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ABSTRACT

We estimate the impact of increased policy uncertainty from Brexit on UK trade in services. We apply an uncertainty-augmented gravity equation to UK services trade with the European Union at the industry level from 2016Q1 to 2018Q4. By exploiting the variation in the probability of Brexit from prediction markets interacted with a new trade policy risk measure across service industries we identify a significant negative impact of the threat of Brexit on trade values and participation. The increased probability of Brexit in this period lowered services exports by at least 20 log points.

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1 Introduction

Brexit represents the most important economic reform in recent UK history. It will change long-standing policies affecting firms, and thus their investment, location, and trading decisions. Uncertainty surrounding the magnitude and timing of policy changes implies that Brexit has been affecting firms since the May 2015 election when the "Leave" referendum became a real possibility and certainly after Brexit passed in June 2016.[1] Measuring policy uncertainty is challenging, but has been done in certain areas. Specifically, recent research finds that Brexit-induced trade policy uncertainty (TPU) reduced UK-EU trade in goods. Services trade is increasingly important— about 40% of UK exports (Borchert et al., 2020) and a source of improved economic performance (Francois and Hoekman, 2010)—so we examine how it is affected by TPU from Brexit.

Deep agreements, such as the EU, aim to provide low and stable trade restrictions. These agreements can lower TPU by encouraging goods' export investments when countries acede (Handley and Limão, 2015) and discourage them when countries vote to exit them (Crowley, Han and Exton, 2018). Export reductions due to TPU can also occur in services due to lower investments from clients (USITC, 2020) or in products to be sold cross-border.[2] Since TPU can affect trade in goods and services via a similar mechanism we build on Graziano, Handley and Limão (Forthcoming)—who estimate the impact of Brexit on goods trade—and adapt it to services.

To estimate the impact of ongoing TPU associated with Brexit we must measure the probability of Brexit and the policy outcomes that it will implement. Under a no-deal Brexit the UK and EU would revert to the multilateral trade restrictions agreed under

[1] Bloom et al. (2018) report that 40% of UK firms in a large survey considered Brexit one of the top three uncertainties for two years after the referendum; this was higher for those in trade-related industries and included uncertainty about the timing of exit and whether it would be "disorderly".

[2] For example, in 2019 Tata Consultancy Services chief executive Rajesh Gopinathan noted a lack of appetite for renewing contracts with foreign services firms to provide cross-border IT services due to uncertainty surrounding Brexit. "Indian IT boss says Brexit makes planning Impossible" (*Financial Times* 8/12/19). UK insurance firms have also started to react to uncertainty, in their case about the validity of insurance policies sold cross-border to EU clients, by setting up affiliates in EU markets. "Brexit uncertainty drives insurers to waste time and money" (*Financial Times* 3/3/19).

the World Trade Organization (WTO) in 1995. These WTO restrictions are more costly than the preferential ones imposed by the UK and EU on each other's goods pre-Brexit. Thus one measure of Brexit policy risk for goods' exporters is the potential increase from preferential to WTO import tariffs. An innovation of this paper is to construct a measure of Brexit policy risk for services using a novel Services Trade Restrictiveness Index (STRI) that reflects EU and UK WTO policies and a comparable measure of their pre-Brexit preferential restrictions. We exploit the variation in this risk across service industries and countries interacted with Brexit probabilities from prediction markets. We find that this interaction term has a significant impact on bilateral services trade between the first quarter of 2016 and the last quarter of 2018. Increases in the probability of Brexit within this period reduced export values and participation where there was any risk of increased protection. Export values were reduced by at least 20 log points (the OLS baseline) and up to 49 log points (using an IV approach).

We contribute to different strands of research. First, there is extensive evidence that preferential trade agreements (PTAs) increase trade in goods but much less evidence for services.[3] This is in large part due to the dearth of data for flows and restrictions in services—which are difficult to measure.[4] This is rapidly changing with the construction of new services' trade datasets and STRIs.[5] These STRIs have been used as determinants of trade (Van der Marel and Shepherd, 2013; Nordås and Rouzet, 2017) and to derive tariff ad valorem equivalents—ranging from 50% to 250% (Benz and Jaax, 2020)—and can be affected by

[3]Limão (2016) reviews the effects of preferential agreements on trade in goods, Egger and Wamser (2013) find these agreements also increase aggregate services trade. Freund and Weinhold (2002) examine the impact of the internet in reducing costs and thus increasing services trade. Anderson et al. (2018) estimate a structural gravity model and find elasticities of services trade with respect to various bilateral trade costs comparable to those found for goods' trade; but the actual trade costs in services tend to be higher than in manufacturing (Anderson, Milot and Yotov, 2014; Gervais and Jensen, 2019).

[4]In WTO (2019) several of these difficulties are outlined. First, trade in services is intangible and can be conducted via multiple modes of supply. Second, service trade barriers include behind-the-border policies that can affect both domestic and foreign firms, so their discriminatory impact on trade is harder to establish, and they can be more opaque.

[5]These indices include those by the Australian Productivity Commission and Australian National University (Findlay and Warren, 2000), the World Bank (Borchert, Gootiiz and Mattoo, 2012) and the OECD (Benz, Ferencz and Nordås, 2020).

provisions in PTAs (USITC, 2019). Our estimates capture the risk of losing preferential access, so as the probability of Brexit goes to one they provide the impact of exiting a PTA on services' trade.

We contribute to the analysis of TPU by focusing on services. The expanding literature that estimates negative effects of TPU on exports focuses on goods, where policy risk is easier to measure. That measurement typically uses some gap between two similarly measured ad valorem tariffs in a product: the current tariff and the one in a counterfactual state.[6] By employing new STRI measures comparable across states we can similarly measure risk; moreover we address potential measurement error via an instrumental variables approach.[7] To our knowledge, we are the first to use this approach along with high frequency industry-level data to analyze the impact of TPU on services. The methodology is applicable to other PTAs that address services and face a risk of exit or renegotiation.

We also complement the research on the trade impacts of Brexit. Dhingra et al. (2018) compute a 3 percent welfare loss for the UK after a no-deal Brexit largely driven by lower trade with the EU. Gravity estimates in Mulabdic, Osnago and Ruta (2017) suggest that the reversal of EU integration reduces goods trade up to 30% after no-deal. Steinberg (2019) obtains reductions in trade and welfare with a calibrated, dynamic model where uncertainty plays only a small role. In contrast, empirical work using product-level risk and the pre-Brexit period finds significant negative effects of TPU on exports between the UK and EU (Crowley, Han and Exton, 2018; Graziano, Handley and Limão, Forthcoming). No comparable analysis exists for services. Douch, Edwards and Soegaard (2018) find lower aggregate service exports to the EU after the referendum relative to a synthetic control group (based on pre-referendum data). Our approach and detailed industry-bilateral data allows us to control for all bilateral shocks as well as identify and quantify a specific policy

[6]For example, Handley (2014) uses the gap between applied and bound multilateral tariffs, Handley and Limão (2015) focus on the gap of preferential and multilateral tariffs, Handley and Limão (2017) use multilateral and column 2 tariffs in the U.S.

[7]Both Lamprecht and Miroudot (2020) and Ciuriak, Dadkhah and Lysenko (2019) construct their own STRI to capture GATS commitments and use its difference relative to the OECD STRI as a measure of risk and find it lowers services trade.

mechanism through which Brexit uncertainty lowers services trade. Services restrictions can affect other industries, e.g. by raising input costs and lowering manufacturing productivity (Beverelli, Fiorini and Hoekman, 2017); thus our approach may be a useful first stage in identifying Brexit uncertainty effects on broader economic outcomes.

2 Conceptual and Empirical Frameworks

2.1 Firm Decisions

We adapt the framework of Graziano, Handley and Limão (Forthcoming), hereafter GHL, and thus provide only its key elements and implications. Providing a service to a new export market requires investments to learn about and meet local regulations, and in some cases establish relationships with local providers. These investments are often sunk and thus delayed (or not incurred) if TPU is sufficiently high.

We consider a demand with constant elasticity of substitution σ over varieties $v \in V$ in market i at time t:

$$q_{ivt} = \left[D_{iVt} \left(\tau^q_{iVt}\right)^{-\sigma}\right] p^{-\sigma}_{ivt}, \tag{1}$$

where D_{iVt} is an exogenous demand shifter and $\tau^q_{iVt} \geq 1$ is the ad valorem equivalent tax imposed on v, which reduces demand; both are specific to industry V. The firm observes all relevant information before producing and pricing in a monopolistically competitive market each period. This leads to a constant mark-up pricing rule over marginal costs and yields a factory-gate price $p_{ivt} = c_v \left[\sigma/(\sigma-1)\right]$. Evaluating demand in (1) at this price results in a standard expression for export revenue $p_{ivt}q_{ivt}$ and the following operating profit:

$$\pi_{ivt} = a_{iVt} c_v^{1-\sigma} \tilde{\sigma}, \tag{2}$$

where $\tilde{\sigma}$ is a constant function of σ. The **business conditions** term, $a_{iVt} = D_{iVt}/\tau_{iVt}$, is decreasing in $\tau_{iVt} \geq 1$, which captures any demand taxes or regulations that affect either sales

or profits.[8] The firm believes that a new a_i' is drawn with probability γ_i from a distribution $\bar{H}_i(a)$, independent of the current a.[9]

Exporting to i requires a sunk cost investment, K_i, to be incurred if the firm either did not export in the previous period or did export, but its export capital fully depreciated, which occurs with probability β. The sunk costs and uncertainty imply that the firm faces a dynamic decision. GHL show that the optimal export entry decision satisfies a cutoff rule requiring the expected value of exporting net of the sunk costs to exceed the value of waiting to enter in a later period. Only firms with cost below the following threshold value enter:

$$c_{iVt}^U = c_{iVt}^D \times U_{iVt}, \tag{3}$$

where c_{iVt}^D is the deterministic cutoff (reflecting the present discounted value of investment) and $U_{iVt} \in (0,1]$ is an uncertainty factor. These are given by

$$c_{iVt}^D = \left[\frac{a_{iVt}\tilde{\sigma}}{(1-\beta)K_i}\right]^{\frac{1}{\sigma-1}} \tag{4}$$

$$\text{and } U_{iVt} = \left[1 + \frac{\beta\gamma_i\left(\bar{\omega}_{iVt}-1\right)}{1-\beta\left(1-\gamma_i\right)}\right]^{\frac{1}{\sigma-1}}, \tag{5}$$

where

$$\bar{\omega}_{iVt} - 1 = -\bar{H}_i(a_{iVt})\frac{a_{iVt} - \mathbb{E}(a_{iV}' \leq a_{iVt})}{a_{iVt}} \in (-1, 0]$$

measures profit tail risk. It is the product of the probability of worsening conditions and the expected proportion of profits lost in that event. The uncertainty factor U_{iVt} implies a stricter entry cutoff whenever future conditions are expected to change and there is some tail risk ($\bar{\omega}_{iVt} - 1 < 0$).

This framework had been extended to firm sunk investments to lower marginal export

[8] Specifically, $\tau_{iVt} \equiv \left(\tau_{iVt}^q\right)^\sigma / \left(1 - \tau_{iVt}^\pi\right)$ where τ^q is defined in (1) and $\tau^\pi \geq 0$ a profit ad valorem tax rate. The services data does not allow us to distinguish these.

[9] This encompasses: no uncertainty ($\gamma_i = 0$); i.i.d demand ($\gamma_i = 1$); or otherwise imperfectly anticipated shocks of uncertain magnitude ($\gamma \in (0,1)$).

costs by Handley and Limão (2017). Thus the export effects we estimate can also reflect intensive margin effects.

2.2 Policy Risks

GHL relate tail risk to Brexit by assuming that Brexit changes the probability of drawing policies from a riskier distribution, m_t, so $\bar{\omega}_{iVt}$ can be written as a weighted average of the risk if Brexit occurs and the risk if the UK remains in the EU:

$$\bar{\omega}_{iVt} = m_t \omega_{iV}^{BR} + (1 - m_t)\omega_{iV}^{EU}. \tag{6}$$

We measure shocks to exporter beliefs about Brexit, m_t, by changes in prediction markets about the leave referendum and invoking Article 50, as described below. Assuming exporters did not expect a deterioration in business conditions in the EU scenario we can use $\omega_{ixV}^{EU} = 1$ and need only model ω_{ixV}^{BR}.[10] We assume that countries revert to their MFN service regulations with probability η and leave them unchanged otherwise, so the associated tail risk is

$$\bar{\omega}_{iVt} - 1 = m_t \times \eta \left(a_{iVt}^{MFN} / a_{iVt}^{EU} - 1 \right), \tag{7}$$

where the term in parenthesis is the percent reduction in operating profits if Brexit occurs and leads to MFN. Using our model this is captured by the percent difference in services taxes or regulations measure: $\tau_{iV}^{EU} / \tau_{iVt}^{MFN} - 1$.

In the model, Brexit is defined as a policy shock that is realized with new policies imposed by i drawn from H^{BR}. This occurs with probability $\gamma_i m_t$ and we capture variation in m_t over time by unanticipated shocks to the probability of a majority vote in the referendum and of invoking Article 50, both of which were necessary conditions for Brexit.

[10] The EU scenario could include the possibility of a renegotiation with reduced service barriers, but in the model this does not change the tail risk and thus leaves current export decisions unchanged.

2.3 Exports

2.3.1 Export Values

We aggregate firm behavior to the industry, denoted by V, in order to match the available quarterly data. Firms $v \in V$ draw their marginal cost from a distribution, $G_V(c)$, and face similar trade barriers in i. Thus the key determinants of an industry's exports to i are the business conditions a_{itV} and tail risk. GHL show that in periods when all exporters have costs below the current export entry cutoff bilateral industry exports are obtained by aggregating over the sales of all $v \in V$ to i at t:

$$R\left(a_{itV}, c_{itV}^{U}\right) = a_{itV} N_V \rho^{\sigma-1} \int_{c^{\min}}^{c_{itV}^{U}} c_v^{1-\sigma} dG_V(c), \tag{8}$$

where N_V is simply the mass of potential exporters and $c^{\min}$ the lowest cost firm.

Using a generalization of this expression to other periods, GHL decompose the export equation into shocks to uncertainty, demand, and supply factors and provide an approach to control for the latter two. To be clear about the level of variation of each variable we include x subscripts to denote the export country. The resulting first-order decomposition around the deterministic equilibrium and focusing on the uncertainty shocks is

$$\ln R_{ixVt} = k_c \bar{b}_i^h \ln U_{ixVt} + \alpha_{ixV}^r + \alpha_{ixt}^r + o_{ixVt}, \tag{9}$$

where $k_c \geq 0$ is the export elasticity to the cutoff around the deterministic equilibrium, and $\bar{b}_i^h \in (0, 1]$ reflects previous conditions in the market.[11] Applied services restrictions vary bilaterally and over industries but not over time in this period; so they are captured by the fixed effect α_{ixV}, which also controls for any heterogeneity in bilateral-industry flows. The bilateral-time effect α_{ixt} controls for any aggregate bilateral shocks to income, price index,

[11] Specifically, $\bar{b}_i^h = 1 - \beta^T$ if conditions have worsened in i for T periods before t or equal to one otherwise. Moreover, under a standard Pareto productivity distribution with dispersion k, we have $k_c \equiv \frac{\partial \ln R(a,c)}{\partial \ln c} = k - (\sigma - 1)$ and $o_{ixVt} = 0$.

productivity, trade costs, etc.

2.3.2 Export Participation

We observe zeros and changes in participation even at the industry level. Therefore we also describe how we relate export participation to the uncertainty cutoff. First, consider an exporter-industry where in period $t-1$ no firm $v \in V$ has surviving capital to export to i, so $K_{ixV,t-1} = 0$. The probability of industry exports in this case is simply the fraction of firms in xV with costs below the threshold, if any: $\Pr\left(R_{ixVt} > 0 | K_{ixV,t-1} = 0\right) = G\left(c^U_{ixtV}\right)$. Alternatively, there is export capital in the previous period and at least one firm survives—with some probability $\bar{\beta}$—so we observe exports at t, otherwise we are back to the first case, so now $\Pr\left(R_{ixVt} > 0 | K_{ixV,t-1} \neq 0\right) = \bar{\beta} + \left(1-\bar{\beta}\right) G\left(c^U_{ixtV}\right)$. We note two basic implications for the estimation. First, current participation depends on current uncertainty via the cutoff even if we don't condition on prior export capital (which is unobservable to us) or its proxy (the export history). Second, this relationship is attenuated if export capital depreciates very slowly: if exports in ixV at t simply reflects entry prior to our sample period and it persists throughout all t then there would be no relationship for that flow. The latter is not an issue for our estimates because we include bilateral-industry effects so the identification for participation relies on switchers.

2.4 Empirical Methodology

We relate exports to observable industry policy risk and time variation in Brexit beliefs by focusing on their interaction. This is obtained from a second order approximation of $\ln U_{ixVt}$ around both $\omega^{BR}_{ixV} = 1$ and $\ln m_0$, i.e. around the EU scenario prior to the possibility of a referendum, which yields

$$\ln U_{ixVt} = \frac{\tilde{\beta}_i}{\sigma - 1}\left(m_0 \ln \frac{m_t}{m_0}\right)\left(\omega^{BR}_{ixV} - 1\right) + \alpha^U_{ixV} + e^U_{ixVt} \tag{10}$$

where $\tilde{\beta}_i \equiv \frac{\beta\gamma_i}{1-\beta(1-\gamma_i)}$ represents the expected duration of an export spell to i under future conditions.

2.4.1 Export Values

Replacing equation (10) in (9), and using our proxies for the time varying probability, denoted by $\ln B_t$, and percent increase in the service restrictiveness factor, $\tilde{\tau}_{ixV}^{MFN}/\tilde{\tau}_{ixV}^{EU} - 1$, we obtain our estimating equation:

$$\ln R_{ixVt} = W_i \times \left[\ln B_t \times \left(\tilde{\tau}_{ixV}^{MFN}/\tilde{\tau}_{ixV}^{EU} - 1\right)\right] + \alpha_{ixV} + \alpha_{ixt} + e_{ixVt}. \tag{11}$$

The key parameter of interest is the cross-elasticity $W_i \equiv k_c \bar{b}_i^h \times \frac{\tilde{\beta}_i}{\sigma-1} \times m_0 r^b \times \eta \times \varepsilon$, which is predicted to be negative. It reflects the elasticity of exports to U, $k_c \bar{b}_i^h$; the elasticity of U with respect to $\bar{\omega}$, $\frac{\tilde{\beta}_i}{\sigma-1}$; the elasticity of $\bar{\omega}$ with respect to both our probability measure given an initial value, $m_0 r^b$, and to the increase of the STRI factor to MFN, which occurs with probability η. Increases in the STRI factor reduce profits by a factor $\varepsilon < 0$ and this is the only negative term.[12] Our baseline assumes W_i is similar across importers and in the robustness we test if there is heterogeneity.

2.4.2 Export Participation

As we note in section 2.3.2, participation also depends on uncertainty via the cutoff. So we use an approach similar to equation (11) using an indicator function $1\left(R_{ixVt}\right) = 1$ if $R_{ixVt} > 0$ and zero otherwise. Given the high dimension of fixed effects we implement a linear probability model (LPM) and note that about 78% of the sample are ones.

[12] We define $\varepsilon \equiv \frac{\partial \ln \pi}{\partial \ln \tilde{\tau}^s}|_{\tilde{\tau}^s = \tilde{\tau}^{EU}} < 0$ if the measured STRI factor, $\tilde{\tau} \geq 1$, reduces operating profits. Moreover, if prediction probabilities of Brexit are positively correlated with firm beliefs then $r^b \equiv \frac{\partial \ln m_t}{\partial \ln B_t}|_{m_0} > 0$.

3 Data

3.1 Trade Data

We employ a newly developed dataset from the UK Office of National Statistics. It provides quarterly bilateral values of UK imports and exports by service industry starting in 2016Q1 and covering 67 countries.[13] The distinguishing feature of this new data is the quarterly availability and detailed industry breakdown, both of which are essential for the identification. This is achieved by aggregating quarterly surveys of 2,200 firms.[14] Below we describe key features of the subsample that matches the trade data and is used in the regression analysis.

3.2 STRI Data

We use the OECD Services Trade Restrictiveness Index (STRI) to measure the policy barriers that the UK and EU would impose on each other in the case of Brexit without a trade deal.

The STRI catalogues country-specific laws and regulations and assigns individual weights to each measure. It aggregates these measures to create an index of services trade restrictions at the country-industry level that ranges from 0 to 1 (from completely open to closed), and applies to all exporters to that market.[15]. The index has limited variation over time in the period we consider; we use the 2016 data for the UK, the EU countries that are OECD members (no data is available for Bulgaria, Croatia, Cyprus, Malta, Romania), and other OECD countries when constructing instruments, as described in the results section.

[13]The data is part of the UK balance of payments statistics publications since October 2019 (Gibbs, 2019). It is available from `www.ons.gov.uk/businessindustryandtrade/internationaltrade/datasets/uktradeinservicesallcountriesnonseasonallyadjusted`

[14]Some flows that do not meet the disclosure rules described in Richard (2018) are suppressed to preserve confidentiality. For this small share of the observations there is positive trade, so we can include them in the participation estimation, but we do not observe the exact value, so we exclude them from the baseline value estimation.

[15]Information on the OECD STRI by industry and detailed policy measure is available at: `https://www.oecd.org/trade/topics/services-trade/`, and data at `https://stats.oecd.org/Index.aspx?DataSetCode=STRI`

Certain regulations in the overall STRI discriminate against international trade whereas others also affect domestic firms, e.g. regulatory transparency. We focus on differential risk faced by foreign firms and thus use the STRI subindex "restrictions to foreign entry". This index includes foreign equity and management limits, required commercial presence in the country where the service is consumed, and cross-border data flow restrictions. In Table A8 we show that 91 percent of the measures in this subindex can be classified as discriminatory, whereas that fraction is zero for the regulatory transparency index.[16]

If before Brexit there were no services barriers between the UK and the EU then we could simply use the STRI as our risk measure. However, that is not the case and thus we require a pre-Brexit measure that is closely comparable to the STRI and takes into account preferential trade relationships. Such a measure became available in 2019: the OECD's Europe-specific STRI, which applies the same methodology to measure barriers between European Economic Area members, as described in Benz and Gonzales (2019). The two indexes share a common weighting scheme and measures so we can use them to compute the risk measure required by the model.

3.3 Matched Trade Data Features

Matching the STRI and trade data yields 12 services industries, which include transportation, professional, financial and information services and others. Table A7 shows the correspondence between the subset of the 22 industries in the STRI and the 32 in the trade data with common descriptions. [17] The matched data represents 49 percent of total UK cross-border services trade in 2016; in Table A1 we show the ones with the largest shares are commercial banking, air transport, and legal, accounting, and management consulting services. In

[16]Two other subindices also include discriminatory measures: restrictions of movement of persons and other discriminatory measures. We test and find evidence that our results are robust to controlling for these other regulations and that the main source of risk is captured by the restrictions to foreign entry subindex.

[17]The match has fewer industries than its components due to different levels of aggregation in the trade and STRI data and missing coverage in the latter for certain industries. The missing industries and associated share in total UK trade in 2016 are travel services (20%), charges for IP use (5%), R&D services (3%), personal, cultural and recreational services (2%).

our baseline specification, we exclude air transportation due to incomplete barriers in the STRI.[18]

There is variation in risk across industries and countries that is essential for our identification strategy. In figure 1 we plot UK service restrictions in 2016 for each industry in the sample from lowest to highest risk. The risk is computed as the growth from the "Preferential" TRI factor, faced by EU countries in this period, to the threat or MFN TRI, captured by the STRI faced by non-EEA countries. There is considerable variation ranging from negligible risk in industries such as Architecture, Engineering and Scientific services to around 5 percent for Legal, accounting and consulting and even higher for other industries including financial, sea and air transportation.[19]

All EU exporters face similar restrictions in any given industry in the UK. However, the UK faces different barriers across EU countries, which provides an additional source of variation for identification for services that is not present for goods.[20] In figure 2 we plot the mean risk faced by UK exporters across EU countries in each industry. The bottom and top six industries in terms of mean risk coincide with the UK with minor variations in their ranking. For the top six industries the UK faces risk above 6 percent on average and we can see there is considerable variation across countries as shown by the standard deviation bars. The air transportation measures in this TRI and risk are about twice as large as the next largest industry, but our baseline regression results exclude it because they do not fully reflect those faced by the trade mode in our data.

In sum, the overall mean services risk in 2016 in our regression sample is around 5 percent and the standard deviation is 3.3 (Table 1). The variation arises from differences in applied

[18]Our cross-border data covers transportation from one country to another via air (mode 1 trade) along with services auxiliary to air transport, such as sales and marketing. However, the STRI for air transportation only covers barriers to trade for foreign providers of air transport services within a single country (mode 3 trade), which does not appear in our data. See appendix A for more information on services trade by mode of supply

[19]Only three industries have no intra-EU restrictions so for all others the variation in risk is driven by both MFN and preferential restrictions.

[20]GHL use EU MFN tariffs to construct a risk for goods and these are common in the UK and all countries in the EU.

and threat restrictions both across industries and importing countries.

Bilateral trade flows also exhibit variation over industries and time. In Table 1 we provide summary statistics for continuously traded industry-bilateral observations in 2016Q1-2018Q4: its coefficient of variation is 0.45. This reflects both firm intensive and extensive margin decisions.[21] Importantly for our identification we require variation within low and within high risk industries over time. To illustrate this variation we construct the log growth of R_{ixVt} relative to 2016Q1 for any ixV continuously traded. In figure 3 we plot a smoothed local polynomial over two groups of industries according to their policy risk. The line labelled "Low" includes the industries with the risk below the country's median: nominal values in this category rise on average over the full period. However, the values for the high risk industries start declining after the referendum and the triggering of Article 50. By the second half of 2017 after these two key Brexit events had been realized, both groups start to comove closely. By 2018Q1 the cumulative growth in the high risk group was about 25 log points lower than in the low risk. The regression analysis estimates how this varies with the probability measures that we now describe.

3.4 Probability of Brexit Measures

We explore the variation over time in the probability of Brexit between 2016Q1 (the earliest quarter of detailed trade data) and 2018Q4. During this period there was ongoing uncertainty about whether and when Brexit would occur. Two necessary events for Brexit were a "Yes" vote in the June 2016 referendum and the UK government triggering of Article 50 to formally notify the European Commission that it would leave the EU, which eventually occurred by the end of March 2017. We use prediction market data for each of these events to construct our proxy for exporter beliefs of the probability of Brexit.

For the referendum we use the average daily price of a contract traded in PredictIt.org

[21] We also summarize participation, measured by an indicator $1(R_{ixVt})$. There is positive trade in 78% of all potential flows on average with variation over time (from 75% to 81%), industries (39% in Other Transportation to 96% in Telecommunications) and importers (from 30% for Estonia to 100% for four countries); the UK average is 74%.

that pays $1 if a majority voted for voted for Brexit in a referendum held by December 2016, and zero otherwise. The daily price reflects the beliefs of traders about the probability of the event, which was about 0.25 in January 2016 and increased after the referendum date was set and further in the month leading up to the vote. The price never exceeded 0.46 before June 23rd (and converged to 1 soon after) so the outcome was unexpected when measured by this variable (as it was in polls).[22] A measure of continued Brexit uncertainty after the referendum was the probability of eventually triggering of Art. 50. Using prediction market contracts from Predictwise the probability of this event occurring between January and June 2017 was around 0.4 in July 2016. This probability increases over time in most but not all months, e.g. the average probability in November 2016, while the Supreme court ruled on it, was about 16 percentage points lower than in October.

We combine both contract price measures into a single measure of uncertainty, which is averaged within each quarter to match the trade data. Before July 2016, the combined probability is the product of the probability of the referendum and the probability of Article 50 in July, 0.4, so all variation in this period is from the referendum prediction. From July 2016 onwards we employ the probability of Article 50 alone. Figure 3 shows the quarterly combined probability of these two sources of uncertainty during the sample period. The quarterly average shows the resulting proxy, which we log and use for exporter beliefs in the regressions. It increases slightly before the referendum, jumps in the third quarter reflecting the vote and increases steadily with an additional jump after Article 50 is invoked on March 29, 2017. In the robustness section we also examine a backward moving average, which has a similar trend.

[22] GHL provide evidence that this measure is strongly positively correlated with political events and polling changes favoring Brexit and thus reflects salient information.

4 Results

We present the results of our baseline specification and robustness checks, and quantify the effect of Brexit on UK services trade with the EU.

4.1 Baseline

In Table 2 we present OLS estimates for the cross-elasticity of interest from equation (11). The estimates are negative and significant as predicted by the model. All specifications include bilateral fixed effects both by industry category (ixV) and by quarter (ixt) and cluster the standard errors by itV, which is the level of variation of the uncertainty variable.

When we use log exports for the continuously traded sample ending in 2018Q4 we obtain $W = -1.77$ (column 2). So increases in the probability of Brexit reduced export values in services where there was any risk of protection. We provide a quantification below.

The LPM estimates use export indicators for each possible flow in an ixV triplet, but given that we include fixed effects at that level, the identification relies on switchers over time. We find that increases in the probability of Brexit reduced the probability of exporting in services where there was risk of protection. In column 4 the parameter estimate is -0.44, which implies a cross-elasticity of participation of -0.57 after we divide by the mean of the dependent variable.[23]

In Table 3 we extend the trade value sample to include zeros and estimate the uncertainty effect using PPML. We continue to use the same set of fixed effects and clustering. The estimated elasticity for the sample ending in 2018Q4 is -1.24 (column 4). The results are qualitatively similar but smaller in magnitude if we focus on the non-confidential sub-

[23]The LPM estimates reflect change in participation by firms and thus provide direct evidence for the model's mechanism. However, at this level of aggregation there is also substantial firm entry and exit in the continuously traded flows. So we do not attempt to categorize the uncertainty effects into firm intensive and extensive margin.

sample (column 2).[24] In each of the specifications, the PPML elasticity is between those in the corresponding specifications for value and participation—as we expect since the PPML reflects both of these.

4.2 Robustness

We provide robustness tests for the baseline specifications, which we choose to be those for values and participation in Table 2 (columns 2 and 4) and their combined effect in Table 3 (column 4).

Timing

Shortening the sample period to 2017Q4 does not change the baseline results. This provides some information about the most relevant events shaping Brexit probabilities. The uncertainty variable assumes the Brexit probability remains constant in the extra periods of the longer sample. This assumption is clearly a simplification since certain events in 2018Q1-2018Q4 could have changed exporter beliefs about the likelihood of Brexit. The fact that the estimates and standard errors are similar across samples in Table 2 suggests that our assumption of a constant probability in that period does not introduce measurement error that would induce attenuation.

The baseline probability is a simple average within all the days in the quarter. However, investments of firms exporting in the first two months of the quarter could have used information from prior month(s) before that quarter. Thus we construct an alternative: a moving average for each month m that includes m as well as the previous two months and then averages the months in the quarter. The results in Table A2 are identical for each of the baseline specifications.

Additional Service Regulations

[24] The "Non-confidential" sample excludes positive traded omitted from the data due to confidentiality reasons. The "All" sample includes the confidential observations by imputing any such omitted flow for exporter-UK-service-quarter with the min(UK-service-quarter) over all EU exporters and UK-importer-service-quarter with the min(UK-service-quarter) over all EU importers.

Our risk measure reflects service regulations in category 1: "restrictions on foreign ownership and other market entry conditions", which is arguably the most relevant for exports in our data, for two reasons. First, category 1 is mostly composed of measures that explicitly discriminate against foreign services providers (91% of all category 1 measures are discriminatory across the industries in our sample). Second, category 1 includes policies that directly impact the ability of services firms to trade cross-border, such as whether a local commercial presence is required for cross-border trade, and restrictions on cross-border data transfers. The underlying restrictiveness in this category is correlated with that in other categories in certain countries. To examine if our baseline captures the relevant risk or simply a correlation we construct a "risk aggregate" that includes category 1 and all other in the OECD data. In Table A3 we replicate the baseline for values (column 1) for comparison. The extended specification including aggregate risk (column 2) shows that the aggregate risk has no significant effect and that the baseline measure has a negative and significantly different impact from this aggregate. The elasticity for category 1 is given by the sum of the two coefficients, -1.7 nearly identical to the baseline. For participation (column 4) and PPML (column 6) we also find the elasticity of category 1 is statistically different from the aggregate measure and quantitatively similar to the baseline. This evidence suggests the baseline measure is capturing the intended effect. [25]

Additional Unobserved Heterogeneity

Our risk measure interacts a time shock that is common for all countries with potential risk, which is positively correlated across importers for any given industry. To account for this correlation in the explanatory variable we also cluster standard errors by industry-quarter in Table A4. Doing so raises the standard errors only marginally (columns 1,3,5).

A potential concern with the baseline is that it captures omitted unobserved industry trends. More specifically, the probability of Brexit rose on average in this period and if

[25] In Appendix A.3 we provide additional evidence of the relevance of the STRI-1 using a standard gravity estimation in a sample without the UK-EU.

industries with higher initial risk had a negative trend due to some unrelated reason then our estimates may simply reflect this trend. To test if the results are robust to this issue we include a set of linear trends for each industry. Doing so reduces the estimated elasticities, but they remain negative and significant for value and PPML (columns 2 and 6). It is important to note that the trends may themselves be picking up some of the Brexit effect due to the mechanism in the model and the risk coefficients then reflect any extra deviation from that trend.

Industry Exclusion

In the data section we describe how the merge of trade and policy variables yields twelve industries. We used all except air transportation since the OECD STRI does not collect information on barriers for one of its main modes of supply (mode 1). This type of measurement error leads to attenuation bias and that likely explains the attenuated elasticities in Table A5 when we include observations for this industry in the baseline.

Given the small number of industries and correlation in their risk across countries we test and find that the baseline is robust to excluding other industries one at a time (results for the 33 regressions are available on request). For example, the coefficient in each of these 11 regressions for values is negative, significant and the median value is -1.7, as in the baseline.

Heterogeneous Effects for UK and EU

The baseline assumes importers have similar elasticity, W_i, and we now examine if the elasticity is significant for UK and EU importers separately and if there is any differential. We do so by adding an EU-exporter interaction with the baseline risk. So the first row of Table A6 now captures the average elasticity when the UK exports to any of the EU countries and it remains negative, significant and qualitatively similar to the baseline. The interaction captures any additional effect faced by EU exporters in the UK, which is significant for values (but not participation).[26]

[26]GHL identify a similar differential (for both values and participation) and provide additional evidence suggesting it reflects additional risk perceived by EU exporters uncertain about future UK policies.

4.3 Measurement Error

We address two potential sources of measurement error with the baseline risk using an IV approach.

One source of measurement error is the fact that the available measures of service restrictions are only a proxy for the ad valorem equivalent of service regulations on operating profits. The other conceptual source of measurement error is that the tail risk that exporters incorporated in their decisions may differ from the measure we use. Either of these imply an attenuation of the estimated elasticities and can be partially addressed by instrumenting baseline risk with an alternative measure.

The instrument that we use is the median STRI that other developed countries set in each industry. As long as any error in these is orthogonal to that in the baseline risk, this IV addresses the first source of the measurement issue. To the extent that exporters believe that the UK STRI towards the EU (or the EU's towards the UK) will be some combination of the current level and what other developed countries do then this measure should help address the second source. The simple correlation of this measure with the baseline risk is over 0.7 which generates a strong first stage; moreover the measure is not UK or EU-specific and is conceptually excludable from the second stage.[27]

We compare the results in Table 4, produced with this IV approach, to the baseline specifications of Table 2. We continue to find negative and significant effects of uncertainty. The elasticities are now 2-3 times larger, which suggests considerable attenuation in the OLS estimates, similar to what GHL find. Therefore the subsequent quantification will consider both approaches.

4.4 Impact of Brexit Uncertainty

We use the permanent cross-elasticity W to quantify the uncertainty impacts of the events that increased Brexit probability evaluated at the average risk. Using the values specification

[27] We use Australia, Canada, Japan and the USA.

in (11) we obtain

$$\mathbb{E}\left(\ln \frac{R_{ixV}(B_t)}{R_{ixV}(B_0)}\right) = \left[W \times \left(\overline{\tilde{\tau}_{ixV}^{MFN}/\tilde{\tau}_{ixV}^{EU} - 1}\right)\right] \times \ln \frac{B_t}{B_0},$$

where the mean risk in the sample in 0.052 (Table 1). We define the uncertainty elasticity at the mean risk as the term in brackets and we see in Table 5 that it is $-0.23 = -4.4 \times 0.052$ using the IV specification.[28]

In Table 5 we use this elasticity to compute the average impact of the referendum and adoption of Article 50. We compute the referendum effect as the impact of the growth in the measured probability in our data between t =2016Q3 and 2016Q1, which is $\ln B_t/B_0 = 1.3$. All else equal, we estimate this shock reduced service exports between 12 and 30 log points (using the OLS and IV estimates respectively). This combined with the passage of Article 50 increased the probability relative to 2016Q1 to $\ln B_t/B_0 = 2.14$ implying an average reduction over the full period in export values between 20-49 log points.

Using a similar approach we find a reduction in average export participation at the industry level relative to 2016Q1 of 6 to 16 log points.

In Appendix A.3 we provide external validation that these STRI export value impacts are reasonable using a novel dataset in a sample without UK-EU flows.[29]

5 Conclusion

Services constitute a large share of the UK economy and its trade, so stable and open market access is of vital importance for both the UK and EU economies. This access was threatened

[28]This elasticity is very similar to what GHL obtain using a similar approach for goods with monthly pre-referendum probabilities, −0.19. The similarity suggests the approach captures deep parameters that reflect common exporter beliefs about trade risk across goods and services as well as before and after the referendum.

[29]Briefly, we apply a standard gravity OLS estimation to a novel bilateral services trade and production dataset to estimate the STRI effect on international services trade. We find that an STRI increase of 0.07 implies a reduction in bilateral services trade of around 42 log points. Thus increases in the STRI of the magnitude expected if a no-deal Brexit occurs with probability one are consistent with trade reductions that are larger than our OLS TPU estimates.

when Brexit became a possibility and particularly after the leave referendum, which made Brexit one of the top sources of uncertainty for firms (Bloom et al., 2018). This uncertainty will have lasted at least five years until any policy change actually occurs, so it is essential to model, measure and quantify its impacts.

We build on and extend research on TPU to examine services. We employ novel and rich data on services' trade and its restrictions between the EU and UK: both current restrictions and those they would face under a no-deal Brexit. This risk varies across industries and countries, and its interaction with Brexit probabilities—from prediction markets—has a significant impact on bilateral trade between 2016Q1-2018Q4. Increases in the probability of Brexit lowered export values—between 20-49 log points—and participation—between 6 to 16 log points. These results are robust to controlling for additional trade restrictiveness measures and unobserved heterogeneity, as well as to dropping industries. Our baseline OLS specification provides the low end of the range of estimates while the IV approach that we use to address the potential risk measurement error provides the high end.

Our results and methodology have implications and applications beyond services' trade and Brexit. First, the TPU effects on services can affect other industries, e.g. by raising input costs, and our methodology can be a useful first stage in identifying Brexit impacts on other outcomes. Second, the results show that PTAs can increase services' trade and, when they do so, threats to renegotiate or exit them are costly even if they do not materialize.

References

Anderson, James, Catherine Milot, and Yoto Yotov. 2014. "How Much does Geography Deflect Services Trade? Canadian Answers." *International Economic Review*, 55(3): 791–818.

Anderson, James, Ingo Borchert, Aaditya Mattoo, and Yoto Yotov. 2018. "Dark Costs, Missing Data: Shedding some Light on Services Trade." *European Economic Review*, 105: 193–214.

Benz, Sebastian. 2017. "Services Trade costs: Tariff equivalents of services trade restrictions using gravity estimation." Organisation for Economic Development and Cooperation OECD Trade Policy Papers 200, Paris.

Benz, Sebastian, and Alexander Jaax. 2020. "The Costs of Regulatory Barriers to Trade in Services: New Estimates of Ad Valorem Tariff Equivalents." Organisation for Economic Development and Cooperation OECD Trade Policy Papers 238, Paris.

Benz, Sebastian, and Frederic Gonzales. 2019. "Intra-EEA STRI Database: Methodology and Results." Organisation for Economic Development and Cooperation OECD Trade Policy Papers 229, Paris.

Benz, Sebastian, Janos Ferencz, and Hildegunn Nordås. 2020. "Regulatory barriers to trade in services: A new database and composite indices." *The World Economy*, Early View.

Beverelli, Cosimo, Matteo Fiorini, and Bernard Hoekman. 2017. "Services Trade Policy and Manufacturing Productivity: The Role of Institutions." *Journal of International Economics*, 104: 166 – 182.

Bloom, Nicholas, Philip Bunn, Scarlet Chen, Paul Mizen, Pawel Smietanka, and Greg Thwaites. 2018. "Brexit and Uncertainty: Insights from the Decision Maker Panel." *Fiscal Studies*, 39(4): 555 – 580.

Borchert, Ingo, Batshur Gootiiz, and Aaditya Mattoo. 2012. "Guide to the Services Trade Restrictions Database." World Bank Policy Research Working Paper 6108, Washington, DC.

Borchert, Ingo, Mario Larch, Serge Shikher, and Yoto Yotov. 2020. "The International Trade and Production Database for Estimation (ITPD-E)." *International Economics*, forthcoming.

Ciuriak, Dan, Ali Dadkhah, and Dmitry Lysenko. 2019. "The Effect of Binding Commitments on Services Trade." *World Trade Review*, 1–14.

Crowley, Meredith, Lu Han, and Oliver Exton. 2018. "Renegotiation of Trade Agreements and Firm Exporting Decisions: Evidence from the Impact of Brexit on UK Exports." *SSRN Electronic Journal*.

Dhingra, Swati, Gianmarco Ottaviano, Veronica Rappoport, Thomas Sampson, and Catherine Thomas. 2018. "UK trade and FDI: A post-Brexit perspective." *Papers in Regional Science*, 97(1): 9–24.

Douch, Mustapha, T. Huw Edwards, and Christian Soegaard. 2018. "UK Services Exports in the Aftermath of the Brexit Announcement Shock." Warwick Economics Warwick Economics Research Paper 1182.

Egger, Peter, and Georg Wamser. 2013. "Multiple faces of preferential market access: their causes and consequences." *Economic Policy*, 28(73): 143 – 187.

Findlay, Christopher, and Tony Warren. 2000. *Impediments to Trade in Services.* London:Routledge.

Francois, Joseph, and Bernard Hoekman. 2010. "Services Trade and Policy." *Journal of Economic Literature*, 48(3): 642 – 692.

Freund, Caroline, and Diana Weinhold. 2002. "The Internet and International Trade in Services." *The American Economic Review*, 92(2): 236–240.

Gervais, Antoine, and J. Bradford Jensen. 2019. "The Tradeability of Services: Geographic Concentration and Trade Costs." *Journal of International Economics*, 118: 331–350.

Gibbs, Chloe. 2019. "UK trade in services by partner country: April to June 2019." UK Office for National Statistics Statistical Bulletin, London.

Graziano, Alejandro, Kyle Handley, and Nuno Limão. Forthcoming. "Brexit Uncertainty and Trade Disintegration." *Economic Journal*.

Gurevich, Tamara, and Peter Herman. 2018. "The Dynamic Gravity Dataset: 1948-2016." United States International Trade Commission USITC Office of Economics Working Paper 2018-02-A, Washington, DC.

Handley, Kyle. 2014. "Exporting under trade policy uncertainty: Theory and evidence." *Journal of International Economics*, 94(1): 50–66.

Handley, Kyle, and Nuno Limão. 2015. "Trade and Investment under Policy Uncertainty: Theory and Firm Evidence." *American Economic Journal: Economic Policy*, 7(4): 189 – 222.

Handley, Kyle, and Nuno Limão. 2017. "Policy uncertainty, trade, and welfare: Theory and evidence for China and the United States." *American Economic Review*, 107(9): 2731–2783.

Lamprecht, Philipp, and Sebastien Miroudot. 2020. "The Value of Market Access and National Treatment Commitments in Services Trade Agreements." *The World Economy*, Early View.

Limão, Nuno. 2016. "Preferential Trade Agreements." *Handbook of Commercial Policy. Volume 1B*, 279 – 367. Elsevier, North-Holland.

Mann, Michael, and Daniel P. H. Cheung. 2019. "Measuring trade in services by modes of supply: 2019 Edition." Publications Office of the European Union Eurostat Statistical Working Papers, Luxembourg.

Mulabdic, Alen, Alberto Osnago, and Michele Ruta. 2017. "Deep integration and UK-EU trade relations." *The Economics of UK-EU Relations*. Palgrave Macmillan.

Nordås, Hildegunn, and Dorothee Rouzet. 2017. "The Impact of Services Trade Restrictiveness on Trade Flows." *The World Economy*, 40(6): 1155–1183.

Richard, Melanie. 2018. "Annual Business Survey Technical Report: August 2018." UK Office for National Statistics, London.

Steinberg, Joseph B. 2019. "Brexit and the Macroeconomic Impact of Trade Policy Uncertainty." *Journal of International Economics*, 117: 175 – 195.

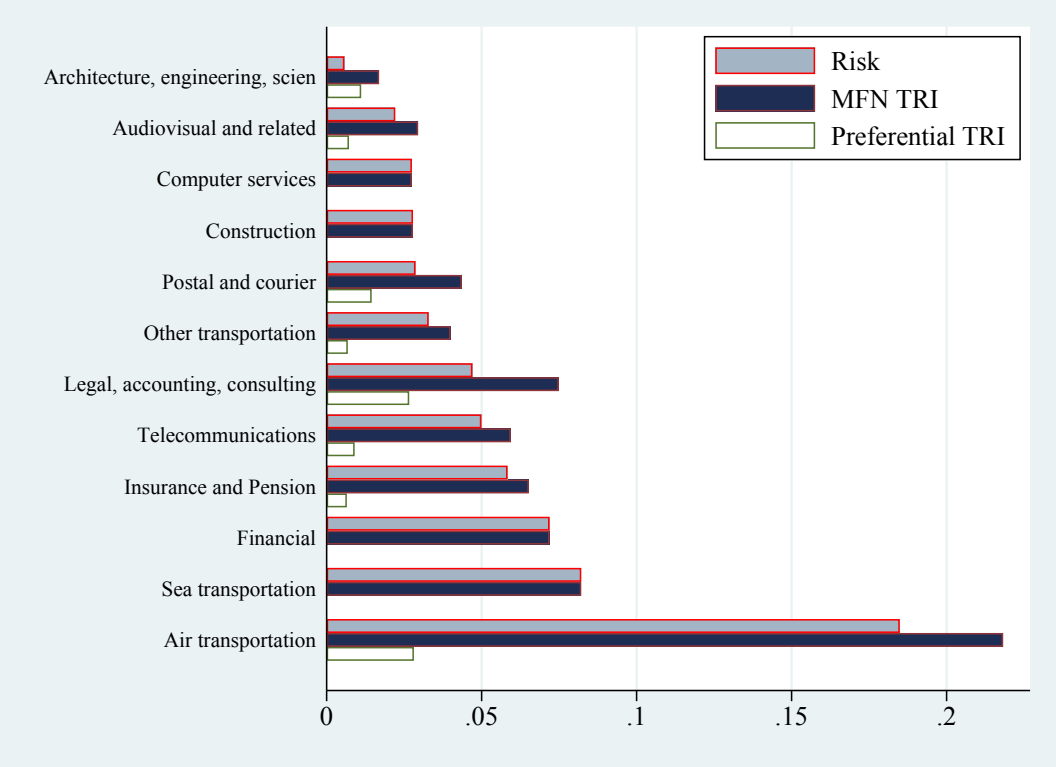
USITC. 2019. "U.S.-Mexico-Canada Trade Agreement: Likely Impact on the U.S. Economy and on Specific Industry Sectors." United States International Trade Commission Investigation Number: TPA 105-003 publication 4889, Washington, DC.

USITC. 2020. "Recent Trends in U.S. Services Trade: 2020 Annual Report." United States International Trade Commission Investigation Number: 332-345 publication 5094, Washington, DC.

Van der Marel, Erik, and Ben Shepherd. 2013. "Services Trade, Regulation and Regional Integration: Evidence from Sectoral Data." *The World Economy*, 36(11): 1393–1405.

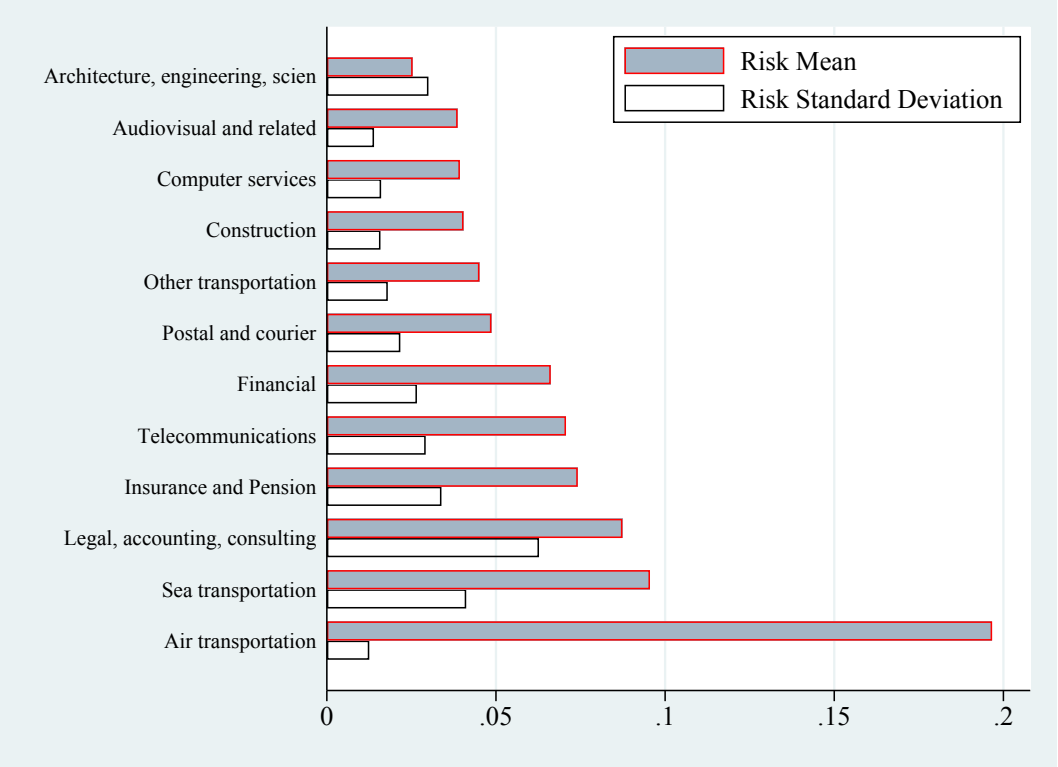
WTO. 2019. "World Trade Report 2019: The Future of Services Trade." World Trade Organization, Geneva.

Figure 1: UK Foreign Entry STRI: MFN, Preferential and Risk Measures



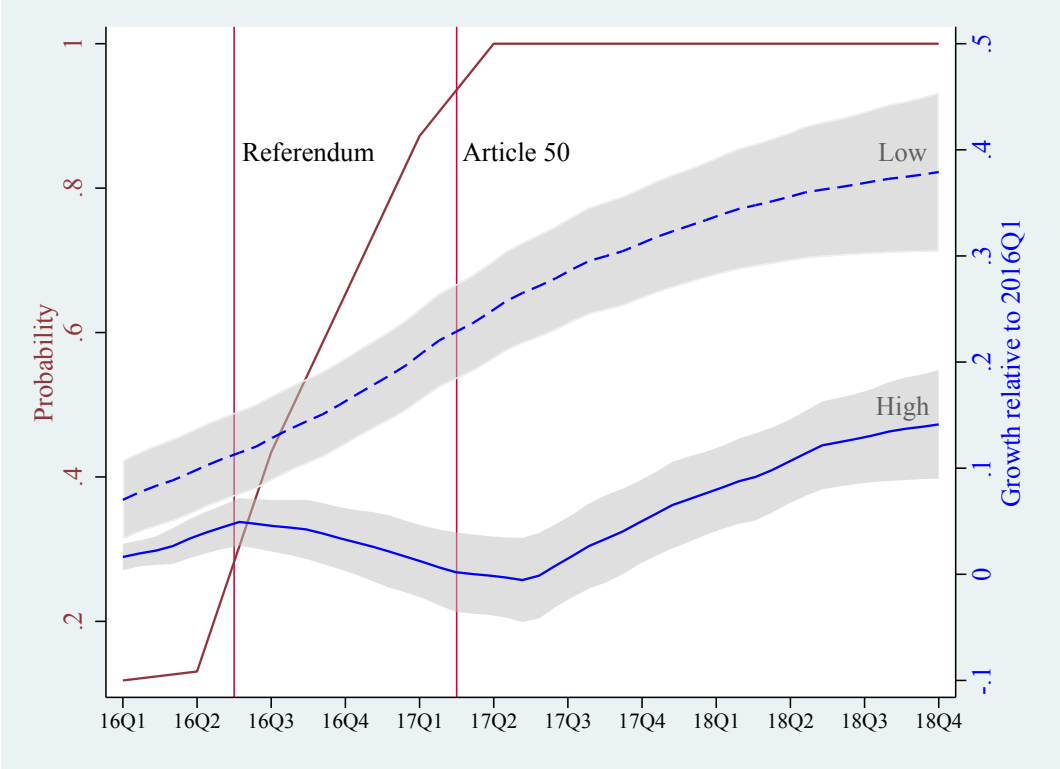
Notes: The MFN and Preferential measures correspond to the OECD's STRI and EEA TRI for category 1 in the UK in 2016 and Risk is defined as (STRI-EEA)/(1+EEA).

Figure 2: EU Foreign Entry STRI: Risk Measures



Notes: Risk is defined as (MFN-EEA)/(1+EEA) for each industry and EU country in the sample; the mean and standard deviation are over those countries.

Figure 3: Brexit Probability and Export Growth of High vs. Low Risk: 2016Q1-2018Q4



Notes: Right hand side measures log difference of bilateral exports at t relative to its 2016Q1 value. Low represents exports in industries with risk below that country's median and high the remaining industries. The dashed and solid lines are first order polynomials over all observations in each of these risk categories with shaded 95% CI. The probability of Brexit (thin line) is the average of contract prices in the quarter from prediction markets described in the text.

Table 1: Regression Data Summary Statistics
Bilateral-Industry in Quarters 2016Q1-2018Q4

Export Values: Continuously Traded Sample					
	Mean	SD	Min	Max	N
Exports (ln)	3.366	1.526	0.00	7.10	2616
STRI category 1	0.081	0.062	0.01	0.31	2616
EEA STRI category 1	0.012	0.014	0.00	0.07	2616
Pr(Brexit) (ln) x Risk	-0.024	0.050	-0.50	0.00	2616
Pr(Brexit) (ln)	-0.464	0.765	-2.14	0.00	2616
Risk	0.052	0.033	0.00	0.24	2616

Export Participation					
	Mean	SD	Min	Max	N
Exported	0.780	0.414	0	1	5748
STRI category 1	0.058	0.036	0.01	0.31	5748
EEA STRI category 1	0.009	0.012	0	0.07	5748
Pr(Brexit) x Risk	-0.023	0.047	-0.50	0.00	5748

Notes: ln(exports) defined at the exporter-importer-industry-quarter level for UK and EU (2015 membership).industries defined by Ebops classification, air transportation excluded as described in text. Pr(Brexit) defined as the probability of a leave referendum and Article 50 invoked. Measured before the referendum as the leave in referendum prediction market contract price averaged within the quarter times the Article 50 probability in July 2016. Measured after the referendum as the probability of Article 50 invoked by end of March 2017 from July 2016 to the end of the sample (averaged over the quarter). We use the ln of this variable. Risk defined as (STRI EEA)/(1+EEA) in 2016.

Table 2: Services Risk and EU-UK (OLS)

	(1)	(2)	(3)	(4)
Dependent Variable	Value (ln)		Participation (0/1)	
End Quarter	2017Q4	2018Q4	2017Q4	2018Q4
Pr(Brexit) x Risk	-1.666***	-1.766***	-0.392***	-0.444***
	(0.33)	(0.36)	(0.10)	(0.11)
N	1,744	2,616	3,832	5,748
R^2	0.96	0.95	0.86	0.83

Notes: All variables defined in Table 1. Value sample is for importer-exporter-service flows traded in all quarters in the sample period. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis.

Table 3: Services Risk and EU-UK (PPML)

	(1)	(2)	(3)	(4)
Sample	Non-confidential		All	
End Quarter	2017Q4	2018Q4	2017Q4	2018Q4
Pr(Brexit)×Risk	-0.610***	-0.875***	-0.563***	-1.240***
	(0.21)	(0.29)	(0.21)	(0.33)
N	2,869	4,466	3,216	4,980
Pseudo R^2	0.95	0.94	0.94	0.94

Notes: All variables defined in Table 1. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis. "Non-confidential" sample excludes positive traded omitted from data due to confidentiality reasons. "All" sample includes the confidential observations by imputing any such omitted flow for exporter-UK-service-quarter with the min(UK-service-quarter) over all EU exporters and UK-importer-service-quarter with the min(UK-service-quarter) over all EU importers. PPML drops singletons so sample is smaller than participation.

Table 4: Services Risk and EU-UK (IV)

	(1)	(2)	(3)	(4)
Dependent Variable	Value (ln)		Participation (0/1)	
End Quarter	2017Q4	2018Q4	2017Q4	2018Q4
Pr(Brexit) x Risk	-4.656***	-4.360***	-0.995***	-1.163***
	(1.06)	(1.14)	(0.35)	(0.36)
N	1,744	2,616	3,832	5,748
First Stage F-Stat	24.0	22.0	42.3	38.8

Notes: All variables defined in Table 1. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis. IV instruments the risk variable with the median STRI in each service industry in 2016 across USA, Japan, Australia and Canada. The first stage F-stat is the Kleibergen-Paap Rk Wald F statistic and high values reject the weak instrument correlation null.

Table 5: Brexit Uncertainty Impacts at Average Risk

	Export		Participation	
	OLS	IV	OLS	IV
Uncertainty Elasticity	-0.093	-0.23	-0.028	-0.073
Referendum Effect (log points)	-12.1	-29.8	-3.6	-9.5
Referendum + Art 50 Effect (log points)	-19.8	-48.8	-5.9	-15.6

Notes: OLS and IV use the long sample specifications in Tables 2 and 4. We compute changes in probabilities relative to 2016Q1 using 2016Q3 (referendum effect) or post 2017Q2 (referendum + Art. 50). The mean risk used to calculate the elasticities is the one listed in the respective samples in Table 1. For participation the elasticity divides the coefficient by the mean of the dependent variable.

A Appendix

A.1 Supplementary Tables

Table A1: Risk by Industry-UK and EU Services Trade

industry	Fraction of Trade (2016Q1)	Risk		
		Mean	SD	CV
Air transportation	0.173	0.191	0.011	0.056
Architectural, engineering, scientific and other	0.029	0.016	0.023	1.494
Audiovisual and related	0.008	0.030	0.013	0.422
Computer	0.080	0.033	0.013	0.381
Construction	0.021	0.034	0.013	0.374
Financial	0.283	0.069	0.019	0.273
Insurance and Pension	0.055	0.066	0.025	0.377
Legal, accounting, management consulting, PR	0.174	0.067	0.048	0.720
Other modes of transportation	0.023	0.039	0.014	0.360
Postal and courier	0.016	0.039	0.018	0.472
Sea transportation	0.061	0.088	0.028	0.313
Telecommunications	0.077	0.060	0.023	0.381

Notes: Trade shares reflect the aggregate of all non-confidential values in 2016Q1 between UK and all EU in sample. The risk measure applies to the same sample, which differs from the participation sample due to any confidential values.

Table A2: Services Risk and UK-EU Robustness Timing (Moving Average)

	1	2	3
Dependent variable	Value (ln)	Participation (0/1)	Value
Estimation	OLS	OLS	PPML
Pr(Brexit MA)×Risk	-1.753	-0.436	-1.272
	(0.347)	(0.105)	(0.331)
N	2,616	5,748	4,980
R^2	0.952	0.833	0.938

Notes: Pr(Brexit MA) uses the ln of a centered 3 month moving average of probabilities described in Table 1. All other variables defined in Table 1. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis.PPML drops singletons so sample is smaller than participation. PPML sample includes imputed confidential data as described in Table 3 (results similar if we drop imputed values).

Table A3: Services Risk and UK-EU Robustness to Other Barriers

	1	2	3	4	5	6
Dependent variable	Value (ln)		Participation (0/1)		Value	
Estimation	OLS		OLS		PPML	
Pr(Brexit)×Risk	-1.766	-1.999	-0.444	-0.408	-1.240	-2.510
	(0.363)	(0.420)	(0.109)	(0.126)	(0.333)	(0.416)
Pr(Brexit)×Risk Aggregate		0.315		-0.043		1.044
		(0.283)		(0.088)		(0.181)
N	2,616	2,616	5,748	5,748	4,980	4,980
R2	0.952	0.952	0.833	0.833	0.938	0.938

Notes: All variables defined in Table 1. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis.PPML drops singletons so sample is smaller than participation. PPML sample includes imputed confidential data as described in Table 3 (results qualitatively similar if we drop imputed values).

Table A4: UK and EU Risk - Robustness to Unobserved Industry Trends and Correlation

	1	2	3	4	5	6
Dependent variable	Value (ln)		Participation (0/1)		Value	
Estimation	OLS		OLS		PPML	
Pr(Brexit)×Risk	-1.766	-0.870	-0.444	-0.175	-1.240	-0.705
	(0.403)	(0.347)	(0.163)	(0.116)	(0.361)	(0.303)
Additional industry-Quarter Cluster	x		x		x	
Additional industry-Time Trend FE		x		x		x
N	2,616	2,616	5,748	5,748	4,980	4,980
R2	0.952	0.958	0.833	0.845	0.938	0.940

Notes: All variables defined in Table 1. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis.PPML drops singletons so sample is smaller than participation. PPML sample includes imputed confidential data as described in Table 3 (results qualitatively similar if we drop imputed values).

Table A5: Services Risk and UK-EU Robustness industry (Air Transport)

	1	2	3
Dependent variable	Value (ln)	Participation (0/1)	Value
Estimation	OLS	OLS	PPML
Pr(Brexit)×Risk	-0.566	-0.231	-0.364
	(0.185)	(0.048)	(0.119)
N	2,952	6,276	5,448
R2	0.956	0.841	0.941

Notes: All variables defined in Table 1. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis.PPML drops singletons so sample is smaller than participation. PPML sample includes imputed confidential data as described in Table 3 (results qualitatively similar if we drop imputed values).

Table A6: Services Risk and UK-EU Heterogeneity

	1	2	3
Dependent variable	Value (ln)	Participation (0/1)	Value
Estimation	OLS	OLS	PPML
Pr(Brexit)×Risk	-0.899	-0.435	-0.927
	(0.367)	(0.128)	(0.334)
Pr(Brexit)×Risk×EU Exporter	-2.685	-0.025	-1.790
	(0.660)	(0.239)	(0.935)
N	2,616	5,748	4,980
R2	0.952	0.833	0.938

Notes: All other variables defined in Table 1. All specifications include exporter-importer-industry, exporter-importer-quarter fixed effects. Robust standard errors clustered at the importer-industry-quarter level in parenthesis. PPML drops singletons so sample is smaller than participation. PPML sample includes imputed confidential data as described in Table 3 (results qualitatively similar if we drop imputed values).

A.2 Data construction

This Appendix provides additional detail on services trade data, the STRI and the construction of our data set. First, as defined in the WTO General Agreement on Trade in Services (GATS), there are four modes of services trade, which are defined based on the location of the supplier and consumer:

- **Mode 1:** cross-border supply (typically via the internet). The service is traded from supplier to consumer without either party physically moving across borders. For example, an architect in one country emails a digital version of their plans to a foreign client. Mode 1 trade also includes the transportation of goods from one country to another (excluding the value of the goods).
- **Mode 2:** consumption abroad. A consumer from one country travels to another country to consume services, such as a tourist staying at hotels and purchasing food while on vacation in a foreign country.
- **Mode 3:** commercial presence. A services provider sets up a local affiliate to sell services in a foreign country.
- **Mode 4:** temporary presence of natural persons. A services provider temporarily sends a representative to another market to perform a service. For example, an engineering firm could temporarily send engineers to another country to advise local staff on a construction project.

Typically, cross-border data collected through balance of payments statistics, including the ONS data we use in this paper, covers trade in modes 1, 2, and 4. Since this data is survey-based, it is often difficult to break cross-border services data into the three modes it comprises. Recently, Mann and Cheung (2019) report on efforts to estimate cross-border trade by mode of supply using survey data in the US and UK. Among the industries covered in our data, the UK Office of National Statistics estimates show that mode 1 trade makes up the majority of cross-border trade for every services industry except construction.[30]

While the quarterly cross-border UK services trade data covers 32 extended balance of payments service categories, the OECD STRI industry coverage is more limited. Table A7 shows the correspondence between OECD STRI industries and EBOPS codes used in this paper. The STRI industries are based on International Standard Industrial Classification (ISIC) categories, while the trade data is based on Extended Balance of Payments services (EBOPS) codes. We concorded these by matching the descriptions in each of the classifications. For example, the commercial banking STRI corresponds to ISIC codes 6419-Other (non-central bank) monetary intermediation, 6492-Other credit granting, and 6491-Financial leasing. When matching to EBOPS we looked for trade flows that similarly, did not cover non-loan based financial services, such as hedge funds. Thus, commercial banking was matched to EBOPS 7.1, rather than EBOPS 7. In some cases, such as legal and accounting services, the STRI is more disaggregated than the trade data. In these cases,

[30]See USITC (2020) for a more detailed discussion of services trade data and various efforts to measure services trade by mode of supply

Table A7: Correspondence between extended balance of payments (EBOPS) industry codes and STRI industries

EBOPS Description	EBOPS Code	Corresponding STRI Industries
Sea transportation	3.1	Maritime transport
Air transportation	3.2	Air transport
Other modes of transportation	3.3	Road transport; rail transport; logistics services
Postal and courier services	3.4	Courier
Construction	5	Construction
Insurance and Pension	6	Insurance and pension services
Explicitly charged and other financial services	7.1	Commercial banking
Telecommunications services	9.1	Telecommunications; broadcasting
Computer services	9.2	Computer services
Legal, accounting, management consulting and public relations	10.2.1	Legal services; accounting services
Architectural, engineering, scientific and other technical services	10.3.1	Architectural services; engineering services
Audiovisual and related services	11.1	Motion pictures; sound recording

we average the STRI value across all sub-industries in the category. The match is further restricted by unavailability of the STRI for the following industries: travel services, charges for the use of intellectual property, research and development services, or personal, cultural, and recreational services.

Table A8: Discriminatory measures by STRI category (percent)

	Restrict. foreign entry	Restrict movt. of people	Other disc. measures	Barriers to competition	Regulatory transparency
Air transport	100	100	92	20	0
Architecture, engineering	80	84	83	45	0
Commercial banking	77	100	57	10	0
Computer	100	100	75	40	0
Construction	100	93	80	40	0
Insurance	86	100	67	11	0
Legal, account., consulting	79	95	83	50	0
Other transport	93	100	84	13	0
Postal and courier	82	100	75	10	0
Sea transport	100	100	95	22	0
Telecommunications	100	100	67	8	0
Average	91	97	78	24	0

Note: Data unavailable for audiovisual services. Counts of discriminatory measures by STRI category were compiled from industry-specific STRI construction methodology papers, available at `www.oecd.org/trade/topics/services-trade/`.

One of the challenges of using the OECD STRI is that it includes measures that explicitly discriminate against foreign firms (such as foreign equity restrictions) along with measures that affect all firms in the market (such as total cost to register a company). While the MFN STRI does provide a breakout of the STRI by discriminatory and non-discriminatory measures, that data is not available for the EEA STRI. In order to account for this, we used industry-specific documentation for the MFN STRI to calculate the share of barriers by category that are considered discriminatory by the OECD. These barrier shares are reported in appendix table A2. Overall, discriminatory measures are concentrated in the first two categories: restrictions to foreign entry and restrictions to movement of people. On average, 91 percent of the measures catalogued in restrictions to foreign entry are discriminatory, while 97 percent of the barriers to movement of people are discriminatory. Based on these classifications, in our main specification, we focus on restrictions to foreign entry.

A.3 Discriminatory Effects of STRI in a Standard Gravity

In this section, we use a standard gravity framework to determine how services trade vary with STRI in a sample that excludes EU-UK flows. We have two goals. First, to show that category 1 of the STRI is relevant and generates discriminatory effects even conditional on other STRI (as we show in the baseline for the EU-UK). Second, to provide an estimate that allows us to gauge how reasonable our uncertainty impacts are. Specifically, whether changes in the STRI that would occur under a no-deal Brexit can generate large enough changes in trade. Our model predicts that the uncertainty elasticity is lower than that of a deterministic change in the STRI; so if the STRI in this sample, which is MFN, is less uncertain than the preferential STRI between the UK and EU, the estimates in this appendix can provide an upper bound on possible uncertainty effects.

We utilize the newly released International Trade and Production Database for Estimation (ITPD-E) (Borchert et al., 2020), which provides bilateral international trade and domestic trade data for service industries from 2000 to 2016.[31] A concordance is performed between the ITPD-E, which follows the ISIC rev. 4 classification, and the data from the UK's Office of National Statistics—classified under a Balance of Payments system. This ensures that we use the same service categories here and in the uncertainty-augmented gravity in the text. We start the analysis in 2014: the first year the STRI is available.

In order to use only MFN STRIs we must go beyond cross-border trade data and explore internal trade. The reason is that MFN STRIs are importer-specific and preclude controlling for unobserved importer heterogeneity, which is essential in standard gravity estimation. By adding information on intra-national trade we can identify the differential impact of MFN STRIs on international trade even after conditioning on importer and exporter fixed effects. Benz (2017) applies this approach to show that increases in the STRI are associated with lower trade between OECD countries. We rely on a similar gravity equation for our analysis:

$$R_{ixVt} = \exp(\beta_1 STRI_{iVt} \times Brdr_{ix} + \beta_2 Brdr_{ix} + \beta_3 FTA_{ixt} + \phi_{ix} + \lambda_{iVt} + \eta_{xVt}) \times \mu_{ixVt} \quad \text{(A.1)}$$

where R_{ixVt} is the value of country x exports to country i in industry V and year t, FTA_{ixt} is a preferential trade agreement dummy, η_{xVt} and λ_{iVt} are the exporter-sector-year and importer-sector-year fixed effects to capture multilateral resistance terms and ϕ_{ix} is a linear function of common bilateral determinants of trade.[32] Lastly μ_{ixVt} is the multiplicative error term.

The coefficient of interest is β_1 and it is identified using the interaction of the STRI score of country i in V at t with a dummy equal to one if the flow is international. Table A9 reports the estimates for (A.1) using annual services data between 2014-16. To match the empirical exercise in section 4, we estimate the model using OLS. In order to avoid any of our estimates being impacted by Brexit uncertainy, we exclude all intra-EEA flows.

Column (1) uses only cross-border flows and thus can only identify bilateral determinants, not the STRI. We use it to verify that distance, contiguity, common official language, colonial relationships and trade agreements all have the expected sign and significance for services in

[31] The data is publicly available at `https://usitc.gov/data/gravity/index.htm`

[32] These are distance, contiguity, common official language and colonial relationships; these and the FTA dummy are from the USITC's Dynamic Gravity Dataset (Gurevich and Herman, 2018).

this sample.

In column (2), we add intra-national flows and estimate the STRI-1 effects. First, we find that international trade is about 500 lp lower than intra-national trade, even after controlling for distance. Second, this international penalty is magnified by policy restrictions. An increase in the STRI-1 from zero to one (moving from an open to a closed economy) lowers international trade by an additional 600 lp.

What does the estimate in column (2) imply for more reasonable increases in the STRI? An increase from 0.012 (the average STRI-1 in our EU-UK sample) to 0.081 (their average MFN STRI-1 value) implies a 42 log point reduction in services trade. Thus even modest changes in the STRI, such as those under a no-deal Brexit, lead to large trade reductions, which indicates that our uncertainty estimates are plausible.

Column (3) examines the robustness to controlling for additional STRI components as we did in the text. Specifically, we add the interaction of the STRI that includes all five categories and find it does not have a significant effect. The STRI-1 coefficient now represents the differential impact and it is negative and significant. Moreover, the overall magnitude of the STRI-1 effect (from adding the coefficients) is similar to the one in column (2). Both findings support our focus on the STRI-1 measure.

Table A9: Gravity estimates with STRI (2014-16)

	(1)	(2)	(3)
Distance	-0.986***	-0.935***	-0.934***
	(0.05)	(0.07)	(0.07)
Contiguity	0.137	0.138	0.139
	(0.15)	(0.15)	(0.15)
Language	0.327***	0.344***	0.342***
	(0.07)	(0.08)	(0.08)
Colony	0.536***	0.544***	0.548***
	(0.15)	(0.15)	(0.15)
FTA	0.681***	0.533***	0.534***
	(0.11)	(0.12)	(0.12)
Border		-5.017***	-5.296***
		(0.50)	(0.66)
Border × STRI1		-6.078*	-9.633*
		(3.35)	(5.79)
Border × STRI			2.408
			(3.55)
N	16443	17054	17054
Imp-Sec-Year FE	Yes	Yes	Yes
Exp-Sec-Year FE	Yes	Yes	Yes
Intra-trade flows	No	Yes	Yes

Standard errors clustered at importer and exporter level in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$