

[9] Specifically, File 12 from `https://population.un.org/wup/Download`