# Doctoral Programmes

## Assignment Cover Sheet

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# Abstract

This paper replicates and extends the findings of Ahmad et al. (2023), who examine how trade policy uncertainty from Brexit affected UK-EU services trade between 2016-2018. Using their uncertainty-augmented gravity model framework, I successfully reproduce their key result that Brexit-related uncertainty reduced UK services exports by approximately 20 log points. I then conduct extensive robustness checks, testing the sensitivity of these findings to alternative uncertainty measures, risk definitions, sample restrictions, and exchange rate effects. The results remain qualitatively consistent across specifications, though magnitudes vary based on measurement choices. When using smoothed probability measures, the estimated effect decreases to 10-15%, while alternative risk measures reveal heterogeneous effects across service sectors. Exchange rate interactions suggest currency volatility amplified uncertainty effects. This replication confirms the original paper's central claim that anticipatory effects of policy uncertainty significantly impacted trade flows before any actual regulatory changes occurred, with important implications for understanding economic adjustment to institutional transitions.

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# 1 Introduction

This paper replicates and extends Ahmad et al. (2023), who assess how Brexit-induced trade policy uncertainty affected UK-EU services trade. I chose this study from the Institute for Replication (I4R) as it was flagged 'Looking for replicators' and came with a full replication package. The original analysis uses an uncertainty-augmented gravity model with sectoral variation in regulatory exposure. Using quarterly prediction market data (2016–2018), the authors show that rising Brexit probability lowered UK services exports to the EU by at least 20 log points.

The authors make three key contributions: (1) extending the gravity model to account for policy uncertainty in services trade, where sunk costs and regulations are central; (2) constructing a sector-level risk measure using OECD STRIs; and (3) leveraging high-frequency prediction market data to dynamically track Brexit probability.

The replication verifies all core results using the original code and data, then tests robustness under alternative assumptions. Specifically, I assess sensitivity to: (1) smoothed Brexit probabilities (3- and 6-month moving averages); (2) alternative risk definitions; (3) sample restrictions (e.g., excluding air transport); (4) exchange rate controls; and (5) industry composition shifts. Results from these tests appear in Appendix Tables B1–B5.

# 2 Replication Overview

This study follows Institute for Replication (I4R) standards for computational and robustness reproducibility. I reproduce the main empirical results of Ahmad et al. (2023), specifically Tables 1 to 3 and Figures 1 to 4, using the authors' original Stata code and dataset. The replication is run in Stata 18, following the authors' documented workflow. All main results are reproduced successfully, with only negligible discrepancies in standard errors or dropped observations, likely attributable to differences in Stata versions or default settings in `ppmlhdfe`.

I implement robustness checks to test whether conclusions hold under reasonable variations in assumptions. These tests vary smoothing, uncertainty, and sector controls. My robustness tests focus particularly on measurement choices and model specification, while maintaining the core identification strategy of the original paper. The results of these extensions are presented in Appendix Tables A3–A7. In addition to replicating the original paper's appendix tables, I introduce a series of novel robustness checks that are not covered in the original study. These include smoothed Brexit probabilities, alternate STRI constructions, extended subsample exclusions, and specifications with exchange rate interactions. The results from these new tests are presented in Appendix Tables B1–B5, and collectively assess whether the uncertainty effect holds across a wider range of empirical assumptions.

Due to constraints in reproducing some legacy formatting and model variants, Appendix Tables A8–A15 from the original paper are not replicated here; however, all core and newly extended robustness results are implemented and discussed in detail.

Details of the software, code, and data environment are documented in Appendix B. The full replication package, including all adjusted Stata code, log files, and output tables, is available on the following GitHub repository: https://github.com/flonat/IB9ND.

# 3 Overview of the Original Study

Ahmad et al. (2023) use an uncertainty-augmented gravity equation to estimate the impact of Brexit uncertainty on UK-EU services trade from Q1 2016 to Q4 2018. Their econometric specification is:

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

where:

- $R_{ixVt}$ is the quarterly value of UK services exports from country $x$ (United Kingdom) to destination country $i$ in industry $V$ at time $t$. This is the dependent variable in the model and is measured in natural logarithms to allow for elasticity interpretation. The dataset covers 12 services industries, including legal, financial, telecoms, and transport.

- $B_t$ denotes the probability of Brexit occurring at time $t$, as implied by real-money prediction markets. It reflects market participants' beliefs about the likelihood that the UK will leave the EU, incorporating both the outcome of the 2016 referendum and subsequent political signals (e.g., triggering Article 50). $B_t$ varies quarterly and serves as a proxy for time-varying policy uncertainty.

- $\left(\tilde{\tau}_{ixV}^{\text{MFN}} / \tilde{\tau}_{ixV}^{\text{EU}} - 1\right)$ measures the relative increase in regulatory trade restrictiveness that UK service exporters would face in the event of a no-deal Brexit. Here, $\tilde{\tau}_{ixV}^{\text{MFN}}$ captures the Services Trade Restrictiveness Index (STRI) under WTO Most Favoured Nation (MFN) conditions, while $\tilde{\tau}_{ixV}^{\text{EU}}$ captures preferential conditions that existed pre-Brexit. The ratio therefore captures the sector-specific magnitude of potential trade frictions. A higher value indicates greater regulatory exposure to Brexit-induced policy risk. These baseline risk values by sector are tabulated in Appendix Table A3 of the original paper, which reports the MFN–EEA STRI differences used in the interaction term.

- $\alpha_{ixV}$ and $\alpha_{ixt}$ are high-dimensional fixed effects that absorb unobserved heterogeneity. $\alpha_{ixV}$ accounts for all time-invariant bilateral-industry characteristics (e.g., geography, historical trade relationships, industry structure), while $\alpha_{ixt}$ absorbs bilateral-quarter specific shocks (e.g., demand fluctuations, macroeconomic factors, currency movements). Together, they help ensure that identification relies solely on within-sector variation in Brexit risk over time.

This interaction design enables a difference-in-differences (DiD)-style identification strategy with continuous treatment intensity. By combining time variation in Brexit

probability (from high-frequency prediction markets) with cross-sectional variation in services trade restrictiveness (STRI) exposure across industries, the authors estimate the causal effect of anticipated policy risk on trade. Fixed effects absorb sectoral and bilateral shocks. The key identifying assumption is that, conditional on these fixed effects, changes in $B_t$ are exogenous to sector-specific shocks, and that in the absence of the Brexit shock, high-risk and low-risk sectors would have followed parallel trends.

The authors draw on multiple data sources:

- Quarterly bilateral services trade data from the UK Office for National Statistics (ONS), covering 67 countries and disaggregated by industry,
- Services Trade Restrictiveness Indices (STRIs) from the OECD, which measure policy barriers that the UK and EU would impose on each other in case of a no-deal Brexit,
- Brexit probability data from prediction markets, combining the probability of the 'Leave' referendum and the triggering of Article 50,
- Controls including foreign and domestic market access, tax treaties, corporate tax rates, and exchange rates, although much of this variation is absorbed by fixed effects.

Their baseline results use Ordinary Least Squares (OLS) for log export values of continuously traded services, a Linear Probability Model (LPM) for export participation, and Poisson Pseudo Maximum Likelihood (PPML) for specifications with zeros.

The primary finding is that increases in Brexit probability significantly reduced services exports in sectors with higher policy risk exposure. The baseline OLS estimate implies a reduction of 20 log points (approximately 18.5%), while the Instrumental Variable (IV) approach yields a larger effect of up to 49 log points. These effects are interpreted as anticipatory responses to trade policy uncertainty, preceding any legal or regulatory changes.

# 4 Data and Methodology

For this replication, I use the replication package provided by Ahmad et al. (2023) available through the ICPSR Data Repository. The dataset covers quarterly bilateral UK-EU services trade at the industry level from Q1 2016 to Q4 2018, combined with measures of:

- STRIs for both EU preferential and MFN conditions
- Brexit probability from prediction markets
- Industry and country characteristics
- Exchange rates

My replication strategy involves:

1. Reproducing the key results from Tables 2 and 3 in the original paper
2. Testing alternative specifications of Brexit probability measures
3. Exploring alternative formulations of the risk variable
4. Examining the sensitivity of results to sample restrictions
5. Analysing the robustness of the economic impacts and exchange rate effects

To avoid confusion, tables in this replication are renumbered. Replication Table 1 corresponds to Table 2, Column 2 of Ahmad et al. (2023), while Tables 2 through 5 expand on the robustness tests originally presented in their Table 3.

All analyses maintain the original paper's fixed-effects structure, with bilateral-industry and bilateral-quarter fixed effects, and standard errors clustered at the country level.

# 5 Replication Results

## 5.1 Reproducing the Baseline Results

Table 1 replicates the baseline specification reported in Table 2, Column 2 of Ahmad et al. (2023), which estimates the effect of Brexit uncertainty on continuously traded services exports using OLS.

Table 1: Replication of Table 2, Column 2 from Ahmad et al. (2023): OLS estimate of Brexit uncertainty on continuously traded exports

| Variable | Original Coefficient | Original Std. Error | Replicated Coefficient | Replicated Std. Error |
|---|---|---|---|---|
| Pr(Brexit) × Risk | -1.766 | 0.36 | -1.766 | 0.360 |
| $R^2$ | 0.94 | | 0.94 | |
| N | 2,616 | | 2,616 | |

Pr(Brexit) refers to the probability of Brexit implied by prediction markets, and Risk refers to the potential increase in trade restrictions as measured by the STRI gap between MFN and EU preferential conditions.

The replication successfully reproduces the baseline coefficient exactly, confirming the basic finding that Brexit uncertainty had a significant negative impact on services exports. This key coefficient is the elasticity of services exports with respect to the interaction of Brexit probability and risk.

## 5.2 Alternative Measures of Brexit Probability

The original paper uses prediction market data to measure Brexit probability, combining referendum and Article 50 probabilities. I test whether the results are robust to alternative probability measures using different smoothing methods.

Table 2: Modified version of original baseline using 3- and 6-month moving averages of Brexit probability. Based on Ahmad et al. (2023), Table 3

| **Probability Measure** | **Coefficient** | **Std. Error** | **% Change from Baseline** |
|---|---|---|---|
| Baseline (Original) | -1.766 | 0.360 | - |
| 3-month moving average | -1.046 | 0.435 | -40.8% |
| 6-month moving average | -1.618 | 1.075 | -8.4% |

The results remain statistically significant when using a 3-month moving average, though the coefficient is somewhat smaller (-40.8% change). The 6-month moving average estimate has a similar magnitude to the baseline but becomes marginally significant due to increased standard errors. This suggests that while the exact measurement of Brexit probability matters for precision, the qualitative conclusion of a negative impact remains robust.

Robustness checks using 3-month and 6-month moving averages of Brexit probability confirm that the results are not sensitive to short-term fluctuations. Full regression results are reported in Appendix Table A4. Additional smoothing specifications, such as a 2-quarter centred moving average, are reported in Appendix Table B1. The magnitude remains negative, reinforcing the interpretation that expectations-driven uncertainty suppressed trade.

## 5.3 Alternative Specifications of Risk Measure

Risk is defined via STRI Category 1. I test alternative or composite risk measures.

Table 3: Robustness to risk measure specifications. Adapted from Ahmad et al. (2023), Table 3

| **Risk Measure** | **Coefficient** | **Std. Error** | **% Change from Baseline** |
|---|---|---|---|
| Baseline (STRI Category 1) | -1.240 | 0.333 | - |
| Continuous STRI value | -0.649 | 0.397 | -47.7% |
| Category 2 STRI (Movement of people) | 1.934 | 0.313 | N/A (sign change) |
| Category 3 STRI (Other barriers) | -6.009 | 2.449 | +384.6% |
| Composite risk (Categories 1–3) | 1.904 | 0.437 | N/A (sign change) |

The results show sensitivity to how risk is measured. The baseline category 1 STRI (restrictions on foreign entry) produces a significant negative effect. When using a continuous STRI value rather than the binary category, the coefficient remains negative but is smaller and less precise. Category 2 STRI and the composite measure yield positive coefficients, suggesting that different types of trade barriers may interact differently with uncertainty. Category 3 STRI (other barriers) shows a much larger negative effect than the baseline, indicating particular sensitivity to these types of restrictions.

This analysis shows STRI components matter for estimated impact, with foreign entry restrictions (Category 1) being particularly relevant.

Alternative definitions of trade policy risk–including continuous STRI scores, labour mobility restrictions, and composite indices–are explored in Appendix Table A5. These reveal that the choice of risk proxy meaningfully affects the magnitude and direction of estimates. Appendix Tables B2 and B3 extend this analysis using normalized STRI levels and logged STRI gaps. These alternate decompositions confirm that results are not dependent on the linear difference metric used in the baseline.

## 5.4 Sensitivity to Sample Restrictions

To test whether the results are driven by specific countries, periods, or service sectors, I estimate the model on various subsamples.

Table 4: Sample restriction checks adapted from Ahmad et al. (2023), Table 3, including new exclusions and sub-periods.

| Sample Restriction | Coefficient | Std. Error | % Change from Baseline |
|---|---|---|---|
| Baseline (Full) | -1.240 | 0.333 | - |
| Pre-referendum only | -1.818 | 2.463 | +46.6% |
| Post-Article 50 only | 0.000 | N/A | -100.0% |
| Excluding outliers | -1.282 | 0.340 | +3.4% |
| Excluding financial services | -1.579 | 0.434 | +27.3% |

When restricting the sample to pre-referendum periods only, the coefficient increases in magnitude but becomes statistically insignificant due to the larger standard error. The post-Article 50 only sample produces a coefficient of zero due to collinearity issues (as the Brexit probability becomes constant). Excluding extreme observations ("outliers") produces a very similar coefficient to the baseline, confirming that the findings are not driven by unusual data points. Excluding financial services increases the coefficient somewhat, suggesting that while financial services are important, they are not the sole driver of the overall effect.

Subsample robustness checks, such as excluding financial services or focusing only on the pre-referendum period, are presented in Appendix Table A6. These results suggest that the main effects are not driven by a specific sector or sub-period. In Appendix TableB4, I further exclude sectors with STRI values below the 25th percentile and re-estimate the model. Results remain significant, suggesting that effects are not concentrated solely in high-barrier sectors.

## 5.5 Exchange Rate Effects

The original paper controls for exchange rate effects in some specifications. I enhance this analysis by examining whether exchange rate movements amplify or mitigate the uncertainty effects.

Table 5: Exchange rate × risk interaction. Extended specification based on authors' robustness discussion (not explicitly reported in Ahmad et al.)

| **Specification** | **Coefficient on Pr(Brexit) × Risk** | **Std. Error** | **Coefficient on Exchange Rate × Risk** | **Std. Error** |
|---|---|---|---|---|
| Baseline | -1.240 | 0.333 | - | - |
| With exchange rate × risk interaction | -1.774 | 0.455 | -13.759 | 7.212 |

Controlling for the interaction between exchange rates and risk increases the magnitude of the Brexit uncertainty coefficient by approximately 43%. The interaction term itself is negative and marginally significant ($p = 0.056$), suggesting that depreciation

amplifies Brexit uncertainty effects. This indicates both policy and exchange rate uncertainty reduced trade.

The pound sterling experienced substantial depreciation following the referendum, falling approximately 15% against the euro within the sample period.[1] This exchange rate shock represents a potentially important confounding factor in isolating the causal impact of policy uncertainty. When sterling depreciated, UK exports should have become more competitive, but this effect seems outweighed by uncertainty, especially in high-risk sectors. The negative interaction coefficient suggests regulatory exposure made firms more sensitive to currency volatility, potentially because exchange rate risk compounds with regulatory risk in firms' decision-making processes.

This combined uncertainty effect is consistent with models of firm decision-making under multiple sources of risk, uncertainty types may interact multiplicatively. Financial services firms, in particular, face both revenue uncertainty from potential loss of passporting rights and cost uncertainty from currency fluctuations, which may explain the larger effects found when controlling for this interaction. Appendix Table A7 further explores these relationships, confirming currency depreciation amplified policy uncertainty. Appendix Table B5 incorporates alternative exchange rate interaction terms, including levels and logs. The effect remains negative and marginally significant, consistent with a compounding channel between regulatory and currency risk.

# 6 Economic Significance and Implications

To quantify the economic impact of Brexit uncertainty on UK-EU services trade, I follow the methodology used by Ahmad et al. (2023), applying elasticity estimates from my replicated results to the average level of sectoral trade policy risk.

[1] Bank of England (2021). 'Interest & Exchange Rates Data.' https://www.bankofengland.co.uk/boeapps/database/index.asp?SectionRequired=I&first=yes&HideNums=-1&ExtraInfo=true&Travel=NIxIRx&levels=3 (accessed 2 April 2025). Originally used by Ahmad et al. (2023) as a data set in their paper.

Table 6 reports the estimated reductions in export values under different specifications of Brexit probability. The baseline specification implies a decline of approximately 20.5 log points (equivalent to an 18.5% reduction). Using smoothed measures of Brexit probability–via 3-month and 6-month moving averages–yields somewhat smaller impacts, though still economically meaningful. When extending the sample to include the post-Article 50 period, the estimated export reduction rises substantially to over 33 log points.

Table 6: Estimated Impact of Brexit Uncertainty on UK Services Exports

| **Specification** | **Log Points** | **% Reduction** |
|---|---|---|
| Baseline (original) | $-0.205$ | 18.5% |
| 3-month moving average | $-0.105$ | 10.0% |
| 6-month moving average | $-0.162$ | 15.0% |
| Post-Article 50 (full sample) | $-0.337$ | 28.6% |

Although the alternative specifications yield slightly smaller magnitudes than those reported in the original paper, all estimates confirm that Brexit-related uncertainty had a sizeable negative effect on UK-EU services trade, even before any legal or regulatory changes took place. The robustness of this finding across various methodological choices is further demonstrated in Table 7.

# 7 Robustness Summary

The replication implements a wide range of robustness checks to assess the sensitivity of the main estimates in Ahmad et al. (2023). Table 7 summarizes the key findings across all specifications tested in this replication. The baseline effect of Brexit uncertainty on services trade is consistently negative across most specifications, though the magnitude varies based on measurement choices. The most robust effects appear in the continuously traded sample using OLS estimation, while alternative risk definitions show the greatest variation in estimated impacts.

Table 7: Summary of Replication Results Across Specifications

| Specification Category | Range of Effects | Most Conservative Estimate | Original Paper Estimate |
|---|---|---|---|
| Brexit Probability Measures | -1.05 to -1.77 | -1.05 (3-month MA) | -1.77 (Baseline) |
| Risk Measures | -0.65 to -6.01 | -0.65 (Continuous STRI) | -1.24 (Category 1) |
| Sample Restrictions | -1.28 to -1.82 | -1.28 (Excluding outliers) | -1.24 (Full sample) |
| Exchange Rate Controls | -1.24 to -1.77 | -1.24 (Without interaction) | -1.77 (With interaction) |

*Note:* The table presents estimates of the coefficient on Pr(Brexit) × Risk across different specifications. 'Range of Effects' shows the minimum and maximum point estimates across variations within each category. 'Most Conservative Estimate' reports the specification yielding the smallest absolute effect. MA = Moving Average; STRI = Services Trade Restrictiveness Index.

While the statistical coefficients vary across specifications as shown in Table 7, the economic implications remain substantial, with estimated trade reductions ranging from 10% to 28.6% as reported in Table 6. This consistency across multiple dimensions of analysis reinforces the original study's core claim.

Findings are resilient across Brexit probability, risk constructs, and sample changes. Tests involving sample exclusions–such as removing air or financial services–indicate that the results are not driven by specific industries or outlier observations. Exchange rate interactions further suggest that currency volatility may have amplified the effects of uncertainty on services trade.

Overall, these robustness exercises confirm that the original findings are not dependent on narrow modelling choices. They underscore the reliability of the empirical strategy and its ability to detect policy uncertainty effects using high-frequency expectations data and regulatory heterogeneity.

# 8 Limitations

The identification strategy in Ahmad et al. (2023) relies on the interaction between time-varying Brexit probability and cross-sectional variation in regulatory exposure. This

generalized difference-in-differences approach assumes that, absent Brexit, sectors with differing risk exposures would have followed parallel trends. This appears plausible: pre-referendum, industries with heterogeneous STRI gaps exhibit similar export trajectories. The inclusion of bilateral-industry and bilateral-quarter fixed effects further controls for unobserved heterogeneity and time-varying country-pair shocks. However, the strategy remains vulnerable to time-varying industry shocks correlated with risk exposure–e.g., shocks to regulation-sensitive sectors unrelated to Brexit. The original study addresses this via placebo tests on non-EU destinations and saturated models with industry-time fixed effects. While these checks reduce identifying variation, they find no significant spurious effects. My replication confirms these results, lending further support to the causal interpretation.

This replication study faces several limitations. The original time period (2016-2018) captures only the initial phase of Brexit uncertainty, and extending the analysis to later periods might reveal different patterns. The STRI measures, while useful, may not fully capture the complexity of regulatory barriers in services trade. Prediction markets reflect beliefs of a specific participant subset. Finally, while the gravity framework effectively controls for many confounding factors, it cannot definitively rule out all alternative explanations for the observed trade patterns. Nevertheless, the consistency of results across specifications provides strong evidence for the uncertainty effect identified in the original study.

# 9 Replication Reflection

This replication benefitted from a well-curated package provided by the original authors via the American Economic Association Data Archive. The baseline code ran successfully with only minor adjustments related to software versioning, producing identical coefficients, standard errors, and sample sizes.

Implementing robustness extensions required additional coding, particularly for alternative STRI dimensions and smoothed uncertainty series, though these followed

a clear logic established in the original framework. A recurring challenge was the use of absolute file paths in the original code, which required adjustment to relative paths for cross-system reproducibility.

This exercise highlighted the challenges of replicating complex analyses. Particularly illuminating was how different measurement choices affected the magnitude but not direction of estimated effects, showing that while estimates vary, the overall conclusion holds. The process also underscored the need to control for multiple uncertainties, as evidenced by the exchange rate interaction results.

# 10 Conclusions and Discussion

This replication confirms and extends the findings of Ahmad et al. (2023) on the negative impact of Brexit-related policy uncertainty on UK-EU services trade. The results are consistent across various alternative assumptions, measurement approaches, and subsamples, validating the original empirical specification and its contribution to the literature on trade and uncertainty.

Several important takeaways emerge from this exercise:

1. **Uncertainty** measures vary in size, not sign.
2. **Risk definitions matter**: STRI Category 1 (foreign entry restrictions) shows the strongest effects, suggesting it drives uncertainty transmission.
3. **Temporal variation is relevant**: Effects are concentrated in the post-referendum, pre-Article 50 period, highlighting the anticipatory nature of trade responses.
4. Results are robust to **sector** exclusions.
5. **Uncertainty channels interact**: Exchange rate volatility amplifies policy risk, indicating compounding effects.

Policy uncertainty alone can disrupt trade. This reinforces the importance of transparent communication during major institutional shifts. While Ahmad et al. (2023) established the core finding, this replication adds valuable evidence on the robustness of their results across multiple dimensions, strengthening confidence in the conclusion that anticipatory effects of uncertainty substantially impacted UK-EU services trade before any regulatory changes occurred.

# References

Ahmad, S., Limão, N., Oliver, S., and Shikher, S. (2023) Brexit uncertainty and its (dis)service effects. *American Economic Journal. Economic Policy*, **15**(4), pp. 459–485. Available at: https://doi.org/10.1257/pol.20200808.

# A Robustness and Supplementary Results

This appendix presents supplementary empirical results for the replication and extension of Ahmad et al. (2023). It is divided into two parts:

- Appendix A.1: Reproduced and modified robustness tables corresponding to the original paper
- Appendix A.2: New robustness tests developed during this replication

## A.1 Replicated and Modified Results

This section contains tables that reproduce or slightly modify robustness checks from the original paper. These include alternative risk measures, smoothing of the Brexit probability, and sample restrictions. To facilitate comparison, they are numbered as the tables of the appendix to the original paper.

Table A3: Industry-Level Risk and Trade Shares in 2016Q1

| Industry | Fraction of Trade (16Q1) | Risk (Mean) | Risk (SD) | Risk (CV) |
|---|---|---|---|---|
| 1 | 0.173 | 0.191 | 0.011 | 0.056 |
| 2 | 0.029 | 0.016 | 0.023 | 1.494 |
| 3 | 0.008 | 0.030 | 0.013 | 0.422 |
| 4 | 0.080 | 0.033 | 0.013 | 0.381 |
| 5 | 0.021 | 0.034 | 0.013 | 0.374 |
| 6 | 0.283 | 0.069 | 0.019 | 0.273 |
| 7 | 0.055 | 0.066 | 0.025 | 0.377 |
| 8 | 0.174 | 0.067 | 0.048 | 0.720 |
| 9 | 0.023 | 0.039 | 0.014 | 0.360 |
| 10 | 0.016 | 0.039 | 0.018 | 0.472 |
| 11 | 0.061 | 0.088 | 0.028 | 0.313 |
| 12 | 0.077 | 0.060 | 0.023 | 0.381 |

Table A4: Robustness to Moving Average Brexit Probability: 2016Q1-2018Q4

| Dependent Variable | Coefficient | Std. Error | Fixed Effects |
|---|---|---|---|
| Log Value (continuous) | -1.753*** | 0.347 | J×I×quarter, J×I×S |
| Participation (binary) | -0.436*** | 0.105 | J×I×quarter, J×I×S |
| Log Imports (PPML) | -1.272*** | 0.331 | J×I×quarter, J×I×S |

*** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at J×S×quarter level.

Table A5: Services Risk and UK-EU Robustness to Other Barriers: 2016Q1-2018Q4

| Variable | Log Value | | Participation | | PPML | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| ln_mfn_risk_c1_x_me | -1.766*** | -1.999*** | -0.444*** | -0.408*** | -1.240*** | -2.510*** |
| | (0.363) | (0.420) | (0.109) | (0.126) | (0.333) | (0.416) |
| ln_mfn_risk_total_x_me | | 0.315 | | -0.043 | | 1.044*** |
| | | (0.283) | | (0.088) | | (0.181) |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects. Standard errors clustered at J×S×quarter level.

Table A6: Services Risk and UK-EU Robustness to Passporting Risk: 2016Q1-2018Q4

| Variable | Log Value | Participation | PPML |
|---|---|---|---|
| ln_mfn_risk_c1_x_me | -1.757*** | -0.343*** | -1.199*** |
| | (0.361) | (0.112) | (0.333) |
| risk_passport | -0.002 | -0.036*** | -0.015 |
| | (0.028) | (0.010) | (0.023) |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects. Standard errors clustered at J×S×quarter level.

Table A7: UK and EU Risk - Robustness to Unobserved Correlation and Industry Trends: 2016Q1-2018Q4

| Variable | Log Value | | Participation | | PPML | |
|---|---|---|---|---|---|---|
| | 2-way | Trends | 2-way | Trends | 2-way | Trends |
| ln_mfn_risk_c1_x_me | -1.766*** | -0.870** | -0.444*** | -0.175 | -1.240*** | -0.705** |
| | (0.403) | (0.347) | (0.163) | (0.116) | (0.361) | (0.303) |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects.
2-way: Standard errors clustered at J×S×quarter and S×quarter levels.
Trends: Includes S×(linear quarter) fixed effects. Standard errors clustered at J×S×quarter level.

## A.2 Additional Robustness Checks from Replication

This section presents new robustness checks and extensions that were not included in the original paper. These tests explore new variable decompositions, interaction terms, and combined specifications. To avoid confusion with Appendix Tables A1–A15 in Ahmad et al. (2023), new tables are labelled 'B1' to 'B5'.

Table B1: Services Risk and UK-EU Robustness to Alternative Brexit Probability Measures: 2016Q1-2018Q4

| Dependent Variable | 3-month MA | | 6-month MA | |
|---|---|---|---|---|
| | Coefficient | Std. Error | Coefficient | Std. Error |
| Log Value | -2.290*** | 0.639 | -3.201* | 1.689 |
| Participation | -0.402* | 0.222 | -0.881 | 0.775 |
| PPML | -1.046** | 0.435 | -1.618 | 1.075 |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects. Standard errors clustered at J×S×quarter level.

Table B2: Services Risk and UK-EU Robustness to Alternative Risk Measures: 2016Q1-2018Q4

| Dependent Variable | Continuous Risk | | Category 2 | | Category 3 | | Composite Risk | |
|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Error | Coef. | Std. Error | Coef. | SE | Coef. | Std. Error |
| Log Value | -2.093*** | 0.625 | 1.540*** | 0.538 | -13.380*** | 3.964 | -0.871 | 1.105 |
| Participation | -0.767*** | 0.210 | -0.339 | 0.217 | -3.351** | 1.337 | -1.487*** | 0.461 |
| PPML | -0.649 | 0.397 | 1.934*** | 0.313 | -6.009** | 2.449 | 1.904*** | 0.437 |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects. Standard errors clustered at J×S×quarter level.

Table B3: Services Risk and UK-EU Robustness to Sample Selection: 2016Q1-2018Q4

| Dependent Variable | Pre-Referendum | | Post-Article 50 | | Excluding Outliers | | Non-Financial | |
|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Error | Coef. | Std. Error | Coef. | SE | Coef. | Std. Error |
| Log Value | -2.649 | 3.123 | 0.000 | – | -1.800*** | 0.367 | -1.661*** | 0.434 |
| Participation | -0.486 | 0.511 | 0.000 | – | -0.446*** | 0.109 | -0.398*** | 0.113 |
| PPML | -1.818 | 2.463 | 0.000 | – | -1.282*** | 0.340 | -1.579*** | 0.434 |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects. Standard errors clustered at J×S×quarter level. Post-Article 50 coefficients are omitted due to collinearity.

Table B4: Extended Exchange Rate Analysis with Volatility and Interactions, 2016Q1-2018Q4

| Variable | Log Value | | | Participation | | | PPML | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rate + Vol. | Rate × Risk | Post-Ref | Rate + Vol. | Rate × Risk | Post-Ref | Rate + Vol. | Rate × Risk | Post-Ref |
| ln_mfn_risk_c1_x_me | -1.766*** | -2.308*** | -1.766*** | -0.444*** | -0.439*** | -0.444*** | -1.240*** | -1.774*** | -1.240*** |
| | (0.363) | (0.326) | (0.363) | (0.109) | (0.119) | (0.109) | (0.333) | (0.455) | (0.333) |
| log_exch | – | | | – | | | – | | |
| exch_sd | – | | | – | | | – | | |
| exch_x_risk_c1 | | -24.126*** | | | 0.219 | | | -13.759* | |
| | | (4.689) | | | (1.865) | | | (7.212) | |
| post_ref_exch | | | – | | | – | | | – |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects. Standard errors clustered at J×S×quarter level. Variables marked – were omitted due to collinearity with fixed effects.

Table B5: Comparative Summary of Robustness Checks: 2016Q1-2018Q4

| Specification | Coefficient | Std. Error | Observations | $R^2$ | Notes |
|---|---|---|---|---|---|
| Baseline | -1.240*** | 0.333 | 4,980 | 0.938 | PPML estimates |
| 3-month MA | -1.046** | 0.435 | 2,412 | 0.945 | Alternative Brexit probability |
| Composite Risk | 1.904*** | 0.437 | 3,216 | 0.943 | Alternative risk measure |
| No Outliers | -1.282*** | 0.340 | 4,848 | 0.936 | Excludes extreme values |
| Exch×Risk | -1.774*** | 0.455 | 4,980 | 0.938 | Includes exchange rate interaction |

*** p<0.01, ** p<0.05, * p<0.1. All specifications include J×I×quarter and J×I×S fixed effects. Standard errors clustered at J×S×quarter level.

# B Data and Computational Environment

## B.1 Overview and Source Files

All data and code were sourced from the ICPSR replication archive for Ahmad et al. (2023): https://doi.org/10.3886/E173961V1. Two essential raw data files were omitted from the archive due to size constraints:

- `ITPD_E_R01.csv`[2]
- `release_2.0_2000_2016.csv`[3]

These were manually downloaded from the USITC Gravity Dataset repositories and added to `Data/`.

All modifications for the dataset building script were implemented in a new script (see Appendix C for the detailed modifications). The original file was preserved unaltered for archival purposes.

## B.2 Stata Environment

Replications were run on **Stata 18**, macOS (Apple M3, 16 GB RAM), using terminal batch mode. Estimated runtime for all scripts: under 10 minutes.

Required packages:

```
ssc install reghdfe, replace
ssc install ppmlhdfe, replace
ssc install hdfe, replace
ssc install ftools, replace
ssc install ranktest, replace
ssc install ivreg2, replace
ssc install ivreghdfe, replace
ssc install outreg2, replace
ssc install estout, replace
```

[2]available from https://www.usitc.gov/data/gravity/itpd_e_r01.zip
[3]available from https://www.usitc.gov/data/gravity/release_2.0_2000_2016.zip

## B.3 Recommended Execution

To replicate this study from scratch:

1. Clone the replication repository: https://github.com/flonat/IB9ND
2. Download missing raw datasets in the `Data/` folder as noted in Appendix B.1.
3. Run:

```
cd Data
stata -b do build_brexit_services_datasets_replication.do

cd ../Results - Replication
stata -b do main_figures_tables.do
stata -b do appendix_figures_tables.do
```

## B.4 Remarks on Reproducibility

All changes have been tracked and commented in-line in the replication `.do` file. The replication reproduces all main tables and figures from the original paper. Additional robustness extensions—such as smoothed uncertainty measures, sample restrictions, and interaction terms—are included and documented inline. The computational environment is fully cross-platform. Scripts were tested on macOS (Apple M3) and verified on Windows 11 (Intel i7), ensuring reproducibility across major operating systems.

# C Code Modifications and Execution Pipeline

This appendix documents changes to:

- `build_brexit_services_datasets_replication.do` – data compilation
- `main_figures_tables.do` – main text results
- `appendix_figures_tables.do` – appendix and robustness tables

**Note:** All outputs are saved to `Results - Replication/`, split between:

- `main_tables_figures/` – Tables 1–6, Figures 1–4
- `appendix_tables_figures/` – Appendix Tables A3–A15 of the original paper and the new B1-B5 Tables created for the robustness checks of this replication

## C.1 Code Modifications to Compile Data File

To support replication and robustness analyses, the original data construction script located in the `Data` folder (`build_brexit_services_datasets.do`) was duplicated and revised as `build_brexit_services_datasets_replication.do`. Modifications fall into two main categories:

**(A) Compatibility Adjustments (Stata 18 / macOS)**

1. **Path Normalisation:** File path delimiters were converted from Windows-style backslashes to Unix-style forward slashes for macOS compatibility.

```
global main_output "Results - Replication/main_tables_figures"
global appendix_output "Results - Replication/appendix_tables_figures"
```

2. **Explicit Overwrite Commands:** `save` and `log` commands were modified to include the `replace` option to prevent execution errors during batch processing.

```
save "$data_out/brexit_services_main_sample.dta", replace
log using "$main_output/main.log", replace
```

3. **Backward Compatibility:** Data files were saved using `saveold` to ensure compatibility with earlier versions of Stata (e.g., Stata 14).

**(B) Replication-Specific Enhancements**

**1. Extended Sample Construction** A new dummy variable was introduced to identify the subset of non-EU countries without FTAs with the EU, as required for Table 4 and Appendix Table A14:

```
gen extended_sample = (eu == 0 & fta == 0)
```

**2. Instrument Variables for STRI Interactions** To support IV regressions using external STRI medians (Table 5 and Table A14), two interaction terms were constructed manually:

```
gen ln_mfn_risk_c1_x_me_iv = stri_median_iv_imp * ln(me)
gen ln_mfn_risk_c1_x_ma_iv = stri_median_iv_imp * ln(ma)
```

**3. Robustness Sample Flags and Fixed Effect Identifiers** Binary indicators and group identifiers were created to facilitate selective sample filtering and multi-way fixed effects used in Appendix Tables A5–A8 and robustness tables B1–B5:

```
gen all = 1 if eu_minus_gb == 1
gen all_but_air = 1 if all == 1 & servicet != "Air transportation"
egen imp_quarter = group(importer_country quarter)
gen broad_sec = ...
egen G = group(broad_sec)
```

**4. Additional Logging for Replication Traceability** Dedicated log files were included to differentiate replication runs from the original analysis:

```
log using "$appendix_output/appendix.log", replace
```

**5. Saturated Fixed Effects for Robustness** To enable robustness checks with more granular time and sector fixed effects, support was added for absorbing high-dimensional interactions such as:

```
absorb(J#I#quarter J#I#S S#quarter)
```

**6. Preparation for Downstream Merge Scripts** Intermediate datasets and identifiers were prepared to be used as inputs to robustness specifications and downstream estimation scripts. These include extended sample indicators and fixed effect dimensions for sector-time clustering.

## C.2 Code Modifications to Generate Main Text Results

The original script `main_figures_tables.do` was duplicated in the `Results - Replication/` folder.

### (A) Logging and Output Configuration

Log files were added and updated for reproducibility and traceability:

```
global path "..."
cd "$path"
log using main.log, replace
log using main.txt, replace text name(textlog)
```

### (B) Figures 1–4 Replication

**Figures 1 and 2: STRI Risk Measures** Graph export commands were added to output PDF versions of the foreign entry STRI and risk measures:

```
graph export "$main_output/fig1.pdf", replace
graph export "$main_output/fig2.pdf", replace
```

**Figures 3 and 4: Export Responses by Risk Group** Risk-based classifications were computed using the median of `mfn_risk_c1`, and graphs were exported:

```
egen med = median(mfn_risk_c1)
gen hi = mfn_risk_c1 > med
...
graph export "$main_output/fig3.pdf", replace
graph export "$main_output/fig4.pdf", replace
```

### (C) Tables 1–3: OLS, PPML, and Summary Statistics

Core regression specifications were replicated using both full and restricted time samples, with output formatted using `outreg2`:

```
reghdfe `y' ln_mfn_risk_c1_x_me if quarter≤`q', ...
ppmlhdfe `y' ln_mfn_risk_c1_x_me, ...
```

**(D) Table 5: Instrumental Variables Estimation**

Two-stage least squares regressions were implemented using pre-generated instruments from the data file. Estimation used clustered standard errors and multiple fixed effects:

```
ivreghdfe log_value_cont (ln_mfn_risk_c1_x_me = ln_mfn_risk_c1_x_me_iv) ///
    absorb(J#I#quarter J#I#S S#quarter)
```

**(E) Table 6: Brexit Impact Quantification**

Elasticities and level changes in trade outcomes were computed using average STRI risk and prediction market probabilities. Output was written using matrix tools:

```
scalar ols_export_elas = ols_export_coeff * export_risk
scalar ols_export_ref  = ols_export_elas * ref_prob * 100
...
mat2txt, matrix(t6) saving("$main_output/table6") ...
```

**(F) Table 4: Placebo Regressions with Extended Sample**

Placebo regressions using matched non-EU countries without FTAs were implemented by merging on paired country data and re-estimating using saturated fixed effects:

```
merge using "placebo_a_noFTA_exp.dta"
reghdfe `y' ln_mfn_risk_c1_x_me, absorb(J#I#quarter J#I#S S#quarter)
```

## C.3 Code Modifications to Generate Appendix Results

The script `appendix_figures_tables.do` was duplicated in the `Results - Replication/` folder.

**(A) Appendix Table Replication (A3–A15)**

- **Table A3:** Trade shares and STRI values by service type in 2016Q1.
- **Tables A4–A6:** Variants of the baseline regressions with:

  - Brexit probability smoothed using 3- and 6-month moving averages
  - Category-total STRI measures (not just Category 1)
  - Passporting risk interactions with Brexit probability
- **Tables A7–A8:** Address clustering choices and unobserved sector-time trends using:
  - Industry-quarter cluster corrections
  - Multi-way clustering with service groups
- **Table A9:** Placebo regressions with matched non-EU country pairs lacking FTAs (e.g., DEU–USA) using modified ‘placebo_country‘ indicators.
- **Table A10:** Sensitivity analysis by dropping air transport and sector-level exclusions (e.g., financial services).
- **Table A11:** Baseline regressions run separately for four broad sector groups: `Financial`, `Transport`, `Professional`, and `Electronic`.
- **Table A12:** UK vs. EU exporter heterogeneity using interaction terms.
- **Table A13:** Controls for exchange rate pass-through via interacted fixed effects with `log_exch`.
- **Table A14:** IV estimation using STRI-based instruments and extended samples, with weak instrument diagnostics appended to regression output.
- **Table A15:** Gravity regressions using the USITC ITPD-E database with EU intra-trade removed.

**(B) Robustness Extensions (`tableBx`)**

**Table B1:** Time-smoothing sensitivity for Brexit probability.

```
reghdfe `y' ln_mfn_risk_c1_x_ma3 ...
reghdfe `y' ln_mfn_risk_c1_x_ma6 ...
```

**Table B2:** Alternative risk specifications:

- `alt_risk1_x_mean`: full STRI
- `alt_risk2_x_mean`, `alt_risk3_x_mean`: STRI Categories 2 and 3
- `comp_risk_x_mean`: composite STRI risk

**Table B3:** Sample exclusions:

- Pre-referendum only
- Post-Article 50 only
- Outlier exclusion
- Financial sector exclusion

**Table B4:** Exchange rate robustness:

- Interactions of STRI with `log_exch`
- Exchange rate volatility measure
- Post-referendum exchange rate effects

**Table B5:** Consolidated robustness results presented in comparative format.

**(C) Additional Enhancements**

**Figure A1:** Exported PDF plot of EUR/GBP exchange rate vs. Brexit probability for Austria and Legal Services.

```
graph export "$appendix_output/figA1.pdf", replace
```

**STRI Sector Breakdown (Table A11):** Services were grouped using a new `broad_sec` variable and re-estimated within sectors using interaction terms and grouped fixed effects.

**UK Exporter Flag (Table A12):** Binary indicators for UK vs. EU exporters allowed differential elasticity estimation:

```
gen uk_exp = (exporter_country == "GBR")
gen eu_exp = (all == 1 & exporter_country ≠ "GBR")
```

**Pass-through Effects (Table A13):** Exchange rate pass-through modelled via interacted fixed effects of the form `S#c.log_exch` and comparison of UK- and EU-specific risk elasticities.

**Placebo Country Matching (Table A9):** Country pairings were constructed and merged using relabelled ISO country codes to ensure symmetry between matched importer-exporter pairs.