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Stephen Byrne & Jonathan Rice

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Non-Tariff Barriers and Goods Trade: a Brexit Impact Analysis *

Stephen Byrne & Jonathan Rice †

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Abstract

This paper estimates the potential loss in trade between Ireland and the United Kingdom arising from increases in non-tariff barriers following the UK's exit from the European Union. Using a difference gravity specification, we estimate a 9.6 per cent decline in trade flows between the UK and Ireland from an increase in border waiting times. This equates to a 1.4 per cent decline in total Irish exports and a 3.1 per cent decline in total Irish imports. We also present evidence of heterogeneity in the exposure (measured by time-sensitivity) across different types of goods, with beverages,fresh foods and raw materials being most exposed. For trade in fuels, chemicals and imperishable foods we do not find evidence of an effect from an increase in time.

JEL classification: E5, G01, G17, G28, R39.

Keywords: Brexit, Non-tariff Barriers, International Trade, Gravity Model.

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†Central Bank of Ireland, Irish Economic Analysis Division. Stephen.Byrne@centralbank.ie, Jonathan.Rice@centralbank.ie

Non-Technical Summary

This paper estimates the effect of an increase in non-tariff barriers on Irish-UK goods trade. Using a conventional empirical approach, we find that the potential increase in non-tariff barriers associated with the UK's exit from the customs union and single market (in the form of additional customs procedures and documentary compliance) is associated with a 9.6 per cent decline in total trade between Ireland and the UK. Looking in more detail, there are significant differences in the degree of exposure among goods. Fresh foods, raw materials (such as metals and some intermediate inputs into firms' supply chains) and bulky goods are particularly exposed to delays. Trade in petrol and other fuels, and chemicals and related goods are least exposed.

It is important to note that the stated decline in Irish trade with the UK may not translate into a decline in total Irish trade with the rest of the world. The issue of import and export substitution is an important one which is beyond the scope of this paper. In the extreme case, all of the estimated decline in trade with the UK could simply be redirected elsewhere. However, current Irish-UK trade is driven by various factors over and above shared membership of the European Union such as the common language, previous colonial relationship as well as similar tastes and preferences among consumers in the two countries.

1 Introduction

The decision of the United Kingdom to leave the European Union (EU) is likely to have significant negative implications for the Irish economy (Lawless, 2016; Bergin et al, 2016 *inter alia*). Ireland is particularly reliant on trade with the United Kingdom in areas such as agriculture, for exports and manufacturing goods, for imports. Recently, there has been a shift toward more high value added sectors such as technology and pharmaceuticals.[1] In addition there are strong inter-linkages between Irish and UK firms' supply chains. The Office of National Statistics (ONS) in the UK highlights the sizeable integration between the agricultural sector in Ireland and food processing firms in the UK (ONS, 2013). While there are obvious historical reasons for close UK and Irish trade relations, joint membership of the European Single Market and customs union have enabled frictionless trade between the two islands.

In trade terms, joint membership of the European Union confers two clear benefits: there are no tariffs or customs duties; and there are EU-wide agreements on product standards, rules of origin, customs inspections and documentary compliance. These agreements ensure a substantial reduction in trade barriers between EU countries. While the impact of a return to WTO tariffs on trade between the UK and current EU member states has been well documented (Lawless, 2016), the impact of increases in non-tariff barriers (NTBs) has received less attention thus far.

This paper's contribution is threefold. First, we add to the literature on the impact of non-tariff barriers on trade, using a methodology that is robust to unobserved variables that may impact on trade flows. Second, we estimate the potential increase in non-tariff barriers resulting from the UK leaving the EU customs union. Third, we estimate aggregate and good-level trade reductions between Ireland and the UK resulting from an increase in non-tariff barriers.

As addressed below, there are a number of important caveats to our approach. Firstly, our estimation strategy does not say anything about possible mitigation measures that may be negotiated between the UK and EU. Secondly, we do not comment on the possibility of a redirection in Irish trade from the UK to other EU countries.[2] These imply that our estimate of trade impacts acts as an upper-bound, or pessimistic scenario, whereby the UK is treated like any other third country trading with the EU.

We find that a 90 per cent increase in non-tariff barriers (in the form of customs inspections and documentary compliance) is associated with a 9.6 per cent decline in total trade.[3] We extend our analysis to consider goods-level exposure and uncover large heterogeneity underlying this aggregate result. In particular, we find that raw

[1] See Byrne, S. and O'Brien, M., 2015

[2] Indeed, the reduction in Irish-UK trade could simply be redirected to other trade partners, although there are reasons to speculate that export and import substitution will not be able to fully offset the trade decline. A full discussion of this is provided in section 8 but quantitative analysis is left to further work.

[3] We discuss the derivation of this 90 per cent increase in section 5

materials (e.g. metals and other intermediate inputs), perishable goods and bulky goods are particularly exposed to delays.

To counter concerns of non-linearities in trade elasticities resulting from the inclusion of extensive border waiting times, we apply the model to a concise sample with more efficient border times (comparable to those of European countries). We predict a 4.5 hour (or 90 per cent) increase in our measure of border delays at the UK border following a UK exit from the EU customs union and, finally, estimate the impact on trade between the UK and Ireland. Despite our application to Irish-UK trade, the estimated elasticities and non-tariff barrier estimates are general, and can be applied to trade between the UK and any EU member state.

Defining Non-Tariff Barriers

Broadly, "non-tariff barriers" encompass a heterogeneous group of distortions that can include minimum standards, anti-dumping duties, and numerous other regulations often referred to as "red tape". The UN Conference on Trade and Development (2012) groups these into two broad categories, namely sanitary measures and technical barriers to trade. Sanitary measures include regulations to protect human, animal or plant life. Technical barriers to trade include all other technical regulations, standards and procedures.

The literature has identified two distinct methods for measuring non-tariff barriers. Firstly, where data are available, one can measure the impact of NTBs on trade directly in a gravity model (as discussed above, a common proxy for NTBs used in the literature is border delays associated with legal proceedings, transit and customs inspections). This approach often involves conversion of NTB's into costs or "tariff equivalents" such as the method employed by Hummels (2007b), Dhingra et. al (2017) and in a recent study by the House of Commons "Exiting the European Union Committee" (2017). The second approach involves comparison of import prices for a specific good into the country of interest with the price of an equivalent good in the free market (with no distortions). After tariffs and local distribution costs, the residual premium on the import price is associated with NTBs (for example, see Ferrantino (2006) and Dean et al. (2009)). We take the former approach, motivated by a timely update in the World Bank's *Doing Business* survey.

The variable we use to capture non-tariff barriers is the delays (in hours) associated with documentary compliance and customs inspections when importing goods through the domestic border. This measure serves as a useful proxy for the vast majority of non-tariff related complexities in cross border goods trade. The survey is conducted and reported at the country-level, and is collected with reference to an identical consignment of commonly imported goods across all countries, allowing for direct cross-country comparability.

The remainder of this paper is structured as follows. Section two discusses the literature on non-tariff barriers, Section three outlines the data and methodology, Section three contains our empirical approach, Section four through six includes results

for the full and efficient samples of countries, Section 7 outlines some robustness checks and finally Section 8 concludes.

2 Literature Review

There has been a significant body of research in recent years estimating the potential impact of the UK's exit on the Irish economy. Examining the impact of a WTO tariff regime, Lawless et al (2016) found that Irish exports to the UK could fall by 30 per cent. Macroeconomic research has focused on structural and general equilibrium model estimates of the Brexit impact in the medium to long run (t̃en years), with long run cumulative GDP estimates averaging around 4 per cent lower than in the no Brexit baseline (Bergin et al, 2016). Our paper is the first to examine the impact of "non-tariff barriers" on trade between Ireland and the UK post-Brexit. Understanding this channel is important to policy-makers and researchers and there is a range of evidence to suggest that NTBs reduce trade (Dhingra et al. (2016); Hummels and Schaur (2013); Djankov et al. (2010); Hummels (2007b)). Further, Obstfeld and Rogoff identify non-tariff barriers as one of the unifying themes in answering the six major puzzles in international macroeconomics (2000). In particular, NTBs introduce a key friction - constituting a significant portion of trade costs in international goods markets.

Goldberg, P.K. and Pavcnik, N. (2016) state that the perception that trade policy is no longer relevant comes about from the difficulty of measuring the various forms of non-tariff barriers that have replaced tariffs as the primary tools of trade policy. The authors highlight the dearth of research measuring the actual impact of policy changes, and state that the existing evidence points to large effects of trade policies, particularly where policy interacts with non-tariff related developments.

Hummels (2007b) directly calculates tariff equivalents of customs and port delays using data from the World Bank "Doing Business" survey. The author combines estimates of (per day) time costs with data on days lost to customs delays and port clearance, and finds customs delays to be a far larger barrier to trade than tariffs. Using similar data from the World Bank "Doing Business" survey, Djankov et al. (2010) use product-specific estimates of per day time costs from an earlier draft of Hummels et al. (2013) and find that the largest trade reductions from border delays occur for the most time sensitive products. Our paper distinguishes from these papers due to the use of more recent detailed data from the World Bank "Doing Business" survey. Previous versions of this dataset measured NTBs as aggregate time (in days) to transit the good from factory to port, clear customs inspections and ensure documentary compliance. However, since 2013 the annual survey has split these three components of delays, and reports each of them in hours, rather than days[4]. Other papers have considered goods-level sensitivity to non-tariff barriers. Hummels et al. (2013) model firms' choice between exporting goods using fast but expensive air cargo and slow but cheap ocean

[4]These recent additions to this rich dataset enable us to construct elasticities to border delays that are standardised across countries. Further, with these data we are able to directly estimate the increase in border delays associated with the UK leaving the customs union.

cargo. In their model this choice depends on the price elasticity of demand and the value that consumers place on quick delivery. The authors then use rich US imports data and exploit variation across US entry ports to control for unobserved trade shocks to estimate goods-level time sensitivity. They find substantial heterogeneity in time-sensitivity across goods, finding that the most time-sensitive trade flows are trade in parts and components, and that the majority of fresh foods are shipped via air transit to ensure minimal delays. A recent study by the House of Commons Exiting the European Union Committee (2017) used tariff equivalents as a proxy for non-tariff barriers, and suggests that the most exposed sectors in the UK to non-tariff barriers are *Agriculture* and *Food and Drink*. These goods-level findings align closely with our own, in particular on the exposure of supply-chain integrated intermediate goods, perishable foods and drinks.

Research by Chen et al. (2018) refers to the spread of Just-in-Time (JIT) production systems across the UK and rest of Europe, which are widespread across manufacturing, engineering, retail and consumer goods markets. JIT production systems are a deep form of supply-chain integration and hold little or no inventory, and supplies are delivered in small quantities at very high frequencies to reduce costs. The authors use input-output tables to capture complex global value-chains spanning borders and estimate regional exposures to negative trade-related consequences of Brexit. They find that Ireland is the only country in the EU with similar levels of exposure to Brexit-related trade risks as regions in the UK.

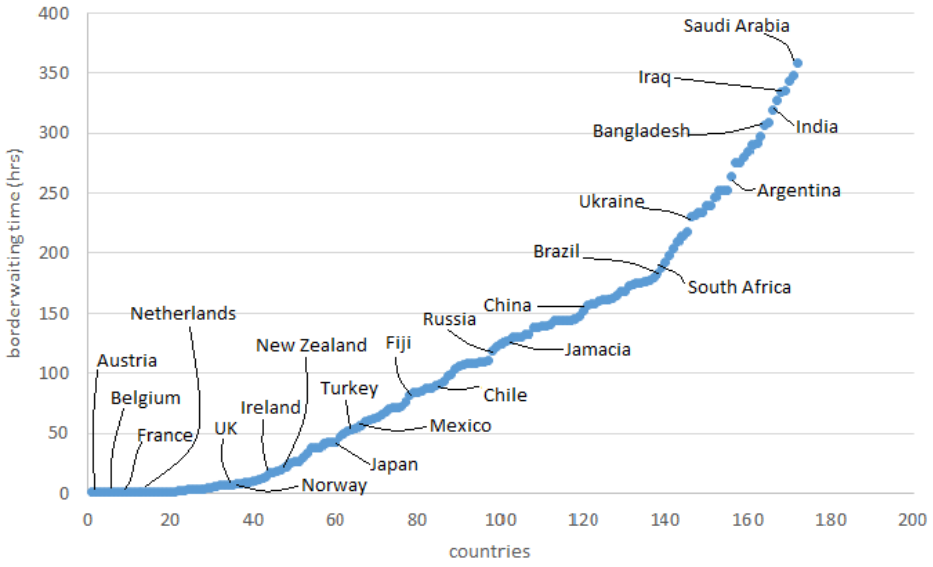
3 Data and Empricial Strategy

The data on non-tariff barriers are sourced from the *Trading Across Borders* module of the "Doing Business" survey, in particular for years 2013 to 2015 inclusive. The survey is collected via a questionnaire administered to local freight forwarders, customs brokers, traders and government agencies. Questionnaire responses are verified through several rounds of follow up communication with respondents as well as consultation of publicly available sources. This dataset has been used for a number of other research questions in international trade, such as the impact of per-shipment costs on the lumpiness of international trade (Hornok & Koren, 2015).

The primary variable of interest in this study is *border waiting time* in the form of total hours taken to ensure documentary and border compliance when importing a good. According to the World Bank, *documentary compliance* captures the time taken for "compliance with the documentary requirements of all Government agencies of the origin economy, the destination economy and any transit economies". *Customs inspections* captures the time taken for "compliance with the economy's customs regulations and with other inspections that are mandatory in order for the shipment to cross the country's border, as well as the time for handling that takes place at its port or border".[5] Customs inspections and documentary compliance data are collected for both imports and exports. In our case we use the imports data, but there is

[5] See www.doingbusiness.org/methodology for a full description of the survey methodology

FIGURE 1. Combined Customs Clearance and Documentary Compliance Time (hrs)



a reasonably high correlation between import and export times[6]. Importantly, the majority of processes required for documentary compliance are completed prior to physical customs inspection, and thus these two measures are unlikely to overlap.

For our purposes we are interested in aggregate border waiting time, and thus sum these two measures together. The data are collected for 190 countries, and the *border waiting time* variable ranges from 1 hour for Germany (among others) to 1,330 hours for Venezuela. We remove outliers, or countries with extreme border waiting times after visual inspection of the data (those greater than 360 hours) and are left with 190 countries. For a number of mainland European countries within the EU, goods are transited from Germany via road with no customs related delays or port congestion. There are no countries, however, with zero hours of documentary compliance delays because each good traded requires accompanying documentation and correspondence between the exporter (or export agent) and the competent authorities in a trade partner country. In some cases documentation (in the form of a carnet or license) is also required for states through which a traded good transits before reaching its final designation.

Figure 1 shows the summation of border and documentary compliance times for the sample of countries after outliers have been removed. The minimum border waiting time is one hour, the maximum is 359 and the mean of the sample is 111 hours.

When answering the survey, it is assumed that each economy imports a "standardized shipment of 15 metric tons of containerized auto parts (HS 8708) from its natural import partner, that is, the economy from which it imports the largest value (price times quantity) of auto parts". Using a standardised measure is advantageous for

[6]This correlation is about 70 per cent depending on our sample. Customs inspections mostly take place on the importer side and imports delays data is collected for an identical shipping consignment across countries, while exports data is collected based on the good of a country's comparative advantage. It is the case therefore that exports delays data for a country will be largely based on customs delays in a foreign country and for a country-specific good

our identification, because our measure is not contaminated by heterogeneity in inspections times across different types of goods. Also, generally speaking, auto parts are widely imported across countries because they rely on a relatively small number of manufacturers in individual countries (Germany, U.S., Japan, etc). Further, regulations on trade in auto-mobile parts are likely to be broadly comparable across regional trade agreements.

The trade data are sourced from the United Nations International Trade Statistics [7]. The COMTRADE database is a comprehensive trade dataset containing bilateral trade flows dissagregated by "Standard International Trade Classification (SITC)" codes. We conduct the goods-level analysis at the one-digit SITC classification.

Empirical Approach

Consumers and firms face disutility to delays in trade. One can attempt to measure this disutility in an expression for import demand (or gravity model), where agents decide between consumption of goods produced domestically and goods imported from abroad. In this setting the total volume of imports is affected by a number of factors including: time and cost of transit, which depends on the distance over which the good is shipped; total domestic output and per capita income; the relative value of domestic currency, as captured by the exchange rate; tariff barriers and other financial costs to trade; non-tariff barriers, such as delays and administrative costs associated with customs clearance; domestic endowments such as access to raw materials and geography; supply shocks in exporting countries; and a number of bilateral factors capturing similarities between the domestic country and its trade partners, such as shared language, past colonial relationships and whether the countries are contiguous.

Since we have insufficient data on endowments and bilateral tariffs and our variable of interest,*border waiting times*, is largely time-invariant across countries, it is necessary to modify the standard gravity equation for cross-sectional use and to control for these otherwise unobserved variables. This modification also allows us to apply a form of exporter fixed effects despite use of cross-sectional data.[8].

To take account of these factors, we estimate a "difference gravity model". In this specification, the dependent variable is the ratio of imports of good i by country j from country k to the imports of good i by country h from country k. We constrain countries j and h to be within the same trade agreement. We express the non-tariff barrier variable as the ratio of border waiting time in country j to country h. This means that our cross-sectional variation comes from the difference in import border waiting time between country j and country h when importing from the same partner (country k).

This technique is based on the assumption that countries within a trade block have identical tariffs with one another and with countries outside of their trade block, and moreover, have similar geography and material endowments. As mentioned, this approach also has the effect of imposing fixed effects on the exporter side, thus

[7] We thank officials at the United Nations Statistics Division for providing an institutional licence for the download of these data

[8] as mentioned, we use averages of annual data from 2013-2015 inclusive

controlling for factors such as exporter production volume, supply shocks and exporter remoteness. Furthermore, this approach also largely controls for non-linearities in the effect of *border waiting times* on trade. An example clarifying this latter point is that, rather than directly comparing the effects of *border waiting times* between African and European countries, we instead compare countries only where they are within the same trade agreement (and therefore are likely to have similar *border waiting times*).

Our data are cross-sectional, although we take variable averages from 2013 to 2015 inclusive (the complete sample of the "Doing Business" survey). Use of a time-series would not be informative in this setting, given that for the majority of countries *Border Waiting Time* does not vary over the three years.[9]

Formally, the empirical specification is expressed as:

$$ln\left(\frac{Imp_{ijk}}{Imp_{ihk}}\right) = \alpha + \beta\, ln\left(\frac{GDP_j}{GDP_h}\right) + \gamma\, ln\left(\frac{Dt_{jk}}{Dt_{hk}}\right) + \lambda\, ln\left(\frac{T_j}{T_k}\right) + \eta\, ln\left(\frac{XR_j}{XR_k}\right) + \phi\,(D_{jk} - D_{hk}) + \epsilon_{ijhk} \tag{1}$$

where Imp_{ijk} and Imp_{ihk} denote imports of product i from country $j(h)$ to country k respectively, Dt_{jk} and Dt_{hk} denote distance between country $j(h)$ to country k respectively and XR is the country's average annual bilateral exchange rate growth vis-a-vis the USD from 2012 to 2015. Our variable of interest, T, is border delays. We also include vectors D_{jk} and D_{hk} of dummy variables including, continuity; colonial relationship; shared language; and whether the country is landlocked. Standard errors are clustered at the matched country-pair level.

We first let i equal aggregate imports, and we run additional tests to examine the robustness of our findings. First we only include ratios between countries within the same income bracket as defined by the *World Bank 2015 Income Classifications*.[10] Second, we consider the potential for endogeneity between GDP growth and border waiting times, by removing any country that had an improvement in border delay times from 2013-2015.[11]

[9] As a test, we run a time-series regression in a robustness section that makes the distinction between positive and negative reforms obtained from a separate dataset. The results are reported in section 7.

[10] Countries are allocated by GDP per capita into one of four categories - *low income, medium-low income, medium-high income and high income*

[11] Annual survey data is only available for these three years

TABLE 1. Regional Trade Agreements

Regional Trade Agreement	Minimum	Maximum	Mean	Standard Deviation	Number of Countries	Avg. Income per cap (USD)
Asian/Australasian						
APEC	3	232	91.22	67.12	18	23,046
ASEAN	38	232	130.00	63.17	8	14,650
SAARC	13	327	169.33	104.83	6	2,825
APTA	130	344	224.40	91.57	5	3,582
Arab League	66	359	187.94	91.01	15	17,687
TPP	3	138	58.33	37.88	8	31,012
Americas						
Mercosur	84	252	162.80	67.61	5	9,516
CAN	144	210	168.50	27.29	4	5,724
NAFTA	3	62	25.00	26.32	3	37,640
CARICOM	41	240	104.00	53.99	14	9,953
OECS	66	359	191.83	113.98	6	39,674
African						
COMESA	9	334	187.67	97.03	14	3,431
ECCAS	158	334	217.40	62.09	5	2,642
SADC	7	309	115.55	108.14	11	3,864
EAC	158	334	262.00	65.01	4	739
ECOWAS	108	348	199.42	73.94	12	799
European						
CEFTA	6	18	11.20	4.45	5	4,034
EAEU	5	139	53.60	49.44	5	7,393
EFTA	3	27	11.33	11.09	3	74,830
EU	1	25	2.79	5.24	28	32,496
Total Sample	1	359	118.91	103.43	178	16,558

We then run the same model, with matched income classifications, at a goods-level for the full sample of countries.[12] We repeat the above for a smaller sample of countries, with border waiting times equal to or less than the highest border waiting time among European countries [13]. We believe this sample adjustment allows us to estimate elasticities that are more appropriate for computing potential trade losses for the UK in a Brexit scenario.

Table 1 overviews the full sample of Regional Trade Agreements (RTAs) into which countries are grouped. The largest border waiting times are found in the African RTAs and the lowest can be found in European RTAs. The RTA with the lowest average "border

[12]We use SITC 1-digit goods categories but further split *Food and Live Animals* into 3 subcategories; "fresh foods" (unprocessed foods); "other foods" (processed foods); and 'live animals"

[13]27 hours, for Iceland

waiting hours" is the EU, at 2.79 hours. There are 60 countries without membership to a recognised RTA, and these are excluded from the pairwise matching process[14], and in the case where a country is a member of more than one RTA, that country is treated as a separate entity for pairwise matching within each RTA to which it is a member.[15]

4 Results

Full-sample: Aggregate Exposure

Column 1 of Table 2 shows results for our specification with the full sample of 161 countries. Each of the coefficients have the expected signs, with estimates of the effect of border delays, the distance between trading partners, the bilateral exchange rate *vis-a-vis* the US Dollar, and being landlocked all having a negative relationship with total imports.[16] Gross Domestic Product, contiguity (sharing a border with the trading partner), having a previous colonial relationship and sharing a common language all exhibit a positive relationship with total imports. The coefficient on *border delays* means that a 10 per cent increase in border delays relative to countries within the same trade block is associated with 0.9 per cent fewer aggregate imports.[17] Column 2 shows the *matched income* sample, where matched countries are further restricted to being in the same income category. These results are broadly similar, although the coefficient on *border waiting time* becomes larger, to a 1.2 per cent decline in aggregate imports. This result is reassuring, and tells us that the result in Column 1 is not driven by comparison of countries at different levels of economic development. Column 3 shows results from our endogeneity robust sample. Again results are reassuring, with only minor differences from our base specification. In particular the relationship between border delays and total imports is of identical magnitude and significance.

Full-sample: Goods-level Exposure

Next we consider whether the impact of border delays varies by type of good imported. We run the *income-matched* specification for each of the ten 1-digit goods classifications in the UN COMEXT trade dataset and display goods in order of most, and least, affected by border delays in Tables 3 and 4 respectively. Due to our interest in the agricultural sector we further split “Food and Live Animals" into unprocessed (or perishable) food, processed (or longer lasting) food and live animals. Our results suggest that *manufacturing materials*, *crude materials* and *fresh foods* are most exposed to border delays, while *live animals*, *petrol and other fuels* and *chemicals and related goods* are least exposed.

[14] These countries remain in the analysis, but as exporters only.

[15] This is the case for 45 countries.

[16] an increase in the bilateral exchange rate constitutes a depreciation in domestic currency.

[17] Aggregate imports are also relative to countries within the same trade block, and therefore results can be interpreted as generalised trade elasticities to border delays.

TABLE 2. Aggregate Goods Results

VARIABLES	(1) ratio_TI	(2) ratio_TI	(3) ratio_TI
Border Time	-0.090***	-0.121***	-0.090***
	(0.025)	(0.027)	(0.025)
Distance	-0.829***	-0.895***	-0.855***
	(0.023)	(0.029)	(0.024)
GDP	0.823***	0.841***	0.827***
	(0.013)	(0.013)	(0.013)
Exchange Rate	-4.297***	-3.810***	-4.859***
	(0.495)	(0.657)	(0.556)
Contiguous	0.796***	0.697***	0.768***
	(0.041)	(0.045)	(0.041)
Colony	0.649***	0.519***	0.640***
	(0.055)	(0.057)	(0.057)
Language	0.238***	0.330***	0.213***
	(0.054)	(0.060)	(0.057)
Landlocked	-0.472***	-0.614***	-0.509***
	(0.057)	(0.063)	(0.061)
Constant	0.011	0.082**	0.028
	(0.030)	(0.033)	(0.031)
Observations	125,454	99,221	114,978
R-squared	0.36	0.39	0.37
Specification	baseline	matched income sample	endogeneity

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

For the most time sensitive goods, our finding that crude and manufacturing materials are most exposed fits with findings in the literature on the sensitivity of intermediate goods in complex supply chains. A large component of crude materials are also perishable by nature and fresh foods, beverages and tobacco also appear to be exposed, perhaps due to their shorter life-span. It is difficult to comment on *commodities and "not elsewhere specified (nes)"* because the predominant component of these goods is undefined.[18] *Machinery and transport* goods also appear sensitive to NTBs, which may be due to the additional costs and complications of holding such bulky goods at the border.

[18] In any case the coefficient on *border waiting time* for these goods becomes insignificant in the Brexit sub-sample.

TABLE 3. Most Time Sensitive Goods

VARIABLES	(1) ratio_MA	(2) ratio_CR	(3) ratio_FF	(4) ratio_BT	(5) ratio_CO	(6) ratio_MT
Border Time	-0.336***	-0.291***	-0.241***	-0.225***	-0.215**	-0.185***
	(0.036)	(0.053)	(0.038)	(0.038)	(0.087)	(0.037)
Distance	-1.297***	-1.648***	-1.413***	-1.243***	-1.092***	-1.058***
	(0.037)	(0.053)	(0.043)	(0.039)	(0.087)	(0.037)
GDP	1.015***	1.093***	0.923***	0.724***	1.047***	0.923***
	(0.018)	(0.024)	(0.019)	(0.021)	(0.045)	(0.023)
Exchange Rate	-5.655***	-5.239***	-1.048	-1.065	-15.568***	-3.767***
	(0.913)	(1.528)	(1.233)	(1.297)	(2.441)	(1.128)
Contiguous	0.677***	1.102***	0.800***	0.854***	0.643***	0.487***
	(0.059)	(0.077)	(0.058)	(0.065)	(0.118)	(0.067)
Colony	0.712***	0.852***	1.056***	1.029***	0.845***	0.648***
	(0.076)	(0.093)	(0.070)	(0.082)	(0.144)	(0.076)
Language	0.521***	-0.011	0.583***	0.644***	0.845***	0.838***
	(0.079)	(0.100)	(0.078)	(0.079)	(0.140)	(0.086)
Landlocked	-0.405***	-0.852***	-0.871***	-0.772***	-0.812***	0.068
	(0.087)	(0.101)	(0.082)	(0.101)	(0.243)	(0.098)
Constant	0.147***	0.289***	0.115***	0.153***	0.605***	-0.048
	(0.042)	(0.055)	(0.042)	(0.046)	(0.111)	(0.043)
Observations	67,488	54,719	52,447	40,623	32,816	74,291
R-squared	0.44	0.44	0.45	0.31	0.34	0.40
Good	manuf. materials	crude material	fresh foods	beverages and tobacco	commodities and nes	machinery and transport

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

For the least time sensitive goods, the lack of statistical significance on *border waiting time* to imports of *live animals* is puzzling, but on inspection, very few countries import live animals from distant countries (for ethical reasons perhaps), and as such are more confined to importing from a smaller number of nearby countries, so these are a special case.[19] *Petrol and other fuels* are not sensitive to *border waiting times*. It is likely that countries face less freedom on where petrol and fuels can be imported from, in some cases infrastructural restrictions and oil ownership rights may be a key driver of trade flows. However, due to product homogeneity and pre-existing shipping arrangements, it is unlikely that these goods would face substantial border delays. Due to travel

[19]This may also be the reason why the coefficient on distance for live animals isn't as large as one might expect.

restrictions and costs *Petrol and other fuels* are also highly sensitive to distance. Finally, *chemicals and related products*, *other foods* and *miscellaneous manufacturing* goods appear to be relatively less affected by border delays.

TABLE 4. Least Time Sensitive Goods

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ratio_LA	ratio_MF	ratio_MM	ratio_CH	ratio_OF	ratio_AV
Border Time	-0.004	-0.033	-0.072***	-0.078**	-0.097***	-0.112***
	(0.044)	(0.074)	(0.025)	(0.033)	(0.032)	(0.041)
Distance	-1.528***	-2.057***	-1.101***	-1.305***	-1.223***	-1.400***
	(0.072)	(0.080)	(0.037)	(0.034)	(0.047)	(0.065)
GDP	0.777***	0.956***	1.040***	0.961***	0.956***	1.017***
	(0.022)	(0.037)	(0.015)	(0.017)	(0.020)	(0.021)
Exchange Rate	-1.374	-9.929***	-4.162***	-2.533***	0.409	0.189
	(0.988)	(2.053)	(1.203)	(0.777)	(1.053)	(1.277)
Contiguous	1.758***	1.880***	0.512***	0.536***	0.969***	1.419***
	(0.093)	(0.114)	(0.058)	(0.057)	(0.063)	(0.091)
Colony	0.540***	1.246***	0.726***	0.617***	0.818***	1.005***
	(0.113)	(0.124)	(0.072)	(0.079)	(0.082)	(0.092)
Language	0.509***	-0.225*	0.738***	0.600***	0.526***	0.077
	(0.091)	(0.125)	(0.049)	(0.061)	(0.070)	(0.084)
Landlocked	0.036	-1.854***	0.085	-0.567***	-1.219***	-1.220***
	(0.113)	(0.176)	(0.078)	(0.103)	(0.107)	(0.105)
Constant	-0.099*	0.123	0.052	0.141***	0.213***	0.171***
	(0.057)	(0.085)	(0.032)	(0.044)	(0.042)	(0.050)
Observations	13,357	27,618	67,334	56,560	52,351	22,582
R-squared	0.38	0.30	0.55	0.41	0.40	0.42
Good	live animals	petrol and other fuel	chemicals and related	other foods	misc. manuf.	animal veg. oil

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

EU-sample: Aggregate Exposure

To apply our model to a post-Brexit scenario, we reduce the sample size to countries whose aggregate "border waiting time" is less than 28 hours. This is to reflect the range of border waiting times for countries in Europe from 1 hour (Germany, among others) to 27 hours (Iceland). As such we are only looking at the effect of non-tariff barriers on trade in countries that are already relatively efficient, and reflective of a European sub-sample. While this may seem like a large cut in the sample size, the reduction in observations is

not as great as one might expect. This is because these highly efficient countries account for a substantial share of world trade.

Table 5 shows the results for aggregate goods trade using the full sample and income-matching (column 1) and the "efficient country sample" with income-matching (column 2).[20] The coefficient on "border waiting time" remains statistically significant at the 1 per cent level. Interpreting this coefficient, a doubling of border waiting time implies a decline in aggregate imports of 10.7 per cent. The negative influence of distance on trade is greater in the European sample, perhaps due to the presence of large mainland European countries importing large quantities of goods from neighbouring countries via land borders.

TABLE 5. Aggregate Goods Results - Brexit sample

	(1)	(2)
VARIABLES	ratio_TI	ratio_TI
Border Time	-0.121***	-0.107***
	(0.027)	(0.026)
Distance	-0.895***	-1.047***
	(0.029)	(0.039)
GDP	0.841***	0.887***
	(0.013)	(0.015)
Exchange Rate	-3.810***	-5.138**
	(0.657)	(2.030)
Contiguous	0.697***	0.524***
	(0.045)	(0.054)
Conlony	0.519***	0.299***
	(0.057)	(0.058)
Language	0.330***	0.551***
	(0.060)	(0.072)
Landlocked	-0.614***	-0.609***
	(0.063)	(0.068)
Constant	0.082**	0.113***
	(0.033)	(0.034)
Observations	99,221	66,246
R-squared	0.39	0.43
Specification	baseline	european sample
	income matched	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[20] As mentioned above, the efficient sample contains countries with border waiting times reflective of EU levels

EU sample: Goods-level Exposure

As was the case for the full-sample of countries, there is substantial good-level heterogeneity in the impact of non-tariff barriers on trade for the efficient-sample. In Table 6 we report the goods categories for which the impact of non-tariff barriers on trade is statistically significant, while the remaining goods are those without a statistically significant coefficient on *Border Time*. The goods-level categories remain the same as those in the full-sample case presented above. Notably, goods-level results from the efficient-sample are not dissimilar to results obtained from the full-sample. In particular the most exposed goods continue to be crude and manufacturing materials, fresh foods and beverages and tobacco. *Crude materials* become substantially more exposed to border waiting times, with a doubling of border waiting times implying a 43 per cent reduction in imports of crude materials. As mentioned above, the perishable quality of these goods and the importance of these goods in the supply chains of manufactured consumer goods combine to make them particularly exposed to border delays. Despite this, while *Crude materials* are a sizeable import for some European countries, trade flows in *Crude materials* between the UK and Ireland are very small, as outlined in Section 6. Fresh foods become less exposed in the efficient sample, but continue to be highly exposed to border waiting times.[21] In section 6 below, we show implied declines in trade between Ireland and the UK using these aggregate and goods-level results

[21] In addition to being highly exposed, these goods are likely to face a greater increase in border waiting times should the UK leave the customs union.

TABLE 6. Results of EU Application

VARIABLES	(1) ratio_CR	(2) ratio_MA	(3) ratio_BT	(4) ratio_FF	(5) ratio_AV	(6) ratio_MT	(7) ratio_MM
Border Time	-0.426***	-0.335***	-0.207***	-0.195***	-0.126***	-0.124***	-0.078***
	(0.042)	(0.034)	(0.042)	(0.036)	(0.044)	(0.031)	(0.025)
Distance	-1.833***	-1.500***	-1.305***	-1.473***	-1.688***	-1.242***	-1.259***
	(0.058)	(0.050)	(0.045)	(0.048)	(0.074)	(0.050)	(0.044)
GDP	1.138***	1.096***	0.702***	0.965***	1.057***	1.021***	1.060***
	(0.024)	(0.021)	(0.019)	(0.019)	(0.022)	(0.021)	(0.015)
Exchange Rate	-8.788**	-5.422*	-4.259	-5.385*	3.004	7.958**	-4.794***
	(3.728)	(2.909)	(2.940)	(3.192)	(3.096)	(3.647)	(1.628)
Contiguous	0.782***	0.263***	0.875***	0.753***	1.281***	0.145**	0.309***
	(0.077)	(0.066)	(0.067)	(0.067)	(0.099)	(0.068)	(0.061)
Colony	0.674***	0.552***	0.996***	0.897***	1.108***	0.618***	0.700***
	(0.089)	(0.076)	(0.079)	(0.066)	(0.094)	(0.078)	(0.066)
Language	0.345***	0.595***	0.362***	0.597***	-0.159*	0.768***	0.641***
	(0.088)	(0.084)	(0.083)	(0.079)	(0.083)	(0.102)	(0.053)
Landlocked	-0.803***	-0.340***	-0.866***	-0.837***	-1.360***	-0.010	0.063
	(0.113)	(0.094)	(0.110)	(0.088)	(0.113)	(0.106)	(0.077)
Constant	0.254***	0.191***	0.282***	0.218***	0.221***	-0.006	0.102***
	(0.056)	(0.048)	(0.047)	(0.044)	(0.055)	(0.045)	(0.033)
Observations	39,590	47,515	30,067	39,047	18,318	52,936	53,972
R-squared	0.48	0.48	0.33	0.50	0.45	0.45	0.58
Good	crude material	manuf. material	beverages & tobacco	fresh foods	animal veg. oil	machinery and trans.	misc. manuf.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5 Estimates of the Brexit-induced increase in *Border Waiting Time*

The scale and form of non-tariff barriers that will exist should the United Kingdom leave the Single Market and Customs Union are currently unknown, and may remain unclear until the end of the proposed "transition period" in December 2020. In order to use the model elasticity estimates to measure the potential impact of Brexit on trade it is necessary to estimate the likely increase in border waiting time associated with the UK leaving the Customs Union. In order to do this we begin by running an OLS regression as follows:

$$time_i = \alpha_i + \gamma_1\, partner\_rta_i + \beta_1\, sea\_port + \beta_2\, gdppc\_cat_i + \beta_3\, openness + \mu_i$$

Here $time_i$ is *border waiting time* for country i and γ is our coefficient of interest, where $partner\_rta(=1)$ is a dummy variable where country i imports car parts from a country outside of its own Regional Trade Agreement. We control for income bracket ($gdppc\_cat$), have a dummy variable $(=1)$ where car parts are arriving through a sea port rather than a land border (sea_port), and a variable for the openness of country i, or imports and exports divided by GDP ($openness$).

We also disaggregate *border waiting times* into *customs inspection* time and *documentary compliance* time. In order to ensure consistency with the "Efficient sample" from the gravity model, we restrict this regression to the same sample of countries (i.e. those with total border waiting times of less than 28 hours), which leaves us with a sample of 41 countries.

The results are shown in Table 5. Importing auto parts from outside of a Regional Trade Agreement (*partner_rta*), rather than from within, is associated with a 4.5 hour increase in *border waiting time* on average. Importing through a sea port, rather than over a land border is associated with an 11 hour increase in *border waiting time*, which is entirely driven by customs inspection related delays - likely due to port congestion or good-handling inefficiencies. Countries with higher levels of GDP per capita have lower *border waiting time* predominantly driven by delays related to documentary compliance. Interestingly, while the coefficient is negative, a country's level of openness to trade is not a statistically significant predictor of lower *border waiting time*. The current UK import delays from the "Doing Business" survey, and implied percentage increase in delays are shown at the end of Table 7. According to these estimates, should the UK leave the EU customs union, border waiting times - defined as the combination of border inspection times and documentary checks - would increase by 90 per cent.

Next we apply this implied increase in border waiting times to the elasticities from the "efficient sample" with income-matching gravity equation and calculate potential declines in trade between the UK and Ireland. Estimates of trade loss are stated in terms of a reduction from 2017 stocks between Ireland and the UK, and elasticities are applied to both Irish imports and exports from and to the UK. It is important to not e that these results do not consider any form of "special relationship" in trade between the UK and EU post-Brexit. This is an important caveat, Norway and Switzerland, for instance, currently have lower border waiting times than the UK, despite neither country being a member of the EU. Despite this, the following results allow for an informative estimate of the potential increase in non-tariff barriers post-brexit.

TABLE 7. Estimates for Brexit-induced increase in border waiting times

VARIABLES	(1) border wait time	(2) border inspect	(3) documentary checks
Partner Outside RTA	4.501**	2.679	1.714**
	(2.162)	(1.973)	(0.688)
Sea Port	11.948***	12.605***	-0.754
	(2.125)	(1.939)	(0.676)
GDP per Capita	-2.420*	-0.953	-1.488***
	(1.258)	(1.148)	(0.400)
Trade Openness	-0.020	-0.022	0.002
	(0.021)	(0.020)	(0.007)
constant	17.884***	9.012*	8.862***
	(5.145)	(4.695)	(1.637)
Observations	41	41	41
R-squared	0.57	0.60	0.40
Current UK Time	5 hours	3 hours	2 hours
Implied % Increase	90%	87%	85%

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6 UK-Ireland Trade Impacts Following UK exit from the EU Customs Union

In this section, we estimate the trade impacts of the UK leaving the EU customs union on trade between Ireland and the UK, on an aggregate and at a goods-level. Figures 2 and 3 apply these estimates to Irish imports from the UK on aggregate and at a goods-level respectively, and Figures 4 and 5 apply estimates to Irish exports to the UK on aggregate and at a goods-level respectively. For the goods-level results, in Figures 3 and 5, the coloured bars are faded where the trade effects of *border waiting times* are insignificant. The implied static decrease in aggregate Irish imports from the UK, is 3.1 per cent and for exports is 1.4 per cent. Looking in more detail, in Figure 3, the largest declines in imports are in *manufacturing materials*, *machinery and transport* and *fresh foods*. For goods-level exports, in Figure 5, the most sizeable declines are in *fresh foods*, *machinery and transport* and *manufacturing materials*. Notably, three goods categories that contribute significantly to overall trade flows - *minerals and fuels*, *chemicals and related* and *other food*, remain unaffected.

Our estimates for trade impacts are sensitive to the chosen increase in border waiting hours. Based on analysis outlined above we estimate this to be approximately 4.5 hours in the case that the UK are granted no “special status" post-Brexit. Secondly, this increase in border delays is based on a single product (auto parts), and therefore can

only be imperfectly applied to 1-digit level goods trade. It may occur, for instance, that in addition to being relatively sensitive to border delays, fresh foods face a more extensive increase in border delays (relative to their current border delay time) than that implied by our proxy measure, and in that case our results would understate the trade impact for this good. According to data we received from Irish customs officials, non-EU imports of agricultural goods currently face waiting times of between 83 minutes and up to 19 hours and 34 minutes where physical examination is required.

FIGURE 2. Aggregate loss in Irish Imports from the UK

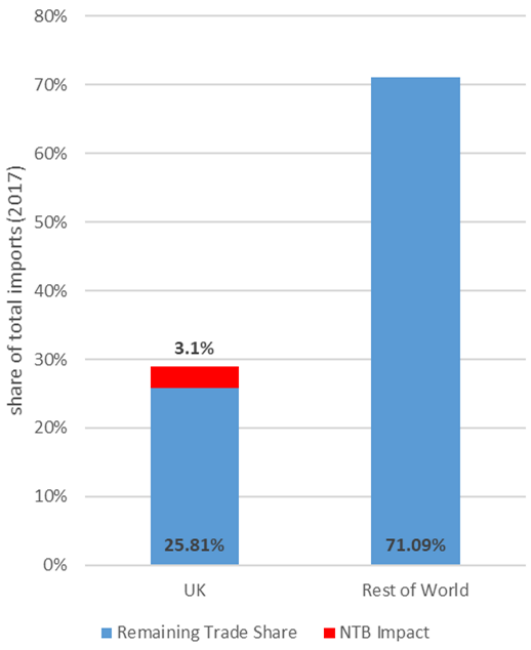
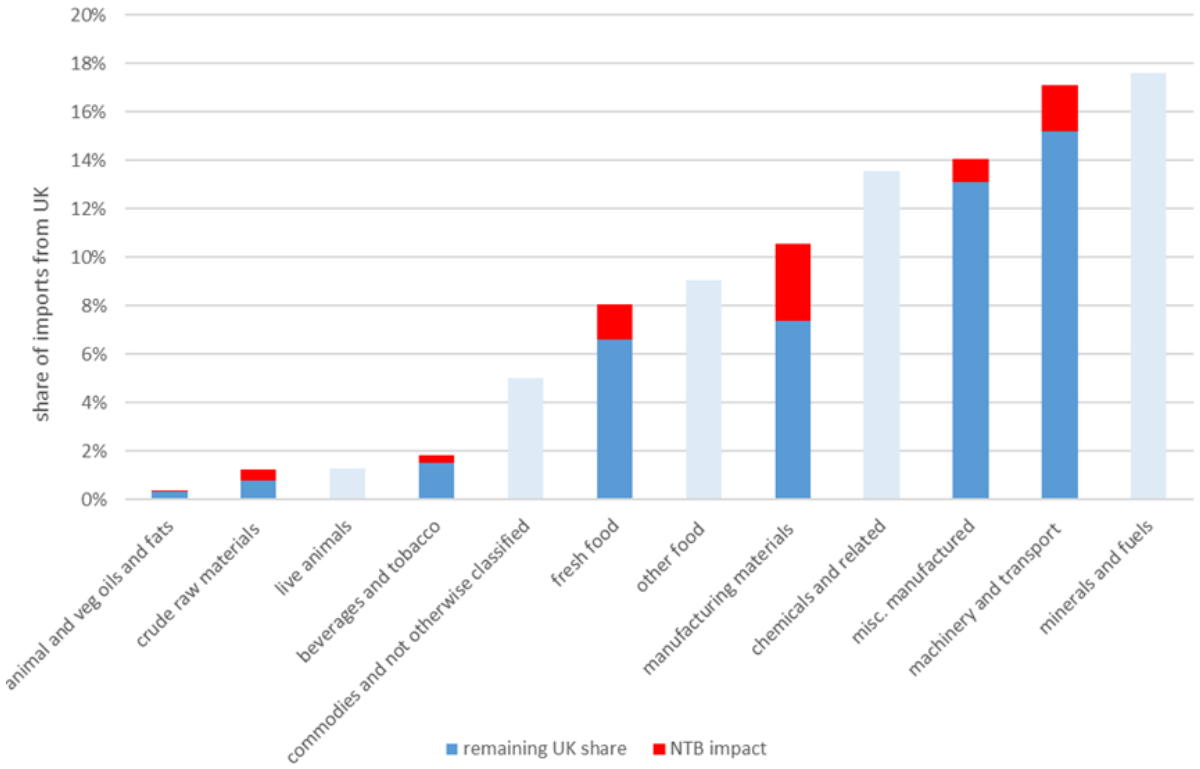


FIGURE 3. Goods-level losses in Irish Imports from the UK



Note: Shaded bars imply the effect is not statistically significant

FIGURE 4. Aggregate loss in Irish Exports to the UK

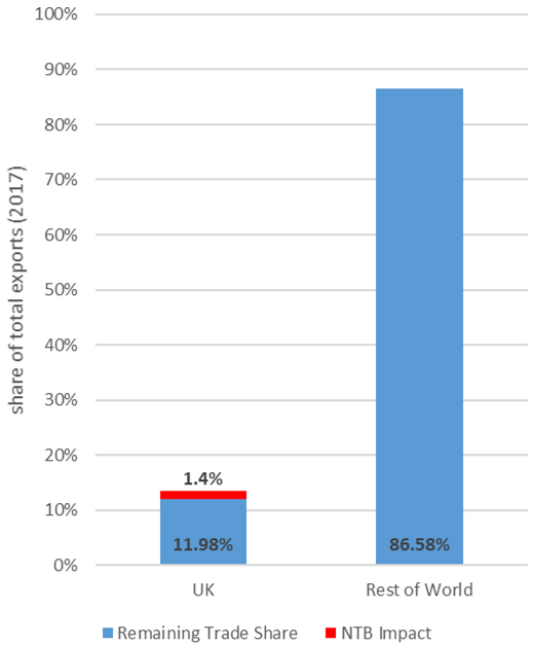
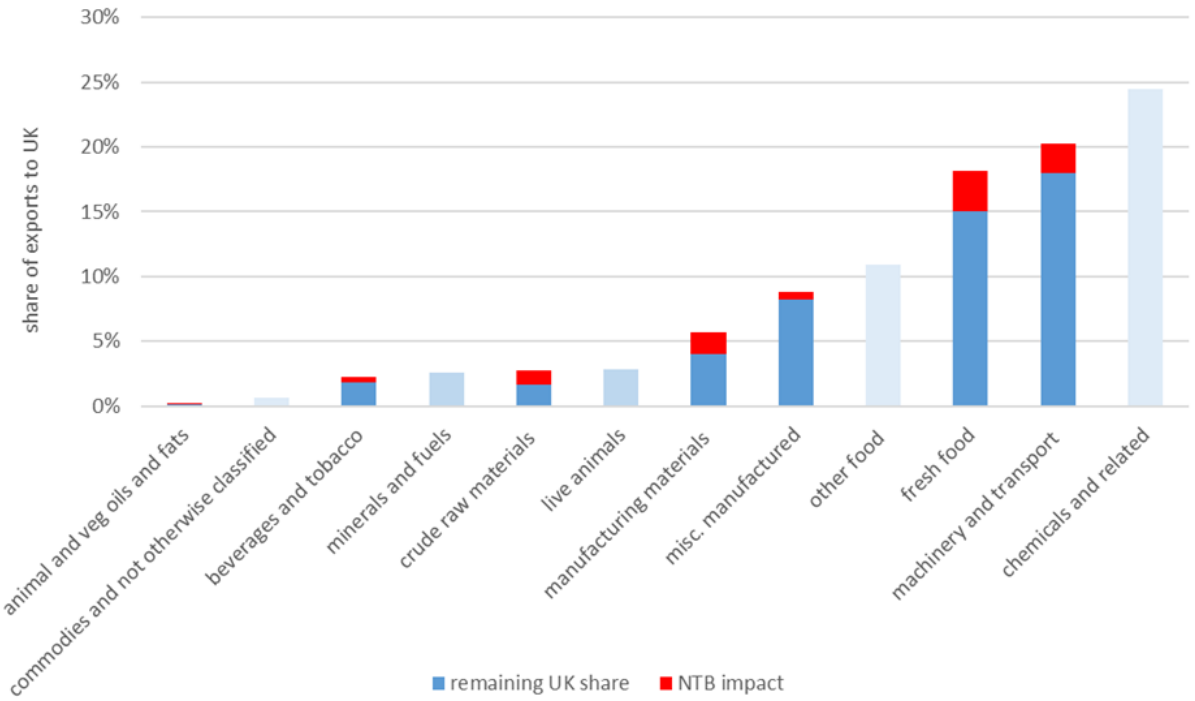


FIGURE 5. Goods-level losses in Irish Exports to the UK



Note: Shaded bars imply the effect is not statistically significant

7 Robustness Checks

Asymmetry in trade reforms

One potential shortfall of our analysis is that we are not able to say anything on the possible asymmetry between developments that increase the time it takes to trade across borders (as in the case of the United Kingdom's leaving the European Union) and developments that decrease trade barriers. Furthermore, due to the lack a sufficient time-series of data we are unable to comment on trade flows before and after non-tariff barriers are put in place (or removed).

Here we attempt to test for these shortcomings using a separate form of data from the World Bank's *Doing Business* report. The *Doing Business Reforms* dataset tracks global trade policies and reforms that facilitate trade by implementing cost-effective, time-efficient and transparent regulatory practices. The data are provided in narrative format, which we convert to dummy variables for positive and negative reforms, respectively. We then combine this information with trade and GDP data from the IMF's *World Economic Outlook* database. Unfortunately, given the format of these data, we are unable to comment on the magnitude of the reforms, yet simply record that a reform has taken place. Due to this restriction, results in this test should not be compared to results in our baseline model in the paper. However, these results are informative to capture time variant dynamics and reform asymmetries.

Summary statistics for the types of reform we consider are presented in Table 8.

TABLE 8. Positive and Negative Reforms By Year

Year	Positive reform	Negative reform
2008	24	2
2009	32	3
2010	37	1
2011	30	0
2012	17	1
2013	22	6
2014	24	4
2015	22	5
2016	19	5

Source: World Bank Doing Business

Using this data, we estimate a regression of the form

$$\Delta lnTrade_{it} = \alpha_{it} + \beta_1 Reform_{it} + \Delta GDP_{it} + \mu_{it}$$

which we estimate separately for both positive and negative reforms. To allay the concern that the impact of reforms may take some time to have an effect, we exclude

countries that had a reform in the previous two years from the analysis. The vast majority of reforms are noted to improve (or dis-improve) imports and exports simultaneously, and therefore net exports are unlikely to be largely affected. We also include year and country fixed effects to control for the global and country specific shocks over the sample period. The results of our estimation are outlined in Table 9.

TABLE 9. Results of Reforms Time-Series

	(1)	(2)
VARIABLES	Δ Log of Trade	Δ Log of Trade
Positive Reform	0.0243*	
	(0.0136)	
Δ Log of GDP	1.092***	1.081***
	(0.362)	(0.359)
Year	-0.0328***	-0.0319***
	(0.00272)	(0.00271)
Negative Reform		-0.112***
		(0.0334)
Constant	63.26***	61.54***
	(4.916)	(4.915)
Country Effects	Yes	Yes
Year Effects	Yes	Yes
Observations	893	893
R-squared	0.213	0.222
Number of id	178	178

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As expected, on average and *ceteris paribus*, positive (negative) reforms are associated with increases (decreases) in trade, and these relationships are positive and statistically well determined at the conventional level. While identification of the direction of causality is beyond the scope of this analysis, it is perhaps noteworthy that the magnitude of the coefficient on negative reforms is larger than that for positive reforms. This finding is difficult to conclusively interpret due to our inability to measure the magnitude of reforms, in particular where negative reforms are more extensive on average, one would expect a larger coefficient on negative reforms. Another possible explanation for the greater magnitude for the coefficient on negative reforms may be that negative reforms affect the extensive margin as well as the intensive margin. Firms who face increased costs in the face of negative reforms may cease trading across borders entirely. In the case of positive reforms, there may be a larger effect on the intensive margin. Firms who are already exporting may increase volumes in the face of a more facilitative trading regime.

Gravity Model in Levels

We have described in detail the econometric justification for choosing to base our results on a difference gravity model. In this section, we estimate the same equation in log levels rather than in pairwise ratios as a robustness check. These results are given in Table 10, for the efficient-sample. In this specification, we are unable to match incomes as was the case with the specification in differences, as such, we include a measure of general regulatory quality as an additional control.[22]

TABLE 10. Gravity Equation in Levels

	(1)
VARIABLES	Total Imports
Border Time	-0.254***
	(0.034)
Distance	-1.350***
	(0.045)
GDP	1.080***
	(0.087)
Reg. Quality	-0.375***
	(0.122)
Exchange Rate	-20.754***
	(1.807)
Contiguous	2.401***
	(0.225)
Colony	1.141***
	(0.208)
Language	0.265*
	(0.136)
Landlocked	-1.147***
	(0.105)
Constant	14.620***
	(0.965)
Observations	7,161
R-squared	0.21
Specification	efficient

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[22] Because these data are not available for all countries in the sample this has the effect of reducing the sample size in this specification.

In this specification, the reduction in trade as a result of an increase in time is again both economically and statistically significant. [23] In this case, on average and *ceteris paribus* a one 10 per cent increase in border waiting time is associated with a 2.5 per cent decline in trade. There are a number of reasons however as to why this estimate is likely to biased. In particular, this specification does not allow us to match country-pairs within the same trade agreement. Due to this, our coefficients are not interpretable as relative to other countries within the same trade agreement and therefore there is likely to be significant non-linearity in the impact of border delays on trade flows. Furthermore we are unable to control for fixed effects in the exporting country. These drawbacks are accounted for in our difference gravity specification.

8 Discussion and Conclusion

The results in this paper have important policy implications. We have shown that the *agriculture* and *machinery and transport* sectors are likely to be most exposed to an increase in non-tariff barriers post-Brexit. This does not include the further effect of tariffs which may also arise. We have also shown that firms with internationally integrated supply-chains either using imports of intermediate goods from (such as crude and manufacturing materials) or exporting such goods to the UK will be heavily exposed to increases in non-tariff barriers. We find that trade in fuels, chemicals and imperishable foods appear less exposed, and the effect is not statistically significant.

In section 5, we provide an estimate for the likely increase in non-tariff barriers post-Brexit. Our model suggests that much of the delay would arise from the customs inspection delays and possible border congestion involved in importing from a "third country" through a sea border. As such, any policy which increases the efficiency of Ireland's customs clearance for goods imported from outside the European Union would likely reduce the magnitude of our estimates.

Importantly, we have shown that non-tariff barriers have significant implications for goods trade. Where firms may be permitted to use EU provisions for outward (and inward) processing for exemptions to tariffs and duties where goods are processed in the UK post-Brexit and re-imported back into the EU (and vice versa in the case of inward processing), no such provision is made for avoidance of non-tariff barriers. As such firms operating in Ireland who are dependent on the ease with which their supply chains are integrated with the UK will be required to either absorb this cost, or else pass it on to consumers. The extent to which these firms react may depend on the market structure in which they operate. Firms in highly competitive markets will likely be forced to either absorb the cost, or diversify their supply chain. Firms who conduct centralised distribution between the Irish and UK jurisdictions will also likely need to restructure this practice in the absence of agreement allowing such arrangements to continue. The extent to which these factors may have an impact on Irish consumer price inflation is left to further work.

[23] Coefficients here are not directly comparable to those in the difference gravity equation.

It is important to note that a decline in Irish trade with the UK is not synonymous with a decline in total Irish trade. The issue of import and export substitution is an important one which is beyond the scope of this paper. In the extreme, all of the decline in trade with the UK modelled in this paper could be simply redirected elsewhere. There are several reasons why this could be difficult to achieve. In the trade literature, the traditional factors which determine the volume of trade between countries are: distance, common language, similar legal systems and a past colonial relationship which acts as a proxy to capture common preferences and tastes. It is clear that there is no other country which meets these criteria for Ireland. The only other country with which we share a language in the European Union is Malta, which is a much smaller market and is clearly more distant than the UK.

To conclude, this paper presents estimates of the potential impact of non-tariff barriers on goods trade resulting from the United Kingdom's exit from the European Union. Our model incorporates the two channels we expect will be most important for goods trade post-Brexit - customs inspections and documentary compliance. Our results suggest the aggregate impact on aggregate trade will be negative and significant, in the order of a 9.6 per cent decline in goods trade between Ireland and the UK. We also find evidence of heterogeneity in exposures across different categories of goods.

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