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THE GAINS FROM ECONOMIC INTEGRATION

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The Gains from Economic Integration *

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Abstract

This paper measures the effect of political integration, such as sharing a national state or economic union, on the degree of trade integration. Consistently with previous work, we find large border effects. However, such estimates may be biased and overestimate the effects of borders because of endogeneity: selection into sharing a political space is correlated with affinities for trade. We propose a method to address this and to estimate a causal effect. We then conduct speculative exercises showing the costs and benefits of the changing levels of integration associated with: the independence of Scotland, Catalonia and the Basque Country from the UK and Spain (but remaining within the European Union); the UK's exit from the EU; the break-up of the EU itself; and the achievement of frictions between members of the EU similar to those expected between regions of a single country. We find that the border effect between countries is an order of magnitude larger than the border effect associated with the European Union.

Key words: Border effect, trade, independence. **JEL Classification:** F15, R13

1 Introduction

The aim of this paper is to measure the effect of political integration, such as sharing a national state or economic union, on the degree of trade integration, and to quantify its welfare implications. We define *the economic integration* as the causal effect of sharing political space - this is the additional welfare gained by entities which come together to form a country or an economic union, due to increased trade.

We calibrate a structural trade model to interregional and international trade data, and obtain the implicit trade frictions that would explain the observed data, something often referred to as the Head Ries Index (HRI)[1]. We do this while treating countries and sub-national units for which we have data, as entities with the same status within a common framework. The average border effect is then the average difference between the interregional and the international frictions, controlling for physical distance, common language, and size. Likewise the average effect of the European Union is the average difference between frictions within and across the EU boundary, controlling for those same characteristics. The existence of very large border effects, even within the European Union, is well known[2] and in this paper we also find large average border effects.

Our main point though is that these average border effects are bound to overestimate the gains from sharing a state. This is because places which share larger affinities are more likely to both trade with each other and to select into sharing a political space (a country, or EU membership). Due to this endogeneity the average effect likely overstates the reductions in trade frictions achieved by sharing a political space.

For instance, the fact that Scotland and England share a country is related to the fact that they trade a lot - but we cannot claim that the high volume of trade is all caused by the fact of

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[1]According to Head and Mayer (2013), Eaton, Kortum, Neiman, and Romalis (2011) coin the label "Head-Ries Index" since this "indicator first appears in Head and Ries (2001)".

[2]Many papers in the economics of international trade literature have looked at the border effect, starting with the seminal contribution of McCallum (1995). This empirical work was embedded into the modern trade theory literature by Anderson and van Wincoop (2003) who found a substantial border effect that differentiated trade between U.S. states and Canadian provinces. The theory consistent econometric estimation approach of Anderson and van Wincoop (2003) is what is typically used in this literature, for example Coughlin and Novy (2013) compare the magnitude on the coefficients of U.S. state-international borders and state-state borders and conclude that the incremental friction increase is greater when comparing state-state trade to intra-state trade, than it is for state-international trade to state-state trade. Our results for the average differences between interregional and international borders are consistent with the estimates from Anderson and van Wincoop (2003).

state sharing. Scotland and England would trade at a relatively high rate even if they did not share a country. The affinities that lead to trade between the two also increase the likelihood of nation state sharing. The causal effect of nation state sharing can be quantified by only changing the status of state sharing or not - not by also changing these affinities. Looking at the average difference in trade within and across national borders, even when controlling for physical distance and common language, does not compare like with like in terms of these affinities. The average friction between the UK with the rest of the countries of the world, after controlling for physical distance, size and language, is much larger than the frictions that plausibly would exist between Scotland and England in the case of independence, even if in that case the frictions were larger than the ones that we observe today. To impute the difference between the current Scotland-England frictions with the average frictions that the UK has with other countries as the benefits of economic integration is likely to overestimate the potential trade benefits of a political union.

Our approach to deal with this endogeneity problem has a certain resemblance to regression discontinuity analysis. We identify *"marginal regions"*, defined as regions or countries which seek to exit the political space under consideration (e.g. Scotland seeking independence from the UK, or the UK seeking to exit the EU). We also identify *"marginal countries"*, based on the countries with the smallest frictions with the country to which the *"marginal region"* currently belongs (e.g. Ireland is the natural counterfactual to Scotland with respect to the UK). Essentially *"marginal regions"* are regions of a larger country that could conceivably be independent, and *"marginal countries"* are independent countries that could easily be regions of the larger country. This comparison should be clean of the endogeneity problem insofar as the ex-ante probabilities for the "marginal country" and the "marginal region" to form a political union to the country to which the "marginal region" belongs, are similar. This comparison gives us our estimate of the causal impact of sharing political space. Conducting counterfactual exercises based on the difference in frictions between *"marginal region"* and *"marginal country"* allows us to quantify welfare implications.

For example we use the difference between the measured Scotland-rest of the UK friction, and the measured Ireland-UK friction (because Ireland is observed to have the lowest measured frictions with the UK) as a measure of economic integration. In addition to having the lowest

measured friction with the UK, Ireland is similar in size to Scotland, shares a common language with Scotland and the rest of the UK, is contiguous with the UK (via Northern Ireland), and shares much common history (including formerly being part of the UK) - and so we observe that our methodology produces appropriate and interesting counterfactuals.

Another issue that needs to be considered is the potential for regions to substitute integration with the rest of their country in place of close links with the rest of the world. For the marginal regions in our analysis, we show that this is not the case and that the frictions that these regions have with the rest of the world are in line with those of similarly sized countries. In this sense, economic integration is a gain: it is not achieved at the expense of higher frictions with the rest of the world.

We conduct speculative exercises to illustrate the quantitative importance of economic integration. We consider the independence scenarios for Scotland, Catalonia, and the Basque Country, as well as looking at "Brexit": the exit of the UK from the European Union. Furthermore we look at combinations of these such as Scotland staying in the EU by becoming independent as the rest of the UK undergoes Brexit. Finally, we consider scenarios which look at the disintegration of the EU, as well as the possibility that the EU furthers its degree of economic integration across countries to the same level that there is within its member states.

Welfare impacts can easily be quantified following the contribution of Arkolakis, Costinot, and Rodríguez-Clare (2012) who show that the total welfare gains from trade, subject to parameters, are the same in all trade models within the class of 'gravity models', and given by a simple formula[3]. The productivity or welfare implications of changes in trade frictions can be examined using policy experiments, and this has been done in many papers in the literature[4]. In this paper we evaluate

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[3]Though particular microfoundations are suggestive of particular values for the trade elasticity parameter and so do matter, a point made by Melitz and Redding (forthcoming). The microfoundations can be very different, e.g.: a love of variety means that the available product range expands with the size of the market and leads to aggregate increasing returns to scale, as in Krugman (1980); a larger market can lead to better firm selection as efficient firms expand to serve this larger market, putting upward pressure on wages, and lowering profitability of low productivity firms who exit, as in Melitz (2003); and traditional Ricardian trade explanations as in Eaton and Kortum (2002). All imply different structural interpretations, and different values, for the trade elasticity. Simonovska and Waugh (2013) estimate different values for the trade elasticity based on different structural models. Further, the simple formula is different for different sub-classes of gravity models: in this paper we use a gravity model with tradable intermediate goods as discussed in Section IV of Arkolakis, Costinot, and Rodríguez-Clare (2012).

[4]Costinot and Rodríguez-Clare (2014) is a review of this literature. Examples of papers within this literature are Bernard, Eaton, Jensen, and Kortum (2003) (examines the impact of a drop in all frictions of 5% in a calibrated

the welfare impacts of changing frictions by the magnitude measured between our marginal regions and marginal countries as a good estimate of the causal impact of state sharing. We find that, for all the examples that we look at, the difference for marginal regions in having their measured interregional frictions and the smallest measured international frictions, accounts for between one third and one half of the total gains from trade relative to autarky. This is irrespective of the particular gravity model used (within a subset of the gravity model class), and highly insensitive to the chosen value for the trade elasticity parameter.

We show that the average econometric estimation exercise (not taking into account the endogeneity) over-estimates the causal effect of sharing a country upon economic integration. Nevertheless, the value of such economic integration once controlling for this endogeneity is still substantial. Belonging or not to the EU also has quantitatively significant welfare effects, but these are observed to be almost an order of magnitude less significant than the impact of sharing a country.

We do not explain the institutional arrangements or mechanisms that lead to economic integration within countries, we simply identify the size of this integration, and quantify its importance within a modern general equilibrium model of trade. The differences in the degree of economic integration may be due to many reasons: biases in government procurement[5], home bias in preferences, regulation favouring local firms, political economy biases, migratory patterns, network formation, etc. In this paper we simply point the facts and leave the investigation of potential causes to further research[6].

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We begin our analysis with an illustration showing that something happens within countries that is different from what happens across countries: the patterns of trade for regions that very

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model); and Corcos, Gatto, Mion, and Ottaviano (2012) (examines a number of policy experiments including undoing non-tariff barrier liberalisations associated with EU membership, implementing 5% tariff barriers on trade with the world outside EU, and implementing 5% tariffs on all international trade). Head and Mayer (2013) provide a toolkit for implementing such policy experiments in general equilibrium.

[5]In a recent paper, Herz and Varela-Irimia (2016) using the universe of public procurement contracts within the EU show that the nationality of the winner of the contract (the supplier) is its most salient characteristic. The border effect in public procurement *within the EU* is enormous, in spite of being explicitly prohibited by the Union treaties to discriminate in favor of domestic suppliers.

[6]A recent literature on internal frictions is also helpful in moving forward this research agenda, for example Atkin and Donaldson (2014), Cosar, Grieco, and Tintelnot (2014), and Ramondo, Rodríguez-Clare, and Saborío-Rodríguez (2014).
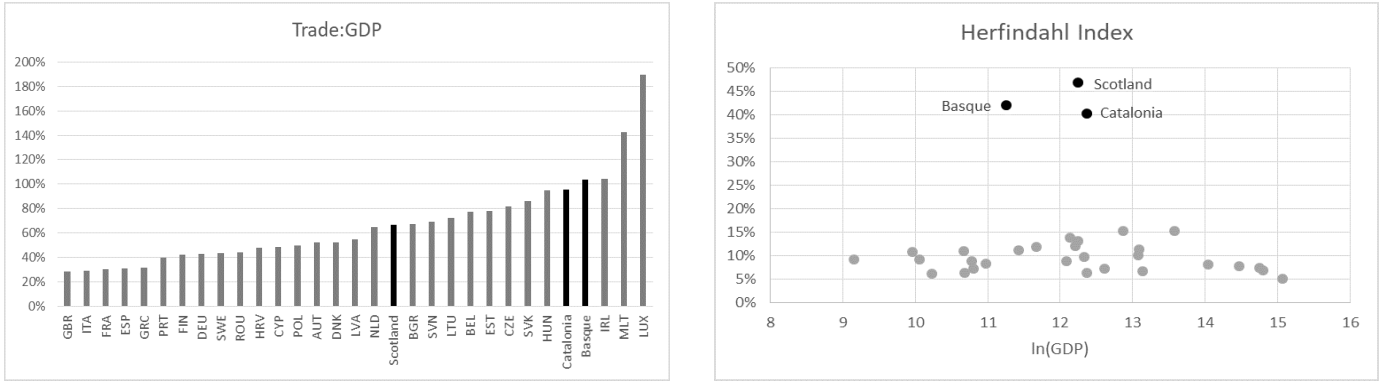
(a) Trade:GDP ratio of EU countries, plus Scotland, Catalonia & Basque Country

(b) Herfindahl Index of Trade Concentration of EU countries, plus Scotland, Catalonia & Basque Country

Figure 1: Trade and trade concentration in regions and countries

plausibly could be independent countries are very different from those of independent countries. These regions exhibit a very high degree of trade concentration that marks them out as very different from otherwise similar countries within the EU. Scotland, Catalonia, and the Basque Country could be countries, but if they were, we would not expect to see their trade patterns be as shown in Figure 1. These regions, viewed as if they were countries, appear to be highly integrated into the global economy with a high share of trade in GDP, however this trade is extremely concentrated with the rest of the country of which they are currently part. Figure 1a[7] shows that the trade share of these regions is typical in a European context, but Figure 1b highlights how anomalous these regions' trade concentrations are compared with EU countries. It shows the Herfindahl index of trade concentration[8] against GDP on the x-axis, since we may expect small countries to trade more, and concentrate this trade with their large neighbours. We would expect regions to have relatively high index values, as they are relatively small, but not nearly as high as we observe. The regional Herfindahl Indices are much higher than that of the most trade concentrated independent EU member[9]: it's almost an order of magnitude type comparison. Our exercise will consist of building reasonable counterfactuals for these regions where they appear as

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[7]The data used in for these graphs, and throughout the paper, is described in Appendix A

[8]If there are N countries, with the exports from country i to country j denoted X_j^i ($X_i^i \equiv 0$), then the Herfindahl Index for country i, $H_i = \sum_{j=1}^{N}[(X_j^i / \sum_{k=1}^{N}[X_k^i])^2]$. $H_i = 1$ indicates complete concentration of trade with a single trading partner. $H_i \to 0$ (equality only possible with infinitely many possible trading partners) indicates complete diversification of trade across all partners.

[9]The most trade concentrated independent EU member is Austria, a relatively small country which concentrates its trade with the EU's largest economy, Germany.

normal countries.

The paper is structured as follows. In Section 2 we develop the Head Ries Index framework for measuring trade frictions, present our cross country and region comparison results (including some interesting results on the differences in the degree of home bias between trade in goods and trade in services), and show the (unsurprising) result that a large border effect exists. Section 3 develops our argument on the endogenous selection of economies into regions and countries - the average border effect is an upwardly biased estimate of the causal effect of the impact of political integration upon trade frictions. In this section we also describe our method of dealing with this selection bias. In Section 4 we conduct counterfactual experiments on regional borders in which we show that, even after allowing for this selection bias, a substantial causal impact remains. The value of integration across the European Union is considered in Section 5, in which we provide some quantification for the costs of Brexit. Section 6 concludes.

2 Measuring Trade Frictions

In this section we show that the border effect, understood as the average difference in bilateral frictions between interregional and international pairs within the EU, is very large. Furthermore, the EU border effect, understood as the average difference in bilateral frictions between EU pairs and other country pairs, is smaller but still significant. Differences of the magnitudes that we obtain have quantitatively significant welfare implications if they are interpreted as the causal effect of borders.

We perform a simple econometric exercise, regressing for all pairs of countries and regions, the Head Ries Index measured for each bilateral pair, against the incomes of each party, the physical distance between them (and this distance squared), a common language dummy, regional border dummies, and a non-EU border dummy[10]. The Head Ries Index (HRI) is the well known indicator

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[10]This is equivalent to running a gravity regression of bilateral trade on GDPs and upon dummies for i and j, and explanatory terms for trade frictions: $\ln X_{ij} - \ln Y_i - \ln Y_j = \alpha_i d_i + \alpha_j d_j + \epsilon \left(\beta_1 B_1 + ... + \beta_n B_n \right)$ where d_k is a dummy variable for k, and so α_k gives its multilateral resistance, and where ϵ is the trade elasticity and $B_1, ..., B_n$ are n factors with which we try to explain trade frictions. Since δ_{ij} is a quantity that already incorporates multilateral resistance, in running $\ln \delta_{ij} = \beta_1 B_1 + ... + \beta_n B_n$, we are doing the same.

of trade frictions implied by all gravity models of trade, it is the friction that would produce the observed bilateral trade within such a gravity model (for a certain trade elasticity). It is a very natural and theory compatible measure of trade frictions, and has been used many times in the literature[11]. It is given by the following expression, where ϵ is the trade elasticity, and it is the same in all models that produce a gravity equation.

$$\delta_{ij} = \left(\frac{X_{ij}^2}{X_{ii}X_{jj}} \right)^{\frac{1}{2\epsilon}} \tag{1}$$

First we outline the data, and then we describe the results of our exercise.

2.1 Data & Methodology

The data used in this paper is fully described in Appendix A. But briefly it is: international data from the WIOD database covering both goods and services; regional data for the USA, Canada, Spain, and Scotland, is taken from local statistical agencies; international, Scottish, and US data is from 2014; Canadian data is from 2013; Spanish (goods only) and Basque (goods and services) data is from 2006; and Catalan (goods and services) data is from 2005. The following procedure is followed to construct an internally consistent dataset:

- From the international data we have: X_j^i, the trade flow from i to j; the Gross Output, X_i, and the GDP_i, for all countries $i \in \{1, ..., N\}$.

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[11] Chen and Novy (2012) label this approach to trade friction measurement as the "Indirect Approach". Other papers which have used this approach include Head and Ries (2001), Eaton, Kortum, Neiman, and Romalis (2011), Novy (2013), Chen and Novy (2011), Head and Mayer (2004), and Jacks, Meissne, and Novy (2011). The HRI between entities i and j is monotonically related to the iceberg cost that appears in many trade models and so is a measure of the total trade frictions between i and j. The version of the HRI used here is that implied by bilaterally balanced trade, which is appropriate here because we create a dataset with notional measures of bilateral trade which imply that all trade is bilaterally balanced.

- Then define:

$$\beta \;=\; \frac{\sum_i \left(X_i - GDP_i \right)}{\sum_i X_i} \tag{2}$$

$$X_{ij} \;=\; \frac{1}{2}\left(X_i^j + X_j^i \right) \tag{3}$$

$$X_{ii} \;=\; X_i - \sum_{j \neq i} X_{ij} \tag{4}$$

$$Y_i \;=\; (1 - \beta) X_i \tag{5}$$

- For each region in our data, we construct a data pair comprising of the region and a virtual "rest of the country", by applying the share of income, the share of external trade, and the ratio of internal trade to external trade, implied by the regional dataset, to the output and international trade from the country dataset[12].

Note that when we try to measure trade frictions consistently across countries and regions and to conduct some basic statistical analysis on these measures, the US states supply the bulk of our regional data points. The US and Spanish regional trade datasets are for goods trade only. We therefore use goods only data for Canada despite goods and services data being available, and we exclude Scotland from the database at this stage. We use the ratio of, say, Texas goods trade with the rest of the USA to its goods trade with the rest of the world, combined with the Texan share of US goods trade with the rest of the world, to generate a consistent measure of Texas's internal trade, from the USA's external combined goods and services trade. Given data limitations, this is a reasonable procedure. But we can infer in which direction it biases our results from the Canadian, Basque, and Catalan data, and it seems to matter quantitatively - we will come back to this. In Section 4 we use goods and services data for Scotland, Catalonia, and the Basque Country[13].

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[12]For example, Catalan output is given by Spanish output from the cross-country dataset multiplied by the ratio of Catalan GDP to Spanish GDP from the regional dataset. Catalan trade with the rest of the world is given by this Catalan output multiplied by the Catalan external trade to output ratio. Catalan trade with the rest of Spain is given by this Catalan external trade multipled by the internal to external trade ratio. Finally, the figures for the rest of Spain are given by the Spanish figures less the Catalan ones.

[13]It is in itself interesting that out of all the autonomous communities of Spain, the regions with substantial independence movements, Catalonia and the Basque Country, are the only two with their own local statistical agencies that produce goods and services data.

To calculate the HRI for the countries and regions in our dataset, we must choose a trade elasticity, ϵ. There is much discussion in the literature (see e.g. Simonovska and Waugh (2013) and Melitz and Redding (forthcoming)) about the appropriate value for the trade elasticity, but based loosely on Simonovska and Waugh (2013), for this exercise we choose $\epsilon = -3.5$[14]. In Section 4 we will reach a conclusion that is extremely insensitive to this choice.

2.2 Average Border Effect Results

We take logs of the set of calculated HRIs and regress against log of gross output, distance, distance squared, common language and border dummies.

We have three different types of border dummies. The regional border dummy takes value 1 only if it is a border between regions of the same country. The non EU border dummy takes value 1 only if it is a border between a non EU country and another country (EU or not). Finally, we include separate dummies for Canadian and Spanish region to region borders to account for country fixed effects representing differential levels of internal integration between the US, Canada, and Spain.

These results are shown in Table 1. They suggest that US internal borders are substantially less frictional than country to country borders *within the EU*, that Canadian internal borders are less frictional than US internal borders, and that Spanish internal borders even less so. Moreover, the borders between two EU countries are 14% less frictional than borders external to the EU (where external means that at least one of the parties is not an EU member).

Note that the results in this table are highly dependent on the value of the trade elasticity, though the significance of each factor is insensitive to this parameter.

Figure 2 shows the measured values of the HRI, adjusted for the impact of physical distance and common language (i.e "log residual delta" is the log of the regression residual plus the impact of size and borders, and these are graphed against size), separating out the regions-rest of country

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[14]Simonovska and Waugh (2013) who report a range of figures for the trade elasticity based on different trade models. Their range is from -2.8 given the model from Bernard, Eaton, Jensen, and Kortum (2003), to -5.2 given the Armington model (Anderson and van Wincoop (2003)) or Krugman (1980) model. Our chosen parameter value is somewhere in the middle of this range and close to the figure of -3.41 which Simonovska and Waugh (2013) estimate for the Melitz (2003) model.

	Coef.
Constant	4.375843***
	(0.1017045)
distance in km	0.0001381***
	(0.00000686)
distance squared	-5.65×10^{-9}***
	(4.18×10^{-10})
common language	-0.1612534***
	(0.0362751)
$\log(X_i X_j)$	-0.1097361***
	(0.0039061)
regional border	-0.2100648***
	(0.0510886)
non EU border	0.1444607***
	(0.0246778)
Canada	-0.2448648***
	(0.0751898)
Spain	-0.4349106***
	(0.0680727)
Number of obs	984
R-squared	0.7536

Table 1: Regression results of log of δ with trade elasticity $= -3.5$

pairs, EU country pairs, and other country pairs. As can be seen, the regional frictions are generally lower than EU frictions, which are generally lower than other country frictions. Figure 2 shows that regions have lower frictions than countries *conditional on size.* That is, any pair of countries is expected to have larger bilateral frictions than a pair of regions of the same size: there is something about being regions of the same country that is associated with a higher degree of integration than between equivalently sized countries (after controlling for physical distance and common language).

An interesting but separate point to our main discourse is to examine this negative relationship of measured frictions upon the size of the parties. This does not impact upon our main point, which is the average border effect, because we report this *conditional on size.* The dependence of frictions upon size however does not, *a priori*, have an obvious sign, and we investigate the systematic negative dependence in Appendix B. There we demonstrate that this slope can be explained purely as a result of aggregation issues. This justifies the definition of "residual delta" in Figure 3 as the measured HRI after controlling for size as well as physical distance and common language. This figure shows that there is almost first order stochastic dominance for regional frictions compared with EU frictions, and likewise for EU frictions compared with other international frictions.

The difference between these CDFs is another graphical representation of the border effect. The border effect is the fact that controlling for size, physical distance, and whether there is a
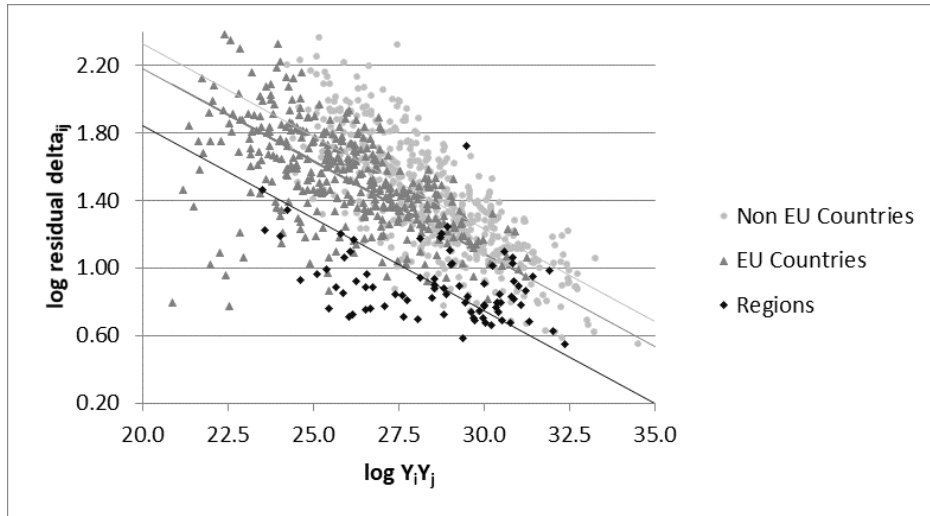
Figure 2: Scatter plot showing bilateral trade frictions against GDP split by countries and regions

common language, the average international friction is larger than the average within-EU friction, which itself is larger than the average inter-regional friction.

In fact we believe that the average border effect is even larger than suggested by the coefficients in Table 1 due to the fact that we have evidence that trade in services is more home biased than trade in goods, and our data procedure has implicitly assumed that the degree of home bias is the same in both. We present this evidence in the next subsection.

2.3 Trade in Services

We have reason to suspect that this analysis is conservative due to the treatment of regional trade in services. The use of goods only inter-regional trade makes comparison between regional and country level frictions appear less stark than it actually is, and so is a conservative basis for conducting this comparison. The method we have used to determine a measure of internal and external trade for the regions that is consistent with the goods and services international trade matrix, given goods regional trade matrices, is valid if the degree of home bias in trade in services is the same as the degree of home bias in trade in goods. If services are more home biased, then our proceedure is conservative: it understates internal trade if there is more home bias in trade in services than in trade in goods.

We have goods and services trade data for the Canadian Provinces and for Catalonia and the
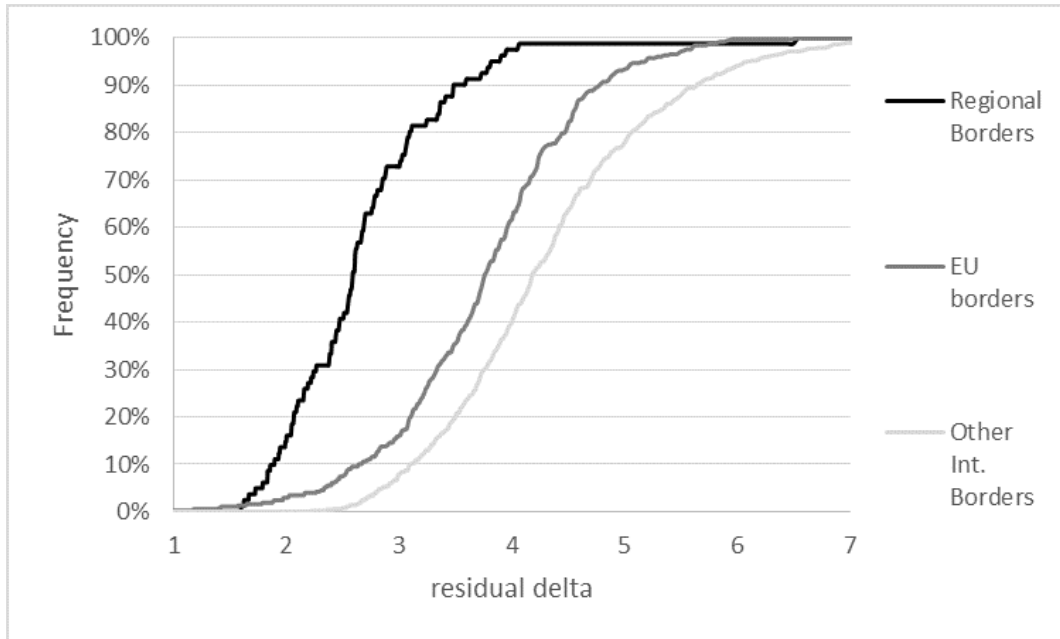
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Figure 3: Empirical CDF of residual trade frictions between regions and between countries

Basque Country. Therefore we can calculate the HRIs based on both a goods only apportionment of the Canadian and Spanish trade data, and a goods and services apportionment of this data. In this way we can infer if the border effect is larger considering goods and services compared to goods only trade, and if so, how much larger. Table 2 shows the measured HRI based on a goods and services apportionment, and for a goods trade only apportionment. As we see, every single region displays more home bias in its trade in services than it does in its trade in goods, and thus the frictions calculated under the goods only apportionment are higher in every case. The average of the log differences in frictions is 14%[15].

Every single region displays more home bias in its trade in services than it does in its trade in goods. Therefore, assuming that this is also true of the US states and the other Spanish Autonomous Communities, then the differences between regional and country level frictions are actually higher than the figures from Table 1. Assuming these results are representative and can be applied across the US States and the other Spanish Autonomous Communities, would imply that average differences in the log of regional and EU country frictions should be higher by an additional 14%.

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[15]The simple average difference is 17% while the average weighted by the size of the region-rest of country trade flow is 14%.

Region	Natural Log of Measured HRI	
	Goods Only Data	Goods & Services Data
Alberta	0.888	0.729
British Columbia	1.075	0.837
Manitoba	1.035	0.886
New Brunswick	1.074	0.937
Newfoundland	1.140	1.014
Northwest Territories	1.460	1.195
Nova Scotia	1.176	1.006
Nunavut	1.456	1.264
Ontario	0.867	0.661
Prince Edward Island	1.353	1.185
Quebec	0.929	0.770
Saskatchewan	1.006	0.864
Yukon	1.670	1.353
Catalonia	0.616	0.547
Basque Country	0.640	0.639

Table 2: Measured HRI for regions when apportioning international trade by regional Ratio of internal to international trade for each region

It is therefore the case that the comparison of country frictions to regional frictions that we have performed, which shows significant differences even when controlling for obvious contributions to trade frictions, is a conservative comparison. A further case for the conservatism of the comparison that we do, is that sales across a border are more likely to be recorded and so we may expect any data quality issues to bias our results against finding significant differences between regional and country level frictions.

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The body of evidence indicating that regional borders are systematically less frictional than country borders is very substantial: even controlling for physical distance and common language, for any given size frictions are systematically lower among regions than among countries (Figure 2). Controlling also for size, country frictions almost first order stochastically dominate regional ones (Figure 3). Taking into account the treatment of services increases this difference between regions and countries further. Our analysis is thus completely in line with other analysis that show that a substantial border effects exist: there is something that happens within countries that facilitates trade, something that does not happen across countries.

Furthermore, a similar, but smaller, effect is seen when comparing frictions internal and external to the European Union.

These large border effects, however, do not imply that the economic integration that could be

achieved by sharing a national state, or in joining the European Union, is as large as these average differences. For this to be the case, it would have to be that these institutional arrangements cause trade effects of this magnitude. In reality, who shares and who does not share a state, and who joins or does not join a trading block, is an endogenous proposition. This endogeneity, and our proposed method to deal with it, is one of the major contributions of this paper, and we turn to this in the next section.

3 Endogenous Country Formation

In the following discussion, we frame everything in terms of the region versus country border effect. The same ideas apply though in considering the impact of trading blocks like the European Union.

The estimated average difference between international frictions and interregional frictions is large, but this does not mean that eliminating national borders would cause such a large fall in frictions. This is because who shares and who does not share a state is an endogenous proposition. This endogeneity means that it is not obvious how to measure the trade enhancing value of sharing a state.

We have already seen that the measure of trade frictions is positively correlated with physical distance and with language differentiation. It is likely that it is positively correlated with all measures of population heterogeneity, and therefore in models of endogenous country formation such as Alesina, Spolaore, and Wacziarg (2005), it would be those pairs who already have a low trade friction that would select into sharing a state. This means that the average difference between international and interregional frictions overestimates the causal effect on trade friction reduction of sharing a state, and thus would overestimate the economic gains from political integration for an average pair of countries. Given a relationship between low frictions and selection into state sharing, the econometric estimate for the Regions dummy in Table 1 will be biased towards being too large (in absolute value).

Suppose that the observed frictions between two entities i and j are a function of intrinsic characteristics of these regions and of whether they share a political union. We call their innate characteristics as θ_i and θ_j respectively. We denote whether i and j are part of the same country

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(political union) by s_{ij}. We say that $s_{ij} = 1$ if they are, and $s_{ij} = 0$ if they are not, part of the same country. The innate characteristics of the entities, θ_i, refer to cultural, social, geographical aspects that escape economic modelling and that we take as exogenous. These are things that, at least from the point of view of an economist, are not altered by trade or by sharing a political union.

It is reasonable to imagine that the frictions between i and j are a function of both entities' characteristics and of whether they share a national-state:

$$\ln \delta_{ij} = F(\theta_i, \theta_j) + \gamma s_{ij} + u_{ij} \tag{6}$$

where γ would be the effect of economic integration, and u_{ij} is some noise.

If θ_i and θ_j are independent of s_{ij} there is no problem with the estimation of equation 6. This is, loosely, what is shown in Table 1, where $F(\theta_i, \theta_j)$ is the geographic distance between i and j, common language, etc.

The estimation conducted to obtain Table 1 has two problems, the first trivial but the second potentially important. The trivial issue is that in our RHS variables we include only a small subset of the factors θ that may affect trade. It is trivial because, insofar as those missing characteristics are orthogonal to s_{ij}, the estimation of γ remains unbiased.

The substantial problem is that those characteristics (missing or not) are very likely to be correlated with s_{ij}: which entities select into being a country is far from an exogenous proposition. The probability of the event $s_{ij} = 1$, is very dependent of the affinities and similarities between the parties. Moreover, these similarities and affinities are also very likely to affect the frictions irrespectively of the value of s_{ij}.

Thus, when we see that regions trade more than countries, this could indicate either that sharing a political union is a trade-enhancing "technology", or that regions are regions (and not countries in our parlance) for precisely the same reason that they have high levels of bilateral trade: they have deep and special affinities. This is, the probability of $s_{ij} = 1$ is a function of $F(\theta_i, \theta_j)$.

$$Prob(s_{ij} = 1) = G(F(\theta_i, \theta_j))$$

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In this case the OLS estimation of γ would suffer from upwards bias.

Given that the problem lies in determining the function $Prob(s_{ij} = 1) = G(\theta_i, \theta_j)$, an intuitive approach for solving this problem is to look at the break-up of nations. Head, Mayer, and Ries (2010) look at the erosion of colonial trade linkages after independence, and find a large fall in trade: on average, bilateral trade is reduced by more than 60% after 30 years of independence. However, colonies are unlikely candidates for economies who self-selected into an empire because of low initial frictions and similarities. Rather these were enforced partnerships that reflected a large difference in power.

Another possibility is to look at the break-up of countries in the former communist Eastern Europe. The obvious examples are the break-ups of Yugoslavia and Czechoslovakia[16]. However this is not a promising approach because the dynamics can of course be highly idiosyncratic: in Yugoslavia there was a war; and in any case they occur over timescales in which structural change, that is not orthogonal to independence, occurs. The set of events comprising the fall of the Soviet Union, the break-up of the states of the Warsaw Pact, the end of a centralised economy, and the subsequent membership for the new states into the EU, are not independent events and their effects can be conflated.

Our approach to control for this endogeneity is also a form of regression discontinuity analysis which attempts to locate quasi-experiments. The difference is that instead of looking at state-disolutions and break-ups, we try to identify what we label as *"marginal regions"* and *"marginal countries"*. These are regions of a larger country that could conceivably be independent, and independent countries that could easily be regions of the larger country. Let i be such a marginal region, j be the associated marginal country, R be the country of which i is a part, and r be the rest of this country other than i (this is, $R = r \bigcup i$). Then our assumption is that $F(\theta_i, \theta_r) \approx F(\theta_j, \theta_R)$ and thus, $\gamma \approx \ln \delta_{jR} - \ln \delta ir$. That is, the observed difference in frictions between such entities should be not dissimilar to the friction reduction that is caused by state sharing. In spite of working

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[16]Following the so-called "Velvet Divorce" of 1993, the share of bilateral trade in total trade fell dramatically, with the share of total Czech exports going to Slovakia going from 22% to 8%, and the share of total Slovakian exports going to the Czech Republic going from 42% to 13%. This is not likely simply due to the opening of trade with the rest of the world following the fall of the Iron Curtain. The same source suggests that the share of trade between other neighbours from the Eastern bloc, e.g. Poland and Hungary, held up much better, or actually increased, following the opening up to trade with the rest of the world. HMTreasury (2013).

with only a small number of examples, we arrive at a conclusion that seems very consistent.[17]

We define *"marginal regions"* as regions within the EU with a strong and credible independence movement. There are three such regions in our dataset: Scotland, Catalonia, and the Basque Country[18]. We present a methodology for determining the best counterfactual to their trade frictions with the rest of the country to which they belong, using what we label as the *"marginal country"*. We define this as the country in the data with the lowest measured bilateral friction with the country that would be broken up upon an independence event.

This generates reasonable and interesting examples. We will conduct this exercise in Section 4, but to give an example of our results, Ireland is determined as the marginal country with respect to the UK, and therefore functions as the counterfactual for Scotland. The measured frictions between Ireland and the UK represent a much smaller increase to Scotland's measured friction with the rest of the UK than the econometrically determined average estimated in Table 1. It does not seem reasonable to increase the frictions that Scotland has with the rest of the UK by the average difference between regional and country frictions when this results in higher frictions than we see for UK trade with other partners in the data. There are many special affinities between Scotland and England that it is unreasonable to suspect that all would disappear in the hypothetical case of independence. And if they do not all disappear they would be fostering trade between Scotland and England to levels that you would not expect between England and (say) Finland. The causal effect of a national border between Scotland and the rest of the UK is whatever is left beyond those special affinities that would not disappear. In other words, we have controlled for the selection bias on which entities are accounted into the labelling of "countries" and "regions" to the extent that Scotland and Ireland are otherwise identical vis-à-vis England.

Thus, we do **not** propose to increase the magnitude of the frictions by the extra bit that regions add on **average** once we control for language, distance and size. Our proposal is to use as

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[17]In any case, the traditional time series approach does not have many other observations either, as the number of informative instances of country break-up is also extraordinarily small (despite the large increase in membership of the UN - which is in large degree explained by decolonisation).

[18]On 18th September 2014 Scotland held an independence referendum in which 45% voted for independence. The Catalan government in the last few years has made an open push for independence. In recent elections and polls the pro-independence parties typically get 44% to 50% of the vote and they have a majority of the Catalan Parliament. In the last elections in the Basque Country 25% of the votes went to a very openly pro-independence party and a further 35% to a party with serious pro-independence inclinations.

a counterfactual the **lowest** friction that we observe in the data that the country has with others. In the next section we use a structural trade model to evaluate the impact that this conterfactual experiment has upon income, and label this as the gain from the economic integration that is **caused** by sharing a state.

Notice also that this methodology is used to provide an estimate on the causal impact of either joining or leaving a shared political space. The comparison between *"marginal regions"* and *"marginal countries"* provides the method to do this. Notice that we assume that it can be applied symmetrically to both the creation and the elimination of borders. The estimate obtained is our best estimate of this causal effect, and should be applicable in non-marginal cases. So for example, the difference between the Scottish and Irish trade frictions with the (rest of the) UK could be applied to Finland's frictions with the UK to model a hypothetical political integration of Finland with the UK. This would increase Finnish-UK trade, but not to a level similar to that of Scotland's trades with the rest of the UK, because Finland is not a *"marginal country"* with respect to the UK, as Finland does not have the same affinities with the UK as Ireland does. Nevertheless, this increase in Finnish-UK trade is our best estimate of the impact of any putative political integration between Finland and the UK. In the long run perhaps economic integration would harmonize these affinities, but this is outside the scope of our exercise. We take affinities as exogenous. In this sense we may be underestimating the impact of economic integration, but we have no way of dealing with this, and in any case we would be talking about the *very* long run here.

Further, in the long run steady state, it seems reasonable to us that the impact of creating or eliminating borders should be symmetric. However, this does not imply that the dynamics are symmetric, and for example it is possible that creating borders could be disruptive with large short run effects overshooting the steady state impact, whereas eliminating borders may have little short run impact with a slow approach to the steady state. We have nothing to say on these dynamics. They are extremely interesting, but beyond the scope of our analysis.

4 Counterfactual experiments on regional borders

In this section we evaluate the welfare consequences of policy experiments applied to the *"marginal regions"* of Scotland, Catalonia, and the Basque Country. We evaluate the cost to these regions of having international borders (though still within-EU borders) with the rest of the country of which they are part, both using the average econometric estimate, and using our *"marginal country"* counterfactual. Our counterfactual approach has a lower impact than imposing the average difference between country level and regional frictions but, as discussed, the comparison between marginal regions and the most closely integrated independent countries is much more informative as to the value of the extra economic integration that comes with political integration. The history of the literature on the border effect has reduced its importance, with McCallum (1995) showing a much stronger effect than Anderson and van Wincoop (2003). By controlling for selection bias we further reduce its importance, but in this section we show that it is still quantitatively significant. As we shall discuss, our estimates are insensitive to parameters (trade elasticity) and independent of model specification within a large subset of the gravity class of modern trade models. We show that the gains from economic integration that come with political integration are worth between a third and a half of the total gains from trade, relative to autarky, enjoyed by the regions that we consider.

4.1 No Substitution

Before we conduct our policy experiments, we consider another reason why the difference between international and inter-regional frictions (both calculated as the econometric average, or as the difference between marginal countries and marginal regions) could over-estimate the causal impact of political integration upon economic integration. It could be thought that regions have such smaller frictions with the rest of the country to which they belong *at the expense* of larger frictions with the rest of the world. This "substitution" in frictions could in principle be a reflection that close ties with a partner foster closer ones with him, but by not interacting with others, you get further apart from them. In such a case the role of the state for fostering trade integration could be overstated, even with our way of controlling for endogeneity of country formation.
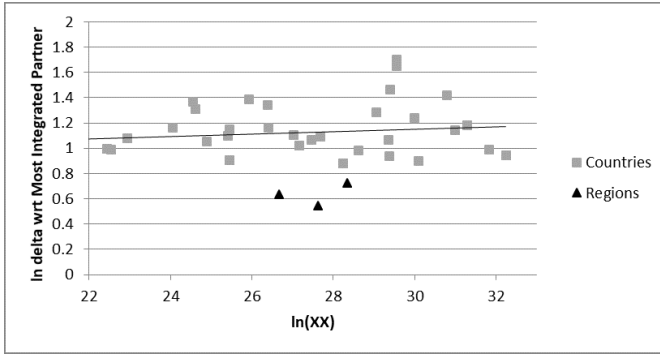
(a) Regions are better than expected at trading with their most integrated trading partner
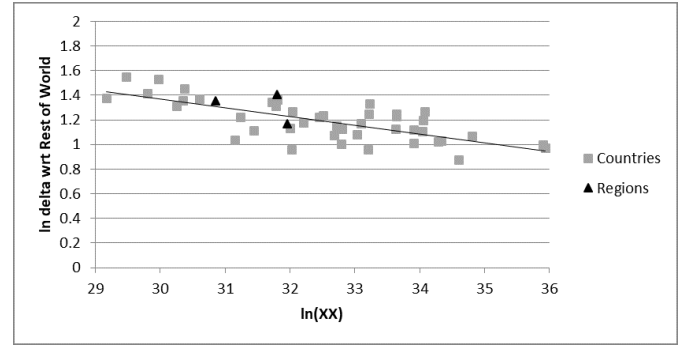
(b) Regions do not seem to be any worse than expected at trade with the rest of the world

Figure 4: HRIs with main trading partner and with rest of the world

We investigate this by looking at the three marginal regions of our dataset within a "three country" framework: the multilateral dataset is aggregated up in each case so that we are considering the three by three trade matrix involving the region, the rest of its nation, and the rest of the world. The results of doing this are compared against the equivalent for every country in the dataset, where the three by three trade matrix now involves the country, its most integrated trading partner (lowest measured frictions[19]), and the rest of the world. The results are presented in Figures 4a and 4b. We can see that the regions have roughly the expected level of trading frictions with respect to the rest of the world, but lower than expected frictions with their most integrated trading partner (which is the rest of their nation).

Regions differ from countries in the frictions that they have with their main partner, not in the frictions that they have with the rest of the world. We do not find that our marginal regions are systematically less integrated into the global economy than are independent countries of the same size. It does not seem to be the case that regions are substituting very close trade links with the rest of their country for slightly closer trade links with all possible partners in the rest of the world. Instead, the close economic integration across regional borders is on top of normal trade links with the rest of the world. Therefore the integration benefits of sharing a nation are apparently additional to the normal integration benefits that countries enjoy within the global economy.

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[19]We do this after controlling for size since the negative relationship between size and frictions is an aggregation issue (see Appendix B) rather than a real feature of close integration.

4.2 Counterfactual exercises

In order to proceed, we need a model in which we can conduct counterfactual analyses. Arkolakis, Costinot, and Rodríguez-Clare (2012) show that there is a map from trade elasticity, ϵ, and home share, λ, to welfare changes, ΔW, in all "gravity models", and we have seen that there is a map from trade flows to the HRI measure of trade frictions implied by such gravity models. We propose to implement policy experiments by changing the HRI measure of trade frictions. However, to quantify the welfare change under these policy experiements, we need to know how the trade flows vary with the HRIs. Unfortunately, as shown in Appendix C, there is no general map from HRIs to trade flows and a model is needed to provide the necessary structure for a specific set of HRIs to imply a specific set of counterfactual trade flows and incomes. The welfare formula from Arkolakis, Costinot, and Rodríguez-Clare (2012) only allows the welfare change to autarky to be evaluated - since it is only under autarky that we know the value of the counterfactual home share, $\lambda' = 100\%$.

Costinot and Rodríguez-Clare (2014) state that gravity models in which fixed exporting costs (if any) are paid in the destination country have a stronger equivalence result. In this case, counterfactual changes in trade flows are exactly the same as in the Armington model. Since this equivalence result holds across a fairly wide class of common models used in the international trade literature, it is a natural benchmark to consider.

However, in the data that we use, reported trade flows include intermediate goods,[20] and so we use an extended version of the Armington model with intermediate goods. Arkolakis, Costinot, and Rodríguez-Clare (2012) note that in "environments with ... tradable intermediate goods ... our simple welfare formula no longer holds [though] we demonstrate that generalized versions can easily be derived". We therefore compute our counterfactual scenarios using our intermediate goods extended version of the Armington model (see Appendix D)[21] in which the welfare formula

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[20]We have found no encompassing regional data reporting trade in value added. Thus, we need to use a model that incorporates trade of intermediates.

[21]The results are fairly stable to changes in the model used. A previous version of this paper, Comerford and Rodríguez-Mora (2014), (as well as using older data) used the basic Melitz (2003) model (which is in the general class of models described in Arkolakis, Costinot, and Rodríguez-Clare (2012)), and obtained very similar results.

is:

$$\Delta W = \left(\frac{\lambda'}{\lambda}\right)^{\frac{1}{(1-\beta)\epsilon}} - 1 \qquad (7)$$

where λ is the non-traded share of output in the data, λ' is its value in the counterfactual scenario, ϵ is the trade elasticity (the elasticity of trade flows with respect to trade frictions), and β is the average share of intermediate goods in total output from Equation (2).

We have detailed regional data, including trade in services, for Scotland, Catalonia, and the Basque Country as described in Appendix A. We find counterfactual countries for these "marginal regions" by identifying the least frictional trading partner, the "marginal" country, with respect to Spain (as a counterfactual for both Catalonia and the Basque Country) and with respect to the UK (as a counterfactual for Scotland). The independent country that is chosen as the counterfactual for the corresponding region is the country with the lowest measured HRI with respect to Spain and the UK. These countries are Portugal and Ireland respectively.

The fact that the counterfactual trading pairs are similar in size to the trading pairs upon which we are conducting these policy experiments gives further validity to these counterfactual exercises beyond their intuitive appeal.

The "Average Impact" HRI is the measured HRI for the Region-Rest of Country pair adjusted by the average border effect. For Catalonia and the Basque Country, we augment the observed frictions by a factor A_{Spain} obtained from the regional border and Spain coefficients from Table 1, as well as the 14% trade in services impact from Table 2. For Scotland, we augment the observed frictions by a factor A_{UK} obtained from the regional border coefficient from Table 1, as well as the 14% trade in services impact from Table 2[22]. Let i be the region, j be the counterfactual, R be the country of which i is a part, and r be the rest of this country other than i. Thus, we measure δ_{ir} and δ_{jR} from trade data, define δ'_{jR} by adjusting δ_{jR} for size and distance[23] using Table 1, and

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[22]The average value of $\left[ln\delta - \left(\alpha_{dist} \times dist + \alpha_{dist^2} \times dist^2 + \alpha_{lnXX} \times lnXX\right)\right]$ (where the αs are the relevant coefficients from Table 1) for the US internal borders is 4.00, while for the Spanish internal borders it is 3.57. The observed HRI for Scotland is calculated using goods and services data, and so on a consistent basis we add the 14% figure from Table 2 to it to produce an equivalent goods only figure. Then adjusting for distance and size as above gives a figure of 3.94 i.e. internal frictions in the UK look much more like those of the US than they do of Spain, and so we create our "average border effect" counterfactual for Scotland by adjusting by the coefficient on the US border effect only from Table 1.

[23]The adjusted counterfactual could also be adjusted for language. However, we believe that it would be problematic to do this. In the cross country dataset that we use, a pair is deemed to have a common language if they

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define $\delta_{ir}^{ave} = \delta_{ir} \times e^{A_R}$.

	Trade Frictions			Welfare Impact	
	δ_{ir}	δ'_{jR}	δ_{ir}^{ave}	δ'_{jR}	δ_{ir}^{ave}
Scotland (Ireland)	2.067	2.707	2.947	-8.5%	-9.8%
Catalonia (Portugal)	1.730	2.990	3.810	-12.5%	-13.7%
Basque C. (Portugal)	1.895	3.066	4.174	-16.0%	-18.3%

Table 3: Imposing HRIs on regions, with trade elasticity $= -3.5$

Table 3 shows the measured HRIs for the marginal regions with respect to the rest of the country of which they are part, the HRIs imposed on these pairs as policy experiments, and the welfare impact on the marginal regions of performing these policy experiements[24].

Notice that the frictions of our *"marginal country"* counterfactuals are lower than those implied by an econometric exercise that produces average effects. This is the sense in which our exercise corrects the selection bias. It would not be reasonable to expect that after a hypothetical Scottish independence, that the trade frictions between Scotland and England were to become as large as the ones that the UK has with the average of its other trading partners. The welfare impacts based on the counterfactual marginal countries are consequently lower than the impact of imposing the average difference between country and regional frictions.

We rationalise this variation in the impact of the *"marginal region"* - *"marginal country"* dif-

share an official language, so Ireland has a common language with the UK, but Portugal does not have a common language with Spain. Regional pairs are deemed always to have a common language (so the assumption is that sufficient Spanish is spoken in Catalonia and the Basque Country for them to share a common language with Spain despite both having local languages. This is a reasonable coding of the data, but strictly following this coding, we would claim that part of the difference between the Portuguese and the Catalonian or Basque frictions was a language effect. We believe that this reading of the relative language frictions in the Catalonia/Basque-Portugal case is incorrect. This is because the business community and professional classes in Portugal can speak Spanish. Designating both cases as positively having a common language designation is therefore reasonable. Modifying one data point in the cross country dataset may not be appropriate - either investigate the data closely in each case or algorithmically code; but sense should be applied when conducting three detailed examples. Note that the purpose of this exercise is to estimate the value of integration directly induced by political integration. It is of course the case that political integration has indirect effects like language homogenization, and perhaps Catalonia and the Basque Country both have a high propensity to cease to have a common language with the rest of Spain if there were to be no political integration in future. In Catalonia, for instance, all education from pre-school to university is given only and exclusively in Catalan, irrespectively of parental language. Moreover there are many voices of the pro-independent movement advocating for Catalan being the solely official language of an independent Catalonia. In the Basque country it is not 100% of the education, but is the large majority in spite of the Basque language being largely minoritarian only one generation ago. In any case, all this is a matter of conjecture (for example it might have been expected that Ireland, upon independence in 1922, would make strong moves away from sharing a common language with the UK and towards being a solely Gaelic speaking country, but this has not happened) and is in any case not the issue we seek to investigate or quantify.

[24]Every figure in this table is of course sensitive to the value chosen for the trade elasticity, here $\epsilon = -3.5$ as before.

	Home Share	Home Share Counterfactual			Welfare Impact / cost autarky		
	Data	$\epsilon = -2.8$	$\epsilon = -3.5$	$\epsilon = -5.2$	$\epsilon = -2.8$	$\epsilon = -3.5$	$\epsilon = -5.2$
Scotland (Ireland)	68%	78%	78%	78%	39%	38%	38%
Catalonia (Portugal)	56%	69%	70%	70%	42%	42%	41%
Basque C. (Portugal)	52%	69%	69%	69%	48%	47%	46%

Table 4: Welfare changes as a proportion of overall gains from trade are insensitive to changes in the trade elasticity

ference across countries as another point in favour of our proposed method: not only does this method do as good a job as we are able to do in dealing with this selection bias, it also controls in some respects for institutional details and country fixed effects. For instance, the fact that the integration benefit to Spanish regions in being part of Spain is seen to be greater than that of Scotland in being part of the UK is because Spanish regions seem to be much more integrated into Spain than Scotland is into the UK.

As well as being sensitive to the value chosen for the trade elasticity, there does not seem to be much common ground between the welfare figures in Table 3. However, in Table 4 we express the results of imposing the marginal country friction, δ_{jR}, as a counterfactual home share of trade in GDP, and the welfare loss as a share of the total welfare loss on autarky, for a range of values of the trade elasticity. We see that the results are remarkably stable. Varying the trade elasticity makes trade more or less important for welfare, but it is always the case that the gains from trade associated with sharing a state are a fraction of between a third and a half of the total value of gains from trade relative to autarky.

This insensitivity of the results to changes in the trade elasticity is implied by insensitivity of trade flows to the elasticity as described by Section V of Anderson and van Wincoop (2003). Changing the trade elasticity will change the trade impact of a given change in frictions, or the welfare impact of a given change in trade. However, conditioning on a counterfactual which is based on an observation in the data means that different trade elasticities imply different changes in frictions such that the implied change in trade flows is not greatly affected. Further, whilst the welfare impact of this implied trade flow change is a strong function of the trade elasticity, it is a fairly constant proportion of the total gains from trade relative to autarky.
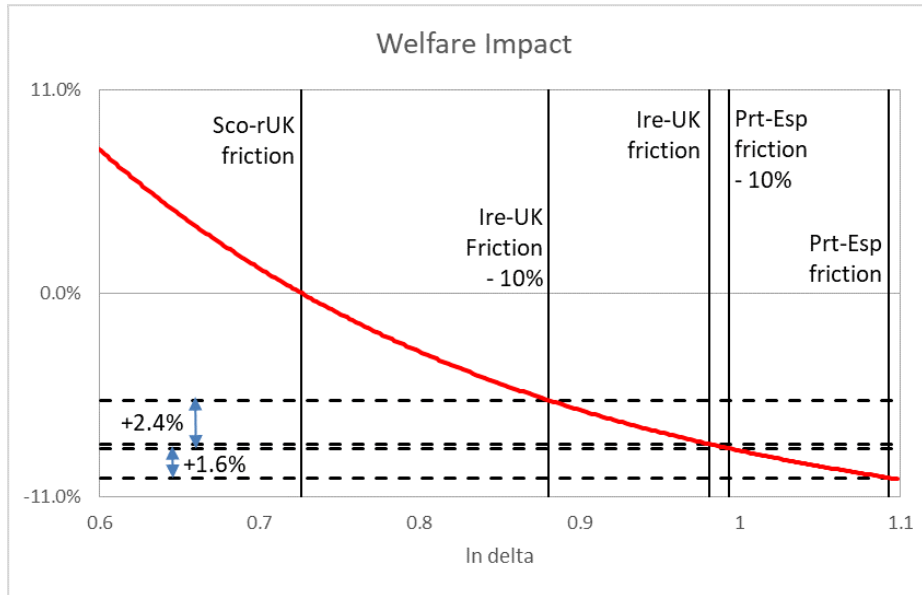
Figure 5: Scottish real income as a function of the trade friction with the rest of the UK. Imposing measured Scot-rUK frictions implies no change in Scottish income relative to the data. Note that infinite frictions with the rest of the UK is not an autarkic Scotland, frictions with the rest of the world are as measured in the data.

4.3 The incentive to integrate

Finally for this section, we note that income is a convex function of bilateral frictions. Figure 5 shows the level of GDP implied by the model for Scotland as a function of log frictions with the rest of the UK, relative to the GDP that it has with current frictions. An intuition behind this convex shape is that it must clearly asymptote to a horizontal line as frictions get very large and you approach zero bilateral trade: the change from nearly infinite frictions to very large but not so large frictions will not change trade patterns much once you are not trading at all. Conversely, the change from medium to small frictions may have a large impact on trade patterns and hence income.

When two entities are closely integrated (due to high affinities, say) the marginal benefit of further integration (via political union, say) is larger than it is for entities which are not so closely integrated (with lower affinities). This supports a selection mechanism whereby pairs with otherwise lower frictions have a greater incentive to form a unified country than those pairs with higher frictions. Trade models, in the general class of gravity models, imply greater integration benefits from marginal reductions in frictions for entities that already have low frictions.

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As an example, in Figure 5 we plot the log frictions that Ireland has with the UK, that Portugal has with Spain, and the impact that imposing these frictions has on Scottish income. Suppose that political integration is associated with a reduction in log frictions of size $I = 0.1$. Then, as can be seen, the income gain, $+2.4\%$, is higher if we start at the less frictional Ireland-UK position, than if we start at the more frictional Portugal-Spain position, in which case it is $+1.6\%$.

This lends additional support to the proposition that there will be selection into state sharing and that econometric estimates of the average difference between regional and international borders is not appropriate for determining the value of the economic integration generated by political integration.

5   EU Integration and Brexit

In this section we look at the degree of integration that the EU provides, the potential costs of losing such integration and the potential benefits of furthering that integration.

We start by performing exercises similar to the ones of the previous section, the difference is that instead of looking at the creation of hypothetical internal borders within countries of the EU, we look at the effects of a hypothetical departure from the EU. Or perhaps not that hypothetical, as the UK voted to leave the European Union and is set to formally do so during 2019.

One could argue that augmenting the frictions between the UK and the rest of the EU by the average impact estimated in the econometric exercise of Section 2, will overestimate the effects of Brexit by the same reasons that we exposed in section 3: Britain has belonged to the EU for 45 years *because* of the large degree of affinities with the rest of EU countries, and those affinities are not likely to disappear as a consequence of Brexit. We consider a set of counterfactual scenarios to inform on the potential costs of Brexit.

We then consider the gains provided by the existence of the EU to its members, and what would be the costs of the dissolution of the EU.

Finally, and for the shake of completeness, we revisit the possibility of independence for Scotland under different hypothetical arrangements vis a vis the EU.

δ	Country	EU	δ	Country	EU
4.229	LUX	1	4.520	PRT	1
4.242	HUN	1	4.521	LVA	1
4.247	MLT	1	4.525	CYP	1
4.290	BEL	1	4.538	FIN	1
4.298	CZE	1	4.550	ITA	1
4.307	SVK	1	4.555	ESP	1
4.313	NLD	1	4.566	GBR	1
4.318	IRL	1	4.640	TUR	0
4.364	DEU	1	4.695	GRC	1
4.369	SVN	1	4.746	RUS	0
4.371	AUT	1	4.944	TWN	0
4.387	EST	1	4.968	KOR	0
4.402	POL	1	4.988	USA	0
4.423	LTU	1	5.006	CAN	0
4.457	DNK	1	5.056	MEX	0
4.463	CHE	0	5.101	CHN	0
4.469	BGR	1	5.101	BRA	0
4.471	SWE	1	5.122	IND	0
4.491	FRA	1	5.137	AUS	0
4.505	ROU	1	5.187	JPN	0
4.508	NOR	0	5.193	IDN	0
4.512	HRV	1			

Table 5: Residual Frictions with the EU after controlling for size of both parties. Residuals frictions with the rest of the Eu if the country belongs to the EU. Residuals frictions given by $\ln \delta - \alpha_{\ln XX} \times \ln XX$, where $\alpha_{\ln XX}$ is the coefficient on $\log(X_i X_j)$ from Table 1.

5.1 Brexit Scenarios

A difficulty in trying to make reasonable counterfactuals for the effects of Britain leaving the UK is the degree of uncertainty on the eventual arrangement. The costs are unlikely to be the same for staying within the single market (in an EEA type arrangement such as that of Norway) or having extensive bilateral arrangements that amount to the same (as Switzerland does), as to having the same frictions that two good neighbors who are both members of the WTO would be expected to have. In order to clarify matters we produce a set of possible scenarios, measure their impact, and let the reader use their own criteria for evaluating how reasonable each of these counterfactuals are.

In Table 5 we order countries by their measured frictions with the EU, once corrected by size. If the country is a member of the EU, we report its frictions with the rest of the EU. There are two things to note in this table. First, notice that the UK is amongst the less integrated countries with the rest of the UK, in the sense than the implied frictions with the rest of the EU are larger than for all other countries of the EU except Greece. Second, the non EU countries with the smallest frictions to the EU are Switzerland, Norway, Turkey and Russia (in that order).

As a matter of comparison, in Table 6 we present the result of some counterfactual exercises of

Mg region⇒Mg country	$\delta_{ir} \Rightarrow \delta'_{jR}$	Welfare Change
Austria ⇒ Switzerland	2.654 ⇒ 2.852	−2.6%
Sweden ⇒ Norway	2.862 ⇒ 3.032	−1.5%
Poland ⇒ Russia	2.649 ⇒ 3.290	−5.4%
Bulgaria ⇒ Russia	3.596 ⇒ 3.593	+0.0%
Romania ⇒ Russia	3.278 ⇒ 3.474	−1.5%
Greece ⇒ Turkey	3.988 ⇒ 3.384	+3.3%

Table 6: Some Hypothetical exercises within the EU. Implied effect on GDP of the *"marginal region"* of substituting the frictions with the rest of the EU for the frictions that the counterfactual country (*"marginal country"*) has with the EU.

the type that we performed in the previous section. Here we define *"marginal countries"* as non EU members highly integrated with the EU, and *"marginal regions"* as the EU countries which are their most natural counterparts. Notice that Austria "becoming like" Switzerland or Sweden "becoming like" Norway have relatively small (albeit not insignificant) effects on GDP (of course, they have larger effects on the size of trade flows with the EU). Poland "becoming like" Russia has much larger negative consequential effects. The most surprising case is Greece "becoming like" Turkey, as Turkey trades with more ease with the EU than Greece does. We are skeptical about this last result, as it might be related to the specific economic circumstances of Greece since 2010, and in what follows we will ignore comparisons with Greece. In any case, it is informative on the fact that as countries go, Turkey is relatively well integrated into the EU economy.

In table 7 we report the value of the frictions between *"marginal regions* and *"marginal countries"* in the European context. For Switzerland the natural choice is Austria, and for Norway it is Sweden. It is not clear what is the natural *"Marginal Region"* counterpart for Turkey so we drop this example. The best counterparts for Russia are probably Poland, Bulgaria, or Romania. Notice that the average differences in log frictions, 0.0736[25] is much lower than the average effect of the EU on log frictions, which is 0.1444 from Table 1. This is consistent with endogenous selection into the EU, and suggests that to imply an increase of frictions to be equal to the average effect of the EU on frictions as a consequence of Brexit could overestimate its effects, as discussed in section 3.

Thus, we call an increase in the log of EU vs other country frictions of 0.0736, the *"causative"*

[25]This is the average of the figures for 'Austria vs Switzerland', 'Sweden vs Norway', and the average of the three '... vs Russia' figures. The simple average of all 5 figures is 0.0806.

	Marginal Region	Marginal Country	log difference
Austria vs Switzerland	2.654	2.852	0.0720
Sweden vs Norway	2.862	3.032	0.0575
Poland vs Russia	2.649	3.290	0.2165
Bulgaria vs Russia	3.596	3.593	-0.0007
Romania vs Russia	3.278	3.474	0.0579
Average			0.0736

Table 7: Frictions with the EU of selected countries along with the frictions with the rest of the EU of selected counterparts.

Counterfactual	δ_{UK-EU}	Δ of log δ	δ'_{UK-EU}	Welfare Change
"Causative effect"	2.668	0.0736	2.871	-1.0%
"Average effect"	2.668	0.1444	3.082	-1.7%

Table 8: Counterfactual *causative* and average effects of Brexit. Implied effect on GDP of the UK of increasing (log of) frictions with the EU by 0.0736 (*"causative effect"*) and 0.1444 (average effect).

effect of the EU on trade frictions. We compare it with the *"average"* effect of the EU which is the increase of 0.1444 obtained in Table 1. In Table 8 we show that the *"causative"* effect of increasing δ_{UK-EU} by the average increase between *"marginal regions and countries"* in the european context is a fall of UK GDP of 1.0%, compared with a 1.7% fall as suggested by the average effect.

Notice that the implied *"causative"* increase in the frictions does not take into account any of the specificities of the relationship between the UK and the EU. In particular it does not account for the fact that the UK is a large supplier of financial services to the rest of the Union. Not only has the UK the largest financial sector share in GDP of all the G7 countries (and more than twice Germany's share), but the contribution of UK financial services exports to GDP is also the highest. This is a sector very sensitive to regulation, and the new political realities in Europe as a consequence of the UK not having political representation in the Union, open the posibility of regulatory changes likely to decrease the relative advantage that the UK has now in the sector. We have seen in section 2.3 that trade in services is typically much more home-biased than goods trade. It is likely to be the case that this is also the case across the EU border, particularly given that the political sphere for regulation in those matters lies in Brussels more than in country states. It seems reasonable to expect regulatory changes making it more difficult for the UK to export financial services to the EU once the voice of Britain ceases to be heard in Europe and once British

Mg region⇒Mg country	$\delta_{ir} \Rightarrow \delta'_{jR}$	Welfare Change
UK ⇒ USA	$2.668 \Rightarrow 2.905$	-1.1%
UK ⇒ Canada	$2.668 \Rightarrow 3.674$	-2.9%
UK ⇒ Australia	$2.668 \Rightarrow 4.247$	-3.5%
UK ⇒ Russia	$2.668 \Rightarrow 3.024$	-1.5%

Table 9: Counterfactuals for the UK outside Europe. Frictions of the counterfactual *"Marginal Country"* are corrected by size, language and distance.

interests are not accounted for in the EU political process. To properly account for those facts lies beyond the scope of this paper, but those realities should be taken into account when considering the possible consequences of Brexit.

An alternative, and perhaps more natural, counterfactual for the UK after Brexit are non European countries that share many cultural, social and political similarities with the UK. Countries like Canada, USA or Australia. A further natural counterfactual is Russia since post-Brexit, the UK and Russia will be the two large, culturally European, countries that border the EU. In Table 9 we present the results of the exercise of substituting the frictions that the UK has with the rest of the union by the frictions that USA, Canada, Australia and Russia have with the EU (after controlling for size and distance). The effects on UK's GDP range from decreases of around 1.1% (if the countarfactual is the USA) to 3.5% (if it is Australia).[26]

In Figure 6 we summarise these results and show how the welfare impact upon the UK of Brexit depends on the frictions that the UK may have with the rest of the EU. Not surprisingly it is a similar to the figure in section 4.3, larger frictions, less trade, worse outcomes, and the gains are larger the closer you are. There is a difference in magnitudes relative to Figure 4.3 though, since the Scottish economy is much smaller than the UK's and it depends much more upon trade (largely with the rest of the UK). In Figure 6 we mark hypothetical values of δ and the corresponding welfare imapct upon the UK. The hypothetical frictions that we mark are (1) the frictions that the UK has currently with the EU. If these were to be the frictions after Brexit (i.e., no change at all in frictions), there would be of course no change in welfare. (2) The frictions resulting from adding to the UK-EU frictions, the *"causative"* effect described above, and the *"average"* effect of the EU from Table 1. These result in a loss of about 1.0% and 1.7% of GDP respectively. And

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[26]Notice that this before the implementation of the free trade agreement between Canada and the EU
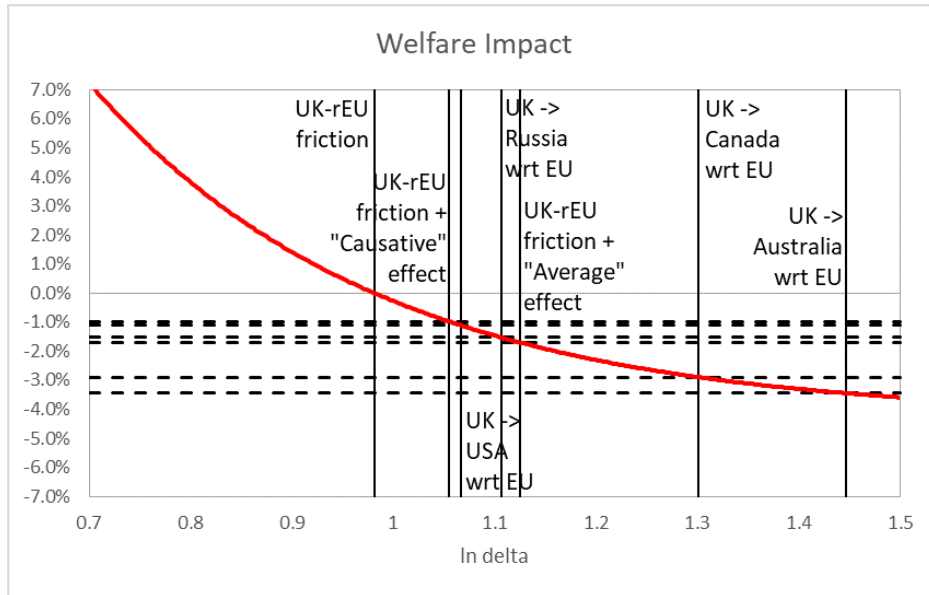
Figure 6: UK real income as a function of the trade friction with the rest of the EU.

(3), the US-EU, Russia-EU, Canada-EU and Australia-EU frictions (all translated to the UK-EU friction by correcting for size and distance). Imputing these frictions to the UK-EU border would result in a loss to the UK of 1.1%, 1.5%, 2.9% and 3.5% of GDP respectively.

Thus, one can conclude that the steady state effects of Brexit on trade are likely to produce a significant, albeit by no means disastrous, reduction in British GDP ranging from 1.0% to 3.5%. This is consistent with other economic estimates which have been generated. Sampson (2017) surveys the literature and finds that plausible estimates of the costs of Brexit to the UK lie in the range of 1% − 10% of GDP. For instance, Dhingra, Huang, Ottaviano, Pessoa, Sampson, and Reenen (2017) find that structural model estimates which only change trading frictions upon Brexit (such as those conducted in this paper) produce costs in the range 1% − 3%. They also find that reduced form estimates (which may also reflect trade impacts upon productivity and technology, capital accumulation and FDI, and immigration) produce costs of Brexit to the UK in the range 6% − 9% of GDP. This is consistent with the arguments in Brooks and Pujolas (2017), which in a dynmaic general equilibrium trade model produce larger gains from trade than estimates based on static models, due to the dynamic adjustment of capital. Other estimates of the costs of Brexit include those of Ebell and Warren (2016) and Ebell, Hurst, and Warren (2016) who run various Brexit scenarios, and find impacts on GDP of 1% − 4%.
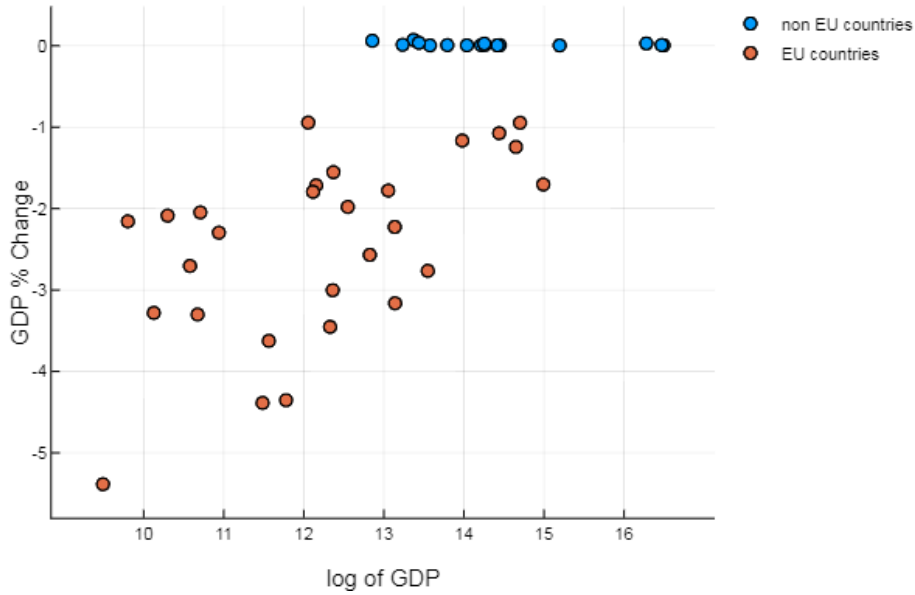
Figure 7: Welfare effects in all countries of increasing log δ of EU-EU borders by the *"causative"* effect, +0.0736, of the EU.

5.2   The Aggregate effects of the EU

The fact that the magnitude of the effects of leaving the EU (from the previous section) are much smaller than the ones of regions getting independent *and both parties remaining in the EU* (as reported in section 4) does not imply that the existence of the EU has small effects on welfare. In this section we perform counterfactual exercises showing (i) that the effects of the EU on welfare are considerable, particularly for small countries, but that (ii) the effects of decreasing the frictions within the EU to those in line with the ones that regions of the same country have between them could be very very large indeed (again, particularly for small countries).

   We first do the exercise of considering that *all* the countries within the EU increase the frictions between themselves by the *"causative"* effect that the EU has on frictions (i.e., an increase of the log δ_{ij} of 0.0736 for all country pairs where both i and j belong to the EU). This has three types of effects: (i) it obviously increases the frictions between the pairs, reducing their welfare, (ii) it produces general equilibrium aggregate demand effects, as the economies affected by the increase in frictions sum to a substantial amount of world GDP, and (iii) it produces a change in terms of trade benefiting non EU countries (whose goods become more demanded as former EU members have more difficulty trading among themselves). This sums to a decrease of World GDP of 0.3%,
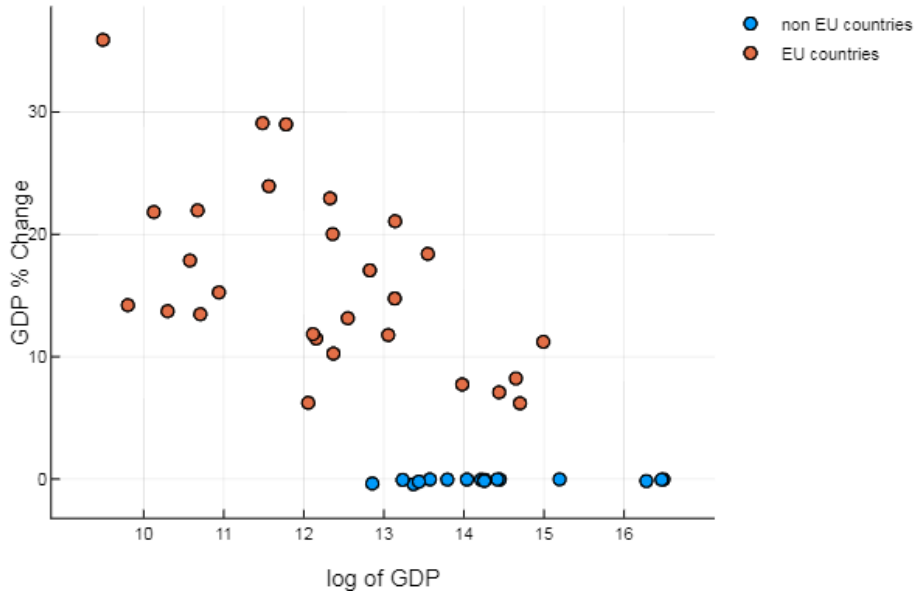
32

Figure 8: Welfare effects in all countries of decreasing log δ of EU-EU borders by the *"causative"* effect, -0.2700, of within-country level integration.

but this change is very unevenly distributed. Non EU countries have a very small increase of 0.01% of GDP, while EU GDP suffers a decrease of 1.7%. In Figure 7 we plot the effect for all countries along with the country size. For small European countries the loss is substantial (close to 5% in some cases) while for larger countries it is much smaller. In the case of the UK the implied loss is of 0.95%[27].

We next turn to do the opposite exercise. We decrease the log frictions between all pairs of EU countries by 0.2700, which is the difference in log frictions between Ireland and Scotland vis-a-vis the UK. We use this difference as it is the smallest of the differences over the three case studies that we looked at, and so is a conservative estimate of what we propose as the *"causative"* effect of integration within a country. That is, we decrease log frictions by 0.2700 whenever both parties are in the EU. As a consequence, world GDP would increase by a substantial 2.3%, but again this increase would be unevenly distributed. Countries outside of the EU see a slight decrease in their

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[27]The Brexit only loss for the UK is 0.97%. In the case of EU disintegration following Brexit, we can imagine the UK suffering the 0.97% loss on Brexit which is then followed on by the disintegration of the EU. When the EU falls apart, the UK (which is already outside the EU) experiences two offsetting effects: the first is a further fall in GDP as its EU trading partners suffer a loss and demand from these countries falls; the second is a trade diversion effect - the EU countries used to trade more with each other, but as their borders become more frictional, some of these purchases are instead made from non-EU countries. The (positive) trade diversion effect dominates the (negative) effect of the fall in income of EU countries, and we see that the overall impact of EU integration, -0.94%, is slightly less bad for the UK than a simple Brexit scenario, -0.97%.

GDP of 0.1% as a consequence of suffering a real depreciation, while EU GDP increases by 10.9%. In Figure 8 we plot the effect for all countries along with the country size. The implied increase in welfare for small European countries is huge, with a smaller but still substantial impact on larger countries. As a benchmark, for the UK the increase is 6.2%.

The corollary of all this is that, even although the effects of the EU are substantial (because it decreases frictions between its members), there is a large difference between the frictions across the countries of the EU, and the friction within countries. Moreover, the welfare implications of those remaining frictions within countries seem to be almost an order of magnitude larger, and further integration between EU members could produce large welfare gains.

5.3 Independence and EU membership

As an example of this almost order of magnitude difference between the welfare implications of within country frictions relative to the frictions between EU members, we revisit the case of Scottish independence. Following the "No" vote in the Scottish Independence Referendum in 2014, this issue may have been thought to have been resolved for a long period of time. However, with Scotland voting to "Remain" in the EU, while the UK-wide vote was to "Leave", in 2016's Brexit Referendum, Brexit has pushed the issue of Scottish independence back on to the political agenda. In this subsection we consider the "choice" now facing Scotland between "Brexit-ing" the EU along with the rest of the UK, or opting for independence and remaining within the EU. In Table 10 we report the implied changes in Scottish and rUK GDP for these two different policy experiments.

The first row conveys Brexit, while Scotland remains in the UK. The frictions for both Scotland and the rest of the UK with the rest of the EU increase by the *"causative"* effect (increase $\log \delta$ by 0.0736) while the frictions between Scotland and the rest of the UK remain as calibrated with the data[28]. The loss for the rest of the UK is 1.0% (about the same size as the loss for the whole of the UK that we saw before in Table 8, which makes sense given the small size of Scotland relative to

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[28]To do this we assume that Scottish external trade is split between the EU and the rest of the world in the same proportion as that of the UK as a whole. We only have export data split by destination for Scotland and in this data Scotland exports 43% of total international exports to the rest of the EU. This is very similar to the UK figure of 42%. In the exercises we do, it is both exports and imports that matter, and we have no data on the source of Scottish imports. Therefore we split Scottish external trade into rEU and RoW using the split that we see in the UK figures.

	$\delta_{Sct-rUK}$	$\delta_{rUK-rEU}$	$\delta_{Sct-rEU}$	Scotland	rUK
(1) Brexit, no independence	2.067	2.882	4.254	-0.8%	-1.0%
(2) Brexit, independence in EU	2.707	2.882	3.952	-8.4%	-1.7%
(3) Brexit, independence in EU	2.914	2.882	3.952	-9.6%	-1.8%
(4) Brexit, independence out of the EU	2.914	2.882	4.254	-10.5%	-1.8%

Table 10: Implied Welfare Changes for Scotland and the rest of the UK of (1) Brexit without Scottish independence, (2) Brexit & independence (Irish friction) while Scotland remains in the EU, (3) Brexit & independence (augmented Irish friction) while Scotland remains in the EU, and (4) Brexit & independence with Scotland out of the EU

the UK), while the loss for Scotland is slightly smaller, 0.8%, due to it being less open to foreign trade than the rest of the UK.

The second row of Table 10 is to (i) increase the frictions between the rest of the UK and the EU in the same manner as before, (ii) to make the frictions between Scotland and the rest of the UK equal to the ones the UK has with Ireland like in section 4, and (iii) while leaving the frictions between Scotland and the EU intact. Thus, this scenario accounts for Scottish independence from the UK, and accession as an independent member state of the EU. This leads to a much larger loss in GDP for Scotland, of 8.4%[29] and a larger loss in GDP for rUK of 1.7% - which has suffered the double effect of Brexit (cost of around 1.0%) and increased trade frictions with Scotland (implied cost of around 0.7% of GDP).

Notice however that in this second row we have increased the frictions between Scotland and the rest of the UK "only" to the level that Ireland has with the UK now, while the UK is a member of the EU. Were we to increase this friction further (by the additional *"causative"* effect of the EU) then we see in the third row that losses are now even larger.

Finally, and for completeness, in the 4th row we show the impact of Scottish independence and Brexit if Scotland does not remain within the EU. Clearly in this case the losses are again larger.

The loses for Scotland associated with Brexit are almost an order of magnitude smaller than

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[29]Notice again that this is a smaller loss than the 8.5% loss from the Scottish independence scenario considered in Table 3. This is because "after" suffering an 8.5% GDP loss on independence, Scotland then benefits marginally from trade diversion effects as rUK leaves the EU.

the loses associated with severing the within-country levels of integration that Scotland has with the rest of the UK. The moral of this exercise is that even controlling for endogeneity effects in the formation of countries, country borders have very large implications for trade frictions, even within the European Union. Their effects are much larger than the, still significant, effects of the European Union. A corrollary of this is that there are large gains from trade still available in making the EU look like an integrated country in trade terms, though the political direction of travel seems to be very much against this at the moment.

6   Conclusion

In this paper we have presented evidence, consistent with the economic literature on the border effect, that regional borders are less frictional to trade than international borders (Table 1), even within the EU. Our econometric exercise can be used to construct policy experiments that provide an estimate of the welfare costs of changing regional borders to international borders (via political independence) or leaving the EU (i.e., Brexit) in standard gravity models of trade (Table 3).

However, we believe that this "average" border effect overestimates the impact of sharing a state: it is reasonable to expect that affinities that promote trade also promote selection into sharing a state. This means that it is likely that entities with otherwise low frictions "choose" to share a state and enjoy the integration benefit, whereas entities with high frictions "choose" to be independent countries. The average difference between borders within and across countries therefore overstates this integration benefit because of this selection bias. The same mechanism is likely to exist for selection into (or out of) organizations like the EU.

We propose a methodology to deal with this selection bias: identify *"marginal regions"* as those regions in our data with credible independence movements; and *"marginal countries"* with respect to country R as those countries with the lowest measured frictions with R; then the difference in frictions between a marginal region of country R and the marginal country with respect to country R, is a better estimate of the true economic integration benefit due to political integration than the average difference between regional and country borders. This is akin to performing a regression discontinuity analysis. By controlling for this selection bias, we reduce the estimated integration

benefit in the case of Scotland, Catalonia and the Basque Country. Nevertheless, the estimates that we obtain are still very large indeed. Likewise by the same logic we estimate a cost of Brexit lower than that obtained by imputing the average difference in frictions between EU and non EU countries.

The history of the literature on the border effect has reduced its importance, with McCallum (1995) showing a much stronger effect than Anderson and van Wincoop (2003). By controlling for selection bias we further reduce its importance, but a central claim of our paper is that it is still quantitatively significant. Our estimates are insensitive to parameters (trade elasticity) and insensitive to model specification (e.g. inclusion of intermediate goods) across a broad class of models from modern trade theory, and they tell the same story across the three examples that are in our data set: the gains from economic integration that come with political integration are worth between a third and a half of the total gains from trade, relative to autarky, enjoyed by these regions (Table 4). This large proportion of total gains from trade is a consequence of the extraordinary degree of integration that a region has with the rest of its country. Despite the EU being a trade promoting body, with quantitatively significant benefits, we do not observe the same degree of integration between countries, even within the European Union.

The differential trade promoting effects of sharing a country have consequences that are almost an order of magnitude larger than consequences of the differential effects of mutual EU membership. These consequences translate into large potential gains in welfare. These are the gains from economic integration that institutions like the European Union should strive to obtain.

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Appendices

A   Data

A.1   Country Data

- WIOT2014_Nov16_ROW.xlsb downloaded from http://www.wiod.org/database/wiots16 - World Input-Output Tables, 2016 Release, WIOT 2014 link.

- This gives GDP, Gross Output and total (goods and services) bilateral trade flows for 2014, for 43 countries plus a rest of the world aggregate.

- Data on distance and common language etc, geo_cepii.xls and dist_cepii.xls, downloaded from GeoDist http://www.cepii.fr/CEPII/fr/bdd_modele/presentation.asp?id=6

A.2   US Data

- US State GDP for 2014, from Bureau of Economic Analysis https://www.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=10&isuri=1&7003=200&7035=-1&7004=naics&7005=1&7006=xx&7036=-1&7001=1200&7002=1&7090=70&7007=2014&7093=levels

- State Gross Output used in constructing the dataset is
$US\,total\,Gross\,Output \times State\,GDP / \sum State\,GDPs$

- 2014 trade flows (goods only) between states and internationally from the Freight Analysis Framework http://faf.ornl.gov/fafweb/Extraction1.aspx

- State International Trade used in constructing the dataset is
$US\,International\,Trade \times State\,International\,Trade / \sum States\,International\,Trade$

- State Internal Trade used in constructing the dataset is
$US\,International\,Trade \times State\,Internal\,Trade / \sum States\,International\,Trade$

- Geographical data taken from http://bl.ocks.org/sjengle/5315515

A.3   Canadian Data

- 2013 Data obtained from Statistics Canada by downloading cansim-3860003-eng-5409715410633866536.csv from http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=3860003&tabMode=dataTable&p1=-1&p2=-1&srchLan=0&pattern=trade

- This gives GDPs and bilateral trade flows (either goods only, or goods and services) internally and internationally.

- Provincial Gross Output used in constructing the dataset is
$Canadian\,total\,Gross\,Output \times Province\,GDP / \sum Province\,GDPs$

- Provincial International Trade used in constructing the dataset is
$Canadian\,International\,Trade \times Province\,International\,Trade / \sum Provinces\,International\,Trade$

- Province Internal Trade used in constructing the dataset is
$Canadian\,International\,Trade \times Province\,Internal\,Trade / \sum Provinces\,International\,Trade$

- Geographical data: "canada_provinces.csv" downloaded from https://www.webtrees.net/index.php/en/add-ons/category/5-gm-files

A.4 Scottish Data

- Scottish and UK GDP for 2014 obtained from "GERS" publication: 00523728.xlsx downloaded from http://www.gov.scot/Resource/0052/00523728.xlsx

- Scottish Gross Output used in constructing the dataset is
$UK\,total\,Gross\,Output \times GERS\,Scottish\,GDP/GERS\,UK\,GDP$

- Goods and services trade with rest of UK and with rest of the world from Scottish Government's Input-Output (IO) tables for 2014. These tables also give a measure of Scottish Gross Output. 00522788.xlsx downloaded from http://www.gov.scot/Resource/0052/00522788.xlsx

- Scottish Trade with i ($i = rUK$ or RoW) used in constructing the dataset is
$Scottish\,Gross\,Output \times Scottish\,IO\,Trade\,with\,i/Scottish\,IO\,Gross\,Output$

- rUK trade with RoW used in constructing the dataset is $UK\,Trade\,with\,RoW - Scottish\,Trade\,with\,RoW$

- Scottish exports to the rest of the world, as calculated above, are split by destination using Export Statistics Scotland 2015 data for 2014 for use in Herfindahl calc: 00526194.xlsx dowloaded from http://www.gov.scot/Topics/Statistics/Browse/Economy/Exports/ESSPublication/ESSExcel

- Geographical data: coordinates for Edinburgh obtained from google search.

A.5 Spanish Data

- Autonomous Community GDPs in 2006 from Eurostat ("Regional gross domestic product by NUTS 2 regions - million EUR, Code: tgs00003")

- A.C. Gross Output used in constructing the dataset is
$Spanish\,total\,Gross\,Output \times A.C.\,GDP/\sum A.C.\,GDPs$

- Goods only trade data, as at 2006, for all Spanish Autonomous Communities in terms of imports and exports to the rest of Spain and internationally, from C-Intereg 2008: Table 6 on p28 of http://www.c-intereg.es/El_Comercio_Interregional_en_Espa%C3%B1a_1995-2006_29_10_08.pdf

- Provincial International Trade used in constructing the dataset is
$Spanish\,International\,Trade \times A.C.\,International\,Trade/\sum A.C.\,International\,Trade$

- A.C. Internal Trade used in constructing the dataset is
$Spanish\,International\,Trade \times A.C.\,Internal\,Trade/\sum A.C.\,International\,Trade$

- Geographical data: Regional capital coordinates for Spanish autonomous communities obtained from individual google searches.

A.6 Catalonia

- Goods and services trade (G&S) data with rest of Spain and with rest of the world as at 2005 is available from Comptes econòmics simplificats de l'economia catalana 2005

- Catalan Gross Output and International trade are as calculated using the Spanish A.C. (AC) data above

- Catalan Internal trade used here is
$Catalan\,(AC)\,International\,Trade \times Catalan\,(G\&S)\,Internal\,Trade/Catalan\,(G\&S)\,Internal\,Trade$

- Catalan exports to the rest of the world, as calculated above, are split by destination using the split for Spain as a whole, for use in Herfindahl calc.

A.7   Basque Country

- Goods and services trade (G&S) data with rest of Spain and with rest of the world as at 2006 is available from http://en.eustat.es/elementos/ele0010000/ti_Gross_Domestic_Product_of_the_Basque_Country_by_components_Supply_and_demand_Current_prices_thousands_of_euros_2005-2012a/tbl0010072_i.html#axzz2vHsbZzjnexpressed

- Basque Gross Output and International trade are as calculated using the Spanish A.C. (AC) data above

- Basque Internal trade used here is
  $Basque\,(AC)\,International\,Trade \times Basque\,(G\&S)\,Internal\,Trade / Basque\,(G\&S)\,Internal\,Trade$

- Basque exports to the rest of the world, as calculated above, are split by destination using the split for Spain as a whole, for use in Herfindahl calc.

B   Negative Relationship Between Size and Measured Frictions

It is obvious that trade frictions should depend positively on physical distance, and negatively on whether the entities have a common language. But it is much less obvious why there should be a significant dependence on the size of the entities. In this section we will show that aggregation can explain this negative dependence. To this end, we conduct the following exercise. We assume the existence economies, and fix their trade patterns. We then view these economies at different scales of aggregation (for small or large "countries") and examine how the measured HRI changes with scale.

Suppose a large number, N, of very small, identical economies. Within these very small economies, there are no trade frictions. Each of these economies has gross output, Y, and home trade share, λ, and every bilateral pair in this world is associated with the same trade friction, $\bar{\delta} > 1$ and consequently, trade flow X. We can then look at aggregations of these small units. Suppose the underying small economies are indexed $1, ..., N$ but that we can only observe aggregations ("countries") $K = \{1, ..., k\}$ and $M = \{k + 1, ..., k + m < N\}$. Then we want to examine the relationship between the size of these aggregations/countries, k & m, and the measured HRI between them. We are imposing the same frictions between any two fundamental units and no extra friction for trade across the border of the *data gathering units* , K & M. Therefore, if the measured HRI reflected only true trade frictions then it should be independent of k & m. On the other hand, if there is a relationship, does it explain the slope in Figure 2, or does this figure show some true relationship between size and HRI?

We can solve for the bilateral trade flow X between each unit, in terms of the home share λ, the true bilateral trade friction $\bar{\delta}$, the gross output Y, and the trade elasticity ϵ, by manipulating Equation (1):

$$\bar{\delta} = \left(\frac{X^2}{(Y - (N-1)X)^2} \right)^{\frac{1}{2\epsilon}} \ \& \ \lambda = \frac{Y - (N-1)X}{Y} \Rightarrow X = \lambda Y \bar{\delta}^{\epsilon}$$

Now consider the case where we cannot observe these small identical units, but instead the observed actual countries are aggregrations $K = \{1, ..., k\}$ and $M = \{k+1, ..., k+m\}$ of non-overlapping underlying

"countries". In this case:

$$
\begin{aligned}
Y_K &= kY \\
Y_M &= mY \\
X_{KK} &= k\lambda Y + k(k-1)X \\
X_{MM} &= m\lambda Y + m(m-1)X \\
X_{KM} &= kmX = X_{MK}
\end{aligned}
$$

If we now measure the HRI associated with this KM bilateral relationship, we obtain

$$
\ln \delta_{KM} = \frac{1}{\epsilon} \ln \left(\frac{X_{KM}}{X_{KK}^{1/2} X_{MM}^{1/2}} \right) = \frac{1}{\epsilon} \ln \left(\frac{k^{1/2} m^{1/2} \bar{\delta}^{\epsilon}}{(1 + (k-1)\bar{\delta}^{\epsilon})^{1/2}(1 + (m-1)\bar{\delta}^{\epsilon})^{1/2}} \right)
$$

Differentiating $\ln \delta_{KM}$ by $\ln Y_K$ and evaluating this at $k = 1$ gives

$$
\frac{\partial \ln \delta_{KM}}{\partial \ln Y_K} = \frac{\partial \ln \delta_{KM}}{\partial \ln k} = \frac{1}{2\epsilon} \left(1 - \frac{\bar{\delta}^{\epsilon} k}{1 + (k-1)\bar{\delta}^{\epsilon}} \right) < 0
$$

$$
\text{i.e. } \frac{\partial \ln \delta_{KM}}{\partial \ln Y_K}(k=1) = \frac{\partial \ln \delta_{KM}}{\partial \ln Y_M}(m=1) = \frac{1 - \bar{\delta}^{\epsilon}}{2\epsilon} < 0
$$

Therefore, purely from aggregation effects rather than any real frictions, we would expect to observe a negative relationship between the log of the HRI and log incomes with a slope in the range $\frac{1}{2\epsilon} < 0$ (for high values of $\bar{\delta}$) to 0 (for a value of $\bar{\delta} \approx 1$). This range, given the value $\epsilon = -3.5$ used to generate Figure 2, is $(-0.142, 0)$. The empirically observed slope shown in Figure 2 is -0.103. There is therefore no evidence of any true relationship between size and HRI, with the negative slope being within the expected range.

The intuition for this negative dependence of HRI upon size is that the HRI measure is a relative measure: it measures the friction for trade with the other party relative to trade with yourself. Larger countries have larger internal trade frictions and so a lower relative increase in frictions with external entities. Ramondo, Rodríguez-Clare, and Saborío-Rodríguez (2014) provide a model for internal frictions which deals with this effect. Doing this requires additional data, and in a simple and parsimonious specification like that used in this paper, we cannot separately identify the productivity of the economies from their internal trade frictions. We can however control for this phenomenon by looking at the residual over and above what we expect given size effects.

We expect frictions to depend positively on physical distance, and negatively on a common official language. We have now shown[30] that we also expect frictions to depend negatively upon the incomes of the trading partners due to aggregation. We now look at the residual frictions controlling (via the regression coeffients from Table 1) for these three factors.

C   HRI destroys information: need for a model

Arkolakis, Costinot, and Rodríguez-Clare (2012) show that there is a map from trade elasticity and home share to welfare in all "gravity models", and we have seen that there is a map from trade flows to the HRI measure of trade frictions. We propose to change the HRI measure of trade frictions based on plausible counterfactuals. However, to quantify the welfare change under these counterfactual experiments, we need to know how the trade flows vary with the HRIs. Unfortunately, as we now show, the map from trade flows to HRIs is not bijective and so we need to propose a model to determine our counterfactual trade flows. The Arkolakis, Costinot, and Rodríguez-Clare (2012) formula only allows the welfare change to autarky to be evaluated - since under autarky we automatically know what the trade flows must be.

---

[30]Coughlin and Novy (2011) also make this point.

Define

$$x_i(j) = \ln \frac{X_{ij}}{X_{ii}}$$

so

$$x_i(i) = 0$$

and

$$A_{ij} = A_{ji} \equiv 2\varepsilon \ln \delta_{ij} = x_i(j) + x_j(i)$$

Write in matrix form:

$$\begin{bmatrix} 0 & A_{12} & ... & A_{1n} \\ A_{12} & 0 & ... & A_{2n} \\ ... & ... & ... & ... \\ A_{1n} & A_{2n} & ... & 0 \end{bmatrix} = \begin{bmatrix} 0 & x_1(2) + x_2(1) & ... & x_1(n) + x_n(1) \\ x_2(1) + x_1(2) & 0 & ... & x_2(n) + x_n(2) \\ ... & ... & ... & ... \\ x_n(1) + x_1(n) & x_n(2) + x_2(n) & ... & 0 \end{bmatrix}$$

i.e. $A = X + X'$ is a mapping from $n(n-1)$ pieces of information, $\{x_1(2), ..., x_1(n), x_2(1), ..., x_2(n),$
$..., x_n(1), ..., x_n(n-1)\}$, into $n(n-1)/2$ piece of information, $\{A_{12}, ..., A_{1n}, A_{23}, ..., A_{2n}, ..., A_{(n-1)n}\}$. We
can therefore conclude that the HRI destroys some of the trade flow information. In order to recover
trade flows from a counterfactual set of HRIs, we need to impose a specific gravity model.

D Armington Model with Intermediate Goods

Extending Anderson and van Wincoop (2003) (which in turn follows from Anderson (1979)) to include
intermediate goods.

- Let $h, j \in \{1, ..., N\}$ index countries in the multilateral trade database

- Let $i_{hj} + c_{hj} \equiv$ the real quantity of goods used in j that were produced in h. These goods as far as
  j is concerned have a unit cost of $p_h \delta_{hj}$ ($\delta_{jj} = 1$ & $\delta_{hj} > 1$ for $h \neq j$). The real quantity of goods
  supplied by h to j however is $\delta_{hj}(i_{hj} + c_{hj})$ at unit cost p_i. The expenditure from j on h goods is
  therefore $p_h \delta_{hj}(i_{hj} + c_{hj})$ no matter where viewed from.

- Production is Cobb-Douglas with share β on intermediate goods (CES aggregate of all produced
  goods with elasticity of substitution σ), and share $1 - \beta$ on the "real endowment of inputs", S_j, in
  economy j (endowment-ish economy i.e. S_j (which is like the supply of effective labour) does not
  change when implementing policy experiments). Output goods are priced at p_j

  i.e. Nominal Gross Output "production function"

  $$X_j = p_j S_j^{1-\beta} \left(\left[\sum_h i_{hj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \right)^\beta = p_j S_j^{1-\beta} I_j^\beta$$

  and Nominal Gross Output by destination of goods produced

  $$X_j = p_j \sum_h \delta_{jh}(i_{jh} + c_{jh})$$
  $$\equiv \sum_h X_{jh}$$

But balanced trade also implies

$$X_j = \sum_h X_{hj}$$

$$= \sum_h p_h \delta_{hj} \left(i_{hj} + c_{hj} \right)$$

where the c's are disaggregated consumption goods and i's are disaggregated intermediate goods

- Nominal GDP (Expenditure)

$$Y_j = P_j C_j = \sum_h p_h \delta_{hj} c_{hj}$$

  Nominal GDP (Income)

$$Y_j = X_j - \sum_h p_h \delta_{hj} i_{hj}$$

- Utility U_j is equal to real consumption C_j which is CES aggregation (elasticity of substitution σ) of disaggregated goods

$$C_j = \left[\sum_h c_{hj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

- Utility maximisation taking prices and income as given

$$0 = \frac{\partial}{\partial c_{hj}} \left[\left[\sum_h c_{hj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} + \lambda_j \left(Y_j - \sum_h p_h \delta_{hj} c_{hj} \right) \right]$$

$$= C_j^{\frac{1}{\sigma}} c_{hj}^{-\frac{1}{\sigma}} - \lambda_j \delta_{hj} p_h$$

$$\text{i.e. } c_{hj} = \left(\lambda_j \delta_{hj} p_h \right)^{-\sigma} C_j$$

$$\text{i.e. } \delta_{hj} p_h = \frac{1}{\lambda_j} \left(\frac{c_{hj}}{C_j} \right)^{-\frac{1}{\sigma}}$$

- Utility maximisation also gives us the price level in j

$$Y_j = P_j C_j = \sum_h p_h \delta_{hj} c_{hj}$$

$$= \sum_h p_h \delta_{hj} \left(\lambda_j \delta_{hj} p_h \right)^{-\sigma} C_j$$

$$= C_j \lambda_j^{-\sigma} \sum_h \left(\delta_{hj} p_h \right)^{1-\sigma}$$

$$\text{i.e. } P_j = \lambda_j^{-\sigma} \sum_h \left(\delta_{hj} p_h \right)^{1-\sigma}$$

$$Y_j = P_j C_j = P_j \left[\sum_h c_{hj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$$= P_j \left[\sum_h \left((\lambda_j \delta_{hj} p_h)^{-\sigma} C_j \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$$= P_j C_j \lambda_j^{-\sigma} \left[\sum_h (\delta_{hj} p_h)^{1-\sigma} \right]^{\frac{\sigma}{\sigma-1}}$$

i.e. $\lambda_j^\sigma = \left[\sum_h (\delta_{hj} p_h)^{1-\sigma} \right]^{\frac{\sigma}{\sigma-1}}$

$$P_j = \lambda_j^{-\sigma} \sum_h (\delta_{hj} p_h)^{1-\sigma}$$

$$= \left[\sum_h (\delta_{hj} p_h)^{1-\sigma} \right]^{-\frac{\sigma}{\sigma-1}} \sum_h (\delta_{hj} p_h)^{1-\sigma}$$

$$= \left[\sum_h (\delta_{hj} p_h)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

$$P_j = \frac{1}{\lambda_j}$$

- Economy j spends $P'_j I_j$ on intermediate goods i.e.

$$P'_j I_j = \sum_h p_h \delta_{hj} i_{hj}$$

Given this level of expenditure, economy j will want to maximise the quantity of the aggregate intermediate good that it purchases i.e.

$$0 = \frac{\partial}{\partial i_{hj}} \left[\left[\sum_h i_{hj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} + \chi_j \left(P'_j I_j - \sum_h p_h \delta_{hj} i_{hj} \right) \right]$$

$$= I_j^{\frac{1}{\sigma}} i_{hj}^{-\frac{1}{\sigma}} - \chi_j \delta_{hj} p_h$$

i.e. $i_{hj} = (\chi_j \delta_{hj} p_h)^{-\sigma} I_j$

i.e. $\delta_{hj} p_h = \frac{1}{\chi_j} \left(\frac{i_{hj}}{I_j} \right)^{-\frac{1}{\sigma}}$

$$P'_j I_j = \sum_h p_h \delta_{hj} i_{hj}$$

$$= \sum_h p_h \delta_{hj} \left(\chi_j \delta_{hj} p_h \right)^{-\sigma} I_j$$

$$= I_j \chi_j^{-\sigma} \sum_h \left(\delta_{hj} p_h \right)^{1-\sigma}$$

$$\text{i.e. } P'_j = \chi_j^{-\sigma} \sum_h \left(\delta_{hj} p_h \right)^{1-\sigma}$$

$$P'_j I_j = P'_j \left[\sum_h i_{hj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$$= P'_j \left[\sum_h \left(\left(\chi_j \delta_{hj} p_h \right)^{-\sigma} I_j \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

$$= P'_j I_j \chi_j^{-\sigma} \left[\sum_h \left(\delta_{hj} p_h \right)^{1-\sigma} \right]^{\frac{\sigma}{\sigma-1}}$$

$$\text{i.e. } \chi_j^{\sigma} = \left[\sum_h \left(\delta_{hj} p_h \right)^{1-\sigma} \right]^{\frac{\sigma}{\sigma-1}}$$

$$P'_j = \chi_j^{-\sigma} \sum_h \left(\delta_{hj} p_h \right)^{1-\sigma}$$

$$= \left[\sum_h \left(\delta_{hj} p_h \right)^{1-\sigma} \right]^{-\frac{\sigma}{\sigma-1}} \sum_h \left(\delta_{hj} p_h \right)^{1-\sigma}$$

$$= \left[\sum_h \left(\delta_{hj} p_h \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

$$P'_j = \frac{1}{\chi_j}$$

$$= P_j$$

i.e.

$$i_{hj} = \left(\frac{1}{P_j} \delta_{hj} p_h \right)^{-\sigma} I_j$$

$$\delta_{hj} p_h = P_j \left(\frac{i_{hj}}{I_j} \right)^{-\frac{1}{\sigma}}$$

Use cost minimisation i.e. an economy that produces X_j does so minimising the cost of doing this. The cost of intermediaries is

$$\sum_h p_h \delta_{hj} i_{hj} = P_j I_j$$

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then the income version of GDP expression implies that the "cost" of the endowment is GDP i.e.

$$X_j = Y_j + P_j I_j$$

If using a unit of the endowment has a price W_j then

$$Y_j = W_j S_j$$

i.e.

$$0 = \frac{\partial}{S_j} \left[W_j S_j + P_j I_j + \mu_j \left(X_j - p_j S_j^{1-\beta} I_j^{\beta} \right) \right]$$

$$= W_j - \mu_j \left(1 - \beta \right) p_j S_j^{-\beta} I_j^{\beta}$$

$$= W_j - \mu_j \left(1 - \beta \right) \frac{X_j}{S_j}$$

i.e. $\mu_j = \dfrac{W_j S_j}{\left(1 - \beta\right) X_j} = \dfrac{Y_j}{\left(1 - \beta\right) X_j}$

$$0 = \frac{\partial}{I_j} \left[W_j S_j + P_j I_j + \mu_j \left(X_j - p_j S_j^{1-\beta} I_j^{\beta} \right) \right]$$

$$= P_j - \mu_j \beta \frac{X_j}{I_j}$$

i.e. $\mu_j = \dfrac{P_j I_j}{\beta X_j}$

$$Y_j = \frac{1 - \beta}{\beta} P_j I_j$$
$$Y_j = \left(1 - \beta \right) X_j$$

which means that

$$X_{jj} = X_j - \sum_{h \neq j} X_{jh}$$

$$= \frac{Y_j}{1 - \beta} - \sum_{h \neq j} X_{jh}$$

Then get

$$i_{hj} = \left(\frac{1}{P_j} \delta_{hj} p_h \right)^{-\sigma} I_j$$

$$\frac{i_{hj}}{c_{hj}} = \frac{I_j}{C_j} = \frac{X_j - Y_j}{Y_j} = \frac{\beta}{1 - \beta}$$

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- Nominal expenditure of economy j in economy i

$$X_{hj} \equiv p_h \delta_{hj} \left(i_{hj} + c_{hj} \right)$$

$$= p_h \delta_{hj} c_{hj} \left(\frac{1}{1-\beta} \right)$$

$$= \left(\frac{1}{1-\beta} \right) p_h^{1-\sigma} \delta_{hj}^{1-\sigma} P_j^{\sigma-1} Y_j$$

- Deriving gravity equation

$$X_h = \sum_k X_{hk} = p_h^{1-\sigma} \left(\frac{1}{1-\beta} \right) \sum_k \delta_{hk}^{1-\sigma} P_k^{\sigma-1} Y_k$$

i.e. $p_h^{1-\sigma} = \dfrac{Y_h}{\sum_k \delta_{hk}^{1-\sigma} P_k^{\sigma-1} Y_k}$

$$X_{hj} = \left(\frac{1}{1-\beta} \right) p_h^{1-\sigma} \delta_{hj}^{1-\sigma} P_j^{\sigma-1} Y_j$$

$$= \left(\frac{1}{1-\beta} \right) \frac{Y_h}{\sum_k \delta_{hk}^{1-\sigma} P_k^{\sigma-1} Y_k} \delta_{hj}^{1-\sigma} P_j^{\sigma-1} Y_j$$

$$= \frac{1}{1-\beta} \frac{Y_h Y_j}{P_h \sum_k \left(\frac{P_h}{P_k} \right)^{-\sigma} \delta_{hk}^{1-\sigma} \left(\frac{Y_k}{P_k} \right)} \left(\frac{P_h}{P_j} \delta_{hj} \right)^{1-\sigma}$$

$$= \frac{1}{1-\beta} \frac{Y_h Y_j}{D_h} \left(\frac{P_h}{P_j} \delta_{hj} \right)^{1-\sigma}$$

where

$$D_h = P_h \sum_k \left(\frac{P_h}{P_k} \right)^{-\sigma} \delta_{hk}^{1-\sigma} \left(\frac{Y_k}{P_k} \right)$$

$$X_{hj} = \frac{1}{1-\beta} \frac{Y_h Y_j}{(D_h D_j)^{\frac{1}{2}}} \delta_{hj}^{1-\sigma}$$

- In logs

$$\ln X_{hj} = - \ln (1-\beta) + \ln Y_h + \ln Y_j - \frac{1}{2} \ln D_h - \frac{1}{2} \ln D_j + (1-\sigma) \ln \delta_{hj}$$

i.e. the Trade Elasticity, $\varepsilon = 1 - \sigma$

- Price index in country 1, P_1, is assumed to be normalised to 1.

- If we impose a large degree of symmetry on the model ($X_{hj} = X_{jh}$ & $\delta_{hj} = \delta_{jh}$) then it beccomes very easy to calibrate and to simulate

- Output price in other countries given by following:

$$P_j = \left[\sum_h (\delta_{hj} p_h)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

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$$X_{hj} = X_{jh} \ \& \ \delta_{hj} = \delta_{jh} \implies$$

$$\frac{1}{1-\beta}\frac{Y_h Y_j}{D_h}\left(\frac{P_h}{P_j}\delta_{hj}\right)^{1-\sigma} = \frac{1}{1-\beta}\frac{Y_j Y_h}{D_j}\left(\frac{P_j}{P_h}\delta_{jh}\right)^{1-\sigma}$$

$$\frac{P_j}{P_h} = \left(\frac{D_j}{D_h}\right)^{\frac{1}{2(1-\sigma)}}$$

allows us to say

$$X_{hj} = \frac{1}{1-\beta}\frac{Y_h Y_j}{(D_h D_j)^{\frac{1}{2}}}\delta_{hj}^{1-\sigma}$$

then

$$\delta_{hh} = 1$$

$$X_{hh} = \frac{1}{1-\beta}\frac{Y_h Y_h}{D_h}\left(\frac{P_h}{P_h}\delta_{hh}\right)^{1-\sigma} = \frac{Y_h^2}{(1-\beta)\,D_h}$$

$$\text{i.e. } D_h = \frac{Y_h^2}{(1-\beta)\,X_{hh}}$$

So

$$X_{hj} = \frac{1}{1-\beta}\frac{Y_h Y_j}{D_h}\left(\left(\frac{D_j}{D_h}\right)^{-\frac{1}{2(1-\sigma)}}\delta_{hj}\right)^{1-\sigma}$$

$$= \frac{1}{1-\beta}Y_h Y_j D_h^{-\frac{1}{2}}D_j^{-\frac{1}{2}}\delta_{hj}^{1-\sigma}$$

$$\text{i.e. } \delta_{hj} = \left(\frac{(1-\beta)\,X_{hj}\,(D_h D_j)^{\frac{1}{2}}}{Y_h Y_j}\right)^{\frac{1}{1-\sigma}}$$

$$= \left(\frac{X_{hj}^2}{X_{hh}X_{jj}}\right)^{\frac{1}{2(1-\sigma)}}$$

and

$$P_j^{1-\sigma} = P_k^{1-\sigma}\left(\frac{D_j}{D_k}\right)^{\frac{1}{2}} = \sum_h (\delta_{hj}p_h)^{1-\sigma}$$

Since data, $\{Y_h, X_{hj}\}$, gives D_h & hence δ_{hj}, and given the normalisation $P_1 = 1$, this is a system of N linear equations in N unknowns, $\{p_1^{1-\sigma}, p_2^{1-\sigma}, ..., p_N^{1-\sigma}\}$

$$P_1^{1-\sigma}\left(\frac{D_j}{D_1}\right)^{\frac{1}{2}} = \left(\frac{D_j}{D_1}\right)^{\frac{1}{2}} = \sum_h (\delta_{h1}p_h)^{1-\sigma}$$

- If we are just estimating the gravity equation emprically, then use

$$X_{hj} = \frac{1}{1-\beta}Y_h Y_j D_h^{-\frac{1}{2}}D_j^{-\frac{1}{2}}\delta_{hj}^{1-\sigma}$$

$$\text{i.e. } \ln X_{hj} = -\ln(1-\beta) + \ln Y_h + \ln Y_j - \frac{1}{2}\ln D_h - \frac{1}{2}\ln D_j + (1-\sigma)\ln\delta_{hj}$$

or

$$\ln X_{hj} - \ln Y_h + \ln Y_j = \alpha_0 + \alpha_h d_h + \alpha_j d_j + [\beta_1 E_1 + ... + \beta_m E_m]$$

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or
$$\ln X_{hj} - \ln Y_h + \ln Y_j + \ln(1 - \beta) = \alpha_h d_h + \alpha_j d_j + [\beta_1 E_1 + \ldots + \beta_m E_m]$$

where we take GDPs over to LHS to ensure unitary coefficients (and can take constant over to LHS to ensure it reflects GDP to GO ratio, and run regression with no constant), and where d_k is a dummy variable for country k, and where $E_l, l \in \{1, \ldots, m\}$ are m explanations, including existence of a border, for bilateral trade frictions. Note that the coefficients on the explanations for trade frictions depend upon elasticity, σ.

- Example with 3 countries

    - Calibration: data & parameters

$$Y_1, Y_2, Y_3$$
$$X_{12} = X_{21}, X_{13} = X_{31}, X_{23} = X_{32}$$
$$X_{11} = \frac{Y_1}{1 - \beta} - X_{12} - X_{13}$$
$$X_{22} = \frac{Y_2}{1 - \beta} - X_{12} - X_{23}$$
$$X_{33} = \frac{Y_3}{1 - \beta} - X_{13} - X_{23}$$
$$\sigma, \delta_{11} = \delta_{22} = \delta_{33} = 1$$

Equations:

$$D_1 = \frac{Y_1^2}{(1 - \beta) X_{11}}$$
$$D_2 = \frac{Y_2^2}{(1 - \beta) X_{22}}$$
$$D_3 = \frac{Y_3^2}{(1 - \beta) X_{33}}$$

$$\delta_{12} = \left(\frac{X_{12}^2}{X_{11} X_{22}} \right)^{\frac{1}{2(1 - \sigma)}}$$
$$\delta_{13} = \left(\frac{X_{13}^2}{X_{11} X_{33}} \right)^{\frac{1}{2(1 - \sigma)}}$$
$$\delta_{23} = \left(\frac{X_{23}^2}{X_{22} X_{33}} \right)^{\frac{1}{2(1 - \sigma)}}$$

$$P_1 = 1 \text{ (normalisation)}$$

$$1 = (\delta_{11} p_1)^{1 - \sigma} + (\delta_{21} p_2)^{1 - \sigma} + (\delta_{31} p_3)^{1 - \sigma}$$
$$\left(\frac{D_2}{D_1} \right)^{\frac{1}{2}} = (\delta_{12} p_1)^{1 - \sigma} + (\delta_{22} p_2)^{1 - \sigma} + (\delta_{32} p_3)^{1 - \sigma}$$
$$\left(\frac{D_3}{D_1} \right)^{\frac{1}{2}} = (\delta_{13} p_1)^{1 - \sigma} + (\delta_{23} p_2)^{1 - \sigma} + (\delta_{33} p_3)^{1 - \sigma}$$

$$
\begin{bmatrix} p_1^{1-\sigma} \\ p_2^{1-\sigma} \\ p_3^{1-\sigma} \end{bmatrix} = \begin{bmatrix} 1 & \delta_{12}^{1-\sigma} & \delta_{13}^{1-\sigma} \\ \delta_{12}^{1-\sigma} & 1 & \delta_{23}^{1-\sigma} \\ \delta_{13}^{1-\sigma} & \delta_{23}^{1-\sigma} & 1 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} \\ \left(\frac{D_3}{D_1}\right)^{\frac{1}{2}} \end{bmatrix}
$$

$$
P_2^{1-\sigma} = P_1^{1-\sigma}\left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} = \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}}
$$

$$
P_3^{1-\sigma} = P_1^{1-\sigma}\left(\frac{D_3}{D_1}\right)^{\frac{1}{2}} = \left(\frac{D_3}{D_1}\right)^{\frac{1}{2}}
$$

$$
I_j = \frac{\beta}{1-\beta}\frac{Y_j}{P_j}
$$

$$
\frac{Y_j}{1-\beta} = X_j = p_j S_j^{1-\beta} I_j^{\beta} = p_j S_j^{1-\beta}\left(\frac{\beta}{1-\beta}\frac{Y_j}{P_j}\right)^{\beta}
$$

$$
S_j = \frac{Y_j}{1-\beta}\left(\frac{\beta}{P_j}p_j^{\frac{1}{\beta}}\right)^{-\frac{\beta}{1-\beta}}
$$

$$
W_j = \frac{Y_j}{S_j}
$$

– Policy experiment: data and parameters

$$
\sigma
$$
$$
S_1, S_2, S_3 \ \text{(exogenous supply)}
$$
$$
\delta_{11} = \delta_{22} = \delta_{33} = 1
$$
$$
\delta_{12} = \delta_{21}, \delta_{13} = \delta_{31}, \delta_{23} = \delta_{32} \ \text{(pol exp)}
$$
$$
P_1 = 1 \ \text{(normalisation)}
$$

8 Unknowns
$$
\{p_1, p_2, p_3, P_2, P_3, D_1, D_2, D_3\}
$$

8 Equations

$$
\begin{bmatrix} p_1^{1-\sigma} \\ p_2^{1-\sigma} \\ p_3^{1-\sigma} \end{bmatrix} = \begin{bmatrix} 1 & \delta_{12}^{1-\sigma} & \delta_{13}^{1-\sigma} \\ \delta_{12}^{1-\sigma} & 1 & \delta_{23}^{1-\sigma} \\ \delta_{13}^{1-\sigma} & \delta_{23}^{1-\sigma} & 1 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} \\ \left(\frac{D_3}{D_1}\right)^{\frac{1}{2}} \end{bmatrix}
$$

$$
P_2^{1-\sigma} = \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}}
$$

$$
P_3^{1-\sigma} = \left(\frac{D_3}{D_1}\right)^{\frac{1}{2}}
$$

where D's must satisfy:

$$D_1 = P_1 \left[\frac{Y_1}{P_1} + \left(\frac{P_1}{P_2} \right)^{-\sigma} \delta_{12}^{1-\sigma} \frac{Y_2}{P_2} + \left(\frac{P_1}{P_3} \right)^{-\sigma} \delta_{13}^{1-\sigma} \frac{Y_3}{P_3} \right]$$

$$D_2 = P_2 \left[\left(\frac{P_2}{P_1} \right)^{-\sigma} \delta_{21}^{1-\sigma} \frac{Y_1}{P_1} + \frac{Y_2}{P_2} + \left(\frac{P_2}{P_3} \right)^{-\sigma} \delta_{23}^{1-\sigma} \frac{Y_3}{P_3} \right]$$

$$D_3 = P_3 \left[\left(\frac{P_3}{P_1} \right)^{-\sigma} \delta_{31}^{1-\sigma} \frac{Y_1}{P_1} + \left(\frac{P_3}{P_2} \right)^{-\sigma} \delta_{32}^{1-\sigma} \frac{Y_2}{P_2} + \frac{Y_3}{P_3} \right]$$

with

$$Y_j = S_j (1 - \beta) \left(\frac{\beta}{P_j} p_j^{\frac{1}{\beta}} \right)^{\frac{\beta}{1-\beta}}$$

$$W_j = (1 - \beta) \left(\frac{\beta}{P_j} p_j^{\frac{1}{\beta}} \right)^{\frac{\beta}{1-\beta}}$$

– Welfare impact:

$$\left(\frac{Y_i'/P_i'}{Y_i/P_i} \right) - 1$$

where dashed quantities are in policy experiment and undashed quantities are in the calibration.

– Counterfactual trade flows given by

$$X_{jj} = \frac{Y_j^2}{(1 - \beta) D_j}$$

$$X_{hj} = \frac{1}{1 - \beta} Y_h Y_j D_h^{-\frac{1}{2}} D_j^{-\frac{1}{2}} \delta_{hj}^{1-\sigma}$$

D.1 Welfare formula

- Data

  – Home share, λ

  $$\lambda = \frac{X_{11}}{X_1} = \frac{X_1 - X_{12}}{X_1}$$

  – Normalise GDP i.e.

  $$Y_1 = 1 = (1 - \beta) X_1$$

  – i.e.

  $$X_1 = \frac{1}{1 - \beta}$$

  $$X_{11} = \frac{\lambda}{1 - \beta}$$

  $$X_{12} = \frac{1 - \lambda}{1 - \beta}$$

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- Have, from gravity equations

$$X_{11} = \frac{1}{1-\beta}Y_1 Y_1 D_1^{-1}$$

$$\text{i.e. } D_1 = \frac{1}{1-\beta}\frac{1}{X_{11}} = \frac{1}{\lambda}$$

$$X_{12} = \frac{1}{1-\beta}Y_1 Y_2 D_1^{-\frac{1}{2}} D_2^{-\frac{1}{2}}\delta^{1-\sigma}$$

$$= \frac{\lambda^{\frac{1}{2}}}{1-\beta}\frac{Y_2}{D_2^{\frac{1}{2}}}\delta^{1-\sigma} = \frac{1-\lambda}{1-\beta}$$

$$X_{22} = \frac{1}{1-\beta}Y_2 Y_2 D_2^{-1}$$

$$\text{i.e. } \frac{Y_2}{D_2^{\frac{1}{2}}} = X_{22}^{\frac{1}{2}}(1-\beta)^{\frac{1}{2}}$$

so

$$\delta = \left(\frac{1-\lambda}{\lambda^{\frac{1}{2}}X_{22}^{\frac{1}{2}}(1-\beta)^{\frac{1}{2}}}\right)^{\frac{1}{1-\sigma}}$$

which is the same as

$$\delta = \left(\frac{X_{12}^2}{X_{11}X_{22}}\right)^{\frac{1}{2(1-\sigma)}}$$

$$\text{i.e. } X_{22} = \frac{X_{12}^2}{X_{11}}\delta^{-2(1-\sigma)}$$

$$= \frac{(1-\lambda)^2}{\lambda(1-\beta)\delta^{2(1-\sigma)}}$$

also have

$$D_2 = \frac{Y_2^2}{X_{22}(1-\beta)}$$

- Adding up in 2nd economy

$$\frac{Y_2}{1-\beta} = X_2 = X_{22} + X_{12}$$

$$D_2 = \frac{Y_2^2}{X_{22}(1-\beta)} = (1-\beta)\frac{(X_{22}+X_{12})^2}{X_{22}}$$

$$= (1-\beta)\frac{(X_{22}+X_{12})^2}{X_{22}}$$

$$= (1-\beta)\frac{\left(\frac{(1-\lambda)^2}{\lambda(1-\beta)\delta^{2(1-\sigma)}} + \frac{1-\lambda}{1-\beta}\right)^2}{\frac{(1-\lambda)^2}{\lambda(1-\beta)\delta^{2(1-\sigma)}}}$$

$$= \frac{\left(1-\lambda+\lambda\delta^{2(1-\sigma)}\right)^2}{\lambda\delta^{2(1-\sigma)}}$$

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- Then 5 Equations

$$1 = p_1^{1-\sigma} + \delta^{1-\sigma} p_2^{1-\sigma}$$

$$\left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} = \delta^{1-\sigma} p_1^{1-\sigma} + p_2^{1-\sigma}$$

$$\begin{bmatrix} 1 \\ \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} \end{bmatrix} = \begin{bmatrix} 1 & \delta^{1-\sigma} \\ \delta^{1-\sigma} & 1 \end{bmatrix} \begin{bmatrix} p_1^{1-\sigma} \\ p_2^{1-\sigma} \end{bmatrix}$$

$$\begin{bmatrix} p_1^{1-\sigma} \\ p_2^{1-\sigma} \end{bmatrix} = \begin{bmatrix} 1 & \delta^{1-\sigma} \\ \delta^{1-\sigma} & 1 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} \end{bmatrix}$$

$$P_2^{1-\sigma} = \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}}$$

where D's must satisfy:

$$D_1 = P_1 \left[\frac{Y_1}{P_1} + \left(\frac{P_1}{P_2}\right)^{-\sigma} \delta^{1-\sigma} \frac{Y_2}{P_2} \right]$$

$$D_2 = P_2 \left[\left(\frac{P_2}{P_1}\right)^{-\sigma} \delta^{1-\sigma} \frac{Y_1}{P_1} + \frac{Y_2}{P_2} \right]$$

with

$$Y_j = S_j (1-\beta) \left(\frac{\beta}{P_j} p_j^{\frac{1}{\beta}} \right)^{\frac{\beta}{1-\beta}}$$

$$W_j = (1-\beta) \left(\frac{\beta}{P_j} p_j^{\frac{1}{\beta}} \right)^{\frac{\beta}{1-\beta}}$$

- i.e.

$$\begin{bmatrix} p_1^{1-\sigma} \\ p_2^{1-\sigma} \end{bmatrix} = \begin{bmatrix} 1 & \delta^{1-\sigma} \\ \delta^{1-\sigma} & 1 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} \end{bmatrix}$$

$$= \frac{1}{1 - \delta^{2(1-\sigma)}} \begin{bmatrix} 1 & -\delta^{1-\sigma} \\ -\delta^{1-\sigma} & 1 \end{bmatrix} \begin{bmatrix} 1 \\ \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} \end{bmatrix}$$

$$p_1^{1-\sigma} = \frac{1}{1 - \delta^{2(1-\sigma)}} \left(1 - \delta^{1-\sigma} \left(\frac{D_2}{D_1}\right)^{\frac{1}{2}} \right)$$

$$= \lambda$$

so

$$p_1 = \lambda^{\frac{1}{1-\sigma}}$$

then

$$\frac{1}{1-\beta} \beta^{-\frac{\beta}{1-\beta}} \lambda^{-\frac{1}{1-\sigma} \frac{1}{1-\beta}} = S_1$$

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- Policy experiment is $\delta \to \infty$

- In this case $p_1 = 1$ so

$$Y_1' = S_1 \left(1 - \beta\right) \left(\beta\right)^{\frac{\beta}{1-\beta}}$$
$$= \lambda^{-\frac{1}{1-\sigma}\frac{1}{1-\beta}}$$

- i.e. welfare change is

$$\left(\frac{Y'}{Y}\right) - 1 = \lambda^{-\frac{1}{1-\sigma}\frac{1}{1-\beta}} - 1$$
$$= \left(\frac{1}{\lambda}\right)^{\frac{1}{(1-\beta)(1-\sigma)}} - 1$$

as required.