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

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Abstract

How does dismantling deep integration affect international trade? This paper studies the consequences of economic 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 UK firm, and caused many firms to stop trading with the EU altogether. But Brexit's impact on aggregate trade was mitigated by three forces: larger firms were less hard hit; exports to non-EU countries were unaffected; and importers partially compensated for reduced EU imports by sourcing more from outside the EU. Our estimates imply that leaving the EU reduced worldwide UK exports by 6.4% and worldwide UK imports by 4.4% within the first two years. Adjustment patterns indicate that these effects were driven by higher variable and fixed UK-EU trade costs and imperfect input substitutability across origins, with little role for scale effects, capacity constraints, input cost shocks, or sourcing complementarities.

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1 Introduction

After decades of widening and deepening globalization, there is fierce controversy about the role of nation states in the global economy. Debate over deep integration is at the core of this controversy (Rodrik 2011). Members of the world's most ambitious integration agreement, the European Union (EU), pursue deep integration through commitments to: abolish customs checks; harmonize economic, trade, and regulatory policies; and allow free movement of capital and labor. These commitments seek to boost trade and growth by removing barriers to economic exchange (Baldwin and Wyplosz 2022). Yet opponents argue that the economic benefits of deep integration are too marginal to justify the loss of national sovereignty.

Brexit exemplifies these tensions. It constitutes a unique juncture between the polar trends of trade wars and disintegration on the one hand (e.g. the US-China relationship) and enhanced integration on the other (e.g. the Regional Comprehensive Economic Partnership in the Asia-Pacific region). Supporters of Brexit claimed that frictionless trade could be achieved through shallow integration focussed on tariff policy, whereas opponents argued that EU membership led to substantially higher trade through deep integration (Grey 2021). In this paper, we use Brexit as a natural experiment to address the question at the heart of this debate: How does deep integration affect international trade? Our research provides the first evidence of the impact of the new UK-EU relationship on UK goods trade based on firm-level UK customs data.

We find that the UK's exit from the EU single market and customs union at the start of 2021 led to immediate declines in UK exports and imports with the EU, due to increases in both variable and fixed trade costs. At the same time, firms responded to this shock in ways that dampened the fall in overall trade. Larger firms were less impacted than smaller firms, exports to the rest of the world (RoW) were not affected, and input substitutability across origins allowed firms to partially compensate for lower imports from the EU by increasing their sourcing from the RoW. On aggregate, we calculate that leaving the EU reduced worldwide UK exports by 6.4% and worldwide UK imports by 4.4% within the first two years.

We study the evolution of UK goods trade over 2012-2022 around two Brexit milestones: the Referendum in June 2016, and the enactment of the Trade and Cooperation Agreement (TCA) governing post-Brexit UK-EU relations in January 2021. These two events affected UK-EU trade relations, and the first and second moments of expectations about future trade relations, in very different ways. The vote to leave the EU created substantial uncertainty about the level and volatility of future trade barriers, but did not change actual trade policy. By contrast, the TCA increased UK-EU trade barriers, while also reducing, though not eliminating, uncertainty over future UK-EU trade policy. 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 single market or customs union. The TCA thus reintro-

duced a customs border between the UK and the EU, and ended automatic regulatory alignment in the future. These higher non-tariff barriers to UK-EU trade may raise variable, fixed, and sunk trade costs.

Our empirical analysis is guided by the mechanisms through which Brexit could potentially affect UK trade. First, UK firms face higher costs of exporting to the EU. We expect this *(i) export cost increase* to directly reduce exports to the EU without directly affecting exports to the RoW. However, any firm-level *(ii) scale economies* or *(iii) capacity constraints* in production and/or exporting would indirectly affect RoW exports. Second, UK firms face higher costs of importing from the EU. This *(iv) import cost increase* is expected to directly reduce imports from the EU with no direct impact on imports from the RoW. However, any *(v) input substitutability* or (*vi) input complementarity* across origins would respectively raise or lower imports from the RoW. Third, supply-chain linkages could trigger additional indirect effects: *(vii) rising input costs* may depress exports worldwide, while *(viii) lower production scale* may lower imports from all sources.

We adopt three strategies to quantify the causal effects of Brexit and inform the mechanisms above. First, our research is the first to use firm-level customs data to study the TCA. Leaving the EU led to a change in how UK-EU trade data is collected (see Section 3). This change significantly expanded firm coverage and observed trade, thereby biasing upwards estimates of TCA effects based on aggregate or product-level trade data. We avoid this bias by studying firms observed both before and after the change in data collection. Second, we evaluate both differential effects on UK trade with the EU versus the RoW and level effects on UK trade with the RoW and with the world as a whole. This approach allows us to disentangle mechanisms (i)-(viii). Third, we study the heterogeneous effects of Brexit across the firm size distribution, and examine both the extensive margin of trading status and the intensive margin of trade flows. This speaks to the role of higher fixed versus variable trade costs.

We start by estimating the causal differential effect of Brexit on UK firms' trade with the EU versus the RoW. We implement both difference-in-differences and event-study specifications anchored around the Referendum and the TCA. We rely on a stringent set of fixed effects and controls to 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 with proxies based on EU and RoW trade with countries other than the UK.

We find no evidence of a significant decline in UK firms' trade with the EU relative to the RoW after the Referendum in 2016 and before the implementation of the TCA in 2021. Consistent with the model-based predictions of Steinberg (2019) and Broadbent et al. (2024), this implies that the uncertainty and anticipation of future trade barriers generated by the Referendum did not reduce relative trade with the EU. Given prior evidence that lower uncertainty boosts trade, this finding

suggests that higher uncertainty need not act in reverse. In particular, when faced with uncertainty over future trade cost increases, firms that have paid the sunk costs of exporting or importing may prefer to wait until uncertainty is resolved before changing their relationships with foreign buyers and suppliers.

By contrast, UK exporters and importers both experienced a sharp and sustained fall in trade with the EU compared to the RoW immediately after the TCA came into effect. This fall is driven by smaller firms, particularly for exports. We estimate that the TCA reduced UK firms' relative exports to the EU by 30% in the bottom quintile of firm size by employment, 15% in the middle quintile, and insignificantly in the top quintile. For imports, the estimated decline in the bottom quintile is similar as for exports at 27%, slightly larger for the middle quintile at 21%, and remains significantly negative for the top quintile at 14%.

We also find that the TCA reduced trade with the EU versus the RoW relatively more for UK 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, and conforming to and proving rules-of-origin compliance is costly. In addition, MFN tariffs are observed metrics of EU protectionism that likely correlate with unobserved non-tariff trade barriers across products 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.

We draw two main conclusions from our analysis of firms' trade with the EU versus the RoW. First, the TCA directly reduced UK trade with the EU relative to the RoW through the export and import cost increase mechanisms (i) and (iv), by raising the variable costs of UK-EU trade. Second, the size heterogeneity we uncover is consistent with an environment where firms can pay a fixed cost to mitigate the higher variable costs. For instance, larger firms may find it profitable to hire trade logistics specialists to facilitate customs and regulatory compliance, or to optimize shipment size and frequency, while smaller firms may not.

In the second part of the analysis, we identify the causal level effect of Brexit on UK firms' trade with the RoW and with the world as a whole. To this end, we estimate difference-in-differences and event-study specifications that compare how trade levels evolved over the Brexit timeline across firms with differential exposure to Brexit. We proxy Brexit exposure using firms' trade with the EU prior to the Referendum, and distinguish between export and import exposure in order to inform the indirect mechanisms (ii)-(iii) and (v)-(viii) through which Brexit may affect trade.

We find no evidence that post-Referendum uncertainty and anticipation impacted UK firms' trade with the RoW prior to the implementation of the TCA. Moreover, our estimates indicate that the TCA did not have an indirect effect on exports to the RoW. This null result implies that any short-run impact of the TCA on firm exports through mechanisms (ii) scale economies, (iii)

capacity constraints, or (vii) higher input costs was too small to be detectable. It also confirms that the decline in exports to the EU relative to the RoW reflects falling sales to the EU driven by mechanism (i) higher export costs.

On the other hand, we do find that UK firms that purchased a higher share of their inputs from the EU before the Referendum significantly increased their imports from the RoW under the TCA. However, this did not fully compensate for the reduction in imports from the EU, and worldwide imports declined. 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 worldwide imports under the TCA. These findings imply that higher costs of importing from the EU led firms to reorganize their global sourcing in line with mechanism (v) (partial) input substitutability across origins. The drop in world imports may also have been reinforced by mechanisms (vi) input complementarity across origins or (viii) lower production scale, depressing import demand.

In the third step of our analysis, we examine whether Brexit led some UK firms to not only contract their international trade activities, but to exit from foreign markets altogether. Consistent with the results above, we show that the Referendum did not significantly affect UK firms' export and import survival probabilities before the TCA came into effect. However, we estimate that the TCA notably reduced the survival rates for UK exporters to the EU and UK importers from the EU, especially among smaller firms. We interpret this as evidence that the TCA increased fixed UK-EU trade costs. Our estimates imply that the TCA caused around $16,400$ UK firms (or 14% of UK exporters to the EU) to stop serving the EU market and caused around $9,900$ UK firms (or 4.4% of UK importers) to stop importing altogether.

We conclude with a back-of-the-envelope aggregation exercise to infer the total effect of the TCA on UK goods trade. We combine estimates of the impact of the TCA on the extensive margin of trade survival and the intensive margin of survivors' trade levels and differential trade adjustments, in an internally consistent manner that accounts for firm heterogeneity.

Our results imply that the TCA reduced worldwide UK goods exports by 6.4% and worldwide UK goods imports by 4.4% within the first two years. The intensive margin accounts for around two-thirds of the fall in both exports and imports. These short-run effects are sizeable, but so far considerably smaller than forecasts of the long-run impact of Brexit.[1] This reflects our findings that, at least in the short run, larger firms have been less affected; exports to the RoW have held strong; and increased sourcing from the RoW has partially compensated for lower EU imports. An important question for future work is how these firm responses will evolve over the longer term.

[1]The UK's official economic forecaster – the Office for Budget Responsibility (OBR) – predicted Brexit would reduce UK trade by 15% in the long run (OBR 2021). 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).

We advance several strands of research. Although a large literature explores tariff policy, much less is known about deep integration, despite its rising prevalence. Prior theoretical work has analyzed the political economy of deep agreements (Maggi and Ossa 2021), while empirical work has sought to estimate their impact on trade. Disentangling the effects of deep integration from those of other policies has, however, been challenging, as integration is often accompanied by prolonged structural reforms. For example, Eastern European countries that joined the EU following the collapse of the Soviet Bloc gradually implemented broad-based reforms alongside integrating with EU institutions over a decade or more.

Preferential trade agreements (PTAs) typically combine tariff cuts with a wide array of measures to promote deeper integration across multiple policy areas, such as cross-border capital and labor flows, intellectual property rights, environmental standards, and public procurement. Most prior research has estimated the overall effects of this bundle of PTA policy changes (e.g. Baier and Bergstrand 2007), although some papers have zoomed in on the impact of specific non-tariff barriers, e.g. Conconi et al. (2018) on rules of origin and Fontagné et al. (2015) on sanitary and phytosanitary (SPS) measures.

More recent work has aimed to identify the effects of deep integration by exploiting the World Bank's Deep Trade Agreements database, the first systematic mapping of PTA breadth and depth (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), though Felbermayr and Teti (2023) argue that these effects become insignificant after correcting for mis-measurement of simultaneous tariff cuts. Firm-level evidence remains limited and mixed. Consistent with our firm size heterogeneity results, Fontagné et al. (2015) find that restrictive SPS measures have a bigger impact on smaller firms. Likewise, Fernandes et al. (2021) conclude that including more SPS measures and technical barriers to trade provisions in PTAs boosts firm exports more 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.

Our analysis contributes to an emerging segment of this literature that uses Brexit to study deep integration. We take advantage of the fact that Brexit led to a reversal of deep integration, but did not lead to tariff changes, and was not accompanied by other structural reforms. Moreover, Brexit allows researchers to assess, for the first time, the consequences of an *industrialized* economy leaving a modern deep integration agreement. Prior work 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) – all events accompanied by massive economic and political reorganization.

This paper is the first to use UK firm-level data to evaluate the TCA, which permits both more

accurate estimates and a richer analysis of mechanisms. First, our results are not biased by the changes in data collection for UK-EU trade. Previous studies using aggregate or product-level data document little or no TCA effect on UK exports to the EU relative to the RoW (Freeman et al. 2022, Gasiorek and Tamberi 2023). Our findings indicate that these estimates are biased upwards, because the broader coverage of measured UK-EU trade post-TCA masked negative effects at the firm level.[2] Second, firm-level data allows us to explore differential impacts across the firm size distribution. This informs how Brexit raised fixed and variable trade costs, and how firm heterogeneity shapes the aggregate response. And third, we can exploit heterogeneity in firms' exposure to EU trade before the Referendum to identify the level effects of Brexit on trade with the RoW and the world as a whole. Estimating indirect effects on RoW trade elucidates the mechanisms through which Brexit affected UK trade.

Two concurrent studies reach differing conclusions about the response of EU firms to Brexit: while De Lucio et al. (2024) conclude that the TCA reduced Spanish firms' trade with the UK, Elsner et al. (2024) find no impact on Irish exporters. This suggests that disintegration may have asymmetric effects on countries of different size, institutional development, and share of trade activity with former PTA members.

We 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 findings imply that these changes did not lead to a significant decline in EU relative to RoW trade before the TCA came into effect. This is consistent with the dynamic trade model in Steinberg (2019), in which uncertainty about post-Brexit trade policies has little effect on UK trade and macroeconomic outcomes before any changes in trade policy are actually implemented. Broadbent et al. (2024) likewise 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 onset of the 2018 trade war.

More broadly, our research complements earlier work on the implications of voting to leave the EU for the UK economy. Prior evidence shows that the Referendum outcome hurt the UK economy through slower GDP growth (Born et al. 2019), higher imported inflation (Breinlich et

[2]Comparing the evolution of UK trade with the EU versus the RoW also allows us to isolate the impact of Brexit from other supply and demand shocks. With this identification strategy, we estimate considerably smaller TCA effects than papers that compare changes in UK trade with the EU to trade growth in other countries (Du et al. 2024, Kren and Lawless 2024). This alternative approach cannot disentangle the impact of the TCA from other contemporaneous shocks that may have had UK-specific effects, such as Covid-19, Russia's invasion of Ukraine, and structural transformation in the UK towards increasing specialization in services.

al. 2022), and greater uncertainty that lowered investment and productivity growth (Bloom et al. 2019).[3] 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 long-run impacts of the TCA, which are yet to be fully realized or empirically quantified. Our findings provide initial evidence on how UK firms are adjusting to life outside the EU.

The remainder of the paper is organized as follows. We first review the Brexit timeline and the mechanisms through which it may have affected UK trade in Section 2. We describe our data in Section 3. 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 conduct the aggregation exercise in Section 7, before presenting concluding remarks in Section 8.

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 his Conservative Party won the next general election (Cameron 2013). For the next decade, Brexit dominated political and economic debate in the UK. Importantly, the debate was not between protectionism and free trade. Both sides professed support for free trade. But they disagreed over what is needed to make trade free. Advocates of remaining in the EU argued that the deep integration resulting from belonging to the EU single market and customs union led to substantially higher trade. By contrast, supporters of Brexit claimed that free and frictionless trade could be achieved through traditional shallow trade agreements.

Our analysis divides the Brexit period into three phases. The first phase – from 2012q1 to 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, as implied by prediction markets, mostly fluctuated between 25% and 35%, and never exceeded 45% (Graziano et al. 2021). However, 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), along 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. Controversy over these questions continued for the next four years. As late as the December 2019 general election, it remained uncertain whether the UK would

[3] See Dhingra and Sampson (2022) for a review of the literature on the pre-TCA economic effects of Brexit.

leave the EU, let alone what would follow Brexit if it did.[4]

The second phase of our sample – from 2016q3 to 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 the 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 to 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. Without a deal the UK and EU would have reverted to trading on WTO terms and imposing tariffs on each other's exports. Agreement was eventually reached on 24 December 2020, and the TCA entered into effect eight days later. Unsurprisingly, this led to significant trade disruption during the first months of 2021, as 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.[5] 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 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 phased 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 was limited during our sample (UKICE 2023), but UK exporters to the EU faced new conformity assessment requirements from 2021 onwards.

[4]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 (Sampson 2017). Dhingra et al. (2017) analyze the potential economic consequences of these options.

[5]To avoid the need for border checks between Northern Ireland and the Republic of Ireland, Northern Ireland has 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). Since Northern Ireland accounted for only 2.2% of UK goods trade in 2019 (ONS 2021), we do not separately analyze Northern Irish trade.

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 impact 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 influence 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 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 three 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) *Input substitutability:* If importing from the EU becomes more costly, UK importers may switch to sourcing more from the RoW.

(vi) *Sourcing complementarity:* If importing from the EU becomes more costly and inputs from the EU are complements to inputs from the RoW, UK importers may reduce their imports from the RoW.

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

(vii) *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.

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

(ix) *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 nine mechanisms provide an organizing framework for understanding 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 to estimate how the TCA has affected firm-level trade, and to shed light on the role played by each of these mechanisms. To this end, 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. We also use variation across firms in exposure to EU exports and imports prior to the referendum, to disentangle the different indirect channels.[6] Because our empirical design exploits variation in trade within and across firms, we are not able to identify general-equilibrium effects operating through mechanism (ix) that impact firms regardless of their participation in international trade.[7]

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

We use four firm-level UK datasets: customs trade data from the HMRC EU and Non-EU Trade Panel Datasets; value-added tax (VAT) data on sales, input purchases and EU trade from the HMRC VAT Returns Panel Dataset; and firm characteristics from the Office for National Statistics (ONS) Interdepartmental Business Register (IDBR). We match these datasets by VAT number, and throughout the paper we refer to unique VAT numbers as firms. We describe the main features of the data here, and relegate further details to Appendix A.

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

[7]In the 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).

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 refer to this dataset as 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 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 customs union, the UK thus switched from collecting data on trade with the EU through Intrastat to using customs declarations. This change occurred in January 2021 for exports and in January 2022 for imports.[8] RoW trade data is sourced from customs declarations throughout the sample.

The change in data reporting presents three challenges when studying Brexit. First, moving from Intrastat to customs declarations increased measured trade with the EU, by around 5% for exports and 6% for imports according to ONS (2022). 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). This discontinuity means that estimates of the impact of the TCA on UK-EU trade that use aggregate or product-level UK data will be biased upwards because of the expansion in the set of traders included in the data. To avoid this bias, we exploit disaggregated data, and identify Brexit effects exclusively from variation in trade at the firm-level.[9]

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 transactions when clearing customs at the border. Indeed, we show in Appendix B that both entry and exit at the firm-product level increased for EU trade 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 artifact of the data collection switch rather than a genuine change in trade activity. We therefore limit our use of the product dimension in the trade data, and do not compare product-level trade before and after the switch.[10]

[8] The switch for imports was delayed due to the UK phasing in import controls under the TCA. Northern Ireland's trade with the EU is still collected via Intrastat due to its special customs status (see footnote 5).

[9] Note that using mirror data on UK trade collected by EU countries, e.g. Spanish data on imports from the UK to measure UK exports to Spain, would pose the same problem, as EU countries also switched from Intrastat to customs declarations for 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.

[10] Note that research on the evolution of the product margin of UK trade after the TCA should likewise be disregarded

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.[11] Nevertheless, to ensure small transactions with the EU are treated consistently throughout the sample, we drop all UK-EU trade observations below £2,500 at the firm-CN8 product-country-month level from the entire panel before aggregating to the firm-region-quarter level.[12]

The second and more substantive difference in reporting thresholds is that Intrastat includes only 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.[13] We will refer to the Intrastat thresholds as the *small-firm thresholds*. To ensure that our estimates are not biased by changes in firm coverage, we impose the small-firm thresholds on EU trade data throughout the sample. Specifically, we drop all firm-quarter observations of EU exports (imports) in calendar years where a firm's EU exports (imports) are below £0.25 million (£1.5 million). We also drop firms that are only observed trading with the EU following the switch to customs declarations.[14]

Because our baseline Customs dataset includes trade with the EU only for relatively large traders,[15] we also use VAT data to build an alternative 'VAT+ dataset' with broader firm coverage at the annual frequency. 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. We combine this information with customs declarations data on RoW trade and on EU trade under the TCA to construct our secondary trade dataset at the firm-region-year level.[16] The small-firm Intrastat thresholds do not affect which

(e.g. the product count analysis in our earlier working paper Freeman et al. 2022).

[11] 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.

[12] We set the cutoff for dropping observations to £2,500, rather than £873, to allow for the possibility that a firm has multiple small transactions in the same month, with the same country, in the same CN 8-digit product. Appendix C shows that our results are not sensitive to the choice of value below which we drop small observations.

[13] 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.

[14] We do not study firm entry into trade with the EU, because the expansion in firm coverage after the data collection switch implies that such entry is not consistently observed over time.

[15] 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.

[16] VAT data is reported for fiscal rather than calendar years, e.g. 2012 data covers 2012q2-2013q1. 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

firms are covered by this VAT+ dataset. However, the small-transaction threshold still applies to trade observed via customs declarations. Consequently, we drop all firm-year observations with EU trade below £$10,000$ from the VAT+ dataset.[17]

The VAT+ dataset is less detailed than the Customs dataset: it is annual rather than quarterly; cannot be disaggregated to the product-country level; and excludes year 2020. In addition, there is no 2021 data in the VAT+ dataset for imports because the switch from Intrastat to customs declarations for imports from the EU did not occur until the start of 2022. However, since the data used to construct the VAT+ dataset covers the universe of VAT-registered businesses that trade with the EU, it has the advantage of covering both small and large traders. Given these differences, we use the Customs dataset in our baseline analysis and the VAT+ dataset to estimate the effects of Brexit on small firms and to study the extensive margin of trade survival.

3.2 Additional 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.

We construct controls for export supply and import demand conditions in other countries using trade data from UN Comtrade by origin, destination, HS 6-digit product, and month. We also obtain exchange rates and consumer prices from the IMF International Financial Statistics to calculate real exchange rates for the UK. Finally, we use 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 SPS Measures or Technical Barriers to Trade. And from the UK Department for International Trade we obtain the UK MFN tariffs introduced in January 2021 after it left 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. Panels A and B cover firms that trade with the EU and RoW

the VAT+ dataset.

[17] The £$10,000 \approx 12 \times 873$ annual cut-off is motivated by the £873 transaction-level cut-off in the monthly data. On average across years, we drop 36% (43%) of UK firms exporting to (importing from) the EU and 0.09% (0.07%) of the value of exports to (import from) the EU.

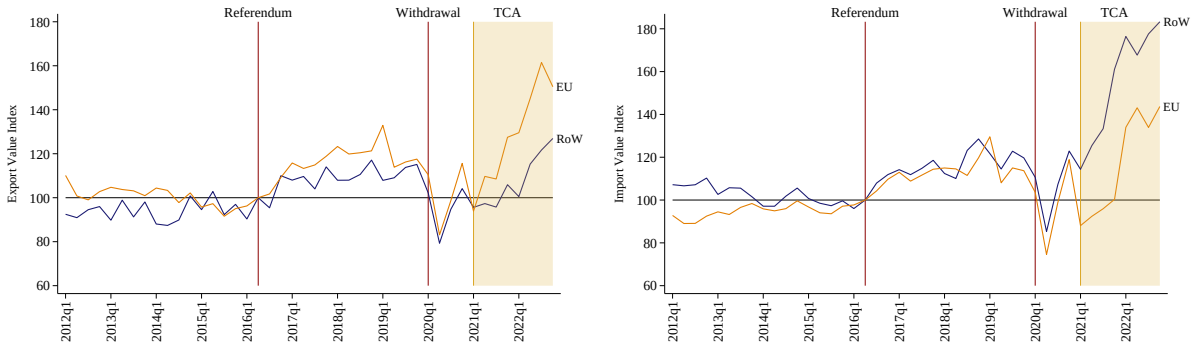
respectively, panel C reports statistics on trade with the world as a whole, and panel D covers firms that trade with both the EU and the RoW. Because of the small-firm thresholds, firms that trade with the EU are fewer in number and, on average, larger than firms that trade with the RoW. However, once the sample is restricted to firms that trade with both regions in panel D, average annual exports and imports are similar for both EU and RoW trade. Appendix Table A1 reports summary statistics for the VAT+ dataset. The VAT+ dataset covers more firms than the customs dataset, but these firms are, on average, smaller and trade less with both the EU and the RoW.

4 EU versus RoW trade

Brexit's primary impact on trade policy was to increase trade barriers between the UK and the EU. Therefore, we start our empirical analysis by analyzing regional differences in changes in UK trade with the EU relative to UK trade with the RoW. In theory, Brexit may have had both direct effects on UK-EU trade and indirect effects on UK trade with all countries, as discussed in Section 2.2. If Brexit in fact triggered only direct effects on trade through higher export and import costs (mechanisms i and iv), then RoW trade would be unaffected, and studying regional differences would be sufficient to identify the total impact of Brexit on UK trade.

Figure 1 plots aggregate UK goods trade by region over 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, meaning all movements are relative to the time of the Brexit referendum in June 2016. UK trade with the EU and the RoW displayed similar trends until 2020. After the TCA came into force in 2021, however, 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.

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 in Figure 1 could be due to changes in the composition of trade across products, firm-level productivity shocks that are correlated with EU trade participation, or differential supply and demand shocks in the UK's trading partners. For example, commodity price rises 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. In order to credibly identify the trade effects of Brexit, we therefore move from aggregate to firm-level trade data.



(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

4.1 Empirical design: regional differences

We identify Brexit effects on EU versus RoW trade by estimating regional differences regressions at the firm level. These 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 these milestones, as well as 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. We condition on 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.[18]

[18]Whenever any of the right-hand-side variables have a missing observation, we set the missing value to zero and include a dummy set to one for any affected observations. This ensures each coefficient estimate exploits all available

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 symmetric effects on the firm's trade across regions, e.g. changes in the firm's productivity or input costs. Lastly, 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:

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

The coefficients of interest β_t now identify changes in EU versus RoW trade within firms relative to the four quarters prior to the referendum, which we set as the benchmark period. We continue to cluster standard errors at the firm level.[19]

Specifications (1) and (2) include a rich set of additional controls. B_t is a vector of time-varying indicators for other events that may have affected EU relative to RoW trade. First, we account for trade shocks due to the onset of the Covid-19 pandemic with a dummy for 2020q1 and 2020q2. Second, we include a 2021q1 dummy to control for the sharp, but temporary disruption to UK-EU trade that occurred when the TCA came into effect only eight days after the negotiations were completed. Lastly, we capture the fact that, as part of the phasing in of UK import controls under the TCA, firms could delay customs declarations for goods imported from the EU in 2021 by up to 175 days. This policy may have resulted in some EU imports in 2021 being reported during the first half of 2022. Consequently, we include a Staged Customs Controls dummy for 2022q1 and 2022q2 in the imports regressions. Of course, the latter two events were themselves 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 further control for shocks that may have differentially impacted EU versus RoW trade with three sets of variables at the region and firm level, X_{rt} and Z_{frt}: (i) foreign supply and demand

variation in the data and keeps the sample stable across specifications.

[19] 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.

shocks; (ii) real exchange rate movements; and (iii) changes to UK tariffs on non-EU imports.

First, we control for foreign import demand in our export regressions and for foreign export supply in our import regressions. These controls capture 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. Likewise, in import regressions we control for 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}, computed by weighting changes in import demand and export supply proxies across country-product pairs with pre-referendum firm-specific trade weights.[20]

Second, we control for movements in the UK's real exchange rate. We combine 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 goods-trade weights to calculate a region-level real exchange rate and using firm-specific goods-trade weights to calculate a firm-region level real exchange rate.[21] To allow for exchange rates to affect trade flows with a lag, we include the current value and eight lags of the regional and firm-specific exchange rate variables in all regressions. The import demand, export supply and real exchange rate controls each enter our regressions in log form.

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

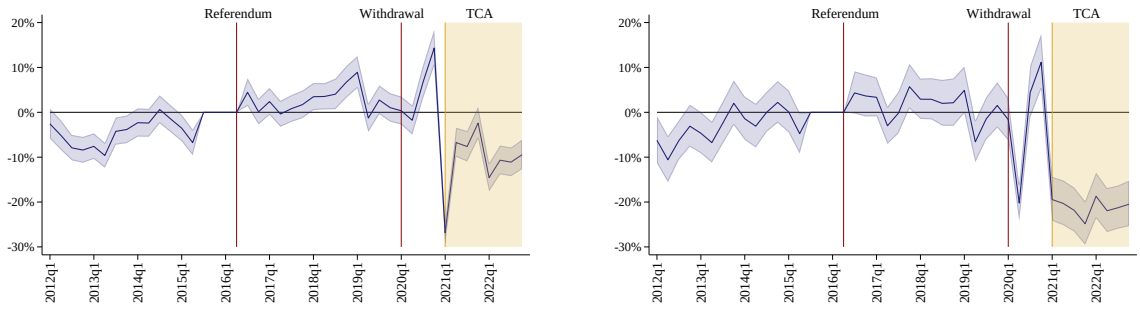
4.2 Baseline results

Figure 2 presents event-study results obtained from estimating equation (2) using the Customs dataset and including all 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 comprises $23,237$ firms that export to both regions, while the imports sample covers $12,409$ 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 referen-

[20] Appendix A.4 provides a detailed explanation of how all the firm-level control variables in Z_{frt} are constructed.

[21] We use export weights to compute the real exchange rates included in export regressions and 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

dum 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 effects on UK-EU trade will be a consistent theme throughout our analysis. That said, the spikes in relative EU trade visible for exports in 2019q1 and 2020q4 and for imports in 2020q4 are likely driven by precautionary stockpiling in advance of deadlines for negotiating the UK's withdrawal from the EU in March 2019 and the TCA in December 2020 (ONS 2021).[22]

We do see in Figure 2 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 consequences 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 imply 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 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

[22]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 2019.

of EU imports due to the Staged Customs Controls policy is not a major source of bias.

Table 2 reports results from estimating equation (1) for UK exports. These regressions are the difference-in-differences counterpart to the event-study estimates in Figure 2. Column (a) shows the estimated referendum and TCA effects in a specification that only includes time, firm-region and region-season fixed effects. Column (b) adds firm-time fixed effects, and restricts the sample to firms that trade with both regions. Column (c) controls for the differential effects of Covid-19 and trade disruption in 2021q1 with the $B_t EU_r$ variables. Column (d) further conditions on 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, these results indicate that Brexit had no effect on EU relative to RoW exports prior to the implementation of the TCA.

Table 3 reports analogous estimates for UK imports. The TCA effect is once again negative across all specifications, and bigger 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. As in Table 2, the Referendum effect is positive without region-level controls, but turns insignificant once they are included.[23]

Appendix C.1 establishes the robustness of the baseline results in Tables 2 and 3. Our findings are not sensitive to: using different cut-off values to trim small observations from the Customs dataset; adopting alternative definitions of the import demand and export supply controls; dropping non-EU countries with which the UK has a preferential trade agreement; imposing the small-firm thresholds on trade with the RoW; and dropping firms in the agriculture and food sectors.

4.3 Firm size heterogeneity

The evidence in Figure 2 and Tables 2-3 reveals that the TCA decreased trade with the EU relative to the RoW for the average UK firm. We next explore whether the Referendum and the TCA exerted heterogeneous effects across firms along the size distribution. This analysis both informs the mechanisms through which the TCA impacted firm-level trade and later allows us to relate its potentially heterogeneous incidence at the firm-level to its aggregate impact.

[23] Although not shown in Table 3, the estimated coefficient on the Staged Customs Control dummy in column (e) implies that late reporting due to delayed customs declarations raised measured EU imports by 5.5% in the first half of 2022. This is reassuring close to the 4% increase estimated by the ONS (ONS 2023).

We expand the baseline regional-differences specification (1) to include the triple interaction terms $Referendum_t EU_r Size_f$ and $TCA_t EU_r Size_f$, where $Size_f$ measures the size of firm f based on its average employment prior to the referendum in 2013-15. We also control for $B_t EU_r Size_f$ to allow firm size to moderate the impact of the other events covered by B_t.

We report the difference-in-differences estimation results for exports in columns (a)-(c) of Table 4. In column (a), we measure firm size by log employment. The triple interaction $TCA_t EU_r Size_f$ has a positive coefficient, implying that larger firms reduced their relative exports to the EU by less under the TCA. We also estimate a positive triple interaction for the Referendum effect, although the coefficient is substantially smaller than for the TCA.

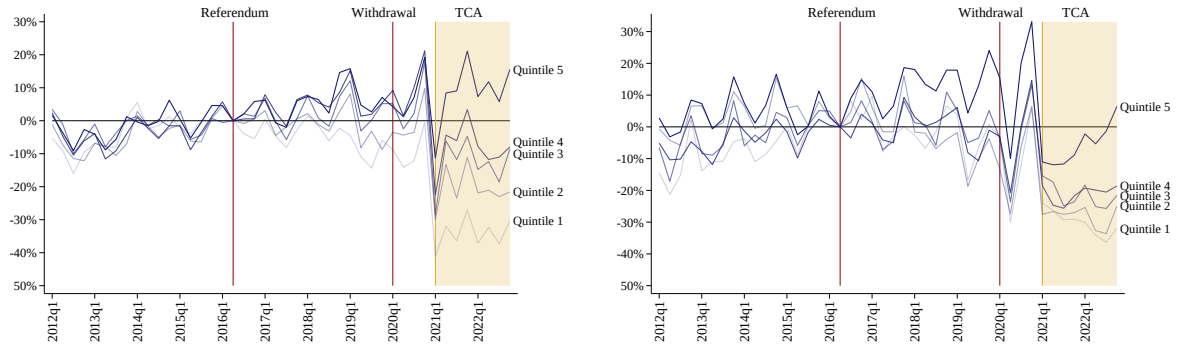
In column (b), we proxy firm size with dummy variables $Size_f^c$ for quintiles $c = 1, \ldots, 5$ of the size distribution, where quintile 1 denotes the smallest firms and is the excluded category.[24] This specification allows for non-monotonic or non-linear Brexit effects across firm size bins. The results confirm that the TCA had a more negative effect on smaller firms. The estimates imply that the TCA reduced relative EU exports by 30% in the bottom quintile and 15% in the middle quintile, but had no significant effect in the top quintile.[25] 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 for the event-study version of the specification in column (b) of Table 4. 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 bottom four quintiles, but not in the top quintile. We also see some evidence that relative EU exports dipped slightly in the smallest quintile between 2018 and the onset of the Covid-19 pandemic in 2020, but this effect is small relative to the collapse under the TCA.

Columns (d)-(f) of Table 4 and panel (b) of Figure 3 display corresponding size heterogeneity estimates for imports. Again, we find that the TCA effect is more negative for smaller firms, although the size gradient is notably weaker than for exports. Consequently, the estimated TCA effect is negative even among the largest quintile of importers. The analysis in column (e) implies 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 EU imports grew more quickly for larger firms between the Referendum and the TCA. However, column (e) demonstrates

[24] 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 regressions. We do so because the distribution of firm size differs significantly for exports versus imports and in the Customs versus VAT+ datasets. In Table 4, the employment quintile thresholds are 6, 17, 39 and 107 for exports, compared to 9, 30, 79 and 249 for imports.

[25] 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

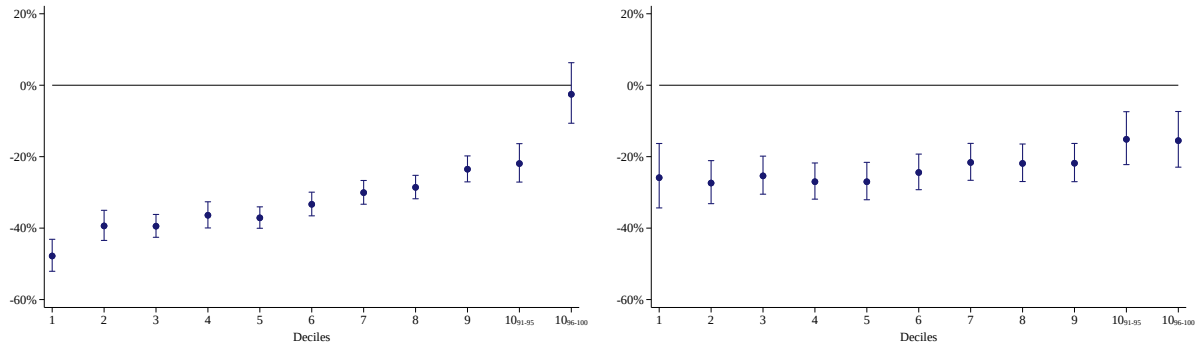
that differences in the Referendum effect across quintiles are statistically insignificant, except for lower growth in quintile two.

In sum, Table 4 and Figure 3 show that the TCA reduced trade by more for smaller firms than for bigger firms. 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 explore the effect of Brexit on small firms, we turn to the VAT+ dataset introduced in Section 3.1, which includes all firm-year observations with EU trade above £10,000.

We replicate the regional differences analysis with firm heterogeneity at the annual frequency in the VAT+ dataset. The VAT+ export and import regression samples cover more than twice as many firms as the baseline Customs dataset samples, but these firms trade less and are smaller on average (see Appendix Table A1). 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. We accommodate the greater size dispersion in the VAT+ sample by distinguishing between employment deciles, and we additionally split the top decile into firms below and above the 95th percentile, yielding eleven size groups in total.

Figure 4 plots the estimated TCA effects by size decile together with their 95% confidence intervals. The estimates confirm that smaller exporters were harder hit than larger exporters, with the TCA effect insignificant for firms above the 95th percentile. The results for imports also reveal 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.

The heterogeneous impact of the TCA on different sized firms implies that larger firms were



(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

better able to adapt to the new trade barriers introduced 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, and their trade flows will be 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.[26]

4.4 Trade policy heterogeneity

The Brexit Referendum generated uncertainty about many aspects of future UK-EU trade relations, and the TCA subsequently ushered in a wide range of new customs and regulatory barriers to trade with the EU. Our baseline analysis estimates the joint impact of all sources of uncertainty following the referendum and the joint impact of all new barriers under the TCA. To shed more light on the nature of the Brexit trade policy shock, we next exploit variation in the EU's MFN tariffs and non-tariff measures across products. Combined with information on UK firms' export and import

[26] Appendix C.1 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 in relative trade with the EU than domestic firms. However, the TCA effect does not vary significantly with ownership (see Appendix Table A4).

product mix, this allows us to construct firm-level proxies for exposure to the Brexit shock.

We define each firm's tariff exposure $Tariff_f$ as a weighted average of the EU's CN 8-digit MFN tariffs prior to the Referendum in 2015. For export regressions, we calculate export tariff exposure using each product's share of the firm's exports to the EU as weights. For import regressions, we use analogous import weights to calculate the firm's import tariff exposure. Similarly, we compute export and import NTM exposure NTM_f as firm-specific weighted averages of the number of MFN NTMs applied by the EU across CN 8-digit products in 2015. We fix the firm-level weights for these variables based on their trade flows in 2012 (or the first available year for firms that we do not observe in 2012). The correlation between tariff and NTM exposure across firms in our regression samples is 0.25 for export exposure and 0.40 for import exposure, meaning that there is in principle sufficient variation to explore the role of both tariff and non-tariff barriers.

What do these tariff and NTM exposure variables measure? Prior to 2021, the EU's MFN trade policy determines the threat-point policies that would have applied to UK-EU trade if negotiations over a new trade relationship failed. Therefore, $Tariff_f$ and NTM_f capture firm-level exposure to a combination of general uncertainty and expectations about future trade policy changes.[27] For example, a firm that exports products with higher EU MFN tariffs faces both greater uncertainty over future tariffs and a greater tariff increase 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.[28] From 2021 onwards, we therefore 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 EU and UK preferences for protection across products. Products with higher MFN protection are thus 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) indeed 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 correlated with those under MFN trade (e.g. requirements to clear customs or prove regulatory compliance), NTM exposure captures barriers introduced by the TCA that do not exist within the EU single market.

We estimate the effect of trade policy exposure on firms' trade with the EU relative to the RoW by adding triple interactions of the exposure measures with EU_r and the time dummies $Referendum_t$, TCA_t and B_t in the difference-in-differences equation (1). We continue to include

[27] Crowley et al. (2019) and Graziano et al. (2021) use EU MFN tariffs in this way to proxy Brexit-related trade policy uncertainty.

[28] Some uncertainty remains over the extent of UK-EU regulatory divergence in the medium term and the possibility of the UK rejoining the EU customs union and/or single market in the longer term.

the firm size quintile interactions, such that we estimate the effect of Brexit exposure conditional on firm size.

The results in Table 5 show that greater tariff exposure reduced firms' relative trade with the EU under the TCA, whereas NTM exposure had no significant effect. The estimates in columns (b) and (d) imply that a one-standard-deviation increase in $Tariff_f$ decreased relative EU exports by 8.2% and relative EU imports by 6.4% under the TCA.[29] Event-study graphs in Figure 5 demonstrate that the decline in relative exports in panel (a) occurred immediately at the start of 2021. However, most of the decline in relative imports in panel (c) was 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 an effective 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 the non-tariff barriers brought about by the TCA.

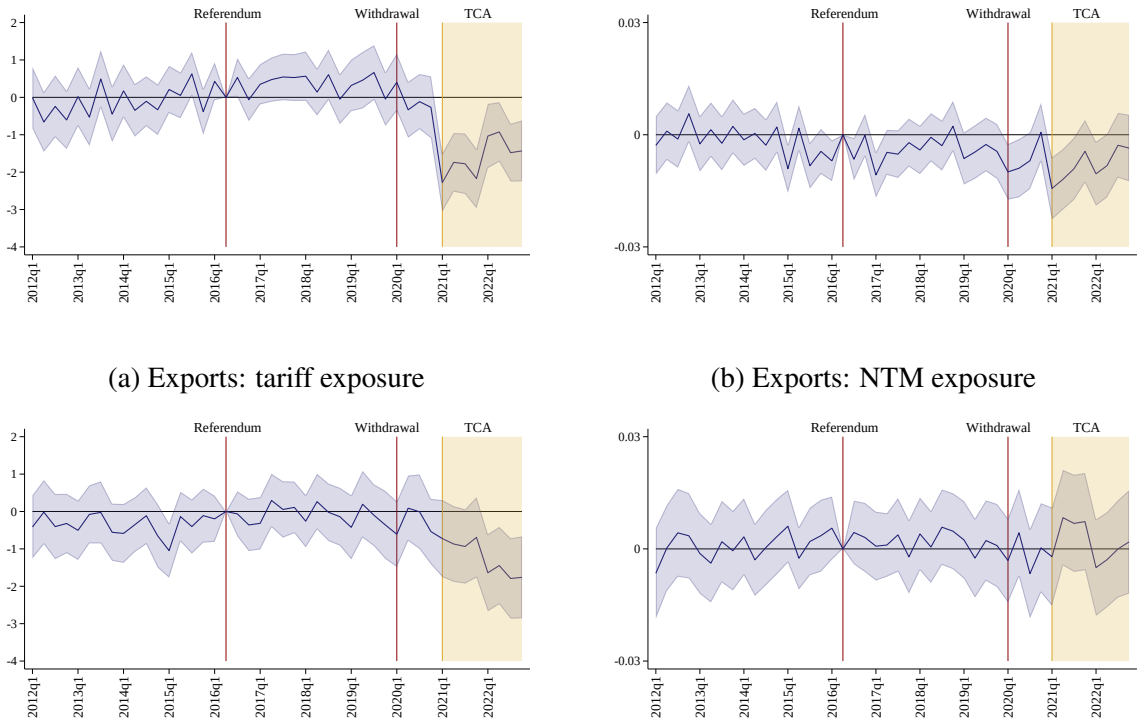
Table 5 and Figure 5 also evidence that the Referendum had no significant negative effect on relative EU exports or imports for UK firms with higher exposure to either tariffs or NTMs. This suggests that uncertainty and anticipation did not reduce relative trade with the EU prior to the introduction of the TCA, consistent with the baseline regional differences results above.

5 Trade levels

The estimates above show that Brexit reduced UK firms' trade with the EU compared to their trade with the RoW. Although Brexit was primarily a shock to UK-EU trade policy however, it may also have had indirect effects on UK trade with the RoW. This section estimates the impact of Brexit on UK trade with the RoW and with the world as a whole.

Our objective is to provide evidence that speaks to the indirect Brexit 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 or complementarity affect imports from the RoW when importing from the EU becomes more costly (mechanisms v and vi)? Do input cost increases reduce exports due to loss of competitiveness (mechanism vii)? And does a reduction in exports reduce import demand (mechanism viii)? We do not seek to identify general-equilibrium adjustments (mechanism ix).

[29] 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

5.1 Empirical design: RoW levels

We identify the indirect effects of Brexit on UK firms' trade with the RoW by comparing how it evolves over time across firms with varying exposure to EU trade prior to the referendum. Exploiting this variation in Brexit exposure allows us to isolate level effects on UK firms' trade while conditioning on time fixed effects that absorb shocks common to all firms.

We define a firm's export exposure to EU trade as the ratio of EU exports to total sales, and its import exposure as the ratio of EU imports to total input purchases. Export and import exposure are computed using the VAT+ dataset for 2012 (or the earliest available year for firms that are not observed in 2012), and are fixed over time.

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 share of EU imports in inputs captures sensitivity to higher import costs (mechanisms v, vi and vii). Likewise, exposure to the scale economies, capacity constraints and production scale mechanisms (mechanisms ii, iii and viii) depends on the share of EU exports in overall production. The weak correlation between export and import exposure to the EU (0.14 in the exporter sample and 0.16 in the importer sample) allows us to jointly explore their respective roles.

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 of the EU exposure measures for firm f. The coefficients of interest are β_1 and β_2, which indicate 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 firm fixed effects α_f to absorb time-invariant differences in firm trade with the RoW, and SIC 4-digit industry-time fixed effects α_{it} to absorb industry-level shocks to UK trade with the RoW, where i denotes the firm's primary industry.

Equation (3) includes similar controls to those in the regional differences estimation. We isolate the role of EU exposure by controlling for the interaction of firm size quintiles $Size_f^c$ with the referendum and TCA dummies, as well as with the Covid-19 and TCA disruption event dummies. We also condition on firm exposure to RoW supply and demand shocks, RoW real exchange rate changes, and UK MFN tariff changes using Z_{ft}^{RoW}. This vector includes the same set of firm-level controls as in the regional differences regressions, except now only the values for the RoW region are needed. Lastly, we add the interactions of $EUExposure_f$ with the event dummies B_t.

We estimate levels regressions on the Customs dataset, which is collected on a consistent basis throughout the sample period for UK trade with the RoW. Because the EU exposure measures are based on 2012 data, we start the sample period in 2013q1. 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. Consequently, the number of firms in the RoW levels regressions is much

larger than in the regional differences regressions. Summary statistics for firms that trade with the RoW are shown in panel B of Table 1.

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

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

where α_{ct} denotes firm size quintile-time fixed effects. The coefficients of interest β_t in the event-study equation (4) identify how EU exposure affects the evolution of UK firms' trade with the RoW over time.

5.2 Results: RoW levels

Table 6 reports results for the level effects of the Referendum and TCA on UK firms' exports to the RoW. The estimates indicate that firms with greater exposure to the EU for their sales and input purchases were not differentially affected by the TCA. In column (a), we consider EU export exposure with the ratio of EU exports to sales. The estimated effect of the $TCA_t EU Exposure_f$ interaction is small and insignificant. In column (b), we add the ratio of EU imports to inputs to also capture import exposure, but neither exposure dimension matters under the TCA. In column (c), we further account for differential EU tariff threat exposure, by multiplying 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 for the event-study version of column (b). Panels (a) and (b) confirm that neither export nor import exposure had a detectable impact on RoW exports either following the referendum or under the TCA.

We conclude that Brexit did not have a significant indirect effect on exports to the RoW through any of the scale economies, capacity constraints, or input cost mechanisms. It follows that the decline in EU relative to RoW exports under the TCA documented in Section 4 was caused by lower exports to the EU due to the direct effect of higher export costs.

Columns (d)-(f) of Table 6 report the analogous analysis for the level of RoW imports. In this case, we find that Brexit did have an indirect effect on UK firms' imports from the RoW. 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 corresponding 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.

(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

These results are consistent with 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 increased under the TCA, firms that were previously more dependent on EU imports raised 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 is consistent with the production scale mechanism, whereby the reduction in exports to the EU under the TCA leads to lower sales, which in turn contracts input demand and thereby imports. However, the event-study estimates in panel (c) of Figure 6 show that the decline in RoW imports for firms with higher EU export exposure began already 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

Having estimated the differential impact of the TCA on UK firms' trade with the EU versus the RoW, as well as its level effects on their trade with the RoW, we next evaluate its consequences for firms' overall trade activity. This allows us to capture Brexit's effect on UK firms more holistically, as firm profitability hinges on total export sales and import purchases rather than their composition. It also helps further unpack the mechanisms shaping firms' response to Brexit.

In the case of firm exports, the results above point to large reductions in exports to the EU relative to exports to the RoW, with no evidence of disruption to the latter. This is consistent with higher export costs to the EU driving down total exports only through their direct effect on sales to the EU, with no spillover effects on sales to other markets. Conversely, the findings reveal both significant declines in firm imports from the EU relative to their imports from the RoW and a notable rise in the latter. This implies that imported input substitutability across regions may have partially or even fully offset the impact of higher import costs from the EU on total imports.

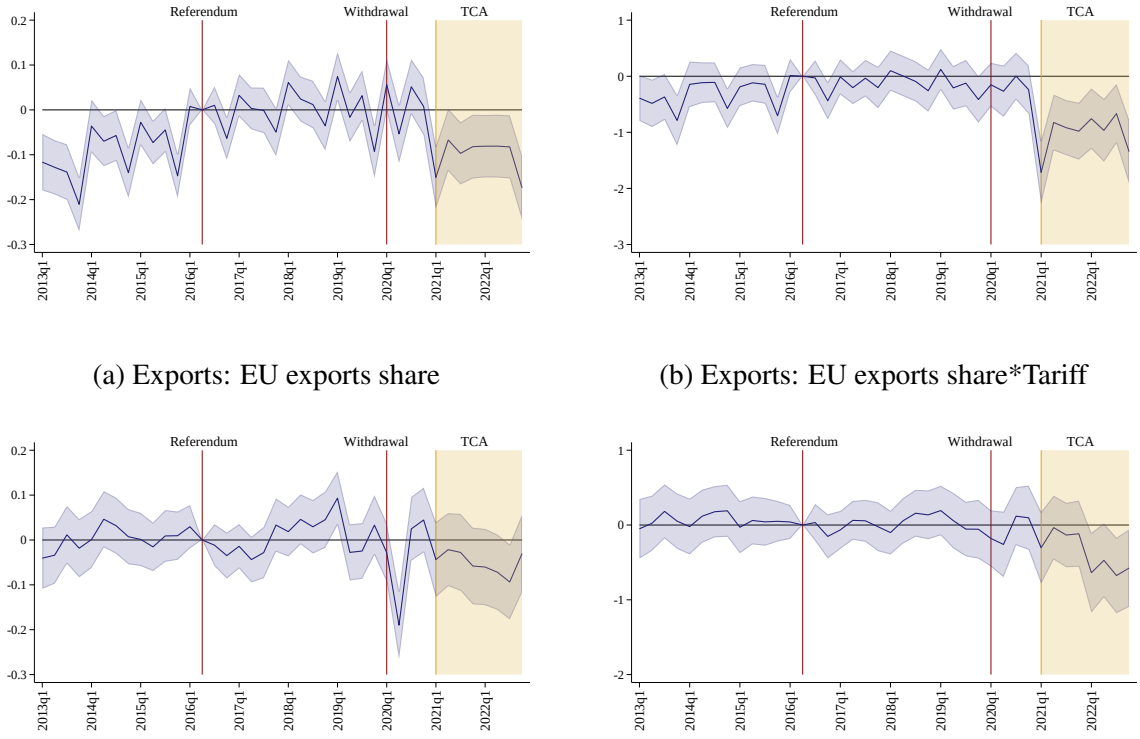
We estimate world levels regressions using the same difference-in-differences and event-study specifications as for firms' trade with the RoW, but using their worldwide exports or imports $V_{ft}^{World} = V_{ft}^{EU} + V_{ft}^{RoW}$.[30] We harness the Customs dataset, and restrict the sample to firm-quarters in which we observe trade with the EU. This ensures that 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 in the VAT+ dataset using 2012 data if available, or the first year with available data otherwise. For importers, we likewise 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.[31] Summary statistics for this sample are shown in panel C of Table 1. The average EU export share among sample exporters is 0.58, while the average EU imports share for importers is 0.48.

Table 7 reports the world levels results using the difference-in-differences specification. We document in column (a) that the TCA had a sizable negative effect on worldwide exports for firms with higher EU export shares. Our estimates imply that a 10 percentage point increase in the initial EU export share led to 0.9% lower world exports under the TCA. In column (b), we consider firms' Brexit exposure through both their EU export share and the potential tariff threat implied by their export product composition. When we multiply the EU export share by export tariff exposure as defined in Section 4.4, we indeed find a more negative TCA effect on the worldwide exports of UK

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

[31] This preference is motivated by the fact that the elasticity of firms' trade with the world to their trade with the EU equals the EU trade share, 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 a firm's world trade would equal its EU trade share.

firms with greater export exposure to EU trade barriers. The corresponding event-study estimates in panels (a) and (b) of Figure 7 show an immediate decline in world exports at the start of 2021, which is moreover sustained for the remainder of the sample period.



(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

We also find that the TCA led to a small, but significant reduction in total imports for firms that initially sourced a greater share of their imports from the EU – see columns (c) and (d) of Table 7 and panels (c) and (d) of Figure 7. The estimates in column (c) imply that a 10 percentage point higher initial EU import share is associated with 0.6% lower world imports under the TCA. This means 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.[32] The TCA thus led to

[32]In principle, the production scale mechanism could also reduce total import demand if lower exports depress

a moderate net fall in worldwide imports for firms with higher EU import exposure.

6 Trade survival

The regional differences regressions in Section 4 and the levels regressions in Section 5 analyze the intensive margin of UK firm trade. In this section, we turn to the extensive margin, and estimate the impact of Brexit on the number of UK firms that engage in international trade. In order to accurately capture firms' export and import status, we exploit the comprehensive firm coverage in the VAT+ dataset, which combines VAT returns data for 2012-19 with customs declarations data for 2021-22 for exports and 2022 for imports.

Figure 8 plots the total number of UK firms that we observe trading with the EU and the RoW by year. There is a sharp drop in the number of exporters to the EU and importers from the EU after the introduction of the TCA. By contrast, the number of firms that trade with the RoW remains stable and, if anything, continues on a slight upward trajectory.

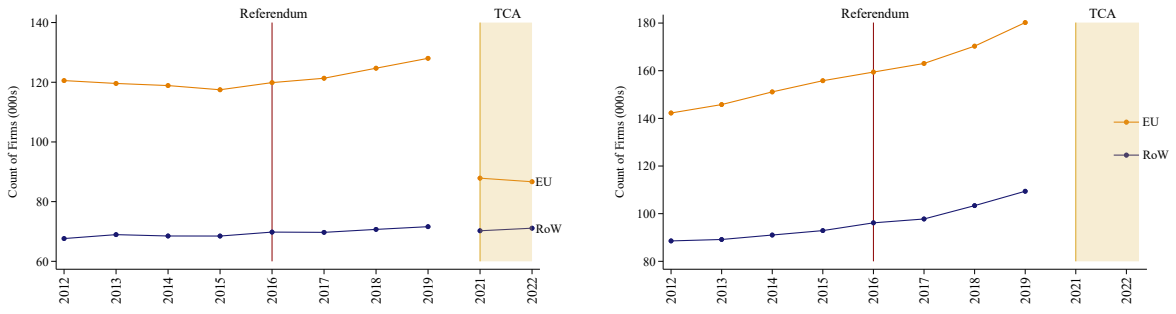
The observed decline in the number of UK firms trading with the EU suggests that the TCA has exerted negative effects on the extensive margin of trade. However, simply counting firms does not account for the change in data reporting due to the small-transaction threshold in customs declarations data. Nor does it tell us anything about which firms stopped trading with the EU. To better understand the patterns in Figure 8, we therefore estimate the impact of the TCA on trade survival across the firm size distribution.

6.1 Empirical design: trade survival

We estimate the impact of Brexit on UK firms' trade survival over three-year windows. That is, we study whether 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 evaluate the impact of the TCA without requiring 2020 data, which is not included in the VAT+ dataset. 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 from the trade survival analysis firms with trade close to the threshold. 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 £$10,000$ are highly

demand for imported inputs. 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 and the TCA. By contrast, the interaction between the TCA dummy and the EU import share remains negative and significant. This suggests that the production scale mechanism did not contribute significantly to the decline in total import demand.



(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

likely to have at least one customs transaction above the £873 small-transaction threshold during the year. It is thus unlikely that such firms would continue to trade but exit our data because of the switch in data collection. 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 $I\left(\cdot\right)$ denotes the indicator function, and $t =$ 2015-19, 2021 (exports only) and 2022. We define trade survival S_{frt} separately for exports and for imports.

We estimate a linear probability model of trade survival that allows the $Referendum_t$ and TCA_t effects to vary with firm size quintiles $Size_f^c$:

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

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 condition on firm size quintile-industry-region fixed effects α_{cir} and firm size quintile-industry-time fixed effects α_{cit}, where industries are defined at the SIC 4-digit level. The α_{cir} absorb time-invariant differences in survival rates by size quintile, industry and region, e.g. survival rates may be lower for smaller firms. The α_{cit} further control for 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 from changes in survival rates within size-industry bins over time for firms' trade with the EU compared to the RoW. The coefficients of interest β_1^c and β_2^c 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 UK exporters in Table 8. Column (a) presents 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 of exporters to the EU relative to exporters to the RoW. Moreover, the decline was greater for smaller firms. Appendix C.2 shows that these conclusions are unaffected by varying the £$10,000$ initial exports cut-off below which we drop firms from the sample.

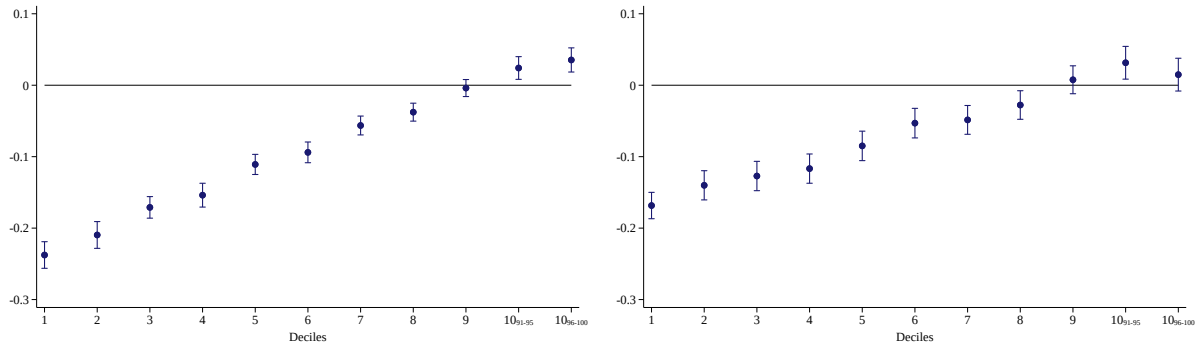
Panel (a) of Figure 9 examines size heterogeneity in the TCA effect in more detail. It plots estimated TCA effects and 95% confidence intervals by size group, using the same employment bins as in Figure 4.[33] We find that the TCA reduced the probability of EU export survival by 24 percentage points 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 turns positive, though still close to zero, for firms in the two largest groups.

We omit the $Referendum_t$ from Table 8 to conserve space, but we do not find that the Referendum affected firms' export survival. Column (c) illustrates this point by reporting results for the event-study version of the specification in column (a). We see that the probability of EU export survival during 2016-19 was only marginally higher than in 2015. However, the relative survival probability of exporters to the EU plummets once the TCA comes into effect in 2021.

The estimates in columns (a)-(c) identify the impact of Brexit by comparing survival rates of exporters to the EU versus the RoW. 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 estimate the following event-study specification:

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

[33] 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.



(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. Whiskers show 95% confidence intervals computed using standard errors clustered by firm. Firm size measured as average employment between 2013q1 and 2015q4. 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.

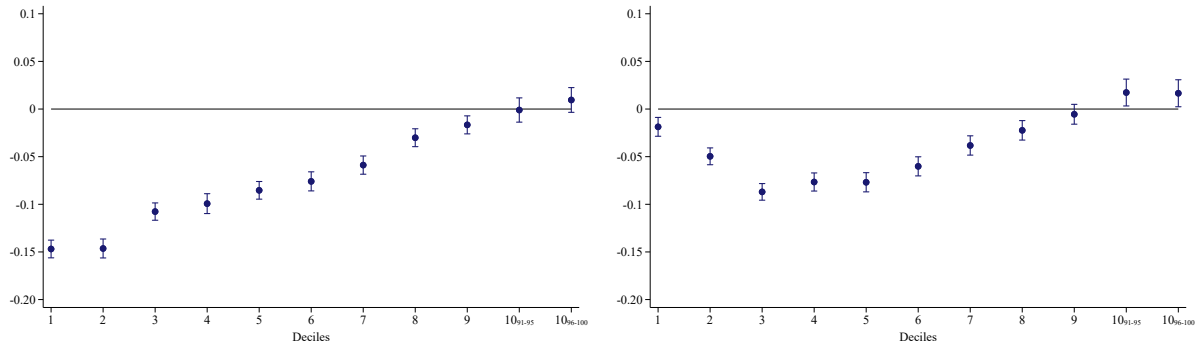
Figure 9: Trade survival in EU versus RoW: average TCA effect by firm size group

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) for export survival in the EU, RoW and the World are shown in columns (d), (e) and (f), respectively. We find that survival probabilities remained stable over time for exporters to all regions until 2019. However, in 2021 and 2022 the probability of export survival dropped sharply for exporters to the EU and the World, but not for exporters to the RoW. It follows that the TCA had a direct negative effect on the survival of exporters to the EU and thereby to the World as a whole, but did not indirectly affect the survival of exporters to the RoW.

Panel (a) of Figure 10 shows the extent of size heterogeneity in the estimated impact of the TCA on the probability that firms continue to export anywhere in the world, where size groups are again the employment bins from Figures 4 and 9. We see that the TCA increased exit from exporting significantly more for smaller firms, and did not have a notable effect on firms in the largest two bins.

Table 9 and panel (b) in Figures 9 and 10 report analogous results for firms' import survival. 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 relative EU import survival rates in column (a) of Table 9 is similar for imports as for exports, but varies less with firm size. Panel (b) of Figure 9 plots estimated TCA effects by size group, defined as in



(a) Export survival

(b) Import survival

Notes: Estimated impact of TCA on probability of World trade survival by firm size group. Difference-in-differences estimates from trade survival regression using VAT+ dataset. Vertical axis in percentage points. Whiskers show 95% confidence intervals computed using standard errors clustered by firm. Firm size measured as average employment between 2013q1 and 2015q4. 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 fixed effects. Industries are SIC 4-digit sectors.

Figure 10: World trade survival: average TCA effect by firm size group

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, it had no impact on firms in the three largest groups, e.g. on firms with over 56 workers.

The levels estimates in columns (d) and (e) of Table 9 indicate that, while the TCA caused firms to stop importing from the EU, it also led more importers to continue sourcing from the RoW. 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 in Section 5.2, this suggests that importers responded to the TCA by substituting RoW imports for EU imports. However, column (f) shows that the substitution effect was only partial, and the TCA resulted in more firms ceasing to import from anywhere in the world. World import survival thus declined by 6 percentage points in 2022. Panel (b) of Figure 10 plots the TCA effect on World import survival by size group. Once again, smaller firms are harder hit, although in this case the effect is non-monotonic and greatest for firms in the third smallest group.

Overall, the trade survival analysis reveals that the TCA reduced UK firms' trade with the EU along the extensive margin of firm exporting and importing, with smaller firms significantly more likely to stop trading. This exit from foreign markets is consistent with a model where the TCA raised the fixed costs of trade, thereby making it unprofitable for some less productive firms to continue trading. This could, for example, reflect customs paperwork and regulatory compliance

burdens introduced by the TCA.

7 Aggregation

Our estimates paint a rich picture of how Brexit has affected UK firms' participation in the global economy. We conclude by quantifying the aggregate implications of our findings with a back-of-the-envelope exercise. We compute the impact of the TCA on overall UK goods trade by combining results from the regional differences, levels, and trade survival regressions, and accounting for heterogeneous effects across firms.

7.1 Exports

The aggregation exercise for exports starts from the observation that the TCA has had no indirect effects on exports to the RoW. This means that the changes in relative exports and relative survival probabilities for the EU versus the RoW identified by our regional differences and trade survival regressions can be interpreted as the causal effect of the TCA on exports to the EU. We therefore use these estimates to compute the TCA impact on aggregate exports to the EU, which we then scale by the share of the EU in total UK exports to infer the TCA impact on aggregate UK exports to the world.

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.[34]

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 any set of firms F, the expected proportional change in total exports to region r caused by the TCA is:

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

[34] As discussed in Section 5, a caveat of our empirical analysis is that it 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 in our aggregation exercise.

The aggregate effect is thus 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.

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 overestimate the decline in trade caused by the TCA. We therefore obtain p_{fEU} from our preferred estimates of the TCA effect on the relative survival probability for exporters to the EU 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 in column (b) of Table 4. In both cases, we choose specifications that allow for firm size heterogeneity in the TCA effect.[35]

We aggregate across all firms in the VAT+ dataset (including firms with annual EU exports below £$10,000$), and 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 export share weights are 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 caused 14.0% of UK exporters to the EU, or $16,431$ firms, to exit the EU market.

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 conclude that the TCA reduced total UK exports by 6.4%, with the intensive margin alone accounting for a 4.5% drop. Thus, the aggregate effect of the TCA on UK goods exports during its first two years was negative, but smaller than the OBR's forecast that Brexit would reduce UK trade by 15% in the long run (OBR 2021).

7.2 Imports

The aggregation exercise for UK imports use our estimates of the level effects of the TCA on the intensive and extensive margins of importing from anywhere in the world. We must use the estimates from our world levels and world survival regressions, instead of the regional differences specifications, because the TCA affected both EU and RoW imports. Specifically, we let $r = World$, and calculate λ_{fWorld} for each firm using the estimated impact of the TCA on world imports from column (c) in Table 7, i.e. allowing for the TCA effect to vary with the firm-level EU imports share. Likewise, we obtain p_{fWorld} from the estimated TCA effect on the overall import

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

survival probability by size group in panel (b) of Figure 10.[36] We then use equation (7) to aggregate across all firms in the VAT+ dataset with pre-TCA import weights from 2015. 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.

We calculate that the TCA reduced total worldwide UK goods imports by 4.4%, with the intensive margin alone accounting for a 3.1% fall. This decline is substantially smaller than the fall in EU relative to RoW imports implied by our regional differences estimates, which illustrates the importance of accounting for the indirect effects of the TCA on imports from the RoW. We also compute that the TCA caused 4.8% of UK importers, or $9,893$ firms, to stop importing from the world.[37]

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). 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 trade 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 increase in RoW imports driven by the imported input substitutability mechanism in determining the overall effect of the TCA on UK imports.

8 Conclusion

Brexit offers an unprecedented opportunity to study economic disintegration. We use this opportunity to 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 UK trade before 2021. Faced with uncertainty and the expectation of future trade barrier increases, UK firms adopted a 'wait and see'

[36] As in the exports aggregation exercise, we only use estimates of the TCA effect that are negative and significant at the 5% level. This means that we set the extensive margin effect to zero for firms with more than 56 employees.

[37] We have also implemented the world levels aggregation exercise for exports by using the estimates from column (a) of Table 7 to obtain λ_{fWorld} and the estimates from panel (a) of Figure 10 to obtain p_{fWorld}. This approach implies that the TCA reduced worldwide UK exports by 7.0% (with the intensive margin accounting for a 4.4% fall), and caused $13,578$ firms to stop exporting. Reassuringly, despite being derived using different data and estimation specifications, these numbers are very similar to those obtained in Section 7.1 from aggregating regional differences estimates.

approach, rather than adjusting in advance of the change in policy. However, once the TCA came into effect at the start of 2021, we find immediate and sustained changes in both UK exports and imports.

For exports, we show that the TCA reduced UK exports to the EU through the direct negative impact of higher trade barriers, but did not have an indirect effect on UK exports to the RoW. Allowing for heterogeneity across firms, we estimate that the fall in exports to the EU was driven by smaller firms and was 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 reduced worldwide UK goods exports by 6.4%.

On the imports side, the TCA decreased UK imports from the EU relative to the RoW along both the intensive and extensive margins. However, this relative decline was partially caused by firms substituting imports across origins and increasing their imports from the RoW. Nevertheless, we find that the TCA reduced total imports of UK firms with higher pre-referendum dependence on imports from the EU, meaning that the increase in imports from the RoW did not fully offset the decline in imports from the EU. Aggregating our estimates implies that the TCA reduced worldwide UK goods imports by 4.4%.

Collectively, the results paint a rich picture of how firms respond to disintegration. Although the overall effect of the TCA on UK trade was negative, we document that UK importers and larger exporters adjusted to the new trade barriers in ways that dampened the reduction in trade. Consequently, aggregate trade has, so far, been more resilient to Brexit than predicted for the long run. 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. We have studied the impacts of the TCA within two years of its introduction, and focused specifically on goods trade. 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, much remains to be learnt about firms' long-run adjustment to disintegration, as well as about its effect on trade in services. Finally, our results open questions about how the TCA has affected UK firms along dimensions other than trade, such as their value added, profitability and productivity.

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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

	EU versus RoW			EU	RoW	World
	(a)	(b)	(c)	(d)	(e)	(f)
TCA*EU	-0.13***	-0.24***				
	(0.002)	(0.009)				
TCA*EU*		0.03**				
Size quintile 2		(0.013)				
TCA*EU*		0.07***				
Size quintile 3		(0.012)				
TCA*EU*		0.12***				
Size quintile 4		(0.010)				
TCA*EU*		0.22***				
Size quintile 5		(0.010)				
2016			0.01***	0.01***	0.00	0.01***
			(0.003)	(0.002)	(0.002)	(0.002)
2017			0.02***	0.02***	0.00	0.02***
			(0.003)	(0.002)	(0.002)	(0.002)
2018			0.02***	0.02***	0.01**	0.02***
			(0.003)	(0.002)	(0.003)	(0.002)
2019			0.01***	0.01***	0.00	0.01***
			(0.003)	(0.002)	(0.003)	(0.002)
2021			-0.11***	-0.13***	0.00*	-0.10***
			(0.003)	(0.002)	(0.003)	(0.002)
2022			-0.13***	-0.13***	0.02***	-0.09***
			(0.003)	(0.002)	(0.003)	(0.002)
R-squared	.14	.2	.14	.16	.033	.012
N	860,894	858,297	860,894	536,361	324,605	665,230
Firms	218,384	217,414	218,384	183,191	93,352	218421
Controls						
Region-level	Yes	Yes				
Referendum*EU	Yes	Yes				
Referendum*EU*Size quintiles		Yes				
Fixed effects						
Industry				Yes	Yes	Yes
Industry-region	Yes		Yes			
Industry-time	Yes		Yes			
Size quintile-industry-region		Yes				
Size quintile-industry-time		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 £10,000 in year t-3. Columns (a)-(c) report regional differences survival regressions. Columns (d)-(f) report levels survival regressions for exports to the EU, RoW and World, respectively. 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

	EU versus RoW			EU	RoW	World
	(a)	(b)	(c)	(d)	(e)	(f)
TCA*EU	-0.11***	-0.09***				
	(0.007)	(0.024)				
TCA*EU* Size quintile 2		-0.09*** (0.025)				
TCA*EU* Size quintile 3		-0.06** (0.024)				
TCA*EU* Size quintile 4		-0.03 (0.023)				
TCA*EU* Size quintile 5		0.06** (0.023)				
2016			0.01**	0.01***	0.00*	0.01***
			(0.002)	(0.002)	(0.002)	(0.001)
2017			0.01***	0.01***	-0.00	0.01***
			(0.003)	(0.002)	(0.002)	(0.002)
2018			0.02***	0.01***	-0.00	0.01***
			(0.003)	(0.002)	(0.002)	(0.002)
2019			0.00	0.00	-0.00	-0.00
			(0.003)	(0.002)	(0.002)	(0.002)
2022			-0.13***	-0.11***	0.04***	-0.06***
			(0.003)	(0.002)	(0.002)	(0.002)
R-squared	.066	.12	.066	.073	.039	.054
N	911,883	909,633	911,883	523,592	388,351	739,789
Firms	247,023	246,234	247,023	176,086	128,847	247045
Controls						
Region-level	Yes	Yes				
Referendum*EU	Yes	Yes				
Referendum*EU*Size quintiles		Yes				
Fixed effects						
Industry				Yes	Yes	Yes
Industry-region	Yes		Yes			
Industry-time	Yes		Yes			
Size quintile-industry-region		Yes				
Size quintile-industry-time		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 £10,000 in year t-3. Columns (a)-(c) report regional differences survival regressions. Columns (d)-(f) report levels survival regressions for imports from the EU, RoW and World, respectively. 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[38] 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 registered for VAT. Firms with annual taxable turnover above the VAT threshold must register, but many firms below the threshold also register voluntarily. 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

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

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.

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 product-country 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:

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

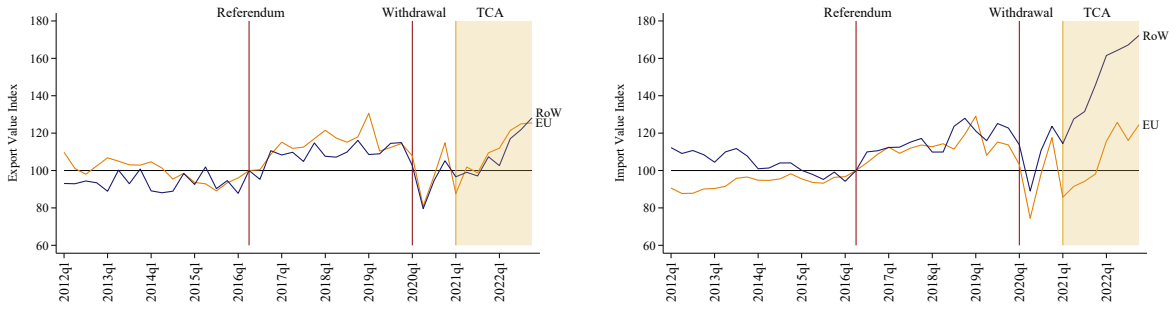
Likewise, let NAV_p be a dummy variable that takes value one for products that experienced non-ad-valorem tariff changes due to the introduction of the UK Global Tariff. The firm-level measure of exposure to non-ad-valorem tariff changes is given by:

$$\sum_{p}\omega_{fp,RoW}^{IMP}NAV_{p}.$$

A.5 Customs dataset versus OTS

In this section, we compare aggregate trade in our Customs dataset to HMRC's Overseas Trade Statistics (OTS). Figure 11 plots total UK goods trade with each region in our 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 11 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

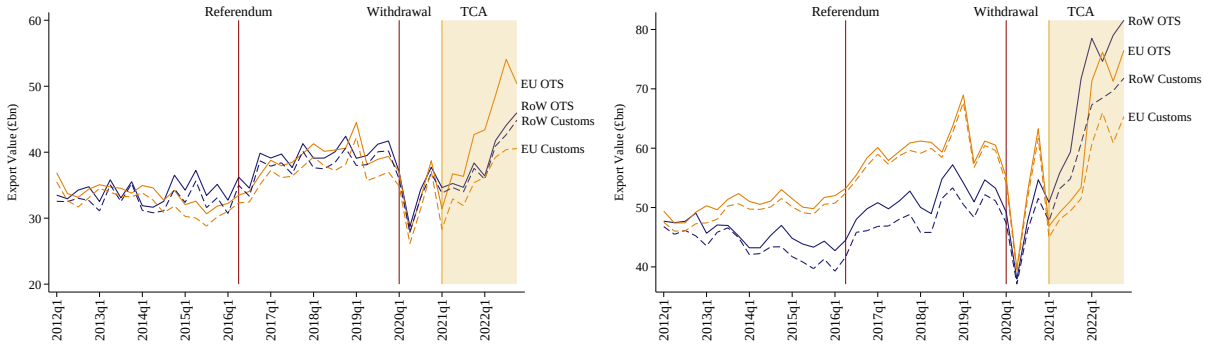
(b) Imports

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

Figure 11: Aggregate trade with EU and RoW: Customs dataset

To compare the Customs and OTS data more directly, Figure 12 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.

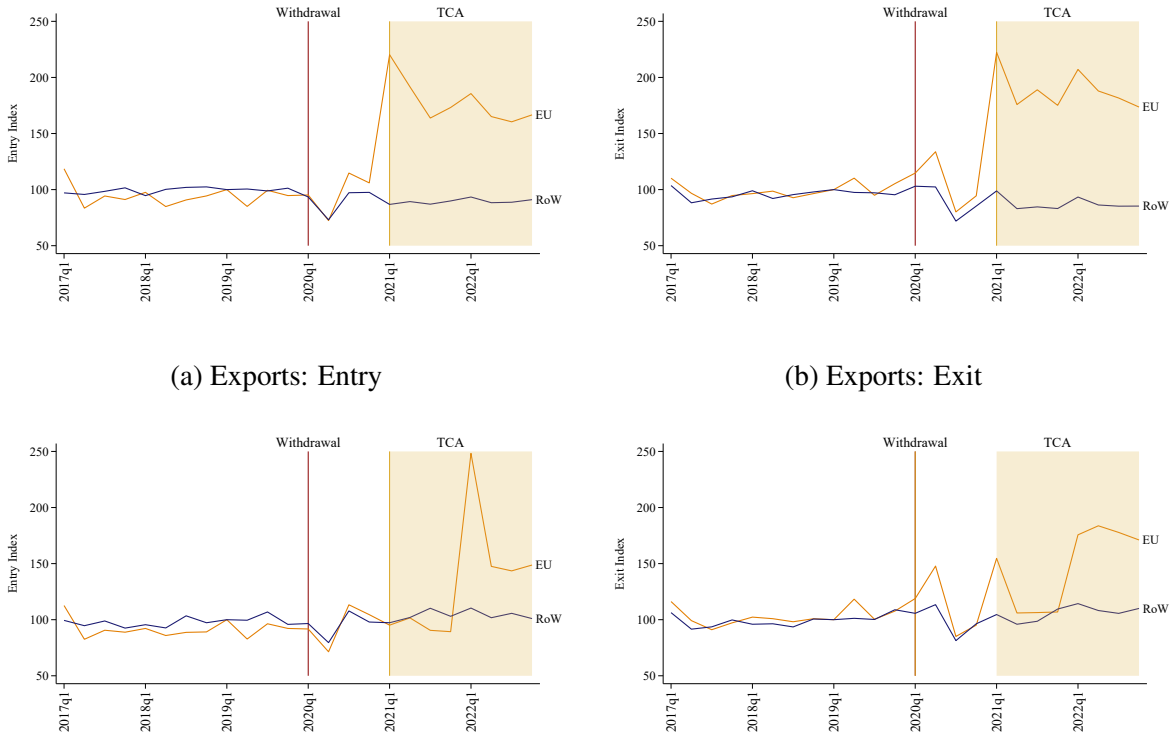
Figure 12: Aggregate trade with EU and RoW: Customs dataset versus HMRC OTS

B Product-level trade reporting

Figure 13 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 13 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%.



(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 13: Firm-product entry and exit

The change in data collection from Intrastat to Customs declarations occurred in 2021q1 for EU exports and 2022q1 for EU imports. Figure 13 shows that for both exports and imports the 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 Section 4.2 and Table 2. For ease of comparison, the baseline estimates in column (e) of Table 2 are repeated in column (a) of Table A2.

When trade data is collected via customs declarations, transactions below £873 are not assigned to individual firms, as discussed in Section 3.1. When constructing the Customs dataset, we adjust for the existence of this small-transaction threshold by dropping all UK-EU trade observations below £2,500 at the CN 8-digit product, country, month level. To assess the robustness of our findings to the choice of value below which we drop small observations, column (b) estimates the baseline specification from column (a) without dropping small observations, while column (c) increases the threshold for dropping observations to £5,000. We find that changing the threshold makes little difference to the estimated TCA effect.

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 (d) by computing the region-level import demand controls using regional imports from the EU excluding the UK instead of imports from the world excluding the UK. This change makes negligible difference to the estimates.

In column (e) 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 (f) 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 (g) 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 (g) 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 Intrastat threshold on RoW imports (column e) and when we drop from the RoW countries with which the UK had a PTA prior to Brexit (column g). 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.

C.2 Trade survival: robustness

Table A5 shows that the trade survival estimates in Tables 8 and 9 are robust to how we adjust for the introduction of the small-transaction threshold on EU trade following the switch to customs declarations. It reports results from estimating the EU versus RoW trade survival specification in equation (5) when using different initial trade thresholds for dropping firms from the sample.

The baseline export survival specification from column (b) of Table 8, which includes firms with regional exports above £$10,000$ in year $t-3$, is repeated in column (a) of Table A5. By contrast, in column (b) we include all firms with positive exports in year $t-3$, in column (c) we set the threshold for sample inclusion to £$25,000$ and in column (d) we set the threshold to £$100,000$. Columns (e)-(h) repeat the same set of specifications, but for import survival. Comparing across columns shows that we obtain similar estimates regardless of the choice of threshold.

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)	(b)	(c)	(d)	(e)	(f)	(g)
	Baseline	Small observations not dropped	Drop observations below £5,000	EU-specific import demand	RoW Intrastat	Drop agri-food	RoW no PTAs
Referendum*EU	-0.0058	-0.0283**	0.0078	-0.0073	0.0063	0.0020	0.0000
	(0.0141)	(0.0140)	(0.0143)	(0.0144)	(0.0151)	(0.0143)	(0.0158)
TCA*EU	-0.1456***	-0.1752***	-0.1377***	-0.1414***	-0.0847***	-0.1455***	-0.1409***
	(0.0102)	(0.0102)	(0.0103)	(0.0101)	(0.0110)	(0.0104)	(0.0112)
R-squared	.93	.92	.93	.93	.92	.92	.92
N	1,030,624	1,067,720	1,022,804	1,030,624	696,368	996,134	912,380
Firms	23,237	26698	23172	23,237	15,435	22,495	21,464
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	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 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) we do not drop UK-EU export observations below £2,500 at the CN 8-digit product, country, month level when constructing the Customs dataset. In column (c) we drop UK-EU export observations below £5,000 at the CN 8-digit product, country, month level when constructing the Customs dataset. In column (d) region-level and firm-level import demand controls calculated using regional imports from EU (excluding UK). In column (e) 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 (f) we drop firms in the agri-food industry (SIC sectors 1-3 and 10-12). In column (g) 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) Small observations not dropped	(c) Drop observations below £5,000	(d) EU-specific export supply	(e) RoW Intrastat	(f) Drop agri-food	(g) RoW no PTAs
Referendum*EU	-0.0012	0.0017	0.0012	-0.0019	0.0584***	-0.0016	0.0127
	(0.0194)	(0.0193)	(0.0194)	(0.0197)	(0.0204)	(0.0195)	(0.0207)
TCA*EU	-0.2344***	-0.2390***	-0.2344***	-0.2308***	-0.1645***	-0.2427***	-0.1716***
	(0.0211)	(0.0212)	(0.0211)	(0.0214)	(0.0230)	(0.0215)	(0.0222)
R-squared	.93	.93	.93	.93	.91	.93	.93
N	500,268	508,912	500,022	500,268	259,104	481,156	440,304
Firms	12,409	13618	12403	12,409	6,424	11,919	11,324
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	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 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) we do not drop UK-EU import observations below £2,500 at the CN 8-digit product, country, month level when constructing the Customs dataset. In column (c) we drop UK-EU import observations below £5,000 at the CN 8-digit product, country, month level when constructing the Customs dataset. In column (d) region-level and firm-level export supply controls calculated using regional exports to EU (excluding UK). In column (e) 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 (f) we drop firms in the agri-food industry (SIC sectors 1-3 and 10-12). In column (g) 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.

Table A5: Firm trade survival in EU versus RoW - robustness

	Exports				Imports			
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Initial trade threshold	10,000	0	25,000	100,000	10,000	0	25,000	100,000
TCA*EU	-0.24***	-0.24***	-0.23***	-0.19***	-0.09***	-0.13***	-0.09***	-0.09***
	(0.009)	(0.007)	(0.011)	(0.016)	(0.024)	(0.022)	(0.024)	(0.026)
TCA*EU*	0.03**	0.02**	0.04**	0.02	-0.09***	-0.10***	-0.07**	-0.03
Size quintile 2	(0.013)	(0.010)	(0.016)	(0.023)	(0.025)	(0.023)	(0.026)	(0.030)
TCA*EU*	0.07***	0.05***	0.07***	0.08***	-0.06**	-0.09***	-0.04*	0.01
Size quintile 3	(0.012)	(0.009)	(0.014)	(0.019)	(0.024)	(0.022)	(0.024)	(0.026)
TCA*EU*	0.12***	0.10***	0.12***	0.12***	-0.03	-0.04*	-0.02	0.02
Size quintile 4	(0.010)	(0.008)	(0.012)	(0.017)	(0.023)	(0.022)	(0.024)	(0.025)
TCA*EU*	0.22***	0.21***	0.21***	0.18***	0.06**	0.06***	0.06**	0.08***
Size quintile 5	(0.010)	(0.008)	(0.012)	(0.016)	(0.023)	(0.022)	(0.024)	(0.025)
R-squared	.2	.2	.21	.2	.12	.16	.11	.11
N	858,297	1,332,725	673,077	402,297	909,633	1,499,933	721,027	448,006
Firms	217,414	356,210	167,495	95,221	246,234	461,852	188,723	111,761
Controls								
Region-level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Referendum*EU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Referendum*EU*Size quintiles	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects								
Size quintile-industry-region	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Size quintile-industry-time	Yes	Yes	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 VAT+ dataset. Dependent variable is dummy for trade survival by region (EU and RoW) in year t (t=2015-19, 2021 (exports only), 2022) of firms with regional trade above the intial trade threshold (in pounds) in year t-3. Direction of trade is exports in columns (a)-(d) and imports in columns (e)-(h). 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. 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.