Deep Integration and Trade: UK Firms in the Wake of Brexit*

Rebecca Freeman Marco Garofalo Enrico Longoni Kalina Manova
Rebecca Mari Thomas Prayer Thomas Sampson†

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Abstract

How does dismantling deep integration affect international trade? This paper provides new evidence on the consequences of disintegration by estimating the impact of Brexit on goods trade by UK firms. The UK's exit from the EU's single market and customs union in January 2021 led to an immediate, sharp drop in both exports and imports with the EU for the average firm. In addition, many exporters and importers stopped trading with the EU entirely. However, heterogeneous firm-level responses to the implementation of trade barriers mitigated Brexit's impact on aggregate trade. The decline in exports was concentrated among smaller firms, but insignificant for the largest firms. Our estimates imply that, in the short run, leaving the EU reduced worldwide UK exports by 6.4% and worldwide imports by 3.1%. The fall in imports was driven by lower imports from the EU, which importers offset by sourcing more from the rest of the world.

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†Freeman, Garofalo, Longoni and Mari: Bank of England. Manova: University College London. Prayer and Sampson: London School of Economics. This work contains statistical data from HMRC which is Crown Copyright. The research datasets used may not exactly reproduce HMRC aggregates. The use of HMRC statistical data in this work does not imply the endorsement of HMRC in relation to the interpretation or analysis of the information. Any views expressed are solely those of the authors and do not represent the views of the Bank of England or state its policy. This paper should not be reported as representing the views of the Bank of England, or members of the Monetary Policy Committee, Financial Policy Committee or Prudential Regulation Committee.

1 Introduction

Brexit was a clash of worldviews: local versus cosmopolitan; the nation state versus internationalism. Central to this clash was a debate over the merits of deep economic integration. That is, of integration that goes beyond tariff reduction through policy commitments aimed at removing non-tariff barriers to trade that arise either at the border or behind-the-border. Members of the European Union (EU) – the world's most ambitious deep integration agreement – pursue deep integration through commitments to abolish customs checks; harmonize economic, trade and regulatory policies, and; allow free movement of labor and capital across borders.

The constraints that deep integration imposes on national policy makers have sparked fierce controversy over the role nation states should play in the global economy. Proponents of deep integration argue that relinquishing some policy control is a price worth paying for higher trade and increased economic efficiency (Baldwin and Wyplosz 2022). Opponents counter that any trade and economic benefits are too small to justify the loss of national sovereignty and democratic accountability that deep integration entails (Rodrik 2011). Brexit exemplifies these tensions. It was not a debate between protectionism and free trade. Both sides professed support for free trade, they simply disagreed over what is needed to make trade free. Advocates of remaining in the EU argued that membership of the EU's single market and customs union reduces non-tariff barriers, leading to substantially higher trade. By contrast, supporters of Brexit claimed that free and frictionless trade could be achieved through traditional trade agreements without the need to cede sovereignty to the EU.

This paper uses Brexit as a natural experiment to study the empirical question at the heart of arguments over deep integration: how does deep integration affect international trade? Working with firm-level goods trade data for the UK, we analyze both the direct effects of Brexit on trade with the EU and any indirect effects on trade with non-EU countries. Our estimates imply that the UK's exit from the EU's single market and customs union at the start of 2021 led to immediate declines in exports and imports with the EU. However, we also show that firms responded to this shock in ways that dampened the fall in overall trade. Large firms did not experience a drop in exports, while importers partly compensated for lower EU imports by sourcing more from outside the EU. Consequently, we find that, at least in the short run, aggregate trade proved moderately resilient to disintegration.

The UK voted to leave the EU in June 2016. This vote created substantial uncertainty, but it did not lead to any trade policy changes until January 2021 when the Trade and Cooperation Agreement (TCA) governing post-Brexit UK-EU relations came into force. The TCA is a zero-tariff, zero-quota free trade agreement. However, under the TCA the UK is no longer a member of the EU's single market or customs union, which has led to the reintroduction of a customs and

regulatory border between the UK and the EU. This means that the TCA has raised non-tariff barriers to UK-EU trade, potentially increasing variable, fixed, and sunk trade costs. Our empirical analysis estimates the effect of Brexit on trade both during the period of uncertainty about UK-EU relations that lasted until the end of 2020, and following the reduction in integration that occurred under the TCA from 2021 onwards.

An unavoidable challenge when studying Brexit and trade is that the UK's exit from the EU's customs union led to a change in how UK-EU trade data is collected (see Section 3 for details). This change expanded the set of firms covered by UK trade data, leading to an increase in observed trade, and generating an upwards bias in estimates of the trade effects of the TCA that are based on either aggregate or product-level data. Working with firm-level data allows us to avoid this source of bias by analyzing variation in trade within-firms that are observed both before and after the change in data collection. Using firm-level data also allows us to uncover important heterogeneities in how different types of firms were affected by the TCA.

To identify the causal effect of Brexit on firm-level trade, we start by estimating regressions that compare changes in trade with the EU versus the rest of world (RoW) within firms from 2012-22. These *regional differences regressions* include a stringent set of fixed effects and controls that capture changes in trade due to shocks other than Brexit. In particular, we absorb firm-specific shocks that affect trade with all countries using firm-time fixed effects, and we control for region-specific shocks to export supply and import demand using EU and RoW trade with countries other than the UK. We estimate both differences-in-differences and event-study specifications, and examine whether key milestones in the Brexit process – particularly the referendum and the TCA – changed UK trade with the EU relative to the RoW.

We find no evidence of a significant decline in either exports or imports with the EU relative to the RoW prior to the implementation of the TCA in 2021. This finding implies that the uncertainty and anticipation of future increases in trade barriers generated by the referendum did not reduce relative trade with the EU. Comparing our estimates with evidence that lower uncertainty boosts trade suggests that increased uncertainty does not have the opposite effect on trade of reduced uncertainty. In particular, when faced with uncertainty over future trade cost increases, firms that have paid the sunk costs of exporting may prefer to wait until uncertainty is resolved before changing their relationships with foreign buyers and suppliers.

By contrast, we find that trade responds immediately when the TCA comes into effect in 2021. We estimate that both exporters and importers experience a sharp and sustained fall in trade with the EU relative to the RoW from the start of 2021 onwards. This fall is driven by smaller firms, particularly for exports. Splitting the sample into quintiles defined by firm employment, we estimate that the TCA reduced relative EU exports by 30% for the smallest quintile of firms and 15% for the middle quintile, but did not have a statistically significant effect on exports amongst the

largest quintile. For imports, the estimated decline is 27% for the smallest quintile, 21% for the middle quintile, and 14% for the largest quintile of firms.

We also find that the declines in exports and imports under the TCA are larger for firms that trade products with higher EU most-favored nation (MFN) tariffs. This result may seem surprising given that the TCA is a zero-tariff trade agreement. However, UK-EU trade that does not satisfy the TCA's rules of origin is subject to MFN tariffs. In addition, the MFN tariff is an observable product-level proxy for EU protectionism. Therefore, it is likely to be correlated with unobserved variation across products in non-tariff trade barriers under the TCA. For example, the heavily protected agriculture sector has high MFN tariffs, but also more stringent customs checks due to sanitary and phytosanitary measures.

The regional differences estimates show that the reversal of deep integration under the TCA had a direct negative effect on the UK's trade with the EU relative to the RoW. Importers sourced relatively less from the EU, and small and medium-sized firms experienced a relative decline in EU exports. The size heterogeneity of the export effect is consistent with a model where disintegration under the TCA raises variable trade costs, but firms can pay a fixed cost – such as hiring staff dedicated to export logistics – to avoid the variable cost increase. Larger firms choose to pay the fixed cost and their exports are unaffected on the intensive margin. Smaller firms do not pay the fixed cost, meaning that their exports decline.

Although the direct effect of Brexit was to increase trade barriers with the EU, it may also have indirectly affected UK trade with the RoW. Indirect effects could arise through many channels including supply chain linkages between trade with the EU and trade with the RoW, interdependencies across origins in import sourcing decisions, scale effects, and capacity constraints in production. To study whether Brexit had such indirect effects, we estimate *levels regressions* that analyze changes over time in the level of firms' trade with the RoW. We identify level effects using variation across firms in exposure to Brexit, where exposure is measured by trade with the EU prior to the referendum. Distinguishing between export exposure and import exposure, and estimating the impact of exposure on both exports and imports, allows us to disentangle the different channels through which indirect effects may occur.

The levels estimates provide no evidence that Brexit-related uncertainty and anticipation effects impacted RoW trade prior to 2021. In addition, we cannot reject the hypothesis that Brexit had no effect on exports to the RoW under the TCA. This null result means that any impact of the TCA on UK exports through supply chain linkages, scale effects or capacity constraints was too small to be detectable in our regressions. It also confirms that the decline in EU relative to RoW exports estimated in the regional differences regressions was driven by a fall in exports to the EU.

However, we do estimate that firms with higher pre-referendum EU imports increased their imports from the RoW under the TCA. This implies that the TCA caused importers to substitute

from EU to RoW suppliers, which highlights the importance of cross-origin interdependencies in import sourcing. That said, the increase in imports from the RoW does not fully compensate for the decline in imports from the EU. In regressions with world imports as the dependent variable, we estimate that a ten percentage point increase in a firm's share of EU imports in total imports pre-referendum leads to a 0.6% decline in world imports under the TCA. This fall is consistent with imperfect substitutability across import suppliers, though it could also result from sourcing complementarities leading to a reduction in total import demand.

Reversing deep integration may not only affect the intensive margin of trade for firms that continue trading, but also lead some firms to exit foreign markets altogether. To examine this possibility, we undertake an extensive margin analysis of firms' export and import survival. In the *trade survival regressions*, we do not find significant extensive margin Brexit effects before the TCA comes into effect. However, we do find that the TCA reduced the survival rate for exporters to the EU and importers from the EU, especially for smaller firms, which we interpret as evidence that the TCA increased fixed trade costs. Our estimates imply that the TCA caused around $16,400$ firms (or 14% of EU exporters) to stop exporting to the EU.

We conclude the paper with a back-of-the-envelope aggregation exercise that combines estimates from the regional differences, levels and trade survival regressions. Our results imply that the TCA reduced total UK goods exports by 6.4% and total goods imports by 3.1%. The exports number accounts for both intensive and extensive margin effects, with the intensive margin playing the larger role. The decline in imports only includes intensive margin adjustments; work on incorporating the extensive margin is ongoing. These estimates imply that, although disintegration under the TCA undoubtedly decreased trade, the decline was not large and, at least in the short run, was smaller than forecasters expected.[1] For exports, the relatively small aggregate impact reflects our finding that the negative effects of the TCA were concentrated on smaller firms, while the largest firms successfully maintained export levels. And, for imports, substitution towards imports from outside the EU partially offset reduced EU imports. These firm-level adaptations to the customs and regulatory barriers introduced by the TCA increased the resilience of overall trade to Brexit.

Our research contributes to several literatures. Despite the rising prevalence of deep trade agreements, evidence on the effects of deep integration is much more limited than the literature on tariff policy. A theoretical literature analyzes the political economy of deep integration agreements (Maggi and Ossa 2021), while empirical work has sought to estimate the impact of deep integration on trade. An important challenge for this work has been the difficulty of disentangling

[1]The UK's official economic forecaster – the Office for Budget Responsibility (OBR) – predicted Brexit would reduce UK trade by 15% (OBR 2021) in the long run. This forecast was informed by predictions that an agreement similar to the TCA would reduce UK-EU trade by around 30%, while having little effect on trade with the RoW (e.g. Bevington et al. 2019).

deep integration from other policy variation. For example, Eastern European countries that joined the EU following the collapse of the Soviet Bloc implemented market-based economic reforms over a decade or more, while also gradually integrating with the EU's economic institutions. And preferential trade agreements typically combine tariff cuts with measures to promote deeper integration across a wide array of policy areas, such as cross-border capital and labor flows, intellectual property rights, environmental standards, and public procurement (Mattoo et al. 2020).

Recent work has made progress in addressing this challenge by exploiting the World Bank's Deep Trade Agreements database, which provides the first systematic mapping of the breadth and depth of preferential trade agreements (Hofmann et al. 2017, Mattoo et al. 2020). Several studies document positive effects of deeper integration on aggregate and industry-level trade (e.g. Dhingra et al. 2021, Mattoo et al. 2022), while a smaller number of papers analyze firm-level effects. Fernandes et al. (2021) find that including more sanitary and phytosanitary, and technical barriers to trade provisions in preferential trade agreements boosts firm-level exports, with bigger effects for smaller firms. By contrast, Neri-Lainé et al. (2023) conclude that the increase in trade from deeper agreements is greater for larger firms and negative for small firms.

Yet the existing literature provides no evidence on the consequences of leaving a deep integration agreement such as the EU because, prior to Brexit, it had never happened. Previous research on disintegration and trade has studied the break-up of Czechoslovakia, Yugoslavia, and the Soviet Union (Djankov and Freund 2002, Fidrmuc and Fidrmuc 2003), the end of the Austro-Hungarian empire (De Ménil and Maurel 1994) and decolonization (Head et al. 2010). But none of these events involved an industrialised economy leaving a modern deep integration agreement. Ex-ante analysis of Brexit was mostly premised on the view that deep integration has large, positive effects on trade, and by necessity had to rely on assumptions about how leaving the EU would affect trade costs (Sampson 2017).

Our paper is the first to use UK firm-level data to study the TCA, which has three major advantages. First, our estimates are not biased by the changes in data collection for UK-EU trade. Prior estimates of the TCA's effect on UK exports to the EU relative to the RoW using aggregate or product-level data find very little or no effect (Freeman et al. 2022, Gasiorek and Tamberi 2023). Our analysis shows that these estimates have a positive bias because the change in how UK-EU trade data is collected increased measured trade with the EU. Second, we are able to study how different types of firms are affected by the TCA, and we document important heterogeneity across the firm size distribution. And third, we can exploit firm-level variation in Brexit exposure to identify whether the TCA has indirectly affected trade with countries outside the EU.

Two concurrent papers reach differing conclusions about the effects of Brexit on trade using firm-level data for Spain and Ireland, respectively. De Lucio et al. (2024) find that the TCA reduced Spanish firm-level trade with the UK, while Elsner et al. (2024) argue that Brexit had no

effect on Irish exporters. By contrast, we analyze the impact of Brexit on UK trade with both the EU and the RoW, which provides a more comprehensive picture of the overall trade effect and its mediating mechanisms. Our estimates of the impact of the TCA on UK trade are considerably smaller than the results of papers that have compared changes in UK trade with the EU to trade growth in other countries (Du et al. 2024, Kren and Lawless 2024). Unlike our identification strategy, this alternative approach does not assess the relative growth of the UK's trade with the EU versus with the RoW. Consequently, it cannot disentangle the impact of the TCA from other contemporaneous shocks that may have had country-specific effects, such as Covid-19, Russia's invasion of Ukraine, and political turmoil in the UK.

Our estimates also provide novel evidence on how uncertainty over the timing and extent of disintegration affects trade. Crowley et al. (2019) and Graziano et al. (2021) estimate that Brexit-induced uncertainty affected firm exit and product-level goods trade, respectively. Our analysis implies that these changes did not lead to a significant decline in EU relative to RoW trade before the TCA came into effect. This finding is consistent with Steinberg (2019) who studied Brexit using a dynamic trade model and predicted that uncertainty about post-Brexit trade policies would have little effect on UK trade and macroeconomic outcomes before changes in trade policy were implemented. Likewise, Broadbent et al. (2024) argue that the short-run macroeconomic effects of the referendum were driven by the expectation of a future slowdown in tradable sector productivity growth, but that tradable sector output growth would not decline until the productivity shock (i.e. leaving the EU) materialized. In a different context, Alessandria et al. (2024) show that uncertainty and anticipation effects did not reduce US-China trade prior to the 2018 trade war.

Finally, existing evidence shows that voting to leave the EU had negative short-run effects on the UK economy through slower GDP growth (Born et al. 2019), higher imported inflation (Breinlich et al. 2022), and an increase in uncertainty that resulted in lower investment and productivity growth (Bloom et al. 2019).[2] The referendum also led to the dollarization of export invoicing for UK exports to non-EU countries (Garofalo et al. 2024). However, the long-run economic effects of Brexit will depend on the impacts of the TCA, which are yet to be fully realized or empirically quantified. Our findings provide early evidence on how UK firms are adjusting to life outside the EU.

The remainder of the paper is organized as follows. We start in Section 2 by reviewing the Brexit timeline and summarizing the mechanisms through which Brexit may have affected UK trade. Section 3 describes the data we use in the paper. We then present the regional differences estimates in Section 4, the levels regressions in Section 5, and the trade survival analysis in Section 6. Finally, we report the aggregation exercise in Section 7, before concluding in Section 8.

[2]See Dhingra and Sampson (2022) for a review of the literature on the economic effects of Brexit prior to the introduction of the TCA.

2 Brexit and the TCA

2.1 Timeline

In January 2013 Prime Minister David Cameron pledged to hold a referendum on the UK's membership of the EU if the Conservative Party he led won the next general election (Cameron 2013). For the next decade, Brexit dominated political and economic debate in the UK. To understand our analysis, it is useful to divide the period we study into three phases.

The first phase – from 2012q1-2016q2 – covers the years prior to the Brexit vote. During phase one, the prospect of a referendum cast some uncertainty over future UK-EU relations, but it seemed unlikely that the UK would leave the EU. In the twelve months before the referendum, the probability of a leave vote implied by prediction markets fluctuated mainly between 25% and 35%, and never exceeded 45% (Graziano et al. 2021). Yet these expectations proved misguided, and on June 23, 2016 the UK voted 52% to 48% in favor of Brexit.

The leave vote was a major political and economic shock that led to immediate turmoil in financial markets (Breinlich et al. 2018) together with Cameron's resignation as Prime Minster. Crucially, the referendum provided no guidance over when Brexit should occur or what form post-Brexit UK-EU relations should take. Fierce debate over these questions dominated public life for the next four years. As late as the December 2019 general election, it remained uncertain whether the UK would ever leave the EU, let alone what would follow Brexit.[3]

The second phase of our sample – from 2016q3-2020q4 – covers the period after the referendum, but before the start of the new UK-EU relationship. Throughout phase two, and even after the UK formally left the EU on 31st January 2020, the UK remained part of the EU's economic institutions including the single market and customs union. Consequently, phase two was marked not by changes in trade policy, but by shocks to expected future trade policy. These shocks affected both the first and second moments of expectations. Agents expected trade barriers between the UK and the EU to increase, but there was great uncertainty over when any increase would occur and what form it would take (Bloom et al. 2018).

The third phase of our sample – from 2021q1-2022q4 – covers the period after the Trade and Cooperation Agreement governing post-Brexit UK-EU relations came into force on January 1, 2021. The TCA was negotiated during 2020 while countries were struggling with the onset of the Covid-19 pandemic. Throughout the negotiations there was uncertainty over whether any deal would be reached before the status quo period expired at the end of the year; without a deal the UK and EU would have reverted to trading on WTO terms and imposing tariffs on each other's

[3] Options debated for post-Brexit trade relations ranged from trading under World Trade Organization rules without a preferential trade agreement, to remaining in the EU's single market and custom union. Dhingra et al. (2017) analyze the potential economic consequences of different options that were considered.

exports. In the event, agreement was reached on 24 December and the TCA entered into effect eight days later. Unsurprisingly this led to significant trade disruption during the first months of 2021, as both firms and governments adjusted to the new rules.

The TCA is a preferential trade agreement under which there are no tariffs or quotas on any trade between the UK and the EU.[4] However, economic integration under the TCA falls short of the free movement of goods, services and people provided by EU membership. Most importantly, the UK has left the EU's single market and customs union, leading to the reintroduction of customs and regulatory barriers to trade. For goods, these non-tariff barriers include customs checks and paperwork, rules of origin requirements, value-added tax (VAT) on imports, excise duties, sanitary and phytosanitary (SPS) checks on the movement of animals and plants, and the need for exporters to prove regulatory compliance in the destination market (Dhingra and Sampson 2022).

The EU introduced all border controls on UK imports at the start of 2021, whereas the UK is phasing in controls over time. Simplified customs declarations and rules of origin compliance were required starting in 2021, but full customs declarations were not implemented until January 2022. Safety and security declarations and most SPS checks were not introduced during the period we study. Regulatory divergence between the UK and EU was limited during our sample (UKICE 2023), but UK exporters to the EU still faced new conformity assessment requirements from 2021 onwards.

2.2 Mechanisms

Collectively, the non-tariff barriers introduced by the TCA have created a customs and regulatory border between the UK and the EU leading to a reversal of the deep cross-border integration that existed prior to Brexit. In theory, the simultaneous increase in barriers affecting both exports to, and imports from, the EU could affect UK firms through many mechanisms, and lead to changes in their trade with both the EU and the RoW. This section lays out a conceptual framework for thinking through these mechanisms and how they may affect trade.

The first three mechanisms are triggered by UK firms facing higher costs of exporting to the EU, and affect their export activity:

(i) Export cost increase: If exporting to the EU becomes more costly, UK firms are likely to export less to the EU, with no direct effect on exports to the RoW.

(ii) Scale economies: If there are increasing returns to scale at the firm level, lower EU exports

[4]To avoid the need for border checks between Northern Ireland and the Republic of Ireland, Northern Ireland has been accorded a special status under which it effectively belongs to the customs territories of both the UK and the EU and is also part of the EU's single market for goods (Hayward 2021). But, since Northern Ireland accounted for only 2.2% of UK goods trade in 2019 (ONS 2021), we do not separately analyze Northern Irish trade in this paper.

may lead to lower productivity through a reduction in scale. In turn, lower productivity could reduce exports to the RoW.

(iii) Capacity constraints: Lower EU exports may boost a firm's RoW exports if either its production capacity or access to external finance is constrained in the short run, and it chooses to redirect output to other markets.

The next two mechanisms are triggered by UK firms facing higher costs of importing from the EU, and affect their import activity:

(iv) Import cost increase: If importing from the EU becomes more costly, UK firms are likely to import less from the EU, with no direct effect on imports from the RoW.

(v) Imported input substitutability: If importing from the EU becomes more costly, UK importers may switch to sourcing more from the RoW.

The final three mechanisms affect trade with both regions through supply-chain linkages or general-equilibrium adjustments:

(vi) Input costs: Rising import costs from the EU may increase firms' overall input costs and make them less competitive, leading to lower exports to both the EU and the RoW.

(vii) Production scale and sourcing complementarities: If firms export less due to effects operating through channels (i), (ii) or (vi), they will require fewer production inputs and may reduce their imports from both the EU and the RoW.

(viii) General equilibrium: Firm-level adjustments to the TCA may generate general-equilibrium changes in domestic factor costs, input costs, and demand. Such changes would, in turn, affect firms' input sourcing and exports.

These eight mechanisms provide an organizing framework to understand the impacts of the TCA on UK trade. Mechanisms (i) and (iv) are the channels through which changes in UK-EU trade costs have a *direct* effect on trade with the EU. However, their impact can be amplified, dampened, or in principle overturned by the other *indirect* channels. The goal of our empirical analysis is not only to estimate how the TCA has affected firm-level trade, but also to shed light on the role played by each of these mechanisms.

To do this, we examine both changes in trade with the EU relative to the RoW, and changes in the level of trade with either the RoW, or the world as a whole. In addition, we use variation across firms in exposure to EU exports and imports prior to the referendum, to disentangle the different

indirect channels.[5] Because our empirical design exploits variation in trade within and across firms, we will not be able to identify general-equilibrium effects operating through mechanism (viii) that impact firms regardless of their participation in international trade.

The increase in trade barriers under the TCA may have affected variable, fixed and sunk trade costs, leading to changes in both the intensive and extensive margins of exporting and importing. Our main analysis studies intensive-margin adjustments within firms that continue to trade, but we also consider the extensive margin by analyzing export and import survival.

3 Data

The data we use comes from four firm-level UK datasets: customs trade data from the HMRC EU and Non-EU Trade Panel Datasets; VAT data on sales, input purchases and EU trade from the HMRC VAT Returns Panel Dataset, and; firm characteristics from the ONS Interdepartmental Business Register (IDBR). We match these datasets by VAT number, and throughout the paper we refer to unique VAT numbers as firms. This section describes the main features of the data; further details can be found in Appendix A.

3.1 Trade

Our primary dataset is constructed using UK customs data from the HMRC EU and Non-EU Trade Panel Datasets for 2012-22. We label this dataset the 'Customs dataset'. The customs data reports exports and imports in pound sterling by trader ID, CN 8-digit product, partner country and month. We aggregate this data to the firm-region-quarter level, where the regions we use are the EU and the RoW.

UK trade with countries outside the EU is reported via customs declarations. However, since EU members belong to a customs union, firms do not submit customs declarations for intra-EU trade. Instead, trade within the EU is measured using the Intrastat survey. After leaving the EU's customs union, the UK began to collect data on trade with the EU using customs declarations in January 2021 for exports and in January 2022 for imports. Therefore, the source of EU trade data in our Customs dataset switches from Intrastat to customs declarations in 2021 for exports and 2022 for imports.[6] RoW trade data is sourced from customs declarations throughout the sample.

The change in data reporting presents three challenges for studying Brexit. First, switching

[5]For example, if higher import costs reduce exports through supply-chain linkages as in mechanism (vi), the fall in exports will be greater for firms that are more dependent on inputs imported from the EU.

[6]The switch for imports was delayed one year due to the UK phasing in import controls under the TCA. Trade between Northern Ireland and the EU is still collected via Intrastat due to Northern Ireland's special customs status mentioned in footnote 4.

from Intrastat to customs declarations increased measured trade with the EU. Customs declarations cover trade by non-VAT-registered businesses, private individuals and parcel post, none of which are included in the Intrastat survey. In addition, there is evidence that some VAT-registered businesses that trade with the EU did not respond to the Intrastat survey (ONS 2022). The Office for National Statistics (ONS) estimates that the switch increased measured trade by around 5% for exports and 6% for imports (ONS 2022).

This discontinuity means that estimates of the impact of the TCA on UK-EU trade that rely on aggregate or product-level UK data will be biased upwards. The bias results from the expansion in the set of traders covered by the data. Therefore, to avoid this bias, we use estimation strategies that identify Brexit effects exclusively from within-firm variation. Being able to implement such strategies, by exploiting differences in firm-level trade across regions and over time, is an important advantage of working with firm-level data.[7]

The second challenge is that switching from Intrastat to customs declarations led firms to report trading different products and a greater variety of products – presumably because firms are more conscientious in disaggregating the value of trade across products when completing customs declaration than when filling out the Intrastat survey. We document this change in reporting behavior in Appendix B where we show that, for EU trade at the firm-product level, both entry and exit increase under the TCA. Crucially, the spikes in reported entry and exit occur at the start of 2021 for exports and the start of 2022 for imports, implying that they are an artefact of the data collection switch rather than a genuine change in trade. To address this challenge, we limit our use of the product dimension of the trade data so that we never compare product-level trade before and after the switch from Intrastat to customs declarations.

The third challenge is that data reporting thresholds differ between customs declarations and Intrastat. We address this challenge by imposing common thresholds on EU trade data coming from both sources. There are two thresholds to consider. First, when trade data is collected via customs declarations, transactions below £873 are aggregated into a low value trade category and not assigned to individual firms. We will refer to this threshold as the small-transaction threshold. Transactions below this threshold are observed under Intrastat, but not following the switch to customs declarations. This is unlikely to be an important source of bias because the missing transactions account for a small share of overall trade.[8] Nevertheless, to ensure small transactions with the EU are treated consistently throughout the sample, we drop all UK-EU trade observations

[7] An alternative approach to avoiding this bias would be to use the mirror data on UK trade collected by EU countries, e.g. use Spanish data on imports from the UK to measure UK exports to Spain. However, this approach does not resolve the problem as EU countries also switched from Intrastat to customs declarations for collecting UK-EU trade data. In addition, Eurostat changed how it measures imports from the UK from a country of dispatch basis to a country of origin basis at the start of 2021, which led to a downwards jump in measured imports.

[8] In 2022 trade below the small-transaction threshold accounted for 2.9% of total trade in the EU Trade Panel Dataset from which our Customs dataset is constructed.

below £$2,500$ at the firm, 8-digit product, country, month level from the entire panel before aggregating to the firm-region-quarter level. Our results are not sensitive to the choice of threshold below which we drop small transactions.

The second and more substantive difference in reporting thresholds is that the Intrastat survey only includes firms that export at least £0.25 million per year to the EU or import at least £1.5 million per year from the EU.[9] We will refer to the Intrastat thresholds as the small-firm thresholds. To ensure that our estimates are not biased by changes in sample selection after the switch to customs declarations, we impose the small-firm thresholds on EU trade data throughout the sample. Specifically, we drop from the Customs dataset all firm-quarter observations of EU exports in calendar years where a firm's exports to the EU are below the Intrastat threshold of £0.25 million. Likewise, we drop EU imports when imports are below £1.5 million in a calendar year. We also drop all firms that are only observed trading with the EU following the switch to customs declarations.[10]

Because of the small-firm thresholds, our Customs dataset only includes trade with the EU for relatively large traders.[11] Therefore, to estimate the effect of Brexit on smaller exporters and importers, we use VAT data to build a secondary dataset with broader firm coverage. For 2012-19, the VAT Returns Panel Dataset reports each firm's total goods exports to the EU and total goods imports from the EU. By combining this information with customs declarations data on RoW trade and on EU trade under the TCA, we construct a firm-region-year level dataset on trade with the EU and the RoW. We refer to this dataset as the 'VAT+ dataset'.[12] The small-firm Intrastat thresholds do not affect which firms are covered by the VAT+ dataset. However, the small-transaction threshold still applies to trade observed via customs declarations, so we drop all firm-year observations with EU trade below £$10,000$ from the VAT+ dataset. This ensures that the dataset does not include firms with annual trade close to the small-transaction threshold.[13]

The VAT+ dataset is less detailed than the Customs dataset: the frequency is annual not quar-

[9] The choice of thresholds is designed to ensure that Intrastat covers 97% of export value and 93% of import value. The import threshold was £0.6 million in 2012-13, £1.2 million in 2014 and £1.5 million from 2015 onwards. The export threshold did not change during our sample period.

[10] Although not relevant for the analysis in this paper, it is worth noting that all three challenges introduce discontinuities in the set of products that are observed in UK-EU trade. Consequently, research on the product-level extensive margin of trade that compares UK data before and after the switch from Intrastat to customs declarations should be disregarded (e.g. the export product count analysis in our earlier working paper Freeman et al. 2022). The expansion in the set of firms included in the data following the switch to customs declarations also means that we do not observe entry into trade consistently over time. Therefore, we do not study this margin of adjustment to the TCA.

[11] In 2015, only 18% of firms that exported to the EU had EU exports above the Intrastat export threshold, but these exporters accounted for 97% of the total value of exports to the EU. For imports, 6% of EU importers had imports above the Intrastat import threshold, but these firms accounted for 93% of the total value of imports from the EU.

[12] VAT data is reported for fiscal years not calendar years. This means that 2012 data covers 2012q2-2013q1 and likewise for other years. Because the 2020 VAT data covers both the onset of the Covid-19 pandemic and the first quarter of the TCA, we omit 2020 from the VAT+ dataset.

[13] On average across years, we drop 36% of EU exporters and 0.09% of the value of EU exports and we drop 43% of EU importers and 0.07% of the value of EU imports.

terly; it cannot be disaggregated to the product-country level, and; it does not include 2020 data or, for imports, 2021 data. However, since the VAT and customs declarations data used to construct the VAT+ dataset cover the universe of VAT-registered businesses that trade with the EU, the VAT+ dataset has the advantage of covering both small and large traders. We therefore use the Customs dataset in our baseline analysis, and exploit the VAT+ dataset to provide complementary evidence of the effects of Brexit on small firms and on trade survival.

3.2 Other data

We match the trade data in the Customs and VAT+ datasets with firm characteristics from the IDBR and from VAT returns. From the IDBR we obtain each firm's employment, 4-digit SIC industry and country of ownership. We use the employment data to construct a time-invariant measure of firm size defined as average employment between 2013q1 and 2015q4. From VAT returns, we observe each firm's annual sales and input purchases.

To construct the control variables included in our estimation, we use data on other countries' trade, which we obtain from UN Comtrade at the origin country, destination country, HS 6-digit product, month level. We also obtain exchange rate and consumer price data from the IMF International Financial Statistics, which we use to calculate real exchange rates for the UK. Finally, we use several trade policy variables to measure exposure to trade policy changes following Brexit. From the World Bank's WITS platform we obtain data for 2015 on the EU's most-favored nation (MFN) tariffs and non-tariff measures (NTMs). The NTM data comprises indicator variables for whether each CN 8-digit product faces different types of non-tariff barriers such as Sanitary and Phytosanitary Measures or Technical Barriers to Trade. Finally, from the Department for International Trade we obtain the UK's MFN tariffs that were introduced in January 2021 after the UK's departure from the EU's customs union.

3.3 Summary statistics

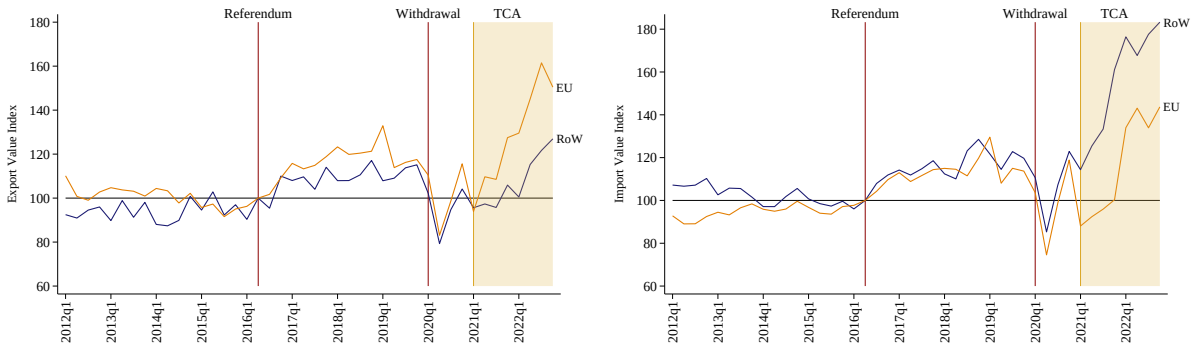
Table 1 reports summary statistics on firm numbers, trade and employment for different subsamples of the Customs dataset. Panel A covers firms that trade with the EU, panel B firms that trade with the RoW, panel C reports statistics on trade with the world as a whole and panel D covers firms that trade with both the EU and the RoW. Because of the small-firm thresholds, firms that trade with the EU are fewer in number and, on average, larger than firms that trade with the RoW. However, once the sample is restricted to firms that trade with both regions in panel D, average annual exports and imports are similar for both EU trade and RoW trade. Appendix Table A1 reports summary statistics for the VAT+ dataset. The most notable differences between the two datasets is that the VAT+ dataset covers more firms, but these firms are, on average, smaller and

trade less.

4 EU versus RoW trade

The main impact of Brexit on trade policy has been to increase trade barriers between the UK and the EU. Therefore, we start our empirical analysis by studying regional differences in the changes in UK trade with the EU relative to UK trade with the RoW during the Brexit process. In general, the regional differences we study depend on both the direct and indirect mechanisms described in Section 2.2. However, in the event that Brexit only has direct effects on trade with the EU through higher export and import costs (mechanisms i and iv), then RoW trade is unaffected, and analyzing regional differences is sufficient to identify the total impact of Brexit on UK trade.

Figure 1 plots aggregate UK goods trade with each region from 2012-22 as reported in HMRC's Overseas Trade Statistics. Exports are in the left-hand panel and imports in the right-hand panel, and all series are indexed to 100 in 2016q2. Trade with both regions displayed similar trends until 2020. However, after the TCA came into force in 2021, exports to the EU increased more rapidly than exports to the RoW, while imports from the RoW grew much faster than imports from the EU.



(a) Exports

(b) Imports

Notes: Total goods trade with EU and RoW in HMRC's Overseas Trade Statistics. Data excludes trade in non-monetary gold and HS Chapters 98 and 99. All series normalized to 100 in 2016q2.

Figure 1: Aggregate trade with EU and RoW: Overseas Trade Statistics

But it would be naive to immediately attribute these differences to Brexit and conclude that the TCA increased exports to the EU while reducing imports from the EU. As discussed in Section 3.1, changes in data collection methods increased measured aggregate trade with the EU in 2021 for exports and 2022 for imports. In addition, the patterns shown in Figure 1 could be due to changes in the composition of trade across products, firm-level productivity shocks that are correlated with exposure to EU trade, or differential supply and demand shocks in the UK's trading partners. For example, commodity price increases following Russia's invasion of Ukraine in February 2022 led

to large increases in the value of the UK's fuel imports from the RoW. Therefore, in order to credibly identify the trade effects of Brexit we move from the aggregate data to firm-level trade.

4.1 Empirical design: regional differences

Our empirical strategy uses regional differences regressions at the firm level to identify Brexit effects. The regional differences regressions compare within-firm changes in trade with the EU relative to the RoW following two Brexit milestones: the referendum in June 2016, and; the implementation of the TCA in January 2021. We use a difference-in-differences specification to estimate baseline average effects of the two milestones. And we complement these average effects with event studies that flexibly trace out the impact of Brexit over time.

Let V_{frt} be the value of firm f's trade (either exports or imports) with region $r = \{EU, RoW\}$ in quarter t. The baseline difference-in-differences equation is:

$$\begin{aligned}\log V_{frt} = {} & \beta_1 Referendum_t EU_r + \beta_2 TCA_t EU_r + \gamma_0 Z_{frt} + \gamma_1 X_{rt} + \gamma_2 B_t EU_r \\ & + \alpha_{fr} + \alpha_{ft} + \alpha_{rs} + \epsilon_{frt}, \end{aligned} \tag{1}$$

where $Referendum_t$ is a dummy for quarters after the referendum that takes value one from $2016q3$ onwards, TCA_t is a dummy for quarters after the implementation of the TCA that takes value one from $2021q1$ onwards, and EU_r is a dummy for the EU region. The equation also includes vectors of firm-level control variables Z_{frt}, region-level control variables X_{rt}, and differential effects of other key events on trade with the EU $B_t EU_r$. Finally, we include fixed effects at the firm-region α_{fr}, firm-time α_{ft}, and region-season α_{rs} level. We cluster standard errors by firm to allow for correlated shocks across regions and over time within firms.[14]

The coefficients of interest in equation (1) are β_1 and β_2. Coefficient β_1 identifies the effect of the referendum outcome on trade with the EU relative to the RoW for the average sample firm by comparing the post-referendum period to the pre-referendum period. If uncertainty and anticipation of future policy changes reduced UK-EU trade following the referendum, we would estimate $\beta_1 < 0$. Coefficient β_2 identifies the effect of the TCA on EU relative to RoW trade for the average sample firm by comparing outcomes before and after the implementation of the TCA. To the extent that the TCA reduced UK-EU trade, we expect to find $\beta_2 < 0$.

The firm-region fixed effects α_{fr} absorb time-invariant differences in how much firm f trades with the EU versus the RoW. The firm-time fixed effects α_{ft} capture firm-level shocks that have

[14] Whenever any of the right hand side variables used in the paper have a missing observation, we set the missing value to zero and include a dummy variable that takes value one for any observations for which the variable is missing. This approach ensures that the sample does not change across specifications that use different control variables.

symmetric effects on the firm's trade with both regions, e.g. changes in the firm's productivity or its input costs. And the region-season fixed effects α_{rs} control for region-specific seasonality in trade, where the seasons are defined as the four quarters of the year.

The event-study counterpart to equation (1) is:[15]

$$\log V_{frt} = \sum_{t=2012q1}^{2022q4} \beta_t EU_r + \gamma_0 Z_{frt} + \alpha_{fr} + \alpha_{ft} + \alpha_{rs} + \epsilon_{frt}. \tag{2}$$

In this case the coefficients of interest β_t identify changes in EU versus RoW trade within firms relative to the four quarters prior to the referendum (which we set as the benchmark periods). We continue to cluster standard errors at the firm level for the event-study estimates.

Controls. B_t is a vector of time-varying dummy variables that capture other events that may have affected EU relative to RoW trade. First, we control for trade shocks due to the onset of the Covid-19 pandemic using a dummy for 2020q1 and 2020q2. Second, we also include a 2021q1 dummy to control for the disruption to UK-EU trade that occurred at the start of 2021. The TCA came into effect on 1 January 2021 only eight days after the negotiations were completed, and this led to a sharp, but temporary, drop in UK-EU trade in January 2021 as traders adjusted to the new rules. Lastly, we account for the fact that firms could delay customs declarations for goods imported from the EU in 2021 by up to 175 days, as part of the phasing in of UK import controls under the TCA. This Staged Customs Controls policy may have resulted in some EU imports from 2021 being reported during the first half of 2022. Consequently, we include a Staged Customs Controls dummy for 2022q1 and 2022q2 in B_t in the imports regressions. Of course, these latter two events were a consequence of Brexit. Nevertheless, we control for them separately to ensure that our estimates capture the persistent impact of the TCA and are not biased downwards by temporary effects.

We choose the region-level and firm-level variables included in X_{rt} and Z_{frt} to control for additional shocks that may have differentially impacted EU versus RoW trade during our sample. Specifically, we include three sets of control variables that are designed to capture: (i) foreign supply and demand shocks; (ii) real exchange rate movements, and; (iii) changes in UK tariffs on non-EU imports.

First, we control for foreign import demand in our export regressions and foreign export supply in our import regressions. These controls are constructed to proxy any changes in the relative importance of the EU and the RoW in global trade that are not due to Brexit. Specifically, in export regressions we include in X_{rt} each region's imports from the world excluding the UK.

[15] Since the region-level controls X_{rt} and the $B_t EU_r$ controls do not vary across firms, they are co-linear with the $\beta_t EU_r$ interactions in the event-study specification. Consequently, when estimating event-study regressions we only include firm-specific controls.

Likewise, in import regressions we control for changes in the export supply capacity of the UK's trade partners using each region's exports to the world excluding the UK. We also include analogous firm-level import demand and export supply controls in Z_{frt}. The firm-level controls are computed by weighting changes in import demand and export supply across country-product pairs using pre-referendum firm-specific trade weights (see Appendix A.4 for details).

Second, we control for movements in the UK's real exchange rate. We use exchange rate and consumer price data to construct quarterly real exchange rate indices for the UK by partner country. We then take the weighted average across countries using total trade weights to calculate a region-level real exchange rate and using firm-specific trade weights to calculate a firm-region level real exchange rate.[16] To allow for exchange rates to affect trade flows with a lag, we include in all regressions the current value and eight lags of the regional and firm-specific exchange rate variables. The import demand, export supply and real exchange rate controls each enter our regressions in log form.

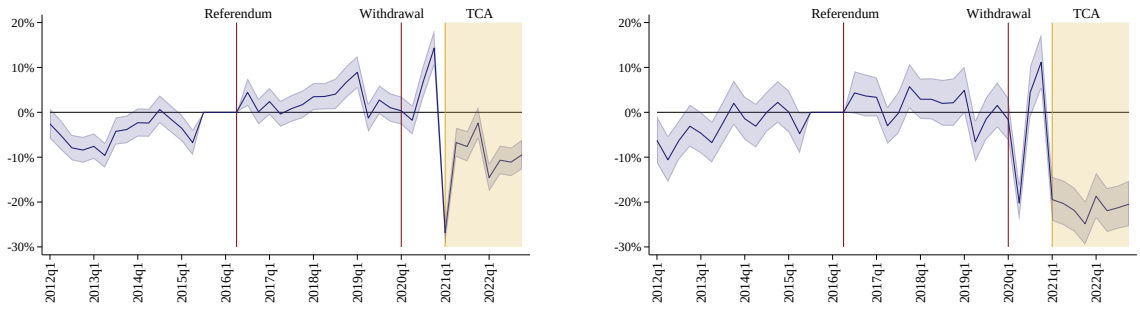
Third, in import regressions we control for the changes in MFN tariffs that the UK implemented in 2021 after leaving the EU's customs union. We construct two firm-specific measures of exposure to tariff changes by taking weighted averages across 8-digit products of ad-valorem tariff changes and indicators for changes to non-ad-valorem tariffs, respectively. Since the tariff changes occurred at the start of 2021 and do not apply to imports from the EU, we set the tariff change exposure variables to zero for EU imports in all periods and for RoW imports in all years before 2021.

4.2 Baseline results

Figure 2 plots event-study results obtained from estimating equation (2) using the Customs dataset and including the firm-level controls. Estimates for exports are shown in the left-hand panel (a) and for imports in the right-hand panel (b). The exports sample includes $23,237$ firms that export to both regions, while the imports sample includes $12,409$ firms. Summary statistics for these samples are shown in panel D of Table 1. The figure plots the event-study coefficients transformed to percentage changes and normalized relative to the four quarters prior to the referendum. The shaded area shows the 95% confidence intervals for the estimates.

Figure 2 provides no evidence of a reduction in EU relative to RoW trade between the referendum in 2016q2 and the start of the TCA in 2021q1. Although the estimates fluctuate from quarter to quarter, there is neither a downwards jump in EU trade after the referendum, nor a gradual decline over time. This implies that uncertainty following the referendum and/or the anticipation of future increases in UK-EU trade barriers did not lead to a fall in firm-level trade with the EU relative to the RoW. The conclusion that uncertainty and anticipation effects prior to 2021 had limited

[16] We use goods export weights to compute the real exchange rates included in export regressions and goods import weights for the import regressions. The region-level real exchange rate is computed using trade weights for 2012.



(a) Exports

(b) Imports

Notes: Event-study estimates showing percent changes in trade with EU relative to RoW from regional differences specification. Shaded area shows 95% confidence intervals computed using standard errors clustered by firm. Estimation uses Customs dataset and includes full set of firm-level controls together with firm-region, region-season and firm-time fixed effects.

Figure 2: Firm trade with EU versus RoW: event study

effects on UK-EU trade will be a consistent theme throughout our analysis. Having said that, the spikes in relative EU trade evident for exports in 2019q1 and 2020q4 and for imports in 2020q4 are likely driven by stockpiling in advance of deadlines for negotiating the UK's withdrawal from the EU in March 2019 and for negotiating the TCA in December 2020 (ONS 2021).[17]

We do see evidence that Covid-19 reduced relative imports from the EU in the first half of 2020. The same was not true of relative exports to the EU. The contrasting effects of the referendum and Covid-19 on trade is consistent with shocks to uncertainty having different effects than shocks to supply, demand or trade costs.

Most importantly, Figure 2 shows that the implementation of the TCA at the start of 2021 led to immediate, large, statistically significant, and persistent declines in trade with the EU relative to the RoW for both exports and imports. The estimates show that relative EU exports fell sharply in 2021q1 amidst the disruption that accompanied the last-minute agreement of the TCA, recovered somewhat during the remainder of 2021, and then stabilized in 2022 at around negative 10%. Relative EU imports declined around 20% in 2021q1 and stayed at that level throughout 2021 and 2022. The stability of the imports estimates during the first half of 2022 suggests that delayed reporting of EU imports due to the Staged Customs Controls policy is unlikely to be an important source of bias.

Table 2 reports results from estimating equation (1) for exports. These regressions are the difference-in-differences counterpart of the event study estimates in Figure 2. Column (a) shows the estimated referendum and TCA effects on EU exports in a specification that only includes

[17]Although Brexit occurred on 31 January 2020, the original deadline for withdrawal negotiations was 29 March 2019. An extension to this deadline was not agreed until late March.

time, firm-region and region-season fixed effects. In column (b) we add firm-time fixed effects and restrict the sample to firms that trade with both regions. Column (c) includes the B_tEU_r variables to control for the differential effects of Covid-19 and trade disruption in 2021q1 on EU exports. Column (d) adds the regional import demand and real exchange rate controls. Finally, column (e) also includes the firm-level import demand and real exchange rate controls. Column (e) is the most stringent specification and, hence, our preferred baseline.

We find that the TCA effect on exports is negative, significant, and stable across specifications. Column (e) implies that the TCA reduced exports to the EU relative to the RoW by 14% for the average exporter in the sample. By contrast, the Referendum effect is positive and significant in columns (a)-(c), but becomes insignificant and close to zero once the region-level controls are included. Consistent with the event study estimates, this result implies that Brexit had no effect on EU relative to RoW exports prior to the implementation of the TCA.

Table 3 reports analogous estimates for imports. Again the TCA effect is negative across all specifications, although the magnitude of the decline is larger than for exports. The estimate in column (e) implies that the TCA reduced imports to the EU relative to the RoW by 21% for the average importer in the sample. And, as in Table 2, the Referendum effect is positive when the region-level controls are absent, but insignificant when they are included.[18]

In Appendix C.1 we confirm the robustness of the baseline results in Tables 2 and 3. We show that our findings are robust to: alternative ways of defining the import demand and export supply control variables; dropping non-EU countries with which the UK has a preferential trade agreement from the RoW region; imposing the small-firm thresholds on trade with the RoW, and; dropping firms in the agriculture and food sectors from the sample. Together with the results in Figure 2 and Tables 2 and 3, these findings provide compelling evidence that the TCA decreased both exports and imports with the EU relative to the RoW for the average firm. Next, we examine whether Brexit has had heterogeneous effects across firms.

4.3 Firm size heterogeneity

Does the impact of Brexit on trade differ for small versus large firms? To address this question, we allow the Referendum and TCA effects in the regional differences regressions to vary with firm size. Specifically, we add to equation (1) the triple interaction terms $Referendum_tEU_rSize_f$ and $TCA_tEU_rSize_f$, where $Size_f$ measures the size of firm f based on the firm's average employment prior to the referendum in 2013-15. We also control for $B_tEU_rSize_f$, which permits firm size

[18] Although not shown in Table 3, the estimated coefficient on the Staged Customs Control dummy from column (e) implies that late reporting due to delayed customs declarations increased measured EU imports by 5.5% in the first half of 2022. Reassuringly, this estimate is close to the findings of the ONS, who estimate that Staged Customs Controls increased EU imports by 4% in the first half of 2022 (ONS 2023).

heterogeneity to matter for the other events included in B_t.

The difference-in-differences estimation results with firm size heterogeneity using the Customs dataset are shown in Table 4. In column (a) we include size heterogeneity interactions where firm size is measured by log employment. The triple interaction $TCA_t EU_r Size_f$ has a positive coefficient, implying that the decline in relative exports to the EU under the TCA is smaller for larger firms. We also estimate a positive triple interaction for the Referendum effect, although the coefficient is substantially smaller than for the TCA.

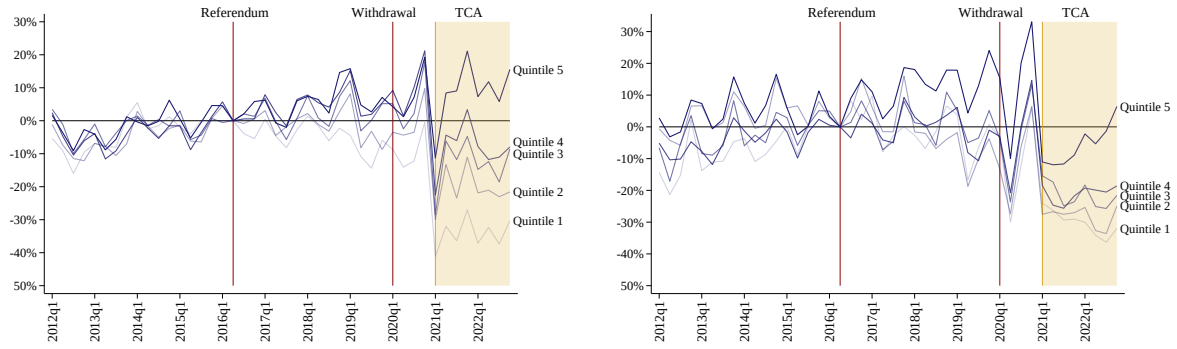
In column (b) we measure firm size using dummy variables $Size_f^c$ for which quintile $c = 1, \ldots, 5$ of the size distribution the firm belongs to, where quintile 1 denotes the smallest firms and is the excluded category.[19] This specification allows for greater flexibility in how effects vary with size. The results show that the TCA effect is more negative for smaller quintiles of firms. The estimates imply that the TCA reduced relative EU exports by 30% in the bottom quintile and 15% for the middle quintile.[20] However, for the largest quintile the TCA effect is insignificantly different from zero. We also find that the Referendum reduced relative EU exports for the smallest quintile of firms, although there is no effect for larger quintiles. In column (c), we obtain similar results when we instead define firm size quintiles based on total sales rather than employment.

Figure 3 plots results obtained from estimating the event-study version of the specification in column (b) of Table 4, i.e. from allowing the event study coefficients to vary by firm employment quintiles. Consistent with the difference-in-differences estimates, we see in panel (a) that the TCA had large negative effects on relative EU exports for firms in the smallest four quintiles, but did not reduce relative exports for firms in the top quintile. We also see some evidence that relative EU exports declined slightly in the bottom quintile between 2018 and the onset of the Covid-19 pandemic in 2020, but this effect is small relative to the decline following the implementation of the TCA.

Columns (d)-(f) of Table 4 and panel (b) of Figure 3 report size heterogeneity estimates for imports. Comparing the export and import results, the main differences is that the size gradient of the TCA effect is weaker for imports. Consequently, the estimated TCA effect in column (e) is negative even among the largest quintile of importers. The employment size quintile estimates in column (e) imply that the TCA reduced relative EU imports by 27% in the bottom quintile, 21% in the middle quintile and 14% in the top quintile of firms. Figure 3 also suggests that relative

[19] Throughout the paper, we define size quintiles based on the set of firms included in a regression (unless noted otherwise), which implies that the quintile thresholds differ across samples. We adopt this approach to defining size quintiles because the distribution of firm size differs greatly across samples depending on whether we use the Customs or VAT+ dataset and on whether we study exports or imports. In Table 4, the employment quintile thresholds are 6, 17, 39 and 107 for exports, compared to 9, 30, 79 and 249 for imports. When assigning firms to quintiles, we use a strict inequality for the lower threshold and a weak inequality for the upper threshold.

[20] Note that quintile 1 is the omitted category and that the TCA effects for quintiles 2-5 are given by adding the triple interaction effect for that quintile to the baseline $TCA_t EU_r$ estimate.



(a) Exports

(b) Imports

Notes: Event-study estimates showing percent changes in trade with EU relative to RoW by firm size quintile from regional differences specification. Firm size measured as average employment between 2013q1 and 2015q4. Estimation uses Customs dataset and includes full set of firm-level controls together with firm-region, region-season and firm-time fixed effects.

Figure 3: Firm trade with EU versus RoW: event study by firm size quintile

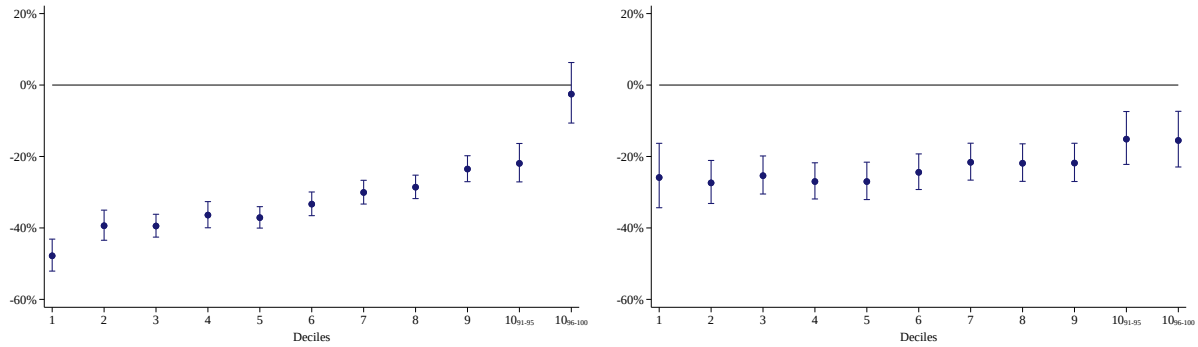
EU imports grew more quickly for larger firms between the Referendum and the TCA. However, the estimates in column (e) show that differences in the Referendum effect across quintiles are statistically insignificant, except for lower growth in quintile two.

Table 4 and Figure 3 show that the TCA affected smaller firms more than larger firms, particularly for exports. However, the Customs dataset only includes relatively large firms with annual trade above the small-firm thresholds of £0.25 million for exports and £1.5 million for imports. To further explore the effect of Brexit on small firms, we use the VAT+ dataset introduced in Section 3.1, which includes all firm-year observations with EU trade above £10,000.

We use the VAT+ dataset to run regional differences regressions using the difference-in-differences specification and including triple interactions of the Referendum and TCA effects on EU trade with firm size. Firm size is measured using deciles of the employment distribution, but we also split the top decile into firms below and above the 95th percentile, giving eleven size groups in total. The VAT+ export and import regression samples cover more than twice as many firms as the samples using the Customs dataset, but, on average, these firms trade less and are smaller. Median annual exports to the EU are £0.20 million in the VAT+ export sample, compared to £1.0 million in the Customs export sample. Likewise, median annual imports from the EU are £0.25 million in the VAT+ sample, compared to £4.4 million in the Customs sample.

Figure 4 plots the estimated TCA effects by size decile together with their 95% confidence intervals. The estimates for exports confirm that smaller exporters were harder hit than larger firms, and the TCA effect is insignificant for firms above the 95th percentile. The results for imports also imply that the TCA effect was more negative for smaller firms. However, the estimates vary less with firm size than for exports, and are negative and significant throughout the employment

distribution.



(a) Exports (b) Imports

Notes: Estimated impact of TCA on trade with EU relative to RoW by firm size decile. Difference-in-differences estimates from regional differences specification using VAT+ dataset. Whiskers show 95% confidence intervals computed using standard errors clustered by firm. Decile 10 split into firms below and above the 95th percentile. Firm size measured as average employment between 2013q1 and 2015q4. The employment decile thresholds for exports are 1, 2, 4, 6, 10, 15, 25, 44, 109, and 269. For imports, the thresholds are 1, 3, 5, 8, 12, 19, 31, 56, 144, and 357. Sample uses annual data for 2012-19, 2021 (exports only) and 2022. Estimation equation includes region-level foreign import demand (export regression) or foreign export supply (import regression), and real exchange rate (current value and two lags) controls, together with firm-region and firm-time fixed effects. Exports sample includes 59,153 firms. Imports sample includes 54,909 firms.

Figure 4: Firm trade with EU versus RoW: average TCA effect by firm size decile

The heterogeneous impact of the TCA on different sized firms implies that larger firms were better able to adapt to the new trade barriers created by the TCA. This finding is consistent with a model where firms have the option to make fixed cost investments to mitigate the increase in variable trade costs under the TCA. If only sufficiently large firms find such investments profitable, then larger firms will face lower increases in variable trade costs, implying that their trade is less affected by the TCA. In practice, such investments could involve hiring customs specialists, consolidating shipments into larger loads, paying new regulatory compliance costs, or establishing warehousing and distribution facilities inside the EU to simplify trade logistics.

4.4 Trade policy heterogeneity

To further unpack how Brexit affected trade, we study heterogeneity across firms that are differentially exposed to changes in UK-EU trade policy. As outlined in Section 2, the Referendum generated uncertainty about future UK-EU trade relations and the TCA created a wide range of new customs and regulatory barriers to trade with the EU. Some products were more exposed to these trade policy shocks than others. However, variation across products in exposure to Brexit-related uncertainty, or to trade barriers introduced under the TCA, is not directly measurable. Consequently, our analysis focuses primarily on estimating the joint impact of all sources of uncertainty

following the referendum, and the joint impact of all new barriers under the TCA, rather than attempting to disentangle the relative importance of each individually. Nevertheless, we can use the EU's MFN tariffs and NTMs to construct two imperfect proxies for exposure to Brexit trade policy changes.

We define each firm's tariff exposure $Tariff_f$ as a weighted average of the EU's CN 8-digit MFN tariffs in 2015. For export regressions, we calculate export tariff exposure using product-level shares of the firm's EU exports as weights. Analogously, for import regressions, we use firm-level import share weights to calculate import tariff exposure. Similarly, we compute export and import NTM exposure NTM_f as firm-specific weighted averages across CN 8-digit products of the count of NTMs applied by the EU to MFN trade in each 8-digit product in 2015. The firm-level weights used to compute these variables are calculated using trade in 2012 (or the first available year for firms that we do not observe in 2012) and fixed over time. The correlation between tariff and NTM exposure in our regression samples is 0.25 for export exposure and 0.40 for import exposure.

What do these tariff and NTM exposure variables measure? Prior to 2021, they measure the threat-point policies that would have applied to UK-EU trade if negotiations over a new trade relationship failed. Therefore, they capture a combination of uncertainty and expectations about future trade policy changes.[21] For example, a firm that exports products with high EU MFN tariffs faces both greater uncertainty over future tariffs and a greater increase in tariffs if there is no trade deal.

After the TCA was agreed in December 2020, most of the uncertainty over the future UK-EU trade relationship was resolved.[22] Therefore, from 2021 onwards, we interpret the exposure variables not as measures of uncertainty, but as proxies for trade barriers created by the TCA. We adopt this interpretation for three reasons. First, the EU's MFN tariffs and NTMs reflect how EU and UK preferences for protection vary across products. Therefore, products with higher MFN protection are likely subject to higher trade barriers under the TCA. Second, although tariffs under the TCA are zero for all products, trade that does not satisfy TCA rules of origin does face MFN tariffs, meaning that tariff exposure measures the costs of not complying with TCA rules of origin. Ayele et al. (2021) show that in the first seven months of 2021, tariffs were paid on around 30% of UK exports to the EU that could have benefitted from preferential zero tariff entry under the TCA. Third, to the extent that non-tariff barriers under the TCA are similar to those under MFN trade, NTM exposure captures barriers introduced by the TCA that do not exist within the EU's single market.

We estimate the effect of trade policy exposure on firms' trade with the EU relative to the RoW

[21] Crowley et al. (2019) and Graziano et al. (2021) use EU MFN tariffs in this way as proxies for Brexit-related trade policy uncertainty.

[22] Some uncertainty remains over the extent of UK-EU regulatory divergence in the medium term and whether the UK may seek to rejoin the EU's customs union and/or single market in the longer term.

by including triple interactions of the exposure measures with EU_r and with the time dummy variables $Referendum_t$, TCA_t and B_t in the difference-in-differences equation (1). We also continue to include the firm size quintile interactions, meaning that we estimate the effect of variation in exposure conditional on firm size. We implement the estimation using the Customs dataset, as the VAT trade data is not disaggregated by product. The results are shown in Table 5 with exports in columns (a)-(b) and imports in columns (c)-(d). In addition, Figure 5 plots the estimated tariff and NTM exposure effects from the event study versions of the specifications in columns (b) and (d).

The estimates show that greater tariff exposure reduced relative trade with the EU under the TCA, whereas NTM exposure did not have a significant effect. The estimates in columns (b) and (d) imply that a one standard deviation increase in tariff exposure $Tariff_f$ reduced relative EU exports under the TCA by 8.2% and reduced relative EU imports under the TCA by 6.4%.[23] The event study graphs show that the decline in relative exports occurred immediately at the start of 2021. However, most of the decline in relative imports is delayed until the start of 2022, which is when the UK started to require full customs declarations for imports from the EU. This timing suggests that tariff exposure is a proxy for the firm-level costs of customs and rules of origin compliance. By contrast, we interpret the absence of a significant NTM effect as indicating that our NTM exposure variable is a poor measure of product-level variation in non-tariff barriers created by the TCA.

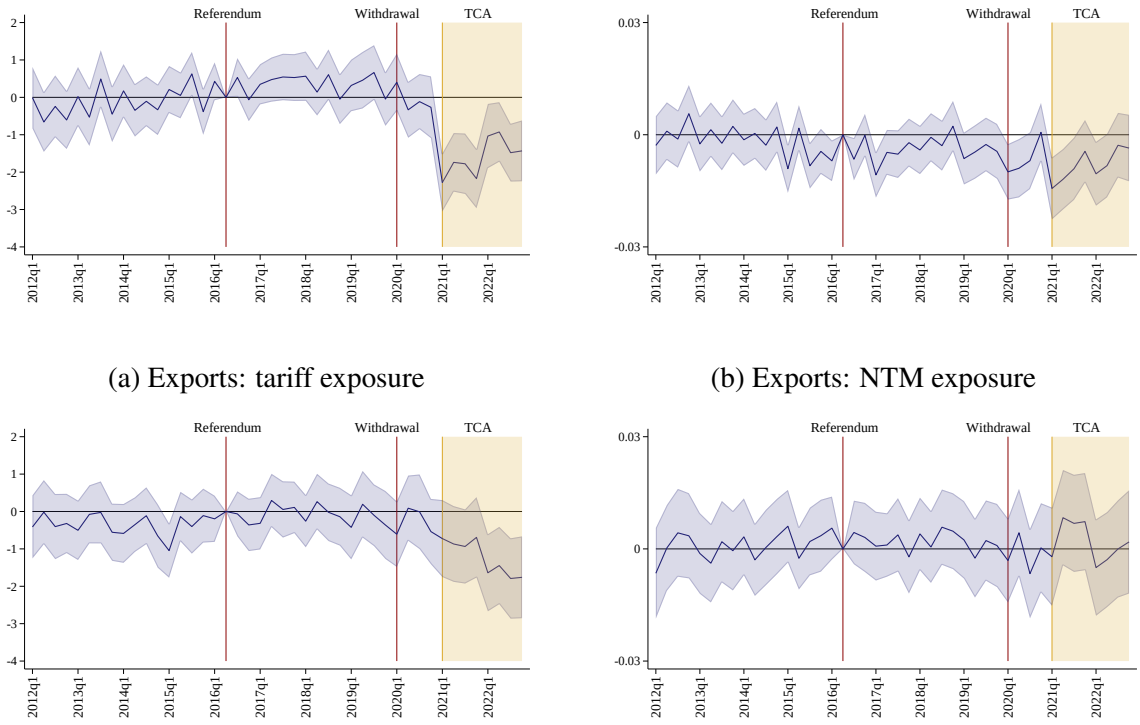
Table 5 and Figure 5 also show that the referendum did not have a significant negative effect on relative EU exports or imports for firms with higher exposure to either tariffs or NTMs. This finding implies that uncertainty and anticipation did not reduce relative trade with the EU prior to the introduction of the TCA, which is consistent with the baseline regional differences results.

Appendix C analyzes another dimension of firm-level heterogeneity by estimating whether the Referendum and TCA effects differ for domestic versus foreign owned firms. We find that, following the referendum, foreign-owned firms experienced slightly bigger increases than domestically-owned firms in relative EU exports and relative EU imports. However, the TCA effect does not differ significantly depending on firm ownership for either exports or imports (see Appendix Table A4).

5 Trade levels

The estimates above show that Brexit reduced trade with the EU compared to the RoW within firms. However, although Brexit was primarily a shock to UK-EU trade policy, it may also have

[23] We have also estimated specifications that allow the tariff exposure effects to vary by firm employment quintile. For exports, the negative effect is bigger for firms in the two largest quintiles, but not much bigger. For imports, there are no significant differences across quintiles.



(a) Exports: tariff exposure

(b) Exports: NTM exposure

(c) Imports: tariff exposure

(d) Imports: NTM exposure

Notes: Event-study estimates showing effect of firm-level tariff and NTM exposure on changes in trade with EU relative to RoW from regional differences specifications. Shaded area shows 95% confidence intervals computed using standard errors clustered by firm. Tariff exposure is firm-specific weighted average of EU's CN 8-digit MFN tariffs in 2015. NTM exposure is firm-specific weighted average of the count of NTMs applied by the EU to MFN trade in each 8-digit product in 2015. Weights given by product-level shares of firm's EU exports for export regressions, and shares of firm's EU imports for import regressions. Weights computed using 2012 data if available, or the first year with available data otherwise. Estimation uses Customs dataset and includes full set of firm-level controls together with firm-region, region-season, firm-time, region-time and employment size quintile-region-time fixed effects.

Figure 5: Firm trade with EU versus RoW: event study based on firm tariff and NTM exposure

had indirect effects on UK trade with the RoW. Therefore, this section studies the impact of Brexit on the levels of UK trade with the RoW, and with the world as a whole. Specifically, we analyze changes in trade levels over time across firms with different pre-referendum exposure to trade with the EU.

Our objective is to provide evidence that speaks to the indirect mechanisms discussed in Section 2.2. Do scale economies or capacity constraints affect exports to the RoW when exports to the EU decline (mechanisms ii and iii)? Does input substitutability increase imports from the RoW when importing from the EU becomes more costly (mechanism v)? Do input cost increases reduce exports due to loss of competitiveness (mechanism vi)? And does a reduction in exports reduce

import demand (mechanism vii)? We do not seek to identify general-equilibrium adjustments.[24]

5.1 Empirical design: RoW levels

We cannot use our regional differences estimating equation to identify the impact of Brexit on trade levels, because the firm-time fixed effects would absorb all the observed variation in trade. Instead, we identify the indirect effects of Brexit on RoW trade by comparing changes in the level of trade with the RoW over time across firms with varying exposure to EU trade prior to the referendum. We define firm-level export exposure to EU trade by the ratio of EU exports to total sales, and import exposure by the ratio of the firm's EU imports to total input purchases.[25]

These exposure variables measure the share of each firm's activity that is directly affected by UK-EU trade policy, which is a proxy for firm-level exposure to the channels through which Brexit may indirectly affect RoW trade. For example, the effect of an increase in EU import costs on total production costs depends on the share of EU imports in input purchases, implying that the ratio of EU imports to inputs captures exposure to the input cost channel. Likewise, exposure to the scale economies and capacity constraints mechanisms depends on the share of EU exports in overall production.

Let V_{ft}^{RoW} be the value of firm f's trade (either exports or imports) with the RoW in quarter t. The difference-in-differences estimation equation for RoW trade in levels is:

$$\begin{aligned}\log V_{ft}^{RoW} = {} & \beta_1 Referendum_t EUExposure_f + \beta_2 TCA_t EUExposure_f \\ & + \gamma_0 Z_{ft}^{RoW} + \gamma_1 B_t EUExposure_f + \gamma_2 Referendum_t Size_f^c + \gamma_3 TCA_t Size_f^c \\ & + \gamma_4 B_t Size_f^c + \alpha_f + \alpha_{it} + \epsilon_{ft}, \end{aligned} \tag{3}$$

where $EUExposure_f$ denotes one or more EU exposure measures for firm f. The coefficients of interest in this equation are β_1 and β_2, which identify whether the referendum and the TCA affected RoW trade differentially depending on firms' exposure to EU trade.

Because β_1 and β_2 are identified from variation across firms over time, we cannot include firm-time fixed effects in equation (3). Instead, we include fixed effects at the firm α_f and 4-digit SIC industry-time α_{it} level, where i denotes the firm's industry. The firm fixed effect α_f absorbs time-invariant differences in firm-level trade with the RoW. And the industry-time fixed effect α_{it}

[24] In future, Brexit may also affect RoW trade through changes in UK trade relations with countries outside the EU, but this did not happen during our sample period. The UK's existing preferential trade agreements with non-EU countries were rolled over essentially unchanged upon leaving the EU's customs union and no new trade agreements entered into force before 2023 (Dhingra and Sampson 2022).

[25] All EU exposure measures included in the RoW and World levels regressions are computed using the VAT+ dataset for 2012 (or the first available year for firms that are not observed in 2012) and are fixed over time.

absorbs industry-level shocks to trade with the RoW.

Equation (3) includes similar controls to those used in the regional differences estimation. We control for the interaction of firm size quintiles $Size_f^c$ with the referendum dummy $Referendum_t$, the TCA dummy TCA_t and the Covid-19 and TCA disruption event dummy variables in B_t. These interactions control for differential changes in RoW trade over time by firm size. We also control for firm-level variation in exposure to RoW supply and demand shocks, real exchange rate changes in the RoW, and changes in UK MFN import tariffs using Z_{ft}^{RoW}. This vector includes the same set of firm-level controls used in the regional differences regressions, except that now only the values for the RoW region are needed. Lastly, we include the interactions of $EUExposure_f$ with the event dummy variables B_t.

We estimate levels regressions using the Customs dataset, which when restricted to RoW trade is collected on a consistent basis throughout the sample period. Note that, since the small-firm thresholds do not apply to RoW trade, we observe all trade with the RoW that exceeds the £873 small-transaction threshold for all firms. Because the EU exposure measures are calculated using 2012 data, we start the sample period in 2013q1 for the levels regressions. Summary statistics for firms that trade with the RoW are shown in panel B of Table 1. The correlation between the export exposure and import exposure variables is 0.14 in the exporter sample, and 0.16 in the importer sample.

In addition to the difference-in-differences levels specification in equation (3), we also estimate the analogous event-study specification, which is given by:

$$\log V_{ft}^{RoW} = \sum_{t=2013q1}^{2022q4} \beta_t EUExposure_f + \gamma_0 Z_{ft}^{RoW} + \alpha_f + \alpha_{ct} + \alpha_{it} + \epsilon_{ft}. \tag{4}$$

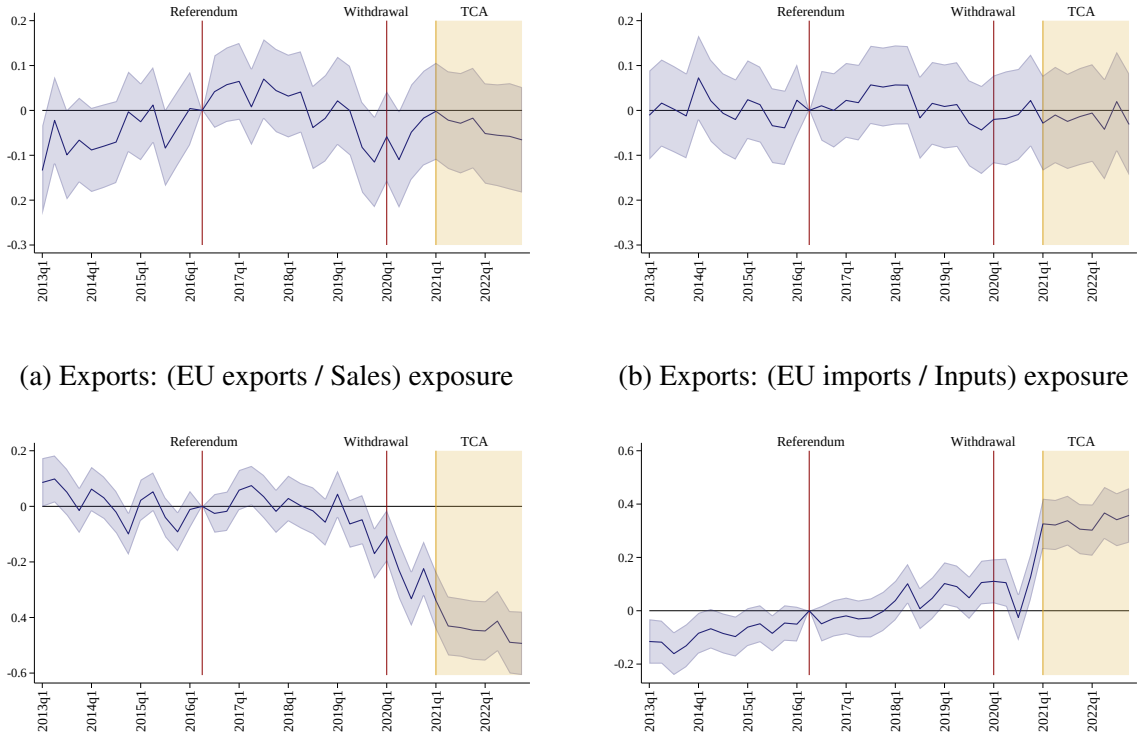
where α_{ct} denotes firm size quintile-time fixed effects. The coefficients of interest β_t in the event-study equation (4) identify how the effect of EU exposure on RoW trade varies over time.

5.2 Results: RoW levels

Table 6 reports RoW levels results for exports to the RoW in columns (a)-(c) and imports from the RoW in columns (d)-(f). In column (a), we measure $EUExposure_f$ by the ratio of EU exports to sales. The estimated effect of the $TCA_t EUExposure_f$ interaction is small and insignificant. Column (b) adds the ratio of EU imports to inputs to capture variation in import exposure, but neither exposure measure has a significant effect under the TCA. Column (c) then multiplies the export and import exposure measures by tariff exposure $Tariff_f$ (as defined in Section 4.4). However, the estimates remain insignificant.

Figure 6 plots results from estimating the event study version of column (b). Panel (a) shows

the event-study estimates for the EU exports to sales ratio, and panel (b) for the EU imports to inputs ratio. The event study estimates confirm that neither export nor import exposure had a detectable impact on RoW exports either following the referendum or under the TCA. Therefore, we conclude that Brexit did not have a significant indirect effect on exports to the RoW through either the scale economies, capacity constraints, or input cost mechanisms. It follows that the decline in EU relative to RoW exports under the TCA was caused by lower exports to the EU due to the direct effect of higher export costs.



(a) Exports: (EU exports / Sales) exposure

(b) Exports: (EU imports / Inputs) exposure

(c) Imports: (EU exports / Sales) exposure

(d) Imports: (EU imports / Inputs) exposure

Notes: Event-study estimates showing effect of firm-level exposure to EU exports and imports on trade with RoW from levels specifications. Shaded area shows 95% confidence intervals computed using standard errors clustered by firm. Dependent variable is log exports to RoW in panels (a) and (b), and log imports from RoW in panels (c) and (d). Firm-specific EU trade exposure measures computed using 2012 data if available, or the first year with available data otherwise. Estimation uses Customs dataset and includes full set of firm-level controls together with firm, employment quintile-time and industry-time fixed effects. Industries are SIC 4-digit sectors.

Figure 6: Firm trade with RoW: event study by EU exposure

Columns (d)-(f) of Table 6 report the analogous set of specifications for RoW imports. In this case, we find that Brexit did have an indirect effect on RoW trade. We estimate that firms with higher EU import exposure increased their imports from the RoW after the introduction of the TCA. The $TCA_t \left(EUimports/Inputs\right)_f$ interaction effect is positive and significant both individually in columns (d) and (e), and when multiplied by tariff exposure in column (f). In addition,

the event-study estimates in panel (d) of Figure 6 show a sharp increase in imports from the RoW at the start of 2021 for firms with higher EU import exposure. This evidence implies the existence of interdependencies in import sourcing decisions that operate through the imported input substitutability mechanism. Moreover, this mechanism must dominate any sourcing complementarities that push in the opposite direction. Consequently, when trade barriers with the EU rise under the TCA, firms that were previously more dependent on EU imports increase their imports from the RoW.

We also find some evidence that firms with higher EU export exposure reduced their RoW imports under the TCA. This finding is consistent with a production scale mechanism, whereby the reduction in exports to the EU under the TCA leads to lower sales, resulting in reduced input demand and, therefore, lower imports. However, the event study estimates in panel (c) of Figure 6 show that the decline in imports for firms with higher EU export exposure began in 2019 and accelerated during the Covid-19 pandemic in the first half of 2020. Therefore, we cannot be confident in attributing this decline to Brexit.

5.3 World trade levels

The RoW levels estimates show that the TCA caused an increase in imports from the RoW through the imported input substitutability mechanism. This means that the fall in imports from the EU relative to the RoW documented in the regional differences regressions conflates changes in both EU and RoW imports. Consequently, it would be a mistake to infer from the regional differences estimates that the TCA led to a decline in imports from the world as a whole. Any decline in EU imports may have been offset by higher imports from the RoW. To estimate the net effect of Brexit on overall trade, this section analyzes trade with the EU and RoW combined.

We estimate world levels regressions using the same difference-in-differences and event study specifications as for RoW trade, except with world exports or imports $V_{ft}^{World} = V_{ft}^{EU} + V_{ft}^{RoW}$ as the dependent variable.[26] The estimation uses the Customs dataset and restricts the sample to firm-quarters in which EU exports (or imports for the import regressions) are observed. This restriction ensures that, when calculating world trade, we do not impose false zeroes on EU trade for firms with trade below the small-firm Intrastat thresholds. For exporters, we measure EU exposure as the share of EU exports in total exports and, for importers, we use the share of EU imports in total imports. These variables capture the share of each firm's pre-referendum trade that is directly exposed to changes in UK-EU trade policy, which is our preferred exposure measure when analyzing world trade.[27] Summary statistics for this sample are shown in panel C of Table 1.

[26] We also replace the RoW firm-level control Z_{ft}^{RoW} in the estimating equations (3) and (4) with the world equivalent Z_{ft}^{World}.

[27] This preference is motivated by the fact that the elasticity of world trade to EU trade equals the EU trade share,

The average EU export share among sample exporters is 0.58, while the average EU imports share for importers is 0.48.

The world levels results using the difference-in-differences specification are reported in Table 7. We showed above that the TCA reduced EU relative to RoW exports (regional differences regressions), but did not affect the level of RoW exports (levels regressions). Therefore, we expect to find that the TCA had a negative effect on worldwide exports for firms with higher EU export shares. Column (a) confirms this expectation. We estimate that a 10 percentage point increase in the initial EU export share reduces world exports under the TCA by 0.9%. In column (b) we multiply the EU export share by export tariff exposure as defined in Section 4.4. Again, the TCA effect is more negative for firms with greater exposure to EU trade barriers. Panels (a) and (b) of Figure 7 plot the event study versions of these specifications. The event study estimates show an immediate decline in world exports at the start of 2021, which is sustained for the remainder of the sample.

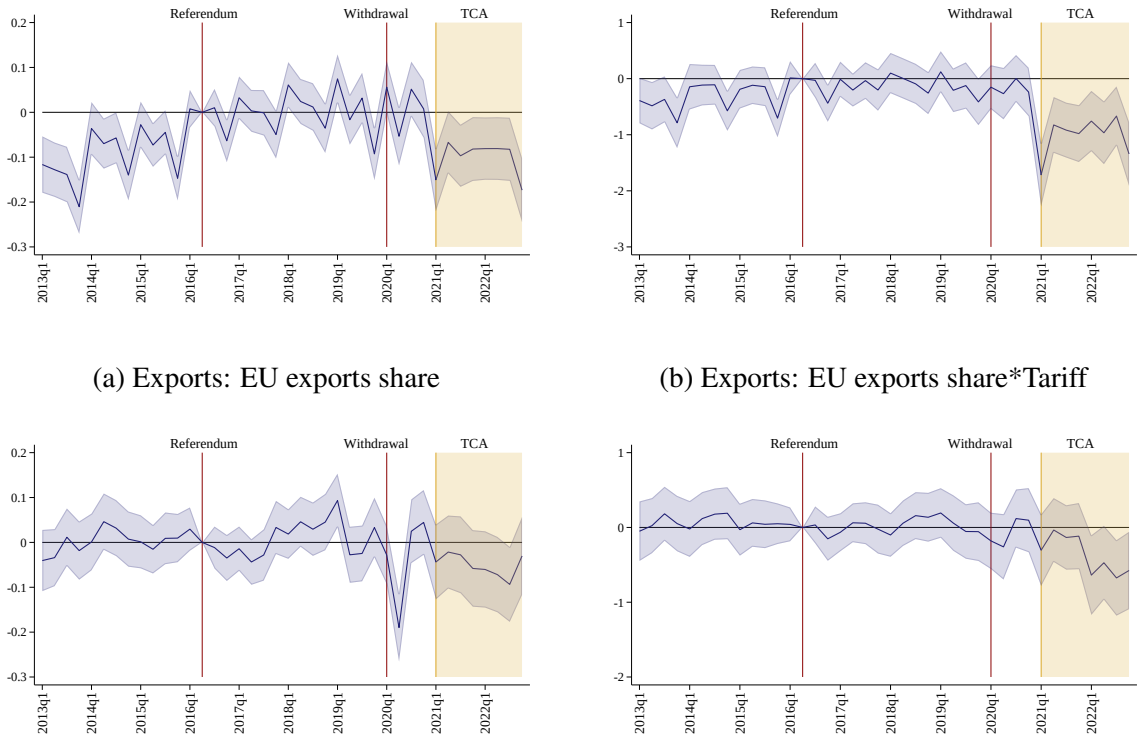
For imports, the world level results shed light on the degree of imported input substitutability. The estimates in columns (c) and (d) of Table 7 and panels (c) and (d) of Figure 7 show that the TCA led to a small, but significant reduction in total imports for firms with higher EU import shares. The estimates in column (c) imply that a 10 percentage point increase in the initial EU import share leads to 0.6% lower world imports under the TCA. This finding implies that RoW imports were imperfect substitutes for EU imports and/or that firms' reduced their total import demand across all origins due to sourcing complementarities.[28] Consequently, on net, the TCA led to a fall in total imports.

6 Trade survival

The regional differences and levels regressions above analyze the intensive margin of firm-level trade. In this section, we turn to the extensive margin and estimate the impact of Brexit on the number of UK firms that are exporters or importers. Because the Intrastat survey does not cover firms with trade values below the small-firm thresholds, it cannot be used to study the firm-level extensive margin. Therefore, throughout this section we use the VAT+ dataset, which combines

i.e. $\frac{\partial \log V_{ft}^{World}}{\partial \log V_{ft}^{EU}} = \frac{V_{ft}^{EU}}{V_{ft}^{World}}$. Consequently, absent indirect effects on RoW trade, the impact of a fall in EU trade on world trade is given by the EU trade share.

[28] In principle, the production scale mechanism could also reduce total import demand. To explore this possibility, we include interactions of the Referendum, TCA and event dummy variables with the (EU exports /Sales) ratio in the specification in column (c) of Table 7. We find that the (EU exports /Sales) interactions are insignificant both following the referendum or under the TCA. By contrast, the interaction between the TCA dummy and the EU import share remains negative and significant. It follows that the production scale mechanism did not contribute significantly to the decline in total import demand.



(a) Exports: EU exports share

(b) Exports: EU exports share*Tariff

(c) Imports: EU imports share

(d) Imports: EU imports share*Tariff

Notes: Event-study estimates showing effect of firm-level EU exposure on worldwide trade from levels specifications. Shaded area shows 95% confidence intervals computed using standard errors clustered by firm. Dependent variable is log exports to world in panels (a) and (b) and log imports from world in panels (c) and (d). Tariff exposure is firm-specific weighted average of EU's CN 8-digit MFN tariffs in 2015. Weights given by product-level shares of firm's EU exports for export regressions and shares of firm's EU imports for import regressions. EU trade shares and tariff weights computed using 2012 data if available, or the first year with available data otherwise. Estimation uses Customs dataset and includes full set of firm-level controls together with firm, employment quintile-time and industry-time fixed effects. Industries are SIC 4-digit sectors.

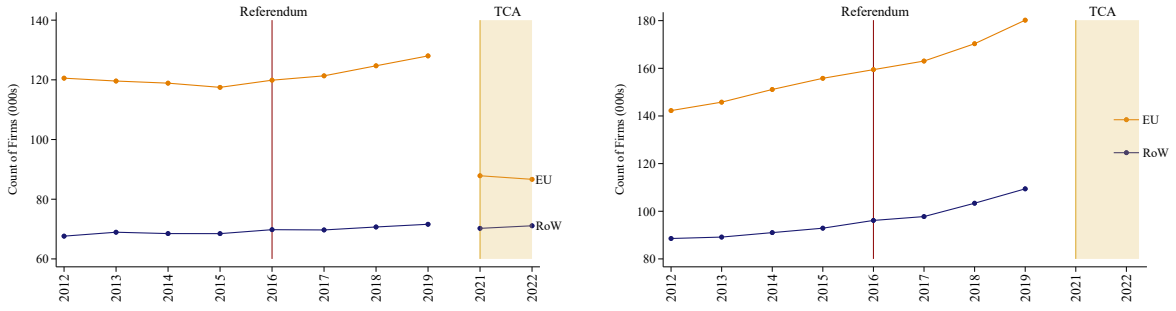
Figure 7: Firm trade with World: event study by EU exposure

VAT returns data for 2012-19 with customs declarations data from 2021-22 for exports and from 2022 for imports.

Figure 8 plots the total number of UK firms that we observe trading with the EU and the RoW by year.[29] For both exporters in the left-hand panel and importers in the right-hand panel, Figure 8 shows a sharp drop in the number of firms that trade with the EU after the introduction of the TCA. By contrast, we do not see a decline in the number of firms that trade with the RoW. This suggests that the TCA has reduced trade with the EU on the extensive margin. However, simply counting firms does not account for any impact of the change in data reporting from VAT returns

[29]Figure 8 does not impose the £10,000 trade threshold on EU trade, meaning that it counts all firms with positive trade.

to customs declarations. Nor does it tell us anything about which firms have stopped trading with the EU. Therefore, to better understand the changes shown in Figure 8, we undertake a regression analysis of firms' trade survival.



(a) Exporters

(b) Importers

Notes: Count of firms (in thousands) trading with EU and RoW by year in VAT+ dataset (including firms with EU trade below £10, 000).

Figure 8: Number of firms trading with EU and RoW

6.1 Empirical design: trade survival

We estimate the impact of Brexit on trade survival at the firm-level over three-year windows. That is, we study whether a firm f that trades with region r in year t-3 also trades with the same region in year t. Using three-year windows allows us to analyze trade survival before and after the introduction of the TCA without requiring 2020 data. Omitting 2020 also has the advantage of avoiding bias that may result from firms temporarily stopping trade during the Covid-19 pandemic.

To address the introduction of the small-transaction threshold for EU trade following the switch to customs declarations, we exclude firms with trade close to the threshold from the trade survival analysis. Specifically, we drop firms for which trade with the EU in year t-3 is below £10, 000. The rationale for choosing this cut-off is that firms with annual trade above the cut-off are highly likely to have at least one customs transaction above the £873 small-transaction threshold during the year. Consequently, the switch in data reporting alone would not cause these firms to exit our data. For comparability, we also apply the £10, 000 sample selection cut-off to trade with the RoW.

Formally, we measure trade survival using a firm-region-year dummy variable S_{frt}. For firm f that has trade with region $r = \{EU, RoW\}$ above £10, 000 in year t-3, we define S_{frt} to take value one if the firm trades with region r in year t and zero otherwise. That is, $S_{frt} = I\left[V_{frt} > 0 | V_{frt-3} > 10,000\right]$ where $I(\cdot)$ denotes the indicator function and $t =$ 2015-19, 2021 (exports only) and 2022. Note that we define trade survival S_{frt} separately for exports and for imports.

Using S_{frt}, we estimate a linear probability model of trade survival that allows the $Referendum_t$ and TCA_t effects to vary with firm size:

$$S_{frt} = \sum_{c=1}^{5} \beta_1^c Referendum_t EU_r Size_f^c + \sum_{c=1}^{5} \beta_2^c TCA_t EU_r Size_f^c + \gamma_0 \Delta_3 X_{rt} + \alpha_{cir} + \alpha_{cit} + \epsilon_{frt}, \tag{5}$$

where $\Delta_3 X_{rt}$ denotes three-year differences of the region-level controls, the $Referendum_t$ dummy takes value one from 2016 onwards, and the TCA_t dummy takes value one from 2021 onwards. Because we are interested in the survival of small firms, few of which trade with both regions, we do not include firm-time fixed effects in equation (5). Instead, we include firm size quintile-industry-region and firm size quintile-industry-time fixed effects, where industries are defined at the SIC 4-digit level. The size quintile-industry-region fixed effects α_{cir} absorb time-invariant differences in survival rates by size quintile, industry and region, e.g. survival rates are lower for smaller firms. The size quintile-industry-time fixed effects α_{cit} absorb changes over time in survival rates that vary by size quintile and industry, but are common across regions.

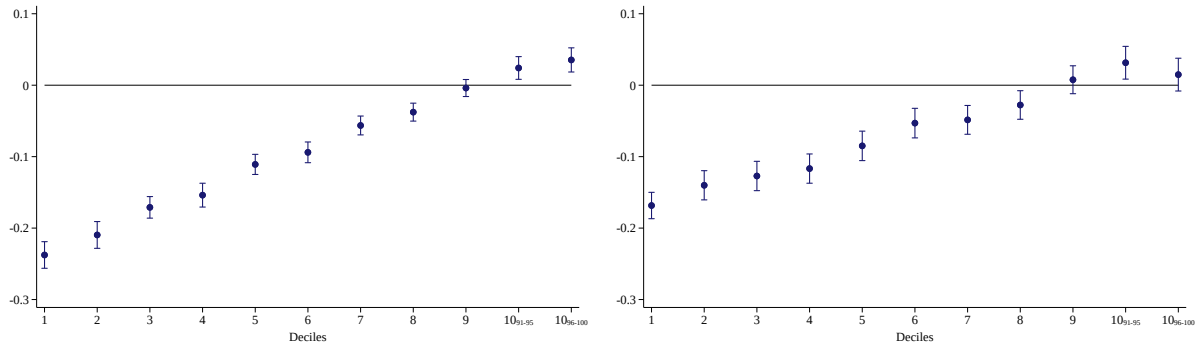
Equation (5) identifies the effect of Brexit on firm exit from variation within size quintile-industry groups in how trade survival rates change over time for the EU compared to the RoW. The coefficients of interest are β_1^c and β_2^c, which give the effect of the referendum and the TCA, respectively, on trade survival by size quintile. We also estimate an event study version of equation (5) where we allow the estimated effects to vary by year.

6.2 Results: trade survival

We report the trade survival estimates for exports in Table 8. Column (a) reports the TCA effect without firm size heterogeneity, while column (b) allows the impact to vary by employment quintile. We find that the TCA led to a significant decline in the survival probability for exporters to the EU relative to exporters to the RoW. Moreover, the decline was greater for smaller firms. Figure 9, panel (a) examines size heterogeneity in the TCA effect in more detail. It plots estimated TCA effects and 95% confidence intervals by size group, when groups are defined using the same employment bins as in Figure 4.[30] We estimate that the TCA reduced the probability of EU export survival by 24 percentage points in the smallest group of firms, 11 percentage points in the fifth group, and 4 percentage points in the eighth group. The TCA effect is insignificant for firms in the ninth group, i.e. for firms with between 44 and 109 workers. And it turns positive, though still

[30] That is, the employment groups used in Figure 9 are defined by the deciles (and 95th percentile) of the employment distribution of firms included in the intensive margin VAT+ sample used for Figure 4. The intensive margin sample contains fewer small firms than the extensive margin sample because it only includes firms that trade with both regions.

close to zero, for firms in the two largest groups.



(a) Export survival (b) Import survival

Notes: Estimated impact of TCA on probability of survival in EU relative to RoW by firm size group. Difference-in-differences estimates from trade survival regression using VAT+ dataset. Vertical axis in percentage points. Firm size measured as average employment between 2013q1 and 2015q4. Whiskers show 95% confidence intervals computed using standard errors clustered by firm. Firm employment groups defined using deciles and 95th percentile of employment distribution of firms in the regional differences VAT+ regression samples used for Figure 4. The employment group thresholds for exports are 1, 2, 4, 6, 10, 15, 25, 44, 109, and 269. For imports, the thresholds are 1, 3, 5, 8, 12, 19, 31, 56, 144, and 357. Estimation equation includes region-level foreign import demand (export regression) or foreign export supply (import regression), and real exchange rate controls, together with size group-industry-region and size group-industry-time fixed effects. Industries are SIC 4-digit sectors.

Figure 9: Trade survival in EU versus RoW: average TCA effect by firm size decile

To conserve space, the $Referendum_t$ effects are omitted from Table 8, but we find that the referendum did not decrease export survival. Column (c) illustrates this point by reporting results for the event study version of the specification in column (a). We see that from 2016-2019 the probability of EU export survival was marginally higher than survival in 2015. However, the relative survival probability for EU exporters drops sharply once the TCA comes into effect in 2021.

Columns (a)-(c) estimate export survival for firms with exports above £$10,000$ in year t-3. Columns (d)-(f) show that our results are robust to how we handle the introduction of the small-transaction threshold. In particular, we obtain similar estimates when we include all firms with positive trade in year t-3 (column d), or set the cut-off for inclusion in the sample to either £$25,000$ (column e) or £$100,000$ (column f).

The estimates in columns (a)-(f) identify the impact of Brexit by comparing survival rates for exporting to the EU versus the RoW. However, as for the intensive margin, we can also estimate levels versions of the survival regressions, which allows us to study changes in trade survival over time within each region. For this purpose, we use an event-study specification and estimate:

$$S_{frt} = \beta_t^r + \alpha_i + \epsilon_{frt}. \tag{6}$$

The coefficients of interest β_t^r identify changes in export survival over time in region r within SIC 4-digit industries i. The results of estimating equation (6) are shown in column (g) for the EU and column (h) for the RoW. We find that survival probabilities remained stable over time in both regions until 2019. However, in 2021 and 2022 the probability of export survival dropped sharply for the EU, but not for the RoW. These estimates imply that the TCA had a direct negative effect on survival for exporters to the EU, but did not indirectly affect survival for exporters to the RoW. The absence of indirect effects on RoW exports is consistent with our intensive margin export results in Sections 4 and 5.

Table 9 and panel (b) of Figure 9 show the analogous set of results for import survival. We estimate that the TCA reduced the survival probability for importing from the EU relative to importing from the RoW, whereas the referendum did not affect import survival. The average decline in EU import survival rates in column (a) is similar for imports as for exports, but the decline in import survival varies somewhat less with firm size. Panel (b) of Figure 9 plots estimated TCA effects by firm size group, where groups are defined using the intensive margin sample employment bins from Figure 4. We estimate that the TCA reduced the relative survival probability for importing from the EU by 17 percentage points in the bottom group, 9 percentage points in the fifth group, and 3 percentage points in the eighth group. However, the TCA did not reduce relative EU import survival for firms in the three largest groups, that is for firms with more than 56 workers.

The levels estimates in columns (g) and (h) of Table 9 show that EU import survival fell by 11 percentage points in 2022 compared to earlier years, while RoW import survival rose by 4 percentage points. Consistent with the intensive margin results for RoW import levels in Section 5.2, these estimates suggest that importers may have responded to the TCA by partially substituting RoW imports for EU imports, leading to a slight increase in RoW survival rates.

Overall, the trade survival regressions show that the TCA reduced trade with the EU on the extensive margin of firm exporting and importing, and that smaller firms were more likely to stop trading. The extensive margin decline is consistent with a model where the TCA raises the fixed costs of trade, thereby making it unprofitable for some less productive firms to continue trading. The increase in fixed costs could be caused by the customs paperwork and regulatory compliance burdens introduced by the TCA.

7 Aggregation

Our estimates paint a rich picture of how Brexit has affected firm-level trade. Before concluding, we quantify the implications of our findings by undertaking a back-of-the-envelope aggregation exercise. The aggregation combines results from the regional differences, levels and trade survival regressions to estimate the impact of the TCA on overall UK goods trade. We consider exports

first, before turning to imports.

7.1 Exports

We have not found any evidence that the TCA had an indirect effect on exports to the RoW through either the intensive or the extensive margin of trade. This means that the changes in relative exports and relative survival probabilities identified by our regional differences and trade survival regressions can be interpreted as the causal effect of the TCA on exports to the EU. Therefore, we use these estimates in the aggregation exercise for exports.

Let p_{fr} be the estimated probability that the TCA causes firm f to stop exporting to region r, that is the estimated decline in the export survival probability due to the TCA. And let λ_{fr} be an estimate of the proportional effect of the TCA on the firm's exports to region r conditional on export survival. Because the levels regressions provide no evidence that the TCA reduced exports to the RoW by firms with higher EU trade exposure, we set $\lambda_{fRoW} = 1$ and $p_{fRoW} = 0$ for all firms f. Implicit in this choice is the assumption that the TCA had no effect on RoW exports for firms that did not trade with the EU prior to Brexit. As discussed in Section 5, our empirical analysis cannot identify any general-equilibrium effects of Brexit on RoW trade that occur through channels unrelated to EU trade exposure. If such effects do operate, they are not accounted for by our aggregation exercise.

Let $V_{fr}^{Pre-TCA}$ denote exports by firm f to region r in the pre-TCA period. Then the firm's expected exports to region r following the implementation of the TCA are given by $(1 - p_{fr})\,\lambda_{fr} V_{fr}^{Pre-TCA}$. Aggregating across firms, we obtain that the expected impact of the TCA on total exports to region r by any set of firms F is given by:

$$\sum_{f \in F} (1 - p_{fr})\,\lambda_{fr} \frac{V_{fr}^{Pre-TCA}}{\sum_{g \in F} V_{gr}^{Pre-TCA}}. \tag{7}$$

That is, the aggregate effect is a weighted average of the firm-level expected changes $(1 - p_{fr})\,\lambda_{fr}$, using firm-specific pre-TCA export shares to region r as weights.

We obtain p_{fEU} from our preferred estimates of the TCA effect on the relative survival probability for EU exporters shown in panel (a) of Figure 9. Likewise, we calculate λ_{fEU} using our preferred estimates of the intensive margin TCA effect from the regional differences estimates reported in column (b) of Table 4. In both cases, we choose specifications that allow for firm size heterogeneity in the TCA effect. Since the estimated impact of the TCA is less negative for larger firms, and larger firms tend to have higher weights in the aggregation, not accounting for firm size heterogeneity would over-estimate the decline in trade caused by the TCA.[31]

[31] When calculating p_{fEU} and λ_{fEU} for each firm, we only use estimates of the TCA effect that are negative and

We implement the calculation in equation (7) by aggregating across all firms in the VAT+ dataset (including firms with annual EU exports below £$10,000$). We use 2015 data to measure pre-TCA exports. Working with the VAT+ dataset maximizes firm coverage, while setting 2015 as the initial year ensures that the employment and export share data used in the aggregation exercise are both measured prior to the Brexit referendum.

Our estimates imply that the TCA reduced overall UK exports to the EU by 13.2%. Both the intensive and extensive margin effects contribute to this decline, but the intensive margin is relatively more important. When we shut down the extensive margin effect, the intensive margin alone yields a 9.3% fall in EU exports. By combining our estimates of p_{fEU} with data on the number of firms exporting to the EU pre-TCA, we also calculate that the TCA resulted in 14.0% of EU exporters, or $16,431$ firms, stopping exporting to the EU.

Since we find no effect of the TCA on exports to the RoW, and exports to the EU accounted for 48% of overall exports in the VAT+ dataset in 2015, we also calculate that the TCA reduced total UK exports by 6.4%, with the intensive margin alone accounting for a 4.5% fall. Thus, the aggregate effect of the TCA on goods exports during its first two years was negative, but relatively small compared to the OBR's forecast that Brexit would reduce UK trade by 15% in the long run (OBR 2021).

7.2 Imports

Because the TCA affected both EU and RoW imports, we cannot use the regional differences regressions to infer λ_{fEU} for imports. Instead, we use our world levels regressions to estimate the impact of the TCA on total worldwide imports. Specifically, we let $r = World$ and calculate λ_{fWorld} for each firm using the estimated impact of the TCA interacted with the firm-level EU import share from the world levels regression in column (c) of Table 7. We also set $p_{fWorld} = 0$, meaning that we shut down the extensive margin. We then use equation (7) to aggregate across all firms in the VAT+ dataset using 2015 to measure pre-TCA imports. This aggregation method implicitly assumes that the TCA had no effect on imports for firms that did not import from the EU prior to Brexit.

Computing the aggregate effect, we estimate that the TCA reduced total UK goods imports from all origins by 3.1%. This decline is substantially smaller than the fall in EU relative to RoW imports implied by our regional differences estimates, which highlights the need to account for the indirect effects of the TCA on imports from the RoW.[32]

significant at the 5% level. In practice, this means that we set the extensive margin effect to zero for firms with more than 44 employees and the intensive margin effect to zero for firms with more than 107 employees.

[32]Note that we can also implement the world levels aggregation exercise for exports, rather than imports. We do this by using the estimates from column (a) of Table 7 to obtain λ_{fWorld}, and setting $p_{fWorld} = 0$. This method implies

Interestingly, for both exports and imports, our aggregate estimates differ starkly from the findings of research that uses aggregate and/or product-level data. Consistent with the aggregate data shown in Figure 1, such research finds very little or no effect of the TCA on exports to the EU relative to the RoW (Freeman et al. 2022, Gasiorek and Tamberi 2023). But our firm-level analysis shows that these estimates are biased upwards. The bias likely arises from both the expansion of the set of firms covered by UK export data from 2021 onwards, and the fact that it is not possible to control for firm-specific supply shocks when using aggregate or product-level data.

For imports, the substantial decline in EU relative to RoW imports that we find in the regional differences regressions is also evident in aggregate and product-level data. But the regional differences estimates overstate the TCA effect on total imports because they do not account for the substitution towards RoW imports uncovered by our levels regressions. This comparison highlights the importance of the imported input substitutability mechanism in quantifying how the TCA has affected UK imports.

8 Conclusion

Brexit offers an unprecedented opportunity to study disintegration. We take advantage of this opportunity, and provide the first firm-level evidence on how reversing deep integration affects international trade. We find that Brexit did not have a significant impact on trade before 2021. Faced with uncertainty and the expectation of future trade barrier increases, firms adopted a wait and see approach rather than adjusting in advance of the change in policy. However, once the TCA comes into effect at the start of 2021, we find immediate and sustained shifts in both exports and imports.

For exports, we show that the TCA reduced exports to the EU through the direct negative impact of higher trade barriers, but did not have any indirect effect on exports to the RoW. Allowing for heterogeneity across firms, we estimate that the fall in EU exports is driven by smaller firms and that the effect is insignificant for the largest firms. This pattern of heterogeneity is consistent with larger firms making fixed cost investments to mitigate the increase in variable trade costs generated by the TCA. The TCA also reduced exports to the EU along the extensive margin, particularly for smaller firms, which implies that Brexit increased the fixed costs of exporting to the EU. Aggregating across firms, we estimate that the TCA has reduced worldwide UK exports by 6.4%.

On the imports side, the TCA decreased imports from the EU relative to the RoW. However, this relative decline was partially caused by firms substituting imports across origins and increasing

that the TCA reduced total UK exports by 4.4%, which is reassuringly close to the intensive margin effect on total exports obtained above.

their imports from the RoW. Nevertheless, we show that firms with higher pre-referendum exposure to EU imports experienced a decline in total imports under the TCA, meaning that the increase in imports from the RoW did not fully offset the decline in imports from the EU. Looking at the extensive margin, we estimate that the TCA led some smaller firms to stop importing from the EU.

Collectively, the results paint a rich picture of how disintegration with the EU affected UK firms through both direct and indirect channels. We show that the TCA reduced both exports and imports. But, we also document that importers and larger exporters adapted to the shock in ways that dampened the reduction in trade. Consequently, aggregate trade has, at least so far, been more resilient to Brexit than forecasters predicted. If this resilience is sustained, the economic costs of reversing deep integration may be lower than anticipated.

Our findings suggest a productive agenda for future research. The data used in this paper only covers the first two years of the TCA. And although our event-study estimates suggest that the impact of the TCA on trade in 2022 was similar to its impact in the second half of 2021, some longer-term effects may be yet to materialize. In addition, our analysis only considers goods trade and does not study trade in services. Finally, our results raise the question of how the TCA has affected firm-level outcomes along dimensions other than trade, such as employment, productivity and value-added. As always, there is more to be done.

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Table 1: Summary Statistics - Customs dataset

	Panel A: EU					
	(i) EU exporters			(ii) EU importers		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.
Firms per year	16,722			9,296		
Annual trade (thousand £)	8,226	1,062	75,418	23,183	4,698	154,045
Employment	265	19	3160	461	29	4,212
	Panel B: RoW					
	(i) RoW exporters			(ii) RoW importers		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.
Firms per year	65,605			94,592		
Annual trade (thousand £)	2,160	35	60,613	2,051	40	49,501
Employment	109	5	1,733	80	2	1,438
EU exports / Sales	0.064	0	0.146	0.042	0	0.126
EU imports / Inputs	0.068	0	0.161	0.053	0	0.147
	Panel C: World					
	(i) World exporters			(ii) World importers		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.
Firms per year	17,120			9,334		
Annual trade (thousand £)	15,198	1,675	171,911	37,676	6,568	238,085
Employment	245	18	3,052	425	26	4,088
EU exports / Exports	0.58	0.70	0.40	0.48	0.49	0.43
EU imports / Imports	0.43	0.29	0.43	0.66	0.88	0.40
	Panel D: EU & RoW					
	(i) Export sample			(ii) Import sample		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.
Firms per year	13,209			6,505		
Annual EU trade (thousand £)	9,092	1,032	82,278	24,946	4,440	157,836
Annual RoW trade (thousand £)	9,097	490	133,558	20,707	1,153	179,997
Employment	313	26	3,580	601	49	4,958
Tariff exposure	0.035	0.024	0.048	0.043	0.027	0.060
NTM exposure	6.66	6.00	4.20	7.09	6.11	4.58

Notes: Firm-level summary statistics for selected sub-samples of Customs dataset 2012q1-2022q4. Panel A: firms that trade with EU. Panel B: firms that trade with RoW (used in RoW levels regressions). Panel C: firms that trade with World with sample restricted to firm-quarters for which EU trade is observed (used in World levels regressions). Panel D: firms that trade with both EU and RoW (used in regional differences regressions). Annual trade refers to exports for export samples and imports for import samples. Employment defined as average employment from 2013q1-2015q4. EU trade share variables in panels B and C calculated using 2012 data if available, or the first year with available data otherwise. Tariff exposure is firm-specific weighted average of EU's CN 8-digit MFN tariffs in 2015. NTM exposure is firm-specific weighted average of the count of NTMs applied by the EU to MFN trade in each 8-digit product in 2015. Weights given by product-level shares of firm's EU exports for export regressions and shares of firm's EU imports for import regressions. Weights computed using 2012 data if available, or the first year with available data otherwise.

Table 2: Firm exports to EU versus RoW

	(a)	(b)	(c)	(d)	(e)
Referendum*EU	0.1281***	0.0719***	0.0769***	-0.0025	-0.0058
	(0.0059)	(0.0080)	(0.0079)	(0.0141)	(0.0141)
TCA*EU	-0.1606***	-0.1505***	-0.1282***	-0.1420***	-0.1456***
	(0.0074)	(0.0094)	(0.0099)	(0.0102)	(0.0102)
R-squared	.82	.93	.93	.93	.93
N	2,654,269	1,030,624	1,030,624	1,030,624	1,030,624
Firms	135,137	23,237	23,237	23,237	23,237
Controls					
Event dummies*EU			Yes	Yes	Yes
Region-level				Yes	Yes
Firm-level					Yes
Fixed effects					
Time	Yes				
Firm-region	Yes	Yes	Yes	Yes	Yes
Region-season	Yes	Yes	Yes	Yes	Yes
Firm-time		Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level exports by region (EU and RoW) and quarter (2012q1-2022q4) as dependent variable. Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. EU is dummy for trade with EU region. Event dummies cover onset of Covid-19 (2020q1 and q2) and start of TCA (2021q1). Region-level and firm-level variables control for regional and firm-specific import demand and real exchange rate (including current value and eight lags of real exchange rate). All specifications include dummy variables that take value one for missing observations of each independent variable.

Table 3: Firm imports from EU versus RoW

	(a)	(b)	(c)	(d)	(e)
Referendum*EU	0.0526***	0.0301**	0.0432***	-0.0035	-0.0012
	(0.0062)	(0.0134)	(0.0133)	(0.0192)	(0.0194)
TCA*EU	-0.1574***	-0.2374***	-0.2615***	-0.2237***	-0.2344***
	(0.0074)	(0.0155)	(0.0163)	(0.0178)	(0.0211)
R-squared	.85	.93	.93	.93	.93
N	3,215,495	500,268	500,268	500,268	500,268
Firms	219,887	12,409	12,409	12,409	12,409
Controls					
Event dummies*EU			Yes	Yes	Yes
Region-level				Yes	Yes
Firm-level					Yes
Fixed effects					
Time	Yes				
Firm-region	Yes	Yes	Yes	Yes	Yes
Region-season	Yes	Yes	Yes	Yes	Yes
Firm-time		Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level imports by region (EU and RoW) and quarter (2012q1-2022q4) as dependent variable. Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. EU is dummy for trade with EU region. Event dummies cover onset of Covid-19 (2020q1 and q2), start of TCA (2021q1) and use of Staged Customs Controls (2022q1 and q2). Region-level and firm-level variables control for regional and firm-specific export supply and real exchange rate (including current value and eight lags of real exchange rate) and for firm-specific changes in UK MFN tariffs. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table 4: Firm trade with EU versus RoW - size heterogeneity

	Exports			Imports		
	(a)	(b)	(c)	(d)	(e)	(f)
Firm size measure	Employment	Employment	Sales	Employment	Employment	Sales
Referendum*EU	-0.0556**	-0.0931***	-0.1335***	-0.1236***	0.0036	-0.0854*
	(0.0247)	(0.0334)	(0.0256)	(0.0407)	(0.0466)	(0.0443)
TCA*EU	-0.3949***	-0.3590***	-0.2517***	-0.3552***	-0.3153***	-0.3727***
	(0.0289)	(0.0365)	(0.0229)	(0.0489)	(0.0600)	(0.0491)
Referendum*EU*	0.0106**			0.0239***		
Size	(0.0054)			(0.0079)		
TCA*EU*Size	0.0704***			0.0259***		
	(0.0075)			(0.0096)		
Referendum*EU*		0.0550	0.0936***		-0.0949*	0.0155
Size quintile 2		(0.0361)	(0.0277)		(0.0535)	(0.0505)
Referendum*EU*		0.0668*	0.1268***		-0.0166	0.0358
Size quintile 3		(0.0351)	(0.0270)		(0.0526)	(0.0505)
Referendum*EU*		0.1085***	0.1916***		-0.0137	0.1289***
Size quintile 4		(0.0350)	(0.0277)		(0.0521)	(0.0495)
Referendum*EU*		0.0905**	0.1410***		0.0342	0.1173**
Size quintile 5		(0.0359)	(0.0289)		(0.0517)	(0.0496)
TCA*EU*		0.1394***	0.0721**		0.0347	0.1625***
Size quintile 2		(0.0419)	(0.0298)		(0.0693)	(0.0576)
TCA*EU*		0.1995***	0.0787***		0.0767	0.1646***
Size quintile 3		(0.0411)	(0.0296)		(0.0690)	(0.0586)
TCA*EU*		0.2231***	0.1156***		0.0962	0.1596***
Size quintile 4		(0.0410)	(0.0302)		(0.0686)	(0.0580)
TCA*EU*		0.3926***	0.2039***		0.1600**	0.1457**
Size quintile 5		(0.0435)	(0.0343)		(0.0676)	(0.0588)
R-squared	.93	.93	.93	.93	.93	.93
N	1,030,624	1,030,624	1,030,624	500,268	500,268	500,268
Firms	23,237	23,237	23,237	12,409	12,409	12,409
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level trade by region (EU and RoW) and quarter (2012q1-2022q4) as dependent variable. Direction of trade is exports in columns (a)-(c) and imports in columns (d)-(f). Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. EU is dummy for trade with EU region. Firm size measured by log employment in columns (a) and (d), employment quintiles in columns (b) and (e) and sales quintiles in columns (c) and (f). All specifications include the full set of region-level, firm-level and event dummy controls as well as firm-region, region-season and firm-time fixed effects. The event dummy controls are also interacted with firm size. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table 5: Firm trade with EU versus RoW - trade policy exposure

	Exports		Imports	
	(a)	(b)	(c)	(d)
Referendum*EU*Tariff	0.3261	0.3675*	0.2406	0.2261
	(0.2170)	(0.2207)	(0.2444)	(0.2766)
TCA*EU*Tariff	-1.8605***	-1.7852***	-1.0146***	-1.1159***
	(0.2384)	(0.2407)	(0.2911)	(0.3290)
Referendum*EU*NTM		-0.0020		0.0005
		(0.0020)		(0.0031)
TCA*EU*NTM		-0.0037		0.0033
		(0.0026)		(0.0038)
R-squared	.93	.93	.93	.93
N	1,030,624	1,030,624	500,268	500,268
Firms	23,237	23,237	12,409	12,409
Firm size heterogeneity	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level trade by region (EU and RoW) and quarter (2012q1-2022q4) as dependent variable. Direction of trade is exports in columns (a)-(b) and imports in columns (c)-(d). Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. EU is dummy for trade with EU region. Tariff exposure is firm-specific weighted average of EU's CN 8-digit MFN tariffs in 2015. NTM exposure is firm-specific weighted average of the count of NTMs applied by the EU to MFN trade in each 8-digit product in 2015. Weights given by product-level shares of firm's EU exports for export regressions and shares of firm's EU imports for import regressions. Weights computed using 2012 data if available, or the first year with available data otherwise. All specifications include triple interactions of the Referendum, TCA and event dummy variables with the EU dummy and firm employment quintile dummy variables. All specifications include the full set of region-level, firm-level and event dummy controls as well as firm-region, region-season and firm-time fixed effects. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table 6: Firm trade with RoW

	Exports			Imports		
	(a)	(b)	(c)	(d)	(e)	(f)
Referendum*(EU	0.0530**	0.0527**			-0.0498**	
exports/Sales)	(0.0266)	(0.0266)			(0.0251)	
TCA*(EU	-0.0467	-0.0422			-0.3974***	
exports/Sales)	(0.0311)	(0.0311)			(0.0320)	
Referendum*(EU		0.0110		0.1047***	0.1059***	
imports/Inputs)		(0.0259)		(0.0219)	(0.0219)	
TCA*(EU		-0.0282		0.2783***	0.3010***	
imports/Inputs)		(0.0306)		(0.0281)	(0.0282)	
Referendum*(EU			-0.6608			-0.2443
exports/Sales)*Tariff			(0.5864)			(1.1511)
TCA*(EU			-0.0507			-3.2863**
exports/Sales)*Tariff			(0.8928)			(1.5982)
Referendum*(EU			0.0230			-0.2213
imports/Inputs)*Tariff			(0.7201)			(0.6579)
TCA*(EU			0.1871			2.1758***
imports/Inputs)*Tariff			(0.7807)			(0.7565)
R-squared	.78	.78	.81	.81	.81	.82
N	1,771,940	1,771,940	574,322	2,584,769	2,584,769	312,778
Firms	123,910	123,910	27,687	207,026	207,026	13,974
Firm size heterogeneity	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level trade with RoW by quarter (2013q1-2022q4) as dependent variable. Direction of trade is exports in columns (a)-(c) and imports in columns (d)-(f). Sample in columns (c) and (f) restricted to firms with above Intrastat threshold (export threshold for column c, import threshold for column f) trade with EU in at least one calendar year during sample. Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. Firm-specific EU trade exposure measures computed using 2012 data if available, or the first year with available data otherwise. Tariff exposure is firm-specific weighted average of EU's CN 8-digit MFN tariffs in 2015. Weights given by product-level shares of firm's EU exports when interacted with EU exports to Sales ratio in column (c), and shares of firm's EU imports when interacted with EU imports to Inputs ratio in column (f). Weights computed using 2012 data if available, or the first year with available data otherwise. All specifications include interactions of the Referendum, TCA and event dummy variables with firm employment quintile dummy variables and interactions of the event dummy variables with any EU exposure measures included in the specification. All specifications include the full set of firm-level and event dummy controls as well as firm and industry-time fixed effects. Industries are SIC 4-digit sectors. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table 7: Firm trade with the World

	Exports		Imports	
	(a)	(b)	(c)	(d)
Referendum*EU exports share	0.0804***			
	(0.0179)			
TCA*EU exports share	-0.0977***			
	(0.0228)			
Referendum*EU exports share*Tariff		0.1538		
		(0.1261)		
TCA*EU exports share*Tariff		-0.7916***		
		(0.1789)		
Referendum*EU imports share			0.0057	
			(0.0197)	
TCA*EU imports share			-0.0605**	
			(0.0285)	
Referendum*EU imports share*Tariff				-0.0324
				(0.1167)
TCA*EU imports share*Tariff				-0.3529**
				(0.1530)
R-squared	.84	.84	.86	.86
N	657,513	657,513	365,586	365,586
Firms	32,181	32,181	17,476	17,476
Firm size heterogeneity	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level trade with world by quarter (2013q1-2022q4) as dependent variable. Direction of trade is exports in columns (a)-(b) and imports in columns (c)-(d). Sample restricted to firm-quarters in which EU trade is observed. Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. Firm-specific EU trade shares computed using 2012 data if available, or the first year with available data otherwise. Tariff exposure is firm-specific weighted average of EU's CN 8-digit MFN tariffs in 2015. Weights given by product-level shares of firm's EU exports when interacted with EU exports share and shares of firm's EU imports when interacted with EU imports share. Weights computed using 2012 data if available, or the first year with available data otherwise. All specifications include interactions of the Referendum, TCA and event dummy variables with firm employment quintile dummy variables and interactions of the event dummy variables with any EU exposure measures included in the specification. All specifications include the full set of firm-level and event dummy controls as well as firm and industry-time fixed effects. Industries are SIC 4-digit sectors. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table 8: Firm export survival in EU versus RoW

	EU versus RoW						EU	RoW
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
TCA*EU	-0.13***	-0.24***		-0.24***	-0.23***	-0.19***		
	(0.002)	(0.009)		(0.007)	(0.011)	(0.016)		
TCA*EU*		0.03**		0.02**	0.04**	0.02		
Size quintile 2		(0.013)		(0.010)	(0.016)	(0.023)		
TCA*EU*		0.07***		0.05***	0.07***	0.08***		
Size quintile 3		(0.012)		(0.009)	(0.014)	(0.019)		
TCA*EU*		0.12***		0.10***	0.12***	0.12***		
Size quintile 4		(0.010)		(0.008)	(0.012)	(0.017)		
TCA*EU*		0.22***		0.21***	0.21***	0.18***		
Size quintile 5		(0.010)		(0.008)	(0.012)	(0.016)		
2016			0.01***				0.01***	0.00
			(0.003)				(0.002)	(0.002)
2017			0.02***				0.02***	0.00
			(0.003)				(0.002)	(0.002)
2018			0.02***				0.02***	0.01**
			(0.003)				(0.002)	(0.003)
2019			0.01***				0.01***	0.00
			(0.003)				(0.002)	(0.003)
2021			-0.11***				-0.13***	0.00*
			(0.003)				(0.002)	(0.003)
2022			-0.13***				-0.13***	0.02***
			(0.003)				(0.002)	(0.003)
R-squared	.14	.2	.14	.2	.21	.2	.16	.033
N	860,894	858,297	860,894	1,332,725	673,077	402,297	536,361	324,605
Firms	218,384	217,414	218,384	356,210	167,495	95,221	183,191	93,352
Initial exports threshold	10,000	10,000	10,000	0	25,000	100,000	10,000	10,000
Controls								
Referendum*EU	Yes	Yes		Yes	Yes	Yes		
Region-level	Yes	Yes		Yes	Yes	Yes		
Referendum*EU*Size quintiles		Yes		Yes	Yes	Yes		
Fixed effects								
Industry-region	Yes		Yes					
Industry-time	Yes		Yes					
Size quintile-industry-region		Yes		Yes	Yes	Yes		
Size quintile-industry-time		Yes		Yes	Yes	Yes		
Industry							Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses VAT+ dataset. Dependent variable is dummy for export survival by region in year t (t=2015-19, 2021-22) of firms with regional exports above the intial exports threshold (in pounds) in year t-3. Columns (a)-(f) report regional differences survival regressions. Columns (g) and (h) report levels survival regressions. Referendum dummy takes value one from 2016 onwards. TCA dummy takes value one from 2021 onwards. EU is dummy for EU region. Firm size measured by employment quintiles. Event study estimates in column (c) are estimated coefficients on year*EU interactions. Region-level controls are three-year difference of regional import demand and real exchange rate variables. Industries are SIC 4-digit sectors. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table 9: Firm import survival in EU versus RoW

	EU versus RoW						EU	RoW
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
TCA*EU	-0.11***	-0.09***		-0.13***	-0.09***	-0.09***		
	(0.007)	(0.024)		(0.022)	(0.024)	(0.026)		
TCA*EU*		-0.09***		-0.10***	-0.07**	-0.03		
Size quintile 2		(0.025)		(0.023)	(0.026)	(0.030)		
TCA*EU*		-0.06**		-0.09***	-0.04*	0.01		
Size quintile 3		(0.024)		(0.022)	(0.024)	(0.026)		
TCA*EU*		-0.03		-0.04*	-0.02	0.02		
Size quintile 4		(0.023)		(0.022)	(0.024)	(0.025)		
TCA*EU*		0.06**		0.06***	0.06**	0.08***		
Size quintile 5		(0.023)		(0.022)	(0.024)	(0.025)		
2016			0.01**				0.01***	0.00*
			(0.002)				(0.002)	(0.002)
2017			0.01***				0.01***	-0.00
			(0.003)				(0.002)	(0.002)
2018			0.02***				0.01***	-0.00
			(0.003)				(0.002)	(0.002)
2019			0.00				0.00	-0.00
			(0.003)				(0.002)	(0.002)
2022			-0.13***				-0.11***	0.04***
			(0.003)				(0.002)	(0.002)
R-squared	.066	.12	.066	.16	.11	.11	.073	.039
N	911,883	909,633	911,883	1,499,933	721,027	448,006	523,592	388,351
Firms	247,023	246,234	247,023	461,852	188,723	111,761	176,086	128,847
Initial imports threshold	10,000	10,000	10,000	0	25,000	100,000	10,000	10,000
Controls								
Referendum*EU	Yes	Yes		Yes	Yes	Yes		
Region-level	Yes	Yes		Yes	Yes	Yes		
Referendum*EU*Size quintiles		Yes		Yes	Yes	Yes		
Fixed effects								
Industry-region	Yes		Yes					
Industry-time	Yes		Yes					
Size quintile-industry-region		Yes		Yes	Yes	Yes		
Size quintile-industry-time		Yes		Yes	Yes	Yes		
Industry							Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses VAT+ dataset. Dependent variable is dummy for import survival by region in year t (t=2015-19, 2022) of firms with regional imports above the intial imports threshold (in pounds) in year t-3. Columns (a)-(f) report regional differences survival regressions. Columns (g) and (h) report levels survival regressions. Referendum dummy takes value one from 2016 onwards. TCA dummy takes value one from 2021 onwards. EU is dummy for EU region. Firm size measured by employment quintiles. Event study estimates in column (c) are estimated coefficients on year*EU interactions. Region-level controls are three-year difference of regional export supply and real exchange rate variables. Industries are SIC 4-digit sectors. All specifications include dummy variables that take value one for missing observations of each independent variable.

A Data

A.1 EU and Non-EU Trade Panel datasets

HMRC's EU and Non-EU Trade Panel datasets report exports and imports in pound sterling by trader ID, CN 8-digit product, partner country and month. Trader ID numbers are unique identifiers provided by HMRC to entities involved in international trade. To construct our Customs dataset, we match trader IDs to firms' VAT numbers using a mapping provided by HMRC.

The Customs dataset measures trade on the 'special trade' rather than 'general trade' basis, meaning that it excludes imports into, or exports from, customs warehouses and free zones. We also drop trade in non-monetary gold[33] and all trade in HS Chapters 98 and 99. And we drop negative trade values at the VAT number-CN 8-digit product-country-month level. Croatia joined the EU in July 2013. However, when aggregating trade flows to the EU and RoW regions, we assign Croatia to the EU throughout the sample.

A.2 VAT Returns Panel dataset

The VAT Returns Panel dataset is an administrative tax dataset collected by HMRC that covers all firms with annual taxable turnover above the VAT threshold. The VAT threshold was £$77,000$ in 2012 and then increased annually until 2017 when it reached £$85,000$. The threshold then remained at £$85,000$ until the end of our sample in 2022.

A.3 Other data

IDBR. We observe SIC industry and employment using the IDBR enterprise-level dataset, which we match to firms' VAT numbers using a mapping available in the IDBR. When firms operate in multiple industries, we assign the firm to the industry in which it has highest turnover. When the firm's industry is missing, we obtain industry data from the VAT Returns Panel dataset. We also use the IDBR enterprise-group level dataset to obtain each firm's country of ultimate ownership and control.

UN Comtrade. From UN Comtrade we obtain monthly bilateral trade data by HS 6-digit product for 25 EU countries (all EU countries except Luxembourg and Malta) and 104 non-EU countries. We aggregate to the quarterly level and impute missing values in cases where a country reports no trade in a quarter. We impute values using the most recent previous value when we observe a previous but no subsequent observation, with the closest subsequent value when we observe a subsequent but no previous observation, and with a linear combination when we observe both.

[33] Specifically, we drop CN products 71081100, 71081200, 71081310, 71081318, 71090000, 71123000 and 71129100.

A.4 Firm-level controls

We compute a firm-specific measure of import demand from each region as a weighted average across product-country pairs of imports from the world excluding the UK, where we use firm-level export shares as weights. Let IMP_{pct} denote imports (indexed relative to 2021) of HS 6-digit product p by country c from the world excluding the UK in period t. Let ω_{frpc}^{EXP} denote the share of product p and country c in firm f's exports to region r. We compute the weights ω_{frpc}^{EXP} using data for the earliest sample year from 2012 onwards in which we observe firm f exporting to region r in the Customs dataset. The firm-level foreign import demand control that we include in Z_{frt} in our export regressions is given by:

$$\log\left(\sum_{p}\sum_{c}\omega_{frpc}^{EXP}IMP_{pct}\right).$$

The firm-level export supply control that we include in our import regressions is computed analogously, except that we weight exports to the world excluding the UK by country c in product p by firm-level import shares.

To construct firm-level real exchange rates, we weight bilateral real exchange rate indices by firm-specific trade weights. Let RXR_{ct} be an index (relative to 2012q1) of country c's real exchange rate with the UK in period t. Let ω_{frc}^{EXP} denote the share of country c in firm f's exports to region r in the earliest sample year in which firm-region exports are observed. The firm-level real exchange rate that we include in Z_{frt} in our export regressions is given by:

$$\log\left(\sum_{c}\omega_{frc}^{EXP}RXR_{ct}\right).$$

Likewise, we compute a firm-level real exchange rate to include in our import regressions by weighting RXR_{ct} using firm-level import shares.

Finally, the firm-level tariff change variables included in Z_{frt} in our import regressions are computed by weighting tariff changes across CN 8-digit products using firm-level RoW import shares. Let $\Delta\tau_p$ be the change in the UK's MFN tariff on product p under the UK Global Tariff introduced at the start of 2021. Let $\omega_{fp,RoW}^{IMP}$ denote the share of product p in firm f's imports from the RoW in the earliest sample year in which we observe the firm importing from the RoW. The firm-level change in ad-valorem tariffs is given by:

$$\log\left(1+\frac{1}{100}\sum_{p}\omega_{fp,RoW}^{IMP}\Delta\tau_p\right).$$

Let NAV_p be a dummy variable that takes value one for products that experienced non-ad-valorem

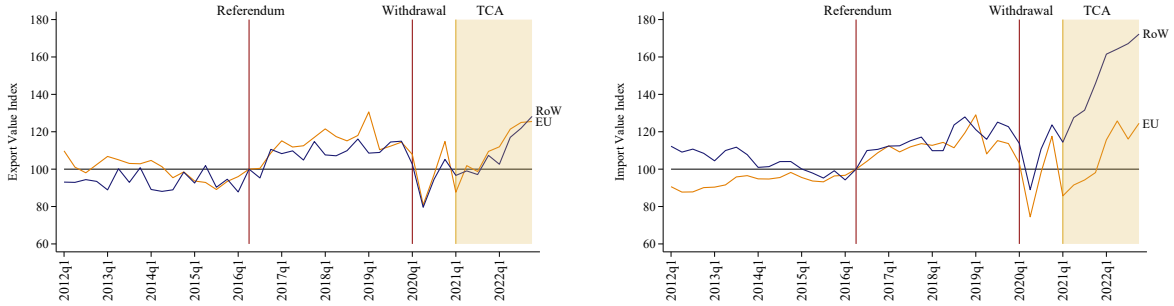
tariff changes due to the introduction of the UK Global Tariff. The firm-level measure of exposure to non-ad-valorem tariff changes is given by:

$$\sum_p \omega_{fp,RoW}^{IMP} NAV_p.$$

A.5 Customs dataset versus OTS

In this section, we compare aggregate trade in our Customs dataset versus HMRC's Overseas Trade Statistics (OTS). Figure 10 plots total UK goods trade with each region in the Customs dataset. The data covers 2012q1-2022q4 and all series are indexed to 100 in 2016q2. Exports to both regions display similar trends throughout the sample, whereas imports from the RoW increase more quickly than imports from the EU under the TCA.

We can compare Figure 10 with Figure 1, which shows aggregate goods trade in the OTS. The main differences are that, in the Customs dataset, exports to the EU grow less quickly from 2021 onwards, and imports from the EU grow less quickly in 2022. These differences are consistent with the switch from Intrastat to customs declarations expanding the set of traders from which data is collected and, therefore, increasing trade with the EU as measured by the OTS. By contrast, firms that are only observed following the switch to customs declarations are not included in the Customs dataset.



(a) Exports

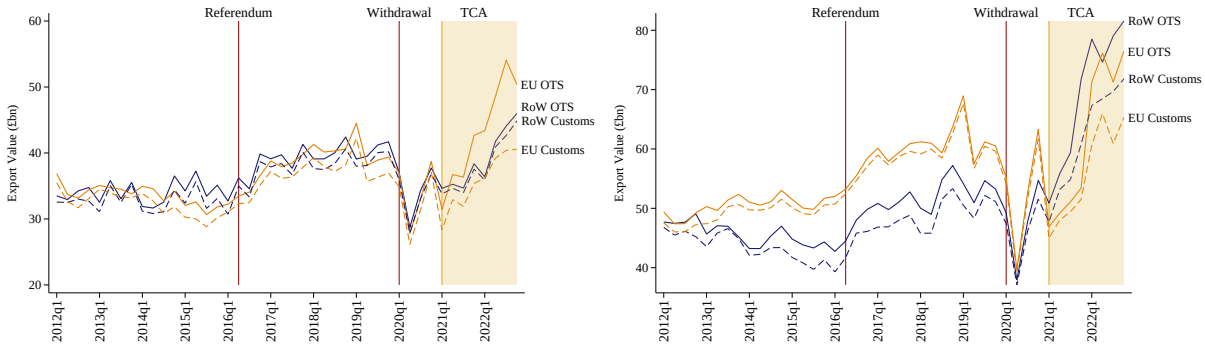
(b) Imports

Notes: Total goods trade with EU and RoW in the Customs dataset. All series normalized to 100 in 2016q2.

Figure 10: Aggregate trade with EU and RoW: Customs dataset

To compare the Customs and OTS data more directly, Figure 11 plots the value (in billion pounds) of total exports and imports by region in each of the two datasets. For both directions of trade and both regions, trade values are always lower in the Customs dataset than in the OTS, but the differences are small prior to 2021. However, under the TCA, EU exports are higher in the OTS than in the Customs dataset. And a similar gap emerges for EU imports in 2022. Again, these

patterns are consistent with the differences in how the OTS dataset and the Customs dataset are constructed.



(a) Exports (b) Imports

Notes: Total goods trade with EU and RoW in the Customs dataset and in HMRC's Overseas Trade Statistics (OTS). OTS data excludes trade in non-monetary gold and HS Chapters 98 and 99. All series are in billion pounds.

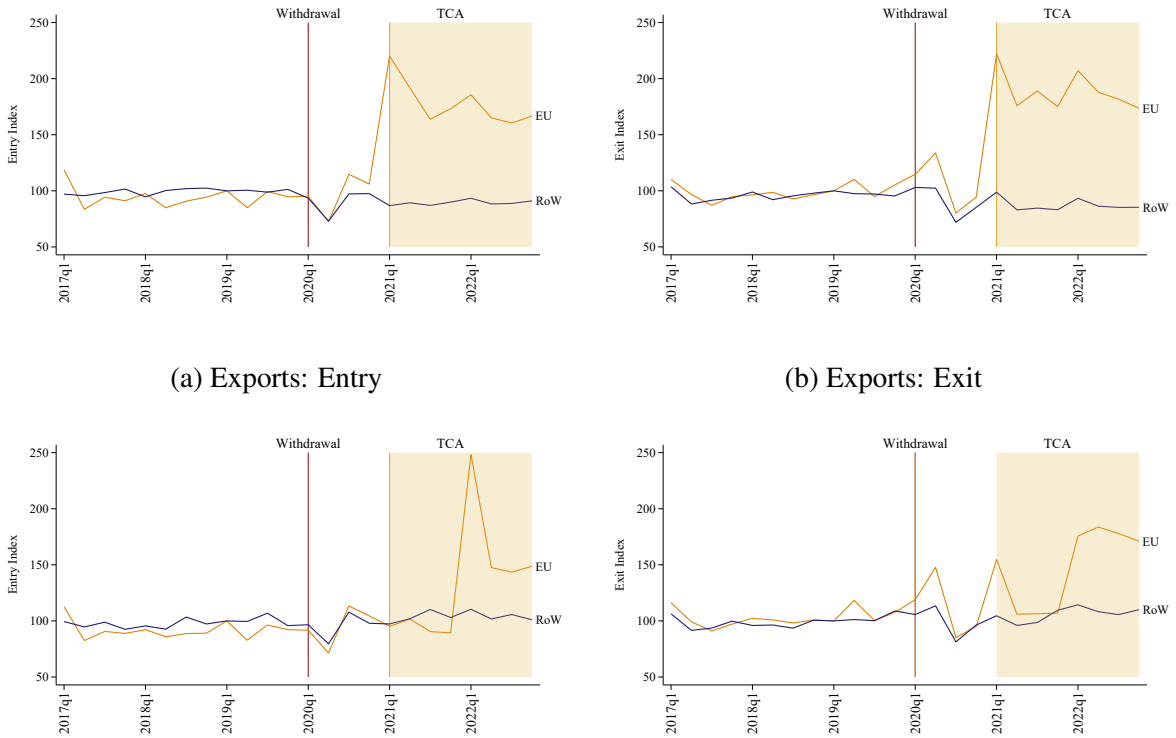
Figure 11: Aggregate trade with EU and RoW: Customs dataset versus HMRC OTS

B Product-level trade reporting

Figure 12 plots data on changes in firm-product-region level entry and exit over time. We compute entry and exit using the Customs dataset, but restricting the export and import samples for each region to balanced panels of firms that are observed in every quarter from 2017q1-2022q4. For each quarter t and each region r, we then define entry as the number of firm-product varieties for which we observe positive trade with region r in period t, but not in period t-1. And we define exit as the number of firm-product varieties with positive trade with region r in period t-1, but not in period t. Products are defined at the CN 8-digit level.

Figure 12 shows export entry in panel (a), export exit in panel (b), import entry in panel (c) and import exit in panel (d). All series are normalized to 100 in 2019q1. For exports, we see that EU entry and exit each more than doubles in the first quarter of 2021 and then declines slightly while remaining at higher rates than in earlier years. By contrast, RoW entry and exit does not change dramatically in 2021 and 2022. For imports, we see similar patterns except that the spikes in EU entry and exit do not occur until the first quarter of 2022. The import data also shows higher EU exit in 2021q1, which likely reflects the reduction in EU imports under the TCA. For both the exports and imports balanced samples, the net effect of the spikes in entry and exit is to increase the number of firm-product varieties traded with the EU by 10%-15%.

The change in data collection from Intrastat to Customs declarations occurred in 2021q1 for EU exports and 2022q1 for EU imports. Figure 12 shows that for both exports and imports the



(a) Exports: Entry

(b) Exports: Exit

(c) Imports: Entry

(d) Imports: Exit

Notes: Entry and exit of firm-product varieties by region. Entry defined as number of varieties traded in quarter t, but not in quarter t-1. Exit defined as number of varieties traded in quarter t-1, but not in quarter t. All series normalized to 100 in 2019q1. Products defined at CN 8-digit level. Entry and exit calculated using Customs dataset for balanced sample of firms that export (or import) every quarter from 2017q1-2022q4.

Figure 12: Firm-product entry and exit

switch in data collection coincided with large spikes not only in entry, but also in exit, at the firm-product level. This suggests that the change in data collection led firms to report trading different sets of products. Based on this evidence, we conclude that product-level data on UK goods trade is not comparable before and after the switch in data collection. Consequently, we do not compare product-level trade before and after the switch at any point in the paper.

C Additional results

C.1 Regional differences: robustness

Table A2 reports robustness checks on the regional differences results for exports from Table 2 in Section 4.2. For ease of comparison, the baseline estimates in column (e) of Table 2 are repeated in column (a).

Springford (2024) argues that, since 2020, trade has become increasingly regionalized, implying that, all else equal, UK trade with the EU should have grown more quickly than UK trade with the RoW. We allow for this possibility in column (b) by computing the region-level import demand control using regional imports from the EU excluding the UK instead of imports from the world excluding the UK. This change makes little difference to the estimates.

In column (c) we impose the Intrastat export threshold on RoW exports by dropping all firm-quarter observations of RoW exports in calendar years where the firm's RoW exports are below £0.25 million. With this sample restriction the TCA effect is somewhat smaller, presumably because average firm size increases and, as shown in Section 4.3, the TCA had less effect on exports for larger firms. In column (d) we drop firms in the agri-food industry (SIC sectors 1-3 and 10-12) from the sample, which does not make a noticeable difference.

Finally, in column (e) we drop from the set of countries included in the RoW those countries with which the UK (as part of the EU's customs union) had a preferential trade agreement (PTA) prior to Brexit. Brexit may have directly affected trade with such countries, since leaving the EU meant renegotiating these agreements. However, comparing column (e) to column (a) we find that the Referendum and TCA effects are similar in both cases. This finding is unsurprising given that all the UK's existing preferential trade agreements with non-EU countries were rolled over essentially unchanged when the UK left the EU's customs union. Note also that, although the UK has negotiated new trade deals with non-EU countries since leaving the EU, no new agreements entered into force during our sample.

Table A3 reports the same set of robustness checks, but for imports instead of exports. Again, we find no evidence that the referendum reduced relative imports from the EU, whereas the TCA effect is negative and significant across all specifications. The magnitude of the TCA effect is slightly smaller when we impose the small-firm threshold on RoW imports (column c) and when we drop from the RoW countries with which the UK had a PTA prior to Brexit (column e). But otherwise the estimates are very similar to the baseline results.

In Table A4 we study whether the impact of Brexit on EU relative to RoW trade differs for domestic versus foreign owned firms. Starting from the firm size heterogeneity specification for exports in column (b) of Table 4, we add triple interactions of the $Referendum_t$, TCA_t and event dummy variables with the EU_r dummy and a dummy for whether the firm is foreign owned. We estimate that foreign owned firms have slightly higher relative EU exports following the referendum, while the TCA effect is insignificant. In column (b) we split foreign owned firms into EU owned and RoW owned. We find that the increase in EU exports following the referendum is driven by EU owned firms. But the TCA effect remains insignificant for both groups. We obtain similar results for imports in columns (c) and (d). Foreign owned firms' imports from the EU relative to the RoW increased slightly after the referendum, due to higher imports by both EU owned and

RoW owned firms. However, there is no evidence that the effect of the TCA on imports differed for foreign owned firms compared to domestic firms.

References

Springford, J. 2024. Brexit, Four Years On: Answers to Two Trade Paradoxes. Centre for European Reform, 25 January.

Table A1: Summary Statistics - VAT+ dataset

	Panel A: EU					
	(i) EU exporters			(ii) EU importers		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.
Firms per year	101,918			118,399		
Annual trade (thousand £)	2,089	86	60,710	2,759	95	55,187
Employment	69	3	1,352	77	3	1,367
	Panel B: EU & RoW					
	(i) Export sample			(ii) Import sample		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.
Firms per year	33,897			32,976		
Annual EU trade (thousand £)	3,989	204	88,792	5,756	248	81,286
Annual RoW trade (thousand £)	3,779	92	85,360	4,862	149	81,583
Employment	157	10	2,358	197	12	2,530

Notes: Firm-level summary statistics for selected sub-samples of VAT+ dataset. Annual frequencey for 2012-19, 2021 (exports only) and 2022. Panel A: firms that trade with EU. Panel B: firms that trade with both EU and RoW (used in regional differences regressions). Annual trade refers to exports for export samples and imports for import samples. Trade with EU from VAT returns for 2012-19 and from customs data for 2021-22. Trade with RoW from customs data for all years. Employment defined as average employment from 2013q1-2015q4. Summary statistics for firms that trade with RoW not shown because data on RoW trade in VAT+ dataset is same as in Customs dataset.

Table A2: Firm exports to EU versus RoW - robustness

	(a) Baseline	(b) EU-specific import demand	(c) RoW Intrastat	(d) Drop agri-food	(e) RoW no PTAs
Referendum*EU	-0.0058	-0.0073	0.0063	0.0020	0.0000
	(0.0141)	(0.0144)	(0.0151)	(0.0143)	(0.0158)
TCA*EU	-0.1456***	-0.1414***	-0.0847***	-0.1455***	-0.1409***
	(0.0102)	(0.0101)	(0.0110)	(0.0104)	(0.0112)
R-squared	.93	.93	.92	.92	.92
N	1,030,624	1,030,624	696,368	996,134	912,380
Firms	23,237	23,237	15,435	22,495	21,464
Controls	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level exports by region (EU and RoW) and quarter (2012q1-2022q4) as dependent variable. Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. EU is dummy for trade with EU region. In column (b) region-level and firm-level import demand controls calculated using regional imports from EU (excluding UK). In column (c) we drop firm-quarter observations in calendar years where firm's RoW exports are below the Intrastat export threshold of £0.25 million. In column (d) we drop firms in the agri-food industry (SIC sectors 1-3 and 10-12). In column (e) the RoW does not include countries that have a preferential trade agreement with the UK. All specifications include the full set of region-level, firm-level and event dummy controls as well as firm-region, region-season and firm-time fixed effects. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table A3: Firm imports from EU versus RoW - robustness

	(a) Baseline	(b) EU-specific export supply	(c) RoW Intrastat	(d) Drop agri-food	(e) RoW no PTAs
Referendum*EU	-0.0012	-0.0019	0.0584***	-0.0016	0.0127
	(0.0194)	(0.0197)	(0.0204)	(0.0195)	(0.0207)
TCA*EU	-0.2344***	-0.2308***	-0.1645***	-0.2427***	-0.1716***
	(0.0211)	(0.0214)	(0.0230)	(0.0215)	(0.0222)
R-squared	.93	.93	.91	.93	.93
N	500,268	500,268	259,104	481,156	440,304
Firms	12,409	12,409	6,424	11,919	11,324
Controls	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level imports by region (EU and RoW) and quarter (2012q1-2022q4) as dependent variable. Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. EU is dummy for trade with EU region. In column (b) region-level and firm-level export supply controls calculated using regional exports to EU (excluding UK). In column (c) we drop firm-quarter observations in calendar years where firm's RoW imports are below the Intrastat import threshold of £1.5 million. In column (d) we drop firms in the agri-food industry (SIC sectors 1-3 and 10-12). In column (e) the RoW does not include countries that have a preferential trade agreement with the UK. All specifications include the full set of region-level, firm-level and event dummy controls as well as firm-region, region-season and firm-time fixed effects. All specifications include dummy variables that take value one for missing observations of each independent variable.

Table A4: Firm trade with EU versus RoW - foreign ownership

	Exports		Imports	
	(a)	(b)	(c)	(d)
Referendum*EU*Foreign owned	0.0489**		0.0853***	
	(0.0201)		(0.0299)	
Referendum*EU*EU owned		0.0811***		0.0965***
		(0.0277)		(0.0347)
Referendum*EU*RoW owned		0.0322		0.0868**
		(0.0222)		(0.0347)
TCA*EU*Foreign owned	0.0214		-0.0605	
	(0.0273)		(0.0386)	
TCA*EU*EU owned		0.0277		-0.0300
		(0.0400)		(0.0450)
TCA*EU*RoW owned		0.0369		-0.0556
		(0.0305)		(0.0480)
R-squared	.93	.93	.93	.93
N	1,030,624	1,030,624	500,268	500,268
Firms	23,237	23,237	12,409	12,409
Firm size heterogeneity	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Notes: Standard errors clustered by firm in parentheses. (***), (**) and (*) indicate significance at the 1%, 5% and 10% levels, respectively. Estimation uses Customs dataset with log firm-level trade by region (EU and RoW) and quarter (2012q1-2022q4) as dependent variable. Direction of trade is exports in columns (a)-(b) and imports in columns (c)-(d). Referendum dummy takes value one from 2016q3 onwards. TCA dummy takes value one from 2021q1 onwards. EU is dummy for trade with EU region. Foreign owned, EU owned and RoW owned are dummy variables for whether ownership and control of firm lies outside of UK, in EU and in RoW, respectively. All specifications include: the full set of region-level, firm-level and event dummy controls; triple interactions of the Referendum, TCA and event dummy variables with the EU dummy and with firm employment quintile dummy variables; triple interactions of the event dummy controls with the EU dummy and with the Foreign owned dummy (columns a and c) or with the EU owned and RoW owned dummies (columns b and d), and; firm-region, region-season and firm-time fixed effects. All specifications include dummy variables that take value one for missing observations of each independent variable.