Quantifying Non-Tariff Barriers: Brexit, Input Sourcing and Firm Performance*

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September 2026

Abstract

How successful is European integration in removing non-tariff trade barriers? We study how Brexit affected UK firms' input sourcing and sales. The post-Brexit Trade and Cooperation Agreement (TCA) reduced sales and input expenditure at firms with higher pre-Brexit EU trade exposure. It also caused firms to switch towards domestic and non-EU inputs. Through the lens of a trade model, the switch in input sourcing implies the TCA increased trade costs on EU imports by 21% and raised unit production costs by 3.1% for the average UK importer. Our results indicate EU membership secures large reductions in trade costs.

†Dillner and Manova: University College London. Freeman: Bank of England. Sampson: London School of Economics. Zonglin Liu provided excellent research assistance. We thank the Economic and Social Research Council for funding through the Governance After Brexit programme under grant ES/V004514/1.

1 Introduction

Imported inputs lower firms' production costs, leading to higher sales and improved performance (Amiti and Konings 2007, Halpern et al. 2015). This paper analyzes how deep integration agreements that seek to reduce non-tariff barriers to trade affect firms through this imported input channel. In particular, we study the reversal of integration that occurred after the United Kingdom (UK) left the European Union's (EU) single market and customs union. Our results quantify the effectiveness of the EU in lowering non-tariff barriers, shed light on how firms adjust to input cost shocks, and provide new evidence on how Brexit impacted the UK economy.

Gravity-based estimates imply non-tariff barriers generate trade costs similar in magnitude to tariffs (Kee et al. 2009) and that the EU's single market has boosted trade between member countries by 50% or more (Mayer et al. 2019, Felbermayr et al. 2022, Nagengast et al. 2026). But such estimates face tricky identification challenges, since non-tariff barriers are frequently not directly observable or measurable,[1] and EU accession is usually accompanied by wide-ranging economic reforms. To overcome these challenges, we exploit Brexit as a natural experiment that led to a sudden, sharp increase in non-tariff barriers without changing tariffs. Since the start of 2021, UK-EU trade has been governed by the Trade and Cooperation Agreement (TCA). The TCA is a zero-tariff free trade agreement, but it does not mandate the same market access as EU membership. Consequently, it has introduced new trade barriers, including customs paperwork, border checks, rules of origin, regulatory requirements, and labor mobility restrictions (Dhingra and Sampson 2022). We estimate the magnitude and consequences of these non-tariff barriers.

We start by developing a firm-level input sourcing model in Section 2. In the model, a firm's response to changes in UK-EU trade costs depends on its pre-shock (i) input exposure, defined as the share of EU imports in its input expenditure; and (ii) output exposure, defined as the share of EU exports in its sales. A higher cost of importing from the EU causes firms to substitute towards domestic and non-EU inputs and reduces their sales by raising production costs. In contrast, costlier access to EU export markets operates primarily through lower sales, which in turn depresses input purchases.

Guided by the model, we undertake two empirical exercises using rich, linked administrative customs and VAT data for UK firms over 2012-22, which we describe in Section 3. First, in Section 4 we estimate the impact of pre-Brexit input and output exposure to EU trade on the evolution of firm sales and input expenditure over time. We find that, under the TCA, firms with higher input

[1] For example, the UK imposes a 10% ad-valorem tariff on imports of new battery electric passenger vehicles (UK commodity code 8703801010) from China. No comparable statement can be made about non-tariff barriers on electric vehicle imports.

exposure had lower sales growth and substituted away from EU imports by increasing domestic input expenditure and imports from outside the EU. In addition, the TCA reduced sales and input purchases from all sources at firms with higher output exposure. Our estimates imply that the TCA decreased sales of the average importing firm in 2022 by 2.5% through the input exposure channel and an additional 1.1% through the output exposure channel, relative to a firm with no EU exposure.

Second, in Section 5 we quantify the effect of the TCA on non-tariff barriers and firms' production costs. We structurally estimate the model equation that determines the reallocation of input expenditure towards domestic inputs. The extent of expenditure switching depends on the product of the Armington elasticity of substitution between domestic and imported inputs and the change in EU input prices inclusive of import costs. We cannot separately identify the Armington elasticity from our data, but conventional values imply a large increase in EU import prices. Assuming an Armington elasticity of 6, and attributing the increase in EU import prices to higher trade costs, we find that the TCA raised ad-valorem equivalent trade costs for UK imports from the EU by 21%. A lower Armington elasticity would imply a larger increase in trade costs. We conclude that EU integration has secured large reductions in non-tariff trade costs.

Finally, we use the estimated 21% rise in UK-EU trade costs to calculate the implied change in UK firms' unit production costs, accounting for both the direct effect of the TCA on import costs and its indirect effect on the price of domestic inputs produced using imports from the EU. Our results indicate that the TCA increased unit production costs by 3.1% for the average importer, with substantial variation across firms. The hardest-hit firms faced cost increases of up to 25%.

The paper contributes to several literatures. Most research on non-tariff barriers analyzes their effects on trade (Fontagné et al. 2015, Neri-Lainé et al. 2023). We provide the first evidence on how firm sales and input sourcing patterns are affected by a broad-based increase in non-tariff barriers. This evidence complements existing firm-level studies that focus on how technical barriers to trade affect mark-ups (Singh and Chanda 2021) and input sourcing (Iodice and Reverdy 2025). Using an input sourcing model to quantify changes in trade and production costs is new to the deep integration literature, but relates to models of firm-level importing developed by Antràs et al. (2017) and Blaum et al. (2018). Applying our model to Brexit gives a new method for estimating the impact of European integration on non-tariff trade costs. We obtain an estimate similar in magnitude to the gravity-based finding in Felbermayr et al. (2022) that the single market reduces intra-EU trade costs on goods by 13%.

Most directly, we advance research on the economic impacts of the TCA.[2] Freeman et al.

[2] Dhingra and Sampson (2022) review research on how the Brexit referendum affected the UK economy before the

(2025) and Bhalotia et al. (2025) document the effects of the TCA on goods and services trade, respectively, while Conconi et al. (2026) show that TCA rules of origin reshaped input sourcing by French firms. Closest to our work are two recent papers that also argue Brexit had negative effects on firm performance (Bloom et al. 2025, Breinlich et al. 2026). Our paper differs from these studies in that we use administrative data on the universe of UK firms; separately identify the effects of input and output exposure to EU trade; and combine theory with estimation to quantify the impact of the TCA on trade barriers and production costs.

2 Input Sourcing Model

This section develops a simple model of input sourcing and sales by UK firms. We assume that the TCA impacts UK firms through a simultaneous increase in the cost of importing inputs from the EU and decline in access to EU markets. Using the model, we characterize how these shocks affect input sourcing, production costs and sales. The theory motivates the reduced-form estimates in Section 4, and informs the structural estimation and quantitative analysis in Section 5.

2.1 Sourcing Problem

Consider the sourcing problem of a UK firm that purchases intermediate inputs from three regions: the domestic economy D, the EU E, and the rest of the world (RoW) R. The firm aggregates its purchases to produce a composite intermediate, which it uses for production. The firm's composite input use M is a constant elasticity aggregate of domestic inputs m_D, inputs from the EU m_E, and inputs from the RoW m_R:

$$M = \left[\zeta_D m_D^{\frac{\epsilon-1}{\epsilon}} + \left(\zeta_E m_E^{\frac{\sigma-1}{\sigma}} + \zeta_R m_R^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}},$$

where σ is the elasticity of substitution between EU and RoW inputs and, ϵ is the Armington elasticity of substitution between domestic and imported inputs. In presenting the model we omit firm subscripts to simplify notation, but quantities, input prices and the technology parameters ζ_D, ζ_E and ζ_R may vary across firms.

The firm chooses m_D, m_E, and m_R to minimize the unit cost c of producing its composite input, taking input prices as given. Solving, we obtain:

TCA came into effect.

$$c = \left[\zeta_D^{\epsilon} p_D^{1-\epsilon} + \left(\zeta_E^{\sigma} p_E^{1-\sigma} + \zeta_R^{\sigma} p_R^{1-\sigma} \right)^{\frac{1-\epsilon}{1-\sigma}} \right]^{\frac{1}{1-\epsilon}}, \tag{1}$$

where the price of inputs from region $J = D, E, R$ can be written as $p_J = \tau_J^{IM} \widetilde{p}_J$ with τ_J^{IM} denoting trade costs on imports from region J and $\widetilde{p}_J$ the price received by suppliers in J.[3]

The firm produces output by combining its composite intermediate with value-added using a constant returns technology. Let $a(c, v)$ be the firm's unit production cost, where the price of value added v, which is exogenous to the firm, depends on factor prices.

2.2 Sales

We assume that the firm's sales in region J can be expressed as $S_J = B_J \left(\tau_J^{EX} \right) a(c, v)^{-\gamma}$, where B_J is a firm-region-specific demand parameter that the firm takes as given, τ_J^{EX} denotes the trade costs for exporting to J, and γ gives the elasticity of sales to production costs. The export demand parameters B_E and B_R are assumed to depend on trade costs, as well as foreign market size and the firm's market entry status. The firm's total demand B can be written as the sum of domestic, EU, and RoW demand, $B = B_D + B_E + B_R$, implying that total sales are: $S = S_D + S_E + S_R = Ba(c, v)^{-\gamma}$.

For any variable x, let $\widehat{x} \equiv dx/x$ be the proportional change in x. Differentiating the sales function for region $J = D, E, R$, and using Shephard's lemma implies:

$$\widehat{S}_J = \widehat{B}_J - \gamma \eta_m \widehat{c} - \gamma (1 - \eta_m) \widehat{v}, \tag{2}$$

where η_m and $1 - \eta_m$ are the production cost shares of intermediates and value added, respectively. Equation (2) decomposes changes in revenue into shocks to demand, input costs and the price of value added. Higher demand increases sales, while higher production costs reduce sales. Differentiating total sales we also obtain:

$$\widehat{S} = \psi_D \widehat{S}_D + \psi_E \widehat{S}_E + \psi_R \widehat{S}_R, \tag{3}$$

where $\psi_J \equiv B_J/(B_D + B_E + B_R)$ is region J's share in the firm's sales. Thus, total sales growth is the weighted average of sales growth across regions with pre-shock regional sales shares as weights.

[3] Appendix A reports the firm's optimal input demands m_D, m_E, and m_R.

2.3 Brexit and Input Sourcing

The UK voted to leave the EU in June 2016, but remained in the EU's single market and customs union until the end of 2020 when the TCA came into effect. Starting in January 2021, the TCA introduced new non-tariff barriers to UK-EU trade, while maintaining zero tariffs on all trade satisfying its rules of origin (Dhingra and Sampson 2022). For UK firms, these non-tariff barriers increased the cost of importing inputs from the EU, and raised export costs for selling to the EU market.

We model these shocks as a rise in the price of inputs sourced from the EU $\widehat{p}_E > 0$, and a reduction in EU demand $\widehat{B}_E < 0$ due to increased trade costs with the EU $\widehat{\tau}_E^{IM} > 0$ and $\widehat{\tau}_E^{EX} > 0$. In addition, the TCA may have also indirectly affected the domestic input price p_D, and triggered general equilibrium effects on domestic demand B_D and the value-added price v. We assume that the TCA did not affect equilibrium in the RoW, implying that p_R and B_R were unchanged.

We first characterize the impact of the TCA on the composition of input expenditure by differentiating the solution to the firm's sourcing problem obtained in Section 2.1. We allow for shocks to prices and demand resulting from both the direct and indirect effects of the TCA. Let $\mu_J \equiv p_J m_J / (p_D m_D + p_E m_E + p_R m_R)$ be the share of region $J = D, E, R$ in the firm's total input expenditure, and $\lambda_E \equiv p_E m_E / (p_E m_E + p_R m_R)$ be the EU's share in the firm's imported input expenditure. Note that $\lambda_E > \mu_E$ whenever $m_D > 0$. Using these definitions, we obtain:

$$\widehat{\mu}_D = (\epsilon - 1)\,\mu_E \widehat{p}_E - (\epsilon - 1)\,(1 - \mu_D)\,\widehat{p}_D, \tag{4}$$

$$\widehat{\mu}_R = \widehat{\mu}_D + (\sigma - \epsilon)\,\lambda_E \widehat{p}_E + (\epsilon - 1)\,\widehat{p}_D, \tag{5}$$

$$\widehat{\mu}_E = -\left[(\epsilon - 1)\,(\lambda_E - \mu_E) + (\sigma - 1)\,(1 - \lambda_E)\right]\widehat{p}_E + (\epsilon - 1)\,\mu_D \widehat{p}_D. \tag{6}$$

Equations (4)-(6) give the impact of the TCA on the firm's input expenditure shares by region. This impact will generally be firm-specific due to differences in pre-shock dependence on EU inputs μ_E and λ_E.

A rise in the price of EU inputs p_E causes the firm to switch towards domestic inputs, increasing μ_D (equation 4). This effect is stronger when the firm's initial EU input expenditure share μ_E is larger and when the elasticity of substitution between domestic and imported inputs ϵ is greater. The firm also switches towards RoW inputs raising μ_R, which increases relative to μ_D if and only if the elasticity of substitution between EU and RoW inputs σ is greater than that between imported and domestic inputs ϵ (equation 5). Unsurprisingly, these changes in sourcing patterns reduce the EU's share of input expenditure μ_E (equation 6).

In addition to these direct effects, the TCA also indirectly affects input sourcing by raising the price of domestic inputs p_D purchased from other firms that themselves source inputs from the EU. A higher domestic input price leads to substitution away from domestic inputs (equation 4) and towards RoW and EU inputs (equations 5 and 6).

Because input expenditure shares are independent of the scale of production, they are unaffected by shocks to either demand or factor prices, and only depend on the input price shocks $\widehat{p}_E$ and $\widehat{p}_D$. This means that reduced export access to the EU market under the TCA does not affect the input expenditure shares. By contrast, input expenditure levels $p_J m_J$ for $J = D, E, R$ adjust to changes in sales in addition to input prices, as shown in Appendix A. This observation motivates our use of input expenditure shares, rather than levels, when structurally estimating the model in Section 5.1.

Next, we differentiate the firm's composite input cost function in equation (1) and its unit cost function $a\left(v, c\right)$ to obtain:

$$\widehat{c} = \mu_E \widehat{p}_E + \mu_D \widehat{p}_D, \tag{7}$$
$$\widehat{a} = \eta_m \widehat{c} + \left(1 - \eta_m\right) \widehat{v}. \tag{8}$$

By increasing p_E and p_D, the TCA raises the cost of the firm's composite input c (equation 7), which pushes up the firm's unit production cost a (equation 8). The latter is also affected by any general equilibrium adjustments in the value-added price v. Cost changes are firm-specific due to pre-shock differences in the regional input expenditure shares μ_E and μ_D and the production cost share of intermediates η_m. Given estimates of $\widehat{p}_E$ and $\widehat{p}_D$, equations (7) and (8) make it possible to quantify the TCA's impact on the production costs of UK firms.

2.4 Brexit and Sales

We next consider the effect of the TCA on firms' sales. Using equation (7) to substitute for $\widehat{c}$ in equations (2) and (3) yields:

$$\widehat{S}_J = \widehat{B}_J - \gamma \eta_m \left(\mu_E \widehat{p}_E + \mu_D \widehat{p}_D\right) - \gamma \left(1 - \eta_m\right) \widehat{v}, \qquad J = D, E, R, \tag{9}$$
$$\widehat{S} = \psi_E \widehat{B}_E + \psi_D \widehat{B}_D - \gamma \eta_m \left(\mu_E \widehat{p}_E + \mu_D \widehat{p}_D\right) - \gamma \left(1 - \eta_m\right) \widehat{v}. \tag{10}$$

These expressions show that the TCA impacts firm-level sales through direct and indirect effects on input costs, through export demand, and through domestic demand and the price of value added (via general equilibrium adjustments).

On the demand side, higher export costs lead to $\widehat{B}_E < 0$, generating a direct negative demand effect. The resulting decline in total sales S is greater when the EU accounts for a larger share ψ_E of the firm's pre-shock sales (equation 10). The TCA may also have an indirect effect on domestic sales due to changes in domestic demand $\widehat{B}_D$, which could be positive or negative.

On the cost side, the direct effect of higher EU input costs $\widehat{p}_E > 0$ and the indirect effect of higher domestic input costs $\widehat{p}_D > 0$ combine to reduce sales to all regions (equation 9). The magnitude of these effects will differ across firms given variation in the regional input expenditure shares μ_E and μ_D and the intermediates cost share η_m. There is also an indirect effect of any factor price changes on production costs and therefore sales through $\widehat{v}$.

Lower sales (due to either the demand or cost shocks) result in a fall in the firm's total input purchases through a contraction in scale. We show in Appendix A that this scale effect reduces input expenditure $p_J m_J$ for all regions J. Consequently, we expect firms with higher ψ_E to have greater declines in input purchases under the TCA.

Our empirical analysis explores the channels highlighted in equations (9) and (10) by estimating how the impact of the TCA on firm sales depends on both input and output exposure to the EU.

3 UK Firm Data

The analysis uses four datasets on UK firms during 2012-22: value-added tax (VAT) data on sales, input purchases and EU trade from the HMRC VAT Returns Panel Dataset; customs trade data from the HMRC EU and Non-EU Trade Panel Datasets; and employment from the Office for National Statistics (ONS) Interdepartmental Business Register (IDBR). We match these datasets by VAT number, and identify unique VAT numbers as firms. The data covers fiscal years rather than calendar years, e.g. 2012 data is for 2012q2-2013q1.

In the matched dataset, we observe annual sales, input expenditure, and goods trade with the EU and the RoW for the universe of VAT-registered firms.[4] As the data does not cover services trade, we set each firm's EU and RoW input expenditures equal to its goods imports from the

[4]Freeman et al. (2025) provide a detailed description of this dataset. Changes in trade data collection methods implemented after the UK left the EU's customs union mean that product-level trade data was not reported consistently before and after the TCA came into effect, implying we cannot directly observe changes in the border price of EU imports. Bakker et al. (2026) find that non-tariff barriers introduced by the TCA raised UK consumer prices for food products.

EU and the RoW, respectively. We then calculate the firm's domestic input expenditure as the difference between its total input expenditure and its goods imports. Note this means that our measure of domestic input expenditure includes any imported services inputs. Similarly, we use the firm's goods exports to measure its sales to the EU and the RoW, and calculate domestic sales as total sales minus goods exports. Using f to denote firms and t to denote years, we construct $\mu_{J,ft}$ for $J = D, E, R$ as region J's share of total input expenditure by firm f in year t, and $\psi_{J,ft}$ as region J's share of the firm's total sales.

We measure firms' pre-Brexit exposure to EU trade at the start of our sample in 2012 (or with data from the earliest available year for firms that are not observed in 2012). Tildes are used to denote pre-Brexit firm-level characteristics. Thus, *input exposure* to the EU $\widetilde{\mu}_{E,f}$ is defined as the firm's initial goods imports from the EU relative to its total input expenditure. Likewise, *output exposure* to the EU $\widetilde{\psi}_{E,f}$ is defined as initial goods exports to the EU relative to total sales. We also observe each firm's UK SIC 2007 4-digit industry i and its employment prior to the referendum.[5] We allocate firms to size quintiles using their average employment over 2013-15.

Our baseline sample includes $303,030$ firms with positive imports in 2012 (or the first year in which the firm is observed). Appendix C.1 reports descriptive statistics for the EU exposure variables for this sample. Average input exposure to the EU $\widetilde{\mu}_{E,f}$ is 11.8% and average output exposure $\widetilde{\psi}_{E,f}$ is 4.6%. Across all firms and years, 52% of observations report imports from the EU, 42% imports from the RoW, 32% exports to the EU, and 26% exports to the RoW.

We also construct measures of indirect exposure to the EU through higher domestic input prices due to the rise in the production costs of upstream domestic suppliers. In the absence of firm-to-firm data, we use industry-level UK input-output tables for 2013 to compute the share of an industry's domestic input expenditure indirectly accounted for by EU imports used by upstream industries. We denote the indirect domestic exposure of industry i to the EU by Ω_i.[6] In an economy with complete price pass-through, $\widehat{p}_{D,i} = \Omega_i \widehat{p}_E$. We also use the input-output tables to compute an industry-level measure of the domestic input expenditure share $\mu_{D,i}$.

Average indirect domestic exposure Ω_i is 12.8% in the baseline sample, which is similar to average direct input exposure. However, indirect domestic exposure varies much less across firms, with a standard deviation of 0.023 compared to 0.24 for direct input exposure. This difference is partly because Ω_i is computed at the industry level, but also because all firms indirectly use imports embodied in domestic input purchases, whereas not all firms import directly from the EU.

[5] Unfortunately, the employment data does not cover the post-referendum period.

[6] Appendix B documents how Ω_i is calculated. Because our measure of domestic input expenditure includes services imports, we include both direct and indirect expenditure on services in Ω_i.

4 Reduced-Form Evidence

Guided by the theory, we estimate how changes in firm-level sales and input expenditure over time depend on pre-Brexit input and output exposure to EU trade.

4.1 Estimation Specification

We estimate a series of event studies for firm outcomes y_{ft} in year t:

$$\log y_{ft} = \delta_f + \delta_{it} + \delta_{st} + \sum_t \beta_t^1 \widetilde{\mu}_{E,f} + \sum_t \beta_t^2 \widetilde{\psi}_{E,f} + \epsilon_{ft}. \tag{11}$$

The coefficients of interest β_t^1 and β_t^2 identify how pre-Brexit input exposure to EU imports $\widetilde{\mu}_{E,f}$ and output exposure to EU exports $\widetilde{\psi}_{E,f}$ affect outcome y over time. The specification conditions on time-invariant firm characteristics, industry supply and demand shocks, and firm-size specific trends using a set of firm δ_f, industry-year δ_{it} and firm size quintile-year δ_{st} fixed effects. Note that δ_{it} also accounts for indirect domestic exposure at the industry level. Thus, identification comes from how within-firm changes in outcomes over time are associated with within-industry and within-size quintile differences in input and output exposure.

We study six different firm outcomes: sales, domestic sales, exports to the RoW, input expenditure, domestic input expenditure, and imports from the RoW. We do not report estimates for EU exports or EU imports as outcomes because of substantial pre-trends in the input and output exposure coefficients in these specifications, likely due to the inclusion of measures of trade with the EU on both sides of the equation. However, Freeman et al. (2025) provide evidence that the TCA reduced firms' exports and imports with the EU, which is consistent with the TCA increasing UK-EU trade costs.

We estimate specification (11) in the 2013-22 panel for the baseline sample of firms with positive imports in 2012 (or in the first year the firm is observed). Appendix C.2 shows that similar results obtain if we expand the sample to include all firms or restrict the sample to firms in goods industries. We cluster standard errors by firm, and normalize the event-study coefficients to zero in 2015, i.e. the year before the referendum.

4.2 Event-Study Estimates

Figure 1 plots the event-study estimates. Each panel shows the effects of input and output exposure to the EU on a different outcome variable. Recall that the data is for fiscal years, meaning results for 2020 cover 2020q2-2021q1 and subsume the immediate TCA effect in 2021q1.

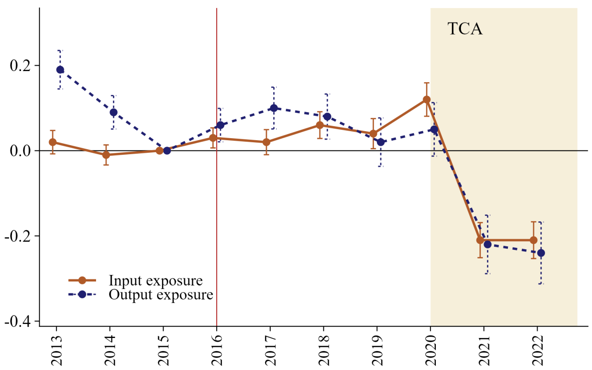
We first consider the role of input exposure. Prior to 2021, firms with greater input exposure experienced slightly higher growth in sales (panel a) and input expenditure (panel b). However, the introduction of the TCA led more input exposed firms to sharply reduce both sales and input purchases in 2021 and 2022. The decline in sales and in associated input demand is consistent with the TCA increasing firms' production costs by raising the price of imports from the EU. The estimates imply that a 10 percentage point increase in input exposure reduced sales by 2.1% and input expenditure by 1.3% in 2022. The TCA thus led to a 2.5% drop in sales and 1.5% fall in input expenditure for an importing firm with average input exposure, relative to a firm that did not import from the EU before Brexit.

Panels (c) and (d) show how the TCA affected the geography of input sourcing. Consistent with the model, we find that firms responded to higher UK-EU trade costs by increasing both domestic input purchases (panel c) and imports from the RoW (panel d). In both cases, there is evidence that input sourcing started to shift following the 2016 referendum, but the adjustment accelerated under the TCA, particularly for domestic sourcing. These results imply that the drop in total input expenditure by more input exposed firms in panel (b) is due to a fall in imports from the EU. Comparing panels (c) and (d), domestic input purchases were more sensitive to input exposure than RoW imports after the TCA. This suggests that domestic and imported inputs are more highly substitutable than EU and RoW inputs in UK firms' production processes, i.e. $\epsilon > \sigma$. This could be the case if, for example, EU inputs are more similar to domestic UK inputs than to RoW inputs.

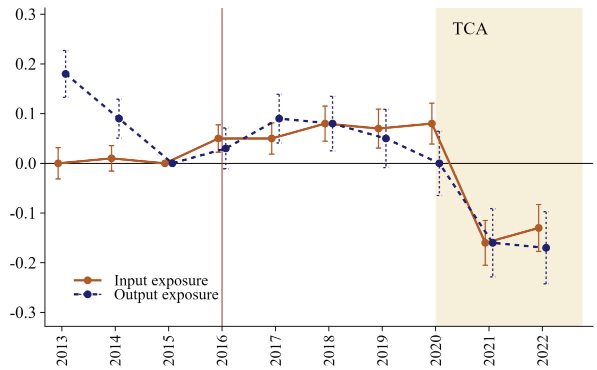
Figure 1 also shows that the TCA lowered domestic sales by firms with higher input exposure (panel e), but did not affect their exports to the RoW (panel f). This contrast suggests that exports may be more sticky than domestic sales when firms are hit by production cost increases, at least in the short run.

We next evaluate the role of output exposure. After the TCA came into effect, firms with higher output exposure experienced greater reductions in both total sales (panel a) and total input purchases (panel b). However, while more output-exposed firms scaled back both their domestic and RoW input expenditure as predicted by the model (panels c and d), they increased domestic sales (panel e) and only marginally reduced RoW exports (panel f). These results imply that the TCA decreased firm sales and, consequently, input demand by cutting access to EU markets. Moreover, firms were unable to fully offset the drop in EU exports by selling more domestically and outside the EU, implying that sales are imperfectly substitutable across markets. The estimates in panel (a) imply that a 10 percentage point increase in output exposure reduced sales by 2.4% in 2022, and that the TCA led to a 1.1% drop in sales for an importing firm with average output

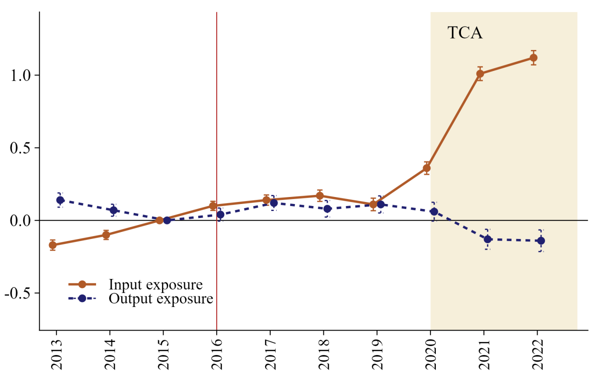
Figure 1: Reduced-form event-study estimates



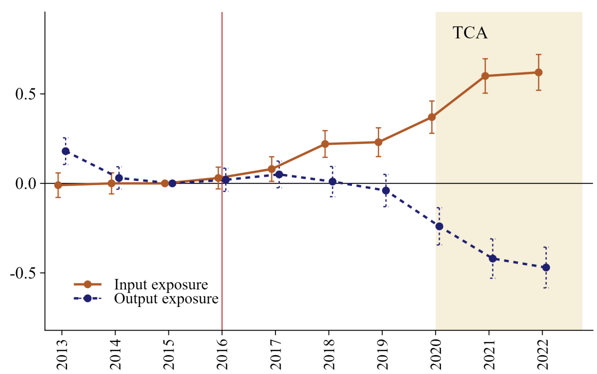
(a) Log sales



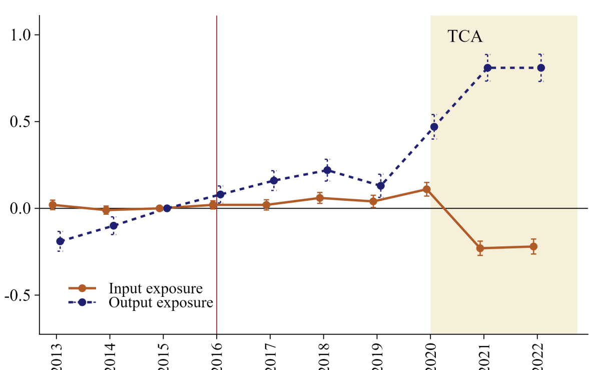
(b) Log input expenditure



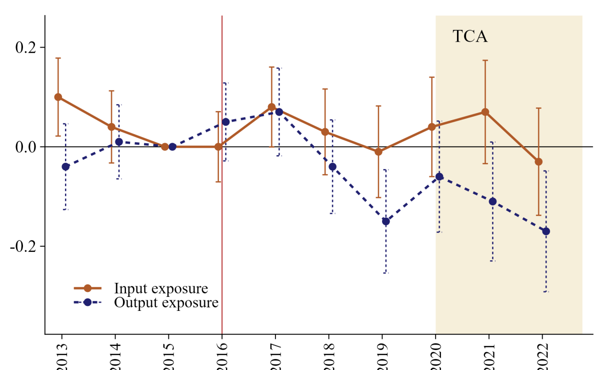
(c) Log domestic input expenditure



(d) Log RoW imports



(e) Log domestic sales



(f) Log RoW exports

Notes: This figure plots event-study estimates and 95% confidence intervals for the impact of pre-Brexit input and output exposure to the EU on firm outcomes from estimating equation (11). Sample includes all importers. Standard errors clustered by firm. Estimated coefficients normalized to zero in 2015. Firm-level input and output exposure calculated in 2012 (or the first year with available data). Years denote fiscal years, e.g. 2013 denotes 2013q2–2014q1. Red vertical line marks Brexit referendum in June 2016. TCA in effect starting in January 2021.

exposure, relative to a firm that did not export to the EU pre-Brexit.

Taken together, the reduced-form estimates reveal that the TCA had significant effects on UK firms' sales and input purchases through both input and output exposure to EU trade. Under the TCA, firms with higher input exposure had lower sales growth and shifted input purchases to domestic and RoW suppliers instead of the EU. At the same time, firms with higher output exposure shrank in terms of both sales and input expenditure, despite increasing domestic sales.

5 Quantitative Analysis

Building on the reduced-form evidence, we use the model to quantify the impact of the TCA on UK firms in two steps. First, we estimate the model structurally to recover $\widehat{p}_E$, i.e. the increase in the price of EU imports caused by the TCA. Second, we use this estimate to infer changes in firms' unit production costs due to the TCA.

5.1 Structural Estimation

Model equation (4) relates firms' domestic input expenditure shares to changes in the price of EU and domestic inputs. We estimate the empirical counterpart of this equation allowing the Brexit referendum and the TCA to cause input price shocks. The estimating equation is:

$$\begin{aligned}\log \mu_{D,ft} = {} & \delta_f + \delta_{it} + \delta_{st} + \beta_1 REF_t \widetilde{\mu}_{E,f} + \beta_2 TCA_t \widetilde{\mu}_{E,f} \\ & + \beta_3 REF_t \left(1 - \widetilde{\mu}_{D,i}\right) \Omega_i + \beta_4 TCA_t \left(1 - \widetilde{\mu}_{D,i}\right) \Omega_i + \epsilon_{ft},\end{aligned} \tag{12}$$

where REF_t is a referendum dummy that takes value one from 2016 onwards, and TCA_t is a TCA dummy that takes value one from the 2021 introduction of the TCA onwards.

The coefficient of interest β_2 identifies how the TCA affected firms' domestic input expenditure shares depending on their pre-Brexit input exposure to the EU $\widetilde{\mu}_{E,f}$. We continue to condition on firm, industry-year and firm size quintile-year fixed effects. From equation (4), $\beta_2 = (\epsilon - 1) \widehat{p}_E$, meaning that estimating β_2 allows us to recover the change in the price of EU inputs $\widehat{p}_E$ given estimates of the Armington elasticity ϵ.

We account for any differential effect of the referendum on firms' domestic input expenditure shares based on their pre-Brexit input exposure using $REF_t \widetilde{\mu}_{E,f}$. We also control for industry-level variation in exposure to domestic input price changes resulting from the shock to the price of

EU imports. Following equation (4) and using $\widehat{p}_{D,i} = \Omega_i \widehat{p}_E$ (as shown in Section 3 and Appendix B), we capture this channel with $(1 - \widetilde{\mu}_{D,i})\,\Omega_i$ interacted with both the Referendum and the TCA dummies.[7] We continue to cluster standard errors by firm.

Table 1 shows results from estimating specification (12). Omitting the domestic input price controls in column (a), we find that firms with higher input exposure slightly increase their domestic input expenditure shares after the referendum, and then experience a much larger increase after the TCA comes into effect.

Table 1: Structural estimates: domestic input expenditure share

Sample	Importers	Importers	Importers, goods sector	EU & RoW importers	EU & RoW importers, goods sector
	(a)	(b)	(c)	(d)	(e)
Referendum × Input exposure $\widetilde{\mu}_{E,f}$	0.21***	0.21***	0.18***	0.15***	0.14***
	(0.008)	(0.008)	(0.018)	(0.013)	(0.023)
TCA × Input exposure $\widetilde{\mu}_{E,f}$	1.05***	1.05***	1.01***	1.18***	1.11***
	(0.010)	(0.010)	(0.024)	(0.018)	(0.032)
Fixed effects					
Firm	Yes	Yes	Yes	Yes	Yes
Sector-year	Yes	Yes	Yes	Yes	Yes
Employment size quintile-year	Yes	Yes	Yes	Yes	Yes
Domestic input price controls	No	Yes	Yes	Yes	Yes
R^2	.67	.67	.68	.70	.71
Observations	1,732,742	1,735,215	354,255	370,940	116,444
# Firms	243,381	243,913	45,331	44,365	13,554

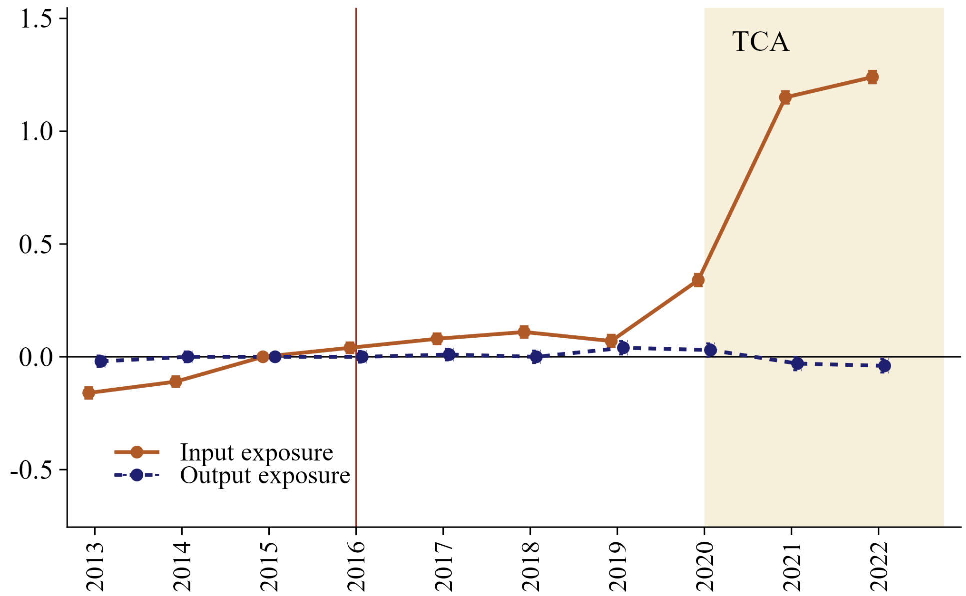
Notes: This table reports estimates of the impact of pre-Brexit input exposure to the EU on firms' log domestic input expenditure share based on equation (12). Standard errors clustered by firm in parentheses. *** denotes significance at the 1% level. Sample covers 2013-22, where years denote fiscal years, e.g. 2013 denotes 2013q2–2014q1. Referendum dummy takes value one from 2016 onwards. TCA dummy takes value one from 2021 onwards. Domestic input price controls are interaction of Referendum and TCA dummies with $\left(1 - \widetilde{\mu}_{D,i}\right)\Omega_i$.

This pattern is also evident in Figure 2, which plots the reduced-form event study estimates of equation (11) using the log of the domestic input expenditure share $\mu_{D,ft}$ as the dependent variable. Pre-Brexit input exposure to the EU matters little for firms' post-referendum sourcing until 2020, but the input exposure effect then increases sharply under the TCA. At the same time, output exposure to the EU does not affect the domestic input expenditure share. This result is consistent with the model's prediction that input expenditure shares are independent of the demand parameters B_J, and therefore unaffected by changes in export access to the EU.

The remainder of Table 1 confirms the robustness of these results to conditioning on the domestic input price controls (column b) or using different samples of firms. Column (c) only includes firms in goods industries (SIC Sections A-D). Column (d) only includes firms with positive initial

[7] We also experimented with using $(1 - \widetilde{\mu}_{D,f})\,\Omega_i$ to control for domestic input price exposure, where $\widetilde{\mu}_{D,f}$ is the firm's initial domestic input expenditure share. The estimates of β_2 shown in Table 1 are robust to this alternative.

Figure 2: Event-study estimates: log domestic input expenditure share



Notes: This figure plots event-study estimates and 95% confidence intervals for the impact of pre-Brexit input and output exposure to the EU on the log of firm domestic input expenditure share $\mu_{D,ft}$ from estimating equation (11). Sample includes all importers. Standard errors clustered by firm. Estimated coefficients normalized to zero in 2015. Firm-level input and output exposure calculated in 2012 (or the first year with available data). Years denote fiscal years, e.g. 2013 denotes 2013q2–2014q1. Red vertical line marks Brexit referendum in June 2016. TCA in effect starting in January 2021.

imports from both the EU and the RoW. Column (e) further restricts the sample in column (d) to firms in goods industries. The estimated effect of input exposure on the domestic input share under the TCA varies little across samples.

The stark reallocation of UK firms' input sourcing towards domestic inputs under the TCA implies a substantial rise in non-tariff barriers on imports from the EU. Our preferred estimate in column (b) gives $\beta_2 = (\epsilon - 1)\,\widehat{p}_E = 1.05$. Since the variation in our data does not identify ϵ, we pick a value based on existing estimates to quantify the impact of the TCA on $\widehat{p}_E$. Halpern et al. (2015) estimate a baseline Armington elastiticy of 4, while Bajzik et al. (2020) conclude the elasticity is likely to lie between 2.5 and 5.1 in a meta-analysis of the literature. If $\sigma = \epsilon$ in our model, then $\epsilon - 1$ equals the trade elasticity. Head and Mayer (2015) review estimates of the trade elasticity, and suggest 5 as a central value.

Informed by these studies, we conservatively set $\epsilon - 1 = 5$, giving $\widehat{p}_E = 0.21$.[8] Attributing this change to increased trade costs implies that the TCA increased ad-valorem equivalent non-tariff

[8]This choice is conservative in the sense that it is relatively high and, therefore, implies a lower estimate of $\widehat{p}_E$.

barriers on imports from the EU τ_E^{IM} by 21%. The magnitude of $\widehat{p}_E$ is sensitive to the value of ϵ, but even if $\epsilon - 1 = 10$, we have $\widehat{p}_E = 0.105$. We conclude that the TCA raised trade costs for UK imports from the EU by at least 10%, and plausibly twice as much.

5.2 Unit Production Costs

We set $\widehat{p}_E = 0.21$ to quantify the TCA's impact on firm f's unit production cost $\widehat{a}_f$ resulting from the rise in the price of EU imports. Using $\widehat{p}_{D,i} = \Omega_i \widehat{p}_E$, equations (7) and (8), and assuming no change in the value-added price $\widehat{v}$, we have:

$$\widehat{a}_f = \underbrace{\widetilde{\eta}_{m,f}\widetilde{\mu}_{E,f}\widehat{p}_E}_{\text{Direct effect, } \widehat{a}_f^{dir}} + \underbrace{\widetilde{\eta}_{m,f}\widetilde{\mu}_{D,f}\Omega_i\widehat{p}_E}_{\text{Indirect effect, } \widehat{a}_f^{indir}}. \tag{13}$$

This equation decomposes $\widehat{a}_f$ into two terms. $\widehat{a}_f^{dir}$ captures the direct effect of an increase in the price of firm f's imports from the EU. It is larger when input exposure to the EU is greater (higher $\widetilde{\mu}_{E,f}$) and when inputs account for a higher share of the firm's production costs (higher $\widetilde{\eta}_{m,f}$). $\widehat{a}_f^{indir}$ reflects the indirect effect of an increase in the price of domestic inputs. It depends on industry-level indirect domestic exposure to EU imports Ω_i, as well as the firm-level domestic input expenditure share $\widetilde{\mu}_{D,f}$ and production cost share of intermediates $\widetilde{\eta}_{m,f}$. Both the direct and indirect terms are proportional to the increase in the price of EU imports $\widehat{p}_E$.

We calculate $\widehat{a}_f$ by firm from equation (13) using $\widehat{p}_E = 0.21$.[9] Alternative values of $\widehat{p}_E$ would simply scale $\widehat{a}_f$ in proportion to $\widehat{p}_E$. We note two caveats that data limitations impose on this exercise. First, indirect domestic exposure Ω_i is at the industry level rather than firm-specific, meaning we do not capture all firm variation in the indirect effect $\widehat{a}_f^{indir}$. Second, as discussed in Section 3, we assume complete price pass-through when computing Ω_i. Incomplete pass-through would dampen the indirect effect.[10]

Panel (a) of Table 2 reports summary statistics on the distribution of $\widehat{a}_f$ in the baseline sample of importers.[11] We estimate that the TCA increased the unit production cost of the average UK importer by 3.1%, with the direct effect averaging 1.9% and the indirect effect 1.3%. Figure 3 plots the distribution of $\widehat{a}_f$ across firms in the importer sample. As the long right tail of the distribution

[9] To obtain $\widetilde{\eta}_{m,f}$ we compute total input expenditure relative to total sales over 2012-14 (or the first three years in which the firm is observed), and cap its value at one.

[10] Breinlich et al. (2022) find evidence of complete pass-through from import prices to consumer prices following the depreciation of sterling triggered by the 2016 Brexit referendum. We are not aware of TCA-specific pass-through estimates.

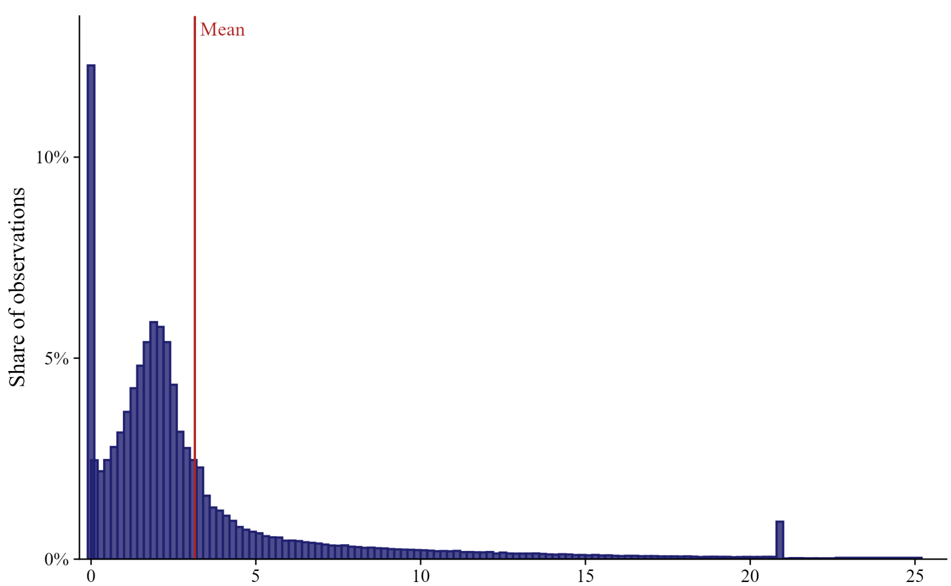
[11] To satisfy data disclosure requirements, the summary statistics are computed after grouping firms into $\widehat{a}_f$ bins of width 0.002 and merging bins where necessary to ensure all bins contain at least 50 firms.

Table 2: Estimated impact of TCA on firms' unit production costs

	Mean	Std. dev.	Sales-weighted mean	Min	p10	Median	p90	Max
			Panel A: Importers					
Unit cost change, $\widehat{a}_f$	0.031	0.039	0.026	0.000	0.000	0.020	0.077	0.252
Direct component, $\widehat{a}_f^{dir}$	0.019	0.040	0.009	0.000	0.000	0.001	0.065	0.210
Indirect component, $\widehat{a}_f^{indir}$	0.013	0.009	0.017	0.000	0.000	0.014	0.024	0.044
			Panel B: All firms					
Unit cost change, $\widehat{a}_f$	0.019	0.016	0.022	0.000	0.003	0.018	0.031	0.254
Direct component, $\widehat{a}_f^{dir}$	0.002	0.014	0.006	0.000	0.000	0.000	0.000	0.210
Indirect component, $\widehat{a}_f^{indir}$	0.017	0.009	0.017	0.000	0.003	0.018	0.030	0.044

Notes: This table reports summary statistics for the percent change in firm-level unit production costs due to the TCA, based on equation (13). Sales-weighted mean uses 2019 sales as weights. Importers sample in Panel A includes $303,030$ firms. All firms sample in Panel B includes $3,330,380$ firms.

Figure 3: Distribution of estimated change in unit production cost across firms



Notes: This figure plots the distribution across firms of the estimated percentage change in unit production costs due to the TCA, as calculated from equation (13). Sample includes all importers. Red vertical line marks simple average increase of 3.1%.

shows, there is considerable cross-firm variation with $\widehat{a}_f$ ranging from zero at the 10th percentile to 7.7% at the 90th percentile and as much as 25.2% for the most affected firm. The cross-firm differences are primarily driven by the direct effect, reflecting substantial heterogeneity in input exposure to the EU $\widetilde{\mu}_{E,f}$.

Panel (b) of Table 2 presents corresponding summary statistics for the full sample of firms, i.e. not restricting the sample to importers. The average increase in unit production costs across all UK firms is 1.9%. Only 0.2 percentage points of this increase comes from the direct effect, since 94% of firms do not import directly from the EU. However, the TCA still causes notable indirect production cost increases for many of these firms by raising the domestic input price.

6 Conclusions

The role non-tariff barriers play in international trade is loosely analogous to that of dark matter in cosmology: we can infer their existence from observed trade patterns, but unlike tariffs (or ordinary matter), they can rarely be directly observed or measured. It should not be surprising, therefore, that the size and impact of non-tariff barriers remains imperfectly understood. Brexit offers a unique experiment through which to study these questions.

This paper documents that non-tariff barriers introduced under the TCA reduced sales and input expenditure by firms more exposed to EU trade prior to Brexit. Firms also switched their input sourcing away from EU imports and towards domestic and RoW inputs. Interpreted through the lens of a model, this adjustment in sourcing strategy reveals the magnitude of the increase in trade costs caused by the TCA. We estimate that the TCA raised the cost of EU imports by 21%, thereby substantially raising UK firms' production costs. These results highlight the effectiveness of EU institutions in reducing non-tariff barriers, and tell the firm-level story of what was lost when the UK exited these institutions.

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Supplementary Appendix

Quantifying Non-Tariff Barriers: Brexit, Input Sourcing and Firm Performance

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September 2026

A Input Demand Levels

Solving the input cost minimization problem implies that the firm's input demand is:

$$
\begin{aligned}
m_D &= M\zeta_D^{\epsilon}p_D^{-\epsilon}c^{\epsilon},\\
m_E &= M\zeta_E^{\sigma}p_E^{-\sigma}\left(\zeta_E^{\sigma}p_E^{1-\sigma}+\zeta_R^{\sigma}p_R^{1-\sigma}\right)^{\frac{\epsilon-\sigma}{\sigma-1}}c^{\epsilon},\\
m_R &= M\zeta_R^{\sigma}p_R^{-\sigma}\left(\zeta_E^{\sigma}p_E^{1-\sigma}+\zeta_R^{\sigma}p_R^{1-\sigma}\right)^{\frac{\epsilon-\sigma}{\sigma-1}}c^{\epsilon}.
\end{aligned}
$$

Note that the firm's composite input use M scales the unit input demands to give its total demand for domestic, EU and RoW inputs.

Next, by differentiating the input demand equations above, we can characterize how the TCA affects the level of input expenditure on each region. This yields:

$$
\begin{aligned}
\widehat{p}_D+\widehat{m}_D &= \widehat{M}+\epsilon\mu_E\widehat{p}_E+\left[1-\epsilon\left(1-\mu_D\right)\right]\widehat{p}_D,\\
\widehat{p}_E+\widehat{m}_E &= \widehat{M}-\left[(\sigma-1)+(\epsilon-\sigma)\lambda_E-\epsilon\mu_E\right]\widehat{p}_E+\epsilon\mu_D\widehat{p}_D,\\
\widehat{p}_R+\widehat{m}_R=\widehat{m}_R &= \widehat{M}+\left[\epsilon\mu_E-(\epsilon-\sigma)\lambda_E\right]\widehat{p}_E+\epsilon\mu_D\widehat{p}_D.
\end{aligned}
$$

In turn, the change in composite input use $\widehat{M}$ satisfies:

$$\widehat{M} = \widehat{S} - \widehat{\chi} - \widehat{c} + \widehat{\eta}_m,$$

where χ denotes the firm's mark-up, which depends on the (unspecified) structure of demand. In this expression, $\widehat{S}$ is given by equation (10) and $\widehat{c}$ by equation (7), while the change in the production cost share of intermediates $\widehat{\eta}_m$ depends on $\widehat{c}$, $\widehat{v}$, and the functional form of the unit cost function $a(v, c)$. In the special case with constant mark-ups and production cost shares, the equation simplifies to $\widehat{M} = \widehat{S} - \widehat{c}$ implying:

$$\widehat{M} = \psi_E \widehat{B}_E + \psi_D \widehat{B}_D - (\gamma\eta_m + 1)\,\mu_E \widehat{p}_E - (\gamma\eta_m + 1)\,\mu_D \widehat{p}_D - \gamma(1 - \eta_m)\,\widehat{v},$$

which illustrates how shocks to demand and production costs affect input expenditure levels through changes in composite input use $\widehat{M}$.

B Indirect Domestic Input Exposure

Suppose the domestic UK economy has K industries indexed by i, k. Let α_{ik} denote the share of industry i's production costs spent on domestically sourced inputs from industry k. Let $\alpha^G_{J,i}$ denote the share of industry i's production costs directly spent on imported goods inputs from region $J = E, R$. And let $\alpha^S_{J,i}$ denote the share of industry i's production costs directly spent on imported services inputs from region $J = E, R$.

Suppose that, consistent with how we measure domestic input expenditure in our empirical analysis, we bundle domestically sourced inputs and imported services inputs into a composite "domestic input". Then the share of industry i's production costs spent on the composite domestic input is:

$$\alpha_{D,i} = \sum_{k=1}^{K} \alpha_{ik} + \alpha^S_{E,i} + \alpha^S_{R,i},$$

and the share of industry i's input expenditure spent on the composite domestic input is:

$$\mu_{D,i} = \frac{\alpha_{D,i}}{\alpha_{D,i} + \alpha^G_{E,i} + \alpha^G_{R,i}}.$$

Now consider a shock to the economy (such as the TCA) that increases the price of imports from the EU by $\widehat{p}_E$. Let $\widehat{P}_i$ be the resulting change in the price of industry i output and $\widehat{p}_{D,i}$ be the change in the cost of the composite domestic input used by industry i. Assuming that there is one-to-one pass through of cost shocks into industry prices, e.g. as occurs in a competitive economy or with constant mark-ups, then:

$$\widehat{P}_i = \left(\alpha^G_{E,i} + \alpha^S_{E,i}\right)\widehat{p}_E + \sum_{k=1}^{K} \alpha_{ik}\widehat{P}_k, \tag{14}$$

$$\widehat{p}_{D,i} = \frac{\alpha^S_{E,i}}{\alpha_{D,i}}\widehat{p}_E + \sum_{k=1}^{K} \frac{\alpha_{ik}}{\alpha_{D,i}}\widehat{P}_j, \tag{15}$$

and substituting (15) into (14) yields:

$$\widehat{p}_{D,i} = \frac{\widehat{P}_i}{\alpha_{D,i}} - \frac{\alpha^G_{E,i}}{\alpha_{D,i}}\widehat{p}_E. \tag{16}$$

Let $\widehat{\boldsymbol{P}}$ be the vector with $\widehat{P}_i$ in row i, $\boldsymbol{\alpha^G_E}$ be the vector with $\alpha^G_{E,i}$ in row i, $\boldsymbol{\alpha^S_E}$ be the vector with $\alpha^S_{E,i}$ in row i, and $\boldsymbol{A}$ be the matrix with α_{ik} in row i and column k. Writing equation (14) using vector notation and solving we have:

$$\widehat{\boldsymbol{P}} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\left(\boldsymbol{\alpha^G_E} + \boldsymbol{\alpha^S_E}\right)\widehat{p}_E,$$

which allows us to write $\widehat{P}_i = \Pi_i\widehat{p}_E$, where Π_i denotes the element in row i of $\boldsymbol{\Pi} \equiv (\boldsymbol{I} - \boldsymbol{A})^{-1}\left(\boldsymbol{\alpha^G_E} + \boldsymbol{\alpha^S_E}\right)$. Substituting this expression back into equation (16) we finally obtain:

$$\widehat{p}_{D,i} = \Omega_i\widehat{p}_E,$$

where $\Omega_i \equiv \frac{\Pi_i - \alpha^G_{E,i}}{\alpha^D_i}$ is the indirect domestic input exposure of industry i.

We calculate Ω_i from the 2013 UK Input-Output Analytical Table provided by the Office for National Statistics, which covers 104 products recorded in the CPA 2008 classification system. We observe the product-by-product Imports Use Table, but not the division of each entry in this matrix into EU versus RoW imports. However, the Imports Table splits total imports of each product by: (1) EU versus RoW; and (2) goods versus services. Therefore, we impose a proportionality assumption and assume that the origin product-specific shares of imports that are attributed to goods and services from EU versus RoW are the same regardless of which using product sources the imports.

We start by computing indirect domestic exposure for CPA 2008 products and then concord our measures to NACE Rev. 2 sectors using a concordance table from Eurostat. NACE Rev. 2 sectors then map directly to the SIC 2007 classification used in our firm-level dataset, which gives

Ω_i by industry.

C Empirics

C.1 Descriptive Statistics

Table C1 reports firm-level descriptive statistics for the baseline sample of importers for variables used to measure exposure to the TCA.

Table C1: Firm-level descriptive statistics

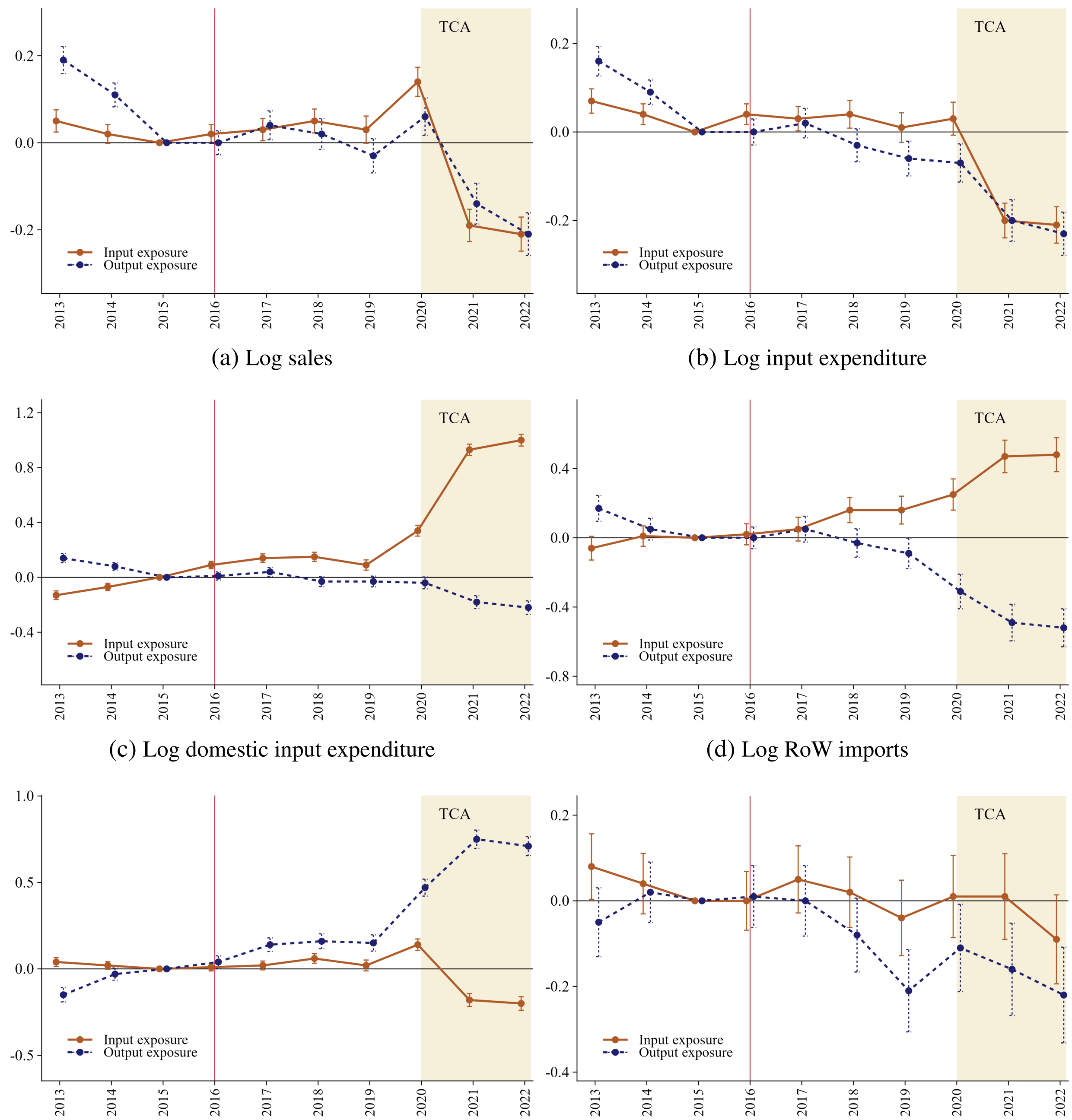
	N	Mean	Std. dev.	p10	p25	Median	p75	p99
Input exposure, $\widetilde{\mu}_{E,f}$	303,030	0.118	0.238	0.000	0.000	0.002	0.099	1.000
Output exposure, $\widetilde{\psi}_{E,f}$	303,030	0.046	0.146	0.000	0.000	0.000	0.004	0.915
Indirect domestic exposure, Ω_i	302,960	0.128	0.023	0.114	0.114	0.120	0.146	0.198

Notes: Table reports descriptive statistics at firm-level for baseline sample of importers. Input and output exposure computed in 2012 (or earliest year with available data). Indirect domestic exposure computed at industry-level using UK input-output tables for 2013.

C.2 Reduced-form Estimates

Figure C1 plots the event-study coefficients for input and output exposure from estimating the reduced-form specification in equation (11) using the all firms in our data. Figure C2 plots the analogous coefficient estimates when we restrict the baseline sample of importers to only include firms in goods industries. There are $3,330,380$ firms in the all firms sample and $49,524$ firms in the goods importers sample.

Figure C1: Reduced-form event-study estimates: all firms



(a) Log sales

(b) Log input expenditure

(c) Log domestic input expenditure

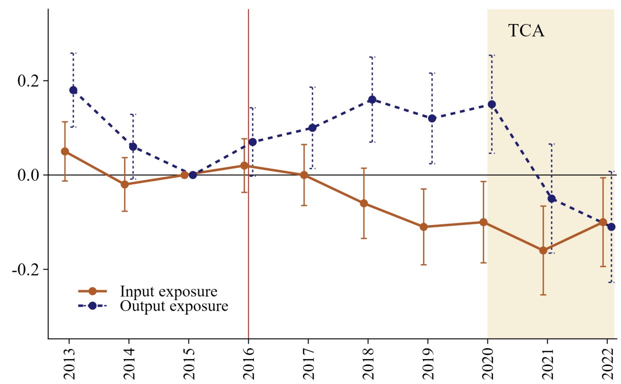
(d) Log RoW imports

(e) Log domestic sales

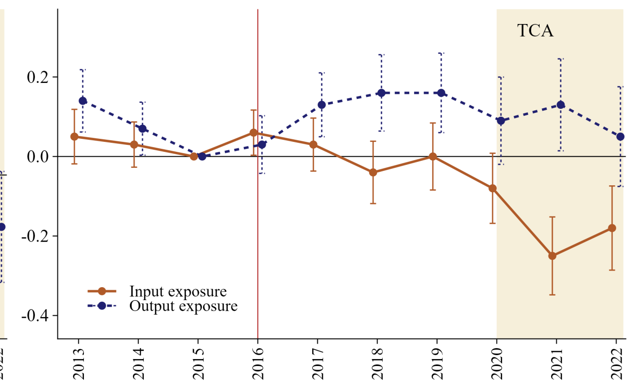
(f) Log RoW exports

Notes: This figure plots event-study estimates and 95% confidence intervals for the impact of pre-Brexit input and output exposure to the EU on firm outcomes from estimating equation (11). Sample includes all firms. Standard errors clustered by firm. Estimated coefficients normalized to zero in 2015. Firm-level input and output exposure calculated in 2012 (or the first year with available data). Years denote fiscal years, e.g. 2013 denotes 2013q2–2014q1. Red vertical line marks Brexit referendum in June 2016. TCA in effect starting in January 2021.

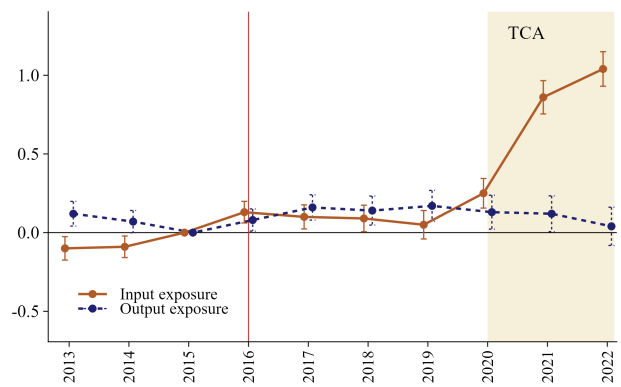
Figure C2: Reduced-form event-study estimates: importers in goods sector



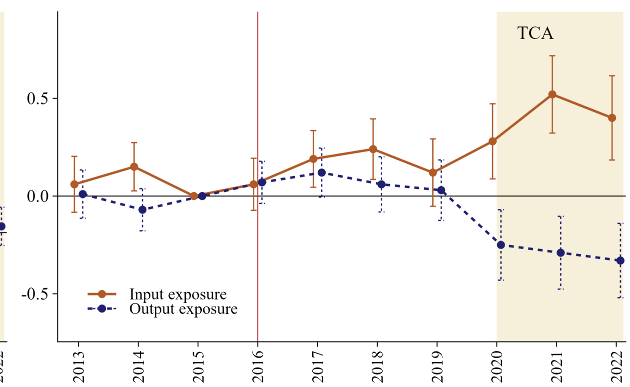
(a) Log sales



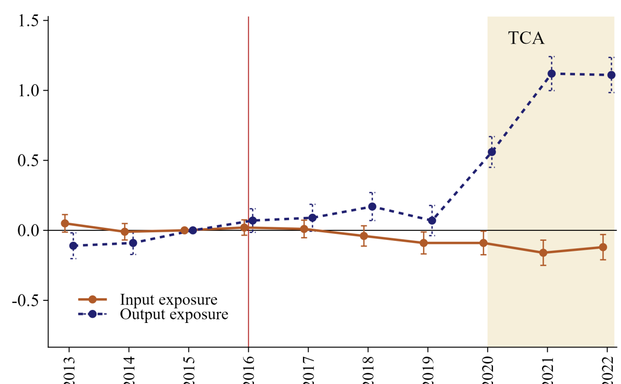
(b) Log input expenditure



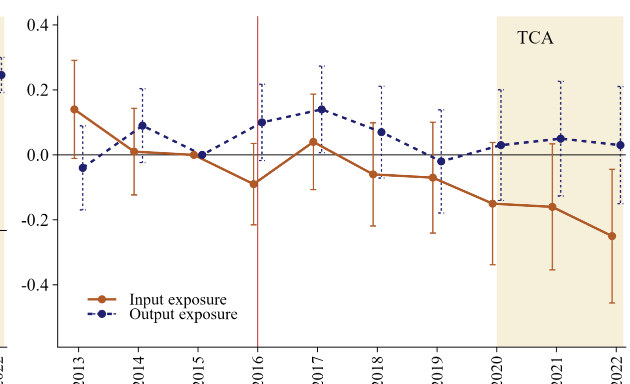
(c) Log domestic input expenditure



(d) Log RoW imports



(e) Log domestic sales



(f) Log RoW exports

Notes: This figure plots event-study estimates and 95% confidence intervals for the impact of pre-Brexit input and output exposure to the EU on firm outcomes from estimating equation (11). Sample includes importer firms in goods industries. Standard errors clustered by firm. Estimated coefficients normalized to zero in 2015. Firm-level input and output exposure calculated in 2012 (or the first year with available data). Years denote fiscal years, e.g. 2013 denotes 2013q2–2014q1. Red vertical line marks Brexit referendum in June 2016. TCA in effect starting in January 2021.