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Estimating the Trade and Welfare Effects of Brexit: A Panel Data Structural Gravity Model

Michael Pfaffermayr
University of Innsbruck, Austrian Institute of Economic Research (WIFO)

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Estimating the Trade and Welfare Effects of Brexit:
A Panel Data Structural Gravity Model

Harald Oberhofer[a,c] Michael Pfaffermayr[b,c]

[a]Vienna University of Economics and Business

[b]University of Innsbruck

[c]Austrian Institute of Economic Research

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Introduction and motivation

Since 29th of March 2017 the UK and EU are negotiating the terms for UK's withdrawal from the EU but the likely outcome is still very uncertain.

Discussion on the likely **costs** and benefits associated with Brexit.

We add to the literature on trade and welfare effects of Brexit by ...

- applying a panel data Constrained Poisson Pseudo Maximum Likelihood Estimator (CPPMLE).
- accounting for full endowment general equilibrium effects (Yotov *et al.* 2016).
- allowing for phasing-in effects of counterfactual policy scenarios (Bergstrand *et al.* 2015).
- relying on a unique dataset which allows to more accurately identify trade policy effects.

Literature review

(Structural) gravity models

Authors/Year	Estimation	Data	Main findings
Brakman *et al.* (2017)	Structural gravity Full endowment GE	WIOD 2014 Total VAX 43 countries	**Hard Brexit**: Drop in UK's VAX of 18% **Soft Brexit:** VAX drop by 14%
Dhingra *et al.* (2017)	Quantitative trade model	WIOD 2011 31 sectors 35 regions	**Hard Brexit**: UK's direct welfare loss -2.7% **Soft Brexit**: UK's direct welfare loss -1.3% Dynamic productivity effects are important
Felbermayr *et al.* (2017)	Structural gravity Quantitative Ifo trade model	WIOD 2000-14 50 sectors 43 countries + ROW	**Hard Brexit**: Welfare loss in UK between 0.8 and 2.9% **Soft Brexit**: Welfare loss in UK might be zero
Graham *et al.* (2017)	Gravity models	Glick and Rose	Brexit effects are sensitive
HM Treasury (2016)	Simple gravity models	Glick and Rose	$\approx$ 20% export drop for UK
Vandenbussche *et al.* (2017)	sector-level input-output model	WIOD 2014 56 sectors 43 countries + ROW	**Hard Brexit**: value added production declines by 4.5% **Soft Brexit**: value added production declines by 1.2% Absolute job losses in EU27 are larger

Structural panel data gravity model I

$$\frac{x_{ijt}}{Y_{t,W}} = t_{ijt}^{1-\sigma}\kappa_{it}\Pi_{it}^{\sigma-1}P_{jt}^{\sigma-1}\theta_{jt}e^{\mu_{ij}}\eta_{ijt} := e^{z'_{ijt}\alpha+\beta_{it}(\alpha)+\gamma_{jt}(\alpha)+\mu_{ij}}\eta_{ijt}$$

and define $s_{ijt} = x_{ijt}/Y_{t,W}$ so that $\sum_{i=1}^{C}\sum_{j=1}^{C} s_{ijt} = 1$.

Multilateral trade resistances enter the model in normalized form as $e^{\beta_{it}(\alpha,\mu)} = \kappa_{it}\Pi_{it}(\alpha,\mu)^{\sigma-1}$ and $e^{\gamma_{jt}(\alpha,\mu)} = \theta_{jt}P_{jt}(\alpha,\mu)^{\sigma-1}$.

For $i,j = 1,...,C$ and period t the system of trade resistances can be compactly written as

$$\begin{aligned}
\kappa_{it} &= \sum_{j=1}^{C} e^{z'_{ijt}\alpha+\beta_{it}(\alpha,\mu)+\gamma_{jt}(\alpha,\mu)+\mu_{ij}},\ i = 1,...,C-1,\\
\theta_{jt} &= \sum_{i=1}^{C} e^{z'_{ijt}\alpha+\beta_{it}(\alpha,\mu)+\gamma_{jt}(\alpha,\mu)+\mu_{ij}},\ j = 1,...,C.
\end{aligned}$$

In case of $\alpha = 0$, $\mu_{ij} = 0$, one may set $\Pi_{it}(0) = c_t$ and $P_{jt}(0) = 1/c_t$, where c_t is a time-specific constant so that $e^{\beta_{it}(\alpha)} = c_t\kappa_{it}$ and $e^{\gamma_{jt}(\alpha)} = \theta_{jt}/c_t$.

Structural panel data gravity model II

The country pair fixed effects need to be normalized as well:

$$\begin{aligned}\widetilde{\beta}_{it} &= \beta_{it}(\alpha,\mu) - \beta_{Ct}(\alpha,\mu) + \mu_{ii},\\ \widetilde{\gamma}_{jt} &= \gamma_{jt}(\alpha,\mu) + \beta_{Ct}(\alpha,\mu) + \mu_{jj},\\ \widetilde{\mu}_{ij} &= \mu_{ij} - \mu_{ii} - \mu_{Cj}.\end{aligned}$$

Under this parametrization it follows that $\widetilde{\beta}_{Ct} = 0$, $\widetilde{\mu}_{ii} = 0$ and $\widetilde{\mu}_{Cj} = 0$.

For estimation rewrite the structural gravity with additive disturbances:

$$s_{ijt} = m_{ijt}(\vartheta_C) + \varepsilon_{ijt}, \quad \varepsilon_{ijt} = m_{ijt}(\vartheta_C)\left(\eta_{ijt} - 1\right),$$

where $m_{ijt}(\vartheta_C) = e^{z'_{ijt}\alpha + \beta_{it}(\alpha,\mu) + \gamma_{jt}(\alpha,\mu) + \mu_{ij}}$.

Full endowment general equilibrium effects

Allow endogenous adjustments of gross productions and expenditures as a response to counterfactual changes in mill prices.

For estimation, production and expenditure shares are observed and are taken as given.

The solutions of counterfactual scenarios fully respect their endogenous adjustment. ▸ Details

Gravity model: Empirical specifications

Specifiction (1):

$$
\begin{aligned}
s_{ijt} &= \exp\left(\alpha_1 B_{ij} t + \alpha_2 B_{ij} contig_{ij} t + \alpha_3 B_{ij} \log(dist_{ij}) t + \alpha_4 B_{ij} D_{GR}\right) \\
* &\quad \exp\left(\sum_{k=0}^{2} \alpha_{5+k} B_{ij} CU_{ij,t-3k} + \sum_{k=0}^{2} \alpha_{8+k} B_{ij} FTA_{ij,t-3k} + \mu_{ij} + \beta_{it} + \gamma_{jt}\right) + \varepsilon_{ijt}
\end{aligned}
$$

Specifiction (2):

$$
\begin{aligned}
s_{ijt} &= \exp\left(\alpha_1 B_{ij} t + \alpha_2 B_{ij} contig_{ij} t + \alpha_3 B_{ij} \log(dist_{ij}) t + \alpha_4 B_{ij} D_{GR}\right) \\
* &\quad \exp\left(\sum_{k=0}^{2} \alpha_{5+k} B_{ij} RTA_{ij,t-3k} + \mu_{ij} + \beta_{it} + \gamma_{jt}\right) + \varepsilon_{ijt}
\end{aligned}
$$

- Domestic trade flows are fully described by fixed country-pair effects and the MRTs.
- Levels of border effects are observed by the country-pair FEs.

Constrained Panel Data Poisson Pseudo Maximum Likelihood Estimator

Exploits the general equilibrium constraints imposed by the system of multilateral resistances. $\Rightarrow$

Allows to calculate **theory consistent confidence intervals** via the delta method.

Accurately addresses and solves the incidental parameter problem. $\Rightarrow$

Allows to fully control for **unobserved heterogeneity** across country pairs.

Delivers predictions that adhere to the restrictions imposed by the system of MRTs even in case of **missing data**.

Allows for three-way clustering across country-pairs, exporter-time and importer-time, respectively.

▸ Details

Data

Data for bilateral goods trade, gross-production, total export and imports for total manufacturing for 65 countries. ▸ Country coverage

The total value of exports of a single country adds-up to its production value and the value of imports to its expenditures.

Domestic trade is defined as gross production minus total exports.

We cover the time period from 1994 to 2012 in three-year intervals.

Sources:

Bilateral trade: OECD's STAN database and Nicita and Olarreaga's (2007) database.

Production and total trade: STAN, UNIDO, CEPII and WIOD

A few data points have been interpolated (Robustness).

Distance and contiguity: Mayer and Zignago (2011)

Trade policies: Mario Larch's Regional Trade Agreements Database (Egger and Larch 2008).

Descriptives I

Share of trade flows in world trade by country-pair group

Country-pair group	1994	1997	2000	2003	2006	2009	2012
UK, domestic	0.027	0.029	0.025	0.023	0.020	0.012	0.011
EU, domestic	0.183	0.172	0.154	0.170	0.148	0.126	0.092
ROW, domestic	0.581	0.554	0.548	0.517	0.524	0.585	0.575
UK-EU	0.007	0.009	0.009	0.008	0.008	0.006	0.006
UK-ROW	0.004	0.005	0.005	0.005	0.004	0.004	0.005
EU-UK	0.009	0.011	0.011	0.012	0.011	0.009	0.009
ROW-UK	0.005	0.007	0.007	0.007	0.007	0.005	0.007
EU-EU	0.057	0.065	0.068	0.081	0.084	0.077	0.075
EU-ROW	0.025	0.030	0.031	0.035	0.037	0.035	0.043
ROW-EU	0.024	0.026	0.031	0.034	0.038	0.036	0.038
ROW-ROW	0.077	0.094	0.112	0.109	0.119	0.105	0.139

Descriptives II

Share of trade flows covered by international trade agreements

	Stan database			WIOD database		
	CUs	FTAs	RTAs	CUs	FTAs	RTAs
All country-pairs						
1994	0.05	0.14	0.18			
1997	0.07	0.16	0.23			
2000	0.07	0.19	0.25	0.15	0.29	0.44
2003	0.07	0.21	0.27	0.15	0.32	0.47
2006	0.14	0.18	0.33	0.34	0.19	0.53
2009	0.16	0.17	0.34	0.40	0.14	0.54
2012	0.16	0.22	0.38	0.40	0.18	0.57
UK						
1994	0.19	0.23	0.42			
1997	0.23	0.25	0.48			
2000	0.23	0.28	0.51	0.39	0.31	0.70
2003	0.23	0.31	0.54	0.39	0.34	0.72
2006	0.36	0.20	0.56	0.58	0.14	0.72
2009	0.39	0.17	0.56	0.63	0.10	0.72
2012	0.39	0.20	0.59	0.63	0.12	0.75

Estimation results

	Specification (1)		Specification (2)	
	Parameter-estimate	t-value	Parameter-estimate	t-value
Border*time	0.17	4.75***	0.20	5.48***
Border*contiguity*time	0.02	1.20	0.02	1.53
Border*(log) distance*time	−0.01	−1.82*	−0.01	−2.50**
Border*Great recession 2009	−0.19	−4.87***	−0.19	−4.55***
Border*Customs union	0.13	1.99**		
Border*Custums union (t-3)	0.33	4.24***		
Border*Custums union (t-6)	0.03	0.45		
Border*FTA	−0.07	−1.36		
Border*FTA (t-3)	0.25	3.64***		
Border*FTA (t-6)	0.11	1.67*		
Border*RTA			−0.06	−1.24
Border*RTA (t-3)			0.25	3.49***
Border*RTA (t-6)			0.14	1.90*
Total customs unions effect	0.50	5.39***		
Total FTA effect	0.29	3.90***		
Total RTA effect			0.33	4.31***

Robustness checks

1. No imputed data.
2. WIOD database for 2000 to 2012.
3. Non-linear border-time effects.
4. Time-constant border effects (Bergstrand *et al.* 2015).

Robustness: No imputed data & WIOD

	No imputed trade flows				Wiod (2000-2012)			
	Spec. (1)		Spec. (2)		Spec. (1)		Spec. (2)	
	Par.-est.	t-val.	Par.-est.	t-val.	Par.-est.	t-val.	Par.-est.	t-val.
Border*time	0.17	4.75***	0.20	5.57***	−0.01	−0.24	0.01	0.12
Border*contiguity*time	0.02	1.24	0.02	1.54	0.01	0.33	0.01	0.26
Border*(log) dist.*time	−0.01	−1.81*	−0.01	−2.54**	0.01	0.91	0.00	0.58
Border*Great recession	−0.19	−4.85***	−0.19	−4.56***	−0.07	−1.96**	−0.07	−1.66*
Border*Customs u.	0.13	1.92**			0.27	2.69**		
Border*Custums u. (t-3)	0.34	4.21***			0.16	2.02**		
Border*Custums u. (t-6)	0.04	0.51			0.08	1.31		
Border*FTA	−0.07	−1.43			−0.01	−0.07		
Border*FTA (t-3)	0.25	3.57***			0.06	0.88		
Border*FTA (t-6)	0.11	1.69*			0.06	1.44		
Border*RTA			−0.06	−1.33			−0.01	−0.19
Border*RTA (t-3)			0.25	3.49***			0.05	0.72
Border*RTA (t-6)			0.14	1.91*			0.09	1.77*
Total customs unions	0.51	5.34***			0.52	3.52***		
Total FTA	0.29	3.84***			0.12	1.34		
Total RTA			0.33	4.31***			0.13	1.39***

Robustness: Different border effects

	No imputed trade flows				Bergstrand *et al.* (2015) specification			
	Spec. (1)		Spec. (2)		Spec. (1)		Spec. (2)	
	Par.-est.	t-val.	Par.-est.	t-val.	Par.-est.	t-val.	Par.-est.	t-val.
Border*time	0.16	3.43^{***}	0.19	3.98^{***}				
Border*time^2	0.00	0.23	0.00	0.25				
Border					0.10	7.72^{***}	0.11	7.94^{***}
Border*contiguity*time	0.02	1.20	0.02	1.53	0.00	0.13	0.00	0.38
Border*(log) dist.*time	−0.01	-1.83^{*}	−0.01	-2.52^{**}	0.00	0.25	0.00	−0.26
Border*Great recession	−0.19	-4.88^{***}	−0.19	-4.56^{***}	−0.19	-4.72^{***}	−0.19	-4.32^{***}
Border*Customs u.	0.13	1.96^{**}			0.14	2.11^{**}		
Border*Custums u. (t-3)	0.34	4.21^{**}			0.35	4.34^{***}		
Border*Custums u. (t-6)	0.04	0.48			0.05	0.61		
Border*FTA	−0.07	−1.39			−0.08	-1.71^{*}		
Border*FTA (t-3)	0.25	3.57^{***}			0.25	3.69^{***}		
Border*FTA (t-6)	0.11	1.73^{*}			0.11	1.56		
Border*RTA			−0.06	−1.27			−0.07	−1.63
Border*RTA (t-3)			0.25	3.43^{***}			0.26	3.50^{***}
Border*RTA (t-6)			0.14	1.98^{**}			0.14	1.77^{*}
Total customs unions	0.50	5.40^{***}			0.54	5.96^{***}		
Total FTA	0.29	3.85^{***}			0.28	3.79^{***}		
Total RTA			0.33	4.27^{***}			0.32	4.31^{***}

Counterfactual Brexit scenarios

1. **Soft Brexit** (Specification 1):
   - UK leaves the customs unions.
   - A free trade agreement with the EU is established.
   - All third-country trade agreements of UK remain unaffected.

2. **Hard Brexit** (Specification 1):
   - A free trade agreement with the EU **cannot** be established.
   - All exiting trade agreements of UK with third countries are abolished.
     $\Rightarrow$ **UK trades under WTO rules**.

3. **Soft Brexit** (Specification 2):
   - The RTA indicator is set to zero for trade between UK and the EU members.
   - All third-country trade agreements of UK remain unaffected.

Brexit impact on international trade I

Full endowment general equilibrium

		Soft Brexit			Hard Brexit		
		%-change	CI lower	CI upper	%-change	CI lower	CI upper
Specification 1							
UK-EU	t	-18.06	-27.68	-8.44	-37.40	-47.59	-27.21
	t+3	-17.19	-26.96	-7.41	-36.26	-46.54	-25.98
	t+6	-16.81	-26.41	-7.21	-35.53	-45.71	-25.34
EU-UK	t	-14.42	-22.04	-6.80	-30.28	-38.89	-21.67
	t+3	-13.87	-21.80	-5.93	-29.55	-38.33	-20.76
	t+6	-13.78	-21.69	-5.88	-29.41	-38.19	-20.62
EU-EU	t	0.39	-0.08	0.85	1.13	0.51	1.75
	t+3	0.40	-0.08	0.89	1.17	0.54	1.81
	t+6	0.43	-0.07	0.92	1.23	0.58	1.88
UK-ROW	t	2.21	0.71	3.71	-3.21	-5.81	-0.62
	t+3	2.64	0.86	4.41	-3.88	-6.65	-1.11
	t+6	3.07	1.03	5.12	-2.84	-5.64	-0.04
ROW-UK	t	5.83	1.91	9.74	5.79	2.14	9.45
	t+3	5.88	1.93	9.83	4.64	0.97	8.31
	t+6	5.99	1.98	10.00	4.86	1.12	8.59
EU-ROW	t	0.73	0.27	1.19	1.60	0.96	2.25
	t+3	0.71	0.26	1.17	1.51	0.89	2.13
	t+6	0.71	0.26	1.15	1.50	0.89	2.11
ROW-EU	t	-0.14	-0.19	-0.08	-0.20	-0.36	-0.05
	t+3	-0.11	-0.16	-0.06	0.06	-0.15	0.27
	t+6	-0.08	-0.13	-0.03	0.12	-0.10	0.35

Brexit impact on international trade II

Full endowment general equilibrium

		Soft Brexit			Hard Brexit		
		%-change	CI lower	CI upper	%-change	CI lower	CI upper
Specification 2							
UK-EU	t	-26.12	-36.02	-16.23	-25.57	-35.28	-15.87
	t+3	-25.56	-35.30	-15.81	-24.95	-34.47	-15.43
	t+6	-25.00	-34.59	-15.41	-24.33	-33.68	-14.99
EU-UK	t	-20.91	-29.19	-12.63	-20.36	-28.34	-12.39
	t+3	-20.80	-29.05	-12.55	-20.23	-28.17	-12.28
	t+6	-20.67	-28.89	-12.44	-20.06	-27.96	-12.15
EU-EU	t	0.71	0.17	1.25	0.67	0.14	1.20
	t+3	0.75	0.19	1.31	0.71	0.16	1.25
	t+6	0.79	0.22	1.36	0.74	0.18	1.29
UK-ROW	t	3.15	1.26	5.05	-4.42	-6.41	-2.44
	t+3	3.88	1.64	6.12	-3.67	-5.47	-1.87
	t+6	4.61	2.02	7.20	-2.91	-4.58	-1.25
ROW-UK	t	9.07	4.62	13.51	1.01	0.03	1.98
	t+3	9.22	4.70	13.73	1.19	0.10	2.28
	t+6	9.40	4.79	14.01	1.41	0.19	2.64
EU-ROW	t	1.06	0.54	1.57	1.11	0.58	1.64
	t+3	1.04	0.54	1.55	1.10	0.57	1.63
	t+6	1.03	0.53	1.53	1.09	0.57	1.62
ROW-EU	t	-0.20	-0.26	-0.13	-0.07	-0.22	0.07
	t+3	-0.15	-0.22	-0.08	-0.02	-0.18	0.13
	t+6	-0.11	-0.19	-0.04	0.02	-0.15	0.19

Brexit impact on domestic trade I

Full endowment general equilibrium

		Soft Brexit			Hard Brexit		
		%-change	CI lower	CI upper	%-change	CI lower	CI upper
Spec. 1							
UK	t	7.94	2.44	13.45	19.66	10.91	28.42
	t+3	8.46	2.58	14.34	21.60	12.05	31.15
	t+6	9.03	2.77	15.30	23.17	12.92	33.42
EU	t	-0.03	-0.11	0.05	1.14	0.51	1.76
	t+3	-0.04	-0.12	0.05	1.18	0.54	1.82
	t+6	-0.04	-0.12	0.04	1.23	0.58	1.89
ROW	t	0.21	0.19	0.22	0.27	0.14	0.39
	t+3	0.20	0.18	0.23	0.39	0.23	0.56
	t+6	0.20	0.17	0.23	0.39	0.23	0.56

Brexit impact on domestic trade II

Full endowment general equilibrium

		Soft Brexit			Hard Brexit		
		%-change	CI lower	CI upper	%-change	CI lower	CI upper
Spec. 2							
UK	t	12.34	5.79	18.89	14.00	6.40	21.59
	t+3	13.30	6.25	20.35	15.11	6.91	23.30
	t+6	14.30	6.72	21.89	16.26	7.44	25.09
EU	t	0.71	0.17	1.26	0.67	0.14	1.20
	t+3	0.75	0.19	1.32	0.71	0.16	1.26
	t+6	0.79	0.22	1.37	0.74	0.18	1.30
ROW	t	0.05	0.04	0.05	0.37	0.24	0.50
	t+3	0.05	0.04	0.05	0.37	0.24	0.50
	t+6	0.05	0.04	0.06	0.38	0.25	0.50

Welfare effects of Brexit I

Full endowment general equilibrium

		Soft Brexit			Hard Brexit		
		%-change	CI lower	CI upper	%-change	CI lower	CI upper
Specification 1							
UK	t	-1.29	-2.29	-0.28	-3.05	-4.85	-1.24
	t+3	-1.37	-2.45	-0.29	-3.32	-5.33	-1.32
	t+6	-1.46	-2.61	-0.30	-3.55	-5.73	-1.36
EU	t	-0.03	-0.11	0.05	-0.12	-0.22	-0.01
	t+3	-0.04	-0.12	0.05	-0.12	-0.23	-0.02
	t+6	-0.04	-0.12	0.04	-0.13	-0.24	-0.02
ROW	t	0.05	0.05	0.05	0.04	0.02	0.07
	t+3	0.05	0.04	0.05	0.04	0.02	0.07
	t+6	0.05	0.04	0.05	0.05	0.02	0.07

Notes: The value of σ is chosen as 6.98 follwing Bergstrand *et al.* (2013, Table 1)

Welfare effects of Brexit II

Full endowment general equilibrium

		Soft Brexit			Hard Brexit		
		%-change	CI lower	CI upper	%-change	CI lower	CI upper
Specification 2							
UK	t	-1.96	-3.22	-0.71	-2.21	-3.69	-0.74
	t+3	-2.11	-3.47	-0.75	-2.38	-3.99	-0.77
	t+6	-2.26	-3.74	-0.78	-2.55	-4.31	-0.79
EU	t	-0.07	-0.16	0.02	-0.07	-0.15	0.02
	t+3	-0.08	-0.17	0.02	-0.07	-0.16	0.02
	t+6	-0.08	-0.18	0.01	-0.08	-0.17	0.02
ROW	t	0.05	0.04	0.05	0.00	0.00	0.00
	t+3	0.05	0.04	0.05	0.04	0.02	0.07
	t+6	0.05	0.04	0.06	0.04	0.02	0.07

Notes: The value of σ is chosen as 6.98 follwing Bergstrand *et al.* (2013, Table 1)

Robustness: Welfare effects of Brexit

Full endowment general equilibrium

		$\sigma = \mathbf{6.858}$			$\sigma = \mathbf{7.106}$		
		%-change	CI lower	CI upper	%-change	CI lower	CI upper
UK	t	-1.31	-2.34	-0.29	-1.26	-2.25	-0.27
	t+3	-1.39	-2.50	-0.29	-1.34	-2.40	-0.28
	t+6	-1.49	-2.67	-0.30	-1.43	-2.56	-0.29
EU	t	-0.03	-0.11	0.05	-0.03	-0.11	0.05
	t+3	-0.04	-0.12	0.05	-0.03	-0.11	0.05
	t+6	-0.04	-0.12	0.05	-0.04	-0.12	0.04
ROW	t	0.05	0.05	0.05	0.05	0.04	0.05
	t+3	0.05	0.04	0.05	0.05	0.04	0.05
	t+6	0.05	0.04	0.06	0.05	0.04	0.05

Notes: Welfare calculations based on the Costinot and Rodrguez-Clare (2014) formula. The values of σ are chosen based on the 1% confidence intervals reported in Bergstrand *et al.* (2013).

Main findings: 6 years after Brexit

UKs (EUs) exports of goods to the EU (UK) are likely to decline within a range between 7.2% and 45.7% (5.9% and 38.2%).

The soft (hard) Brexit scenario of Specifiction (1) fosters UK domestic trade by 9.0% [2.8%, 15.3%] (23.2% [12.9%, 33.4%]).

Trade effects for the ROW a relatively small but more important for the relationship with the UK.

Specifiction (2) produces larger (smaller) effects for the soft (hard) Brexit scenarios.

For the UK, a hard Brexit likely induces a decline in UKs real income by around 3.6% [1.4%, 5.7%].

The estimated welfare effects for the EU are negligible in magnitude and statistically not different from zero.

Conclusions

This paper empirically assesses the trade and welfare effects from Brexit concentrating on goods trade by exploiting the system of multilateral resistances for calculating confidence intervals.

We provide a meaningful and theory consistent bandwidth for the possible general equilibrium trade effects for the UK, the EU and the ROW.

The estimates suggest that the largest adverse trade and welfare effects are to be expected in case of a hard Brexit in which UK would only trade under WTO rules.

The "Global Britain' strategy would most likely be able to only dampen these negative effects.

$\Rightarrow$ The expected decline in bilateral trade will be much more damaging for the UK as compared to the EU.

The provided estimates might be considered as only a lower bound of the potential economic costs involved in the Brexit.

Thank you very much for your attention!!

FEGEE formally I

Following Yotov *et al.* (2016), we write demand as

$$\begin{aligned} s_{ijt} &= \left(p_{it} b_{it} t_{ijt}\right)^{1-\sigma} \theta_{jt} P_{jt}^{\sigma-1} \\ P_{jt} &= \left(\sum_{j=1}^{C} \left(p_{it} b_{it} t_{ijt}\right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \end{aligned}$$

where b_{it} is a preference parameter or may be determined by another isomorphic model.

Market clearing implies

$$\kappa_{it} = \sum_{j=1}^{C} s_{ijt} = \sum_{j=1}^{C} \left(p_{it} b_{it} t_{ijt}\right)^{1-\sigma} \theta_{jt} P_{jt}^{\sigma-1} = \left(p_{it} b_{it}\right)^{1-\sigma} \underbrace{\sum_{j=1}^{C} t_{ijt}^{1-\sigma} \theta_{jt} P_{jt}^{\sigma-1}}_{\Pi_{it}^{1-\sigma}}$$

and

$$\left(p_{it} b_{it}\right)^{1-\sigma} = \kappa_{it} \Pi_{it}^{\sigma-1} \rightarrow p_{it} = \frac{1}{b_{it}} \left(\kappa_{it} \Pi_{it}^{\sigma-1}\right)^{\frac{1}{1-\sigma}}.$$

FEGEE formally II

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Production may be written as

$$Y_{it} = p_{it} \frac{Y_{it,0}}{p_{it,0}}.$$

The index 0 refers to the initially observed values in the baseline situation. Using the parametrization in the text

$$\begin{aligned} p_{it} &= b_{it}^{-1} \left(\kappa_{it} \Pi_{it}^{\sigma-1}\right)^{\frac{1}{1-\sigma}} = b_{it}^{-1} e^{\frac{\beta_{it}(\alpha,\mu)}{1-\sigma}} \\ \frac{p_{it}}{p_{it,0}} &= \frac{b_{it}^{-1} e^{\frac{\beta_{it}(\alpha.\mu)}{1-\sigma}}}{b_{it}^{-1} e^{\frac{\beta_{it,0}(\alpha,\mu)}{1-\sigma}}} = e^{\frac{\beta_{it}(\alpha,\mu)-\beta_{it,0}(\alpha,\mu)}{1-\sigma}} \end{aligned}$$

and production and expenditure shares can be written as

$$\begin{aligned} \kappa_{it} &= \frac{\frac{p_{it}}{p_{it,0}} \frac{Y_{it,0}}{Y_{t,W}}}{\sum_{k=1}^{C} \frac{p_{kt}}{p_{kt,0}} \frac{Y_{kt,0}}{Y_{t,W}}} = \frac{e^{\frac{\beta_{it}(\alpha,\mu)-\beta_{it,0}(\alpha,\mu)}{1-\sigma}} \kappa_{it.0}}{\sum_{k=1}^{C} e^{\frac{\beta_{kt}(\alpha,\mu)-\beta_{kt,0}(\alpha,\mu)}{1-\sigma}} \kappa_{kt,0}} \\ \theta_{jt} &= \frac{p_{it}}{p_{0it}} \theta_{jt,0} = e^{\frac{\beta_{it}(\alpha,\mu)-\beta_{it,0}(\alpha,\mu)}{1-\sigma}} \theta_{jt,0}. \end{aligned}$$

CPPMLE formally I

Nested iterations in a partial Gauss-Seidel algorithm. In each iteration step r the iterative estimation procedure calculates the following vectors and matrices:

$$
\begin{aligned}
\widehat{m}_{ijt,\phi,r} &= e^{z'_{ijt}\widehat{\alpha}_r+\beta_{it}(\widehat{\alpha}_r,\widehat{\mu}_r)+\gamma_{jt}(\widehat{\alpha}_r,\widehat{\mu}_r)} \\
\widehat{m}_{ijt,r} &= \widehat{m}_{ijt,\phi,r}e^{\widehat{\mu}_{ij,r}} \\
\widehat{M}_r &= diag(\widehat{m}_{ijt,r}) \\
\widehat{Q}_{\mu,r} &= \widehat{M}_r V - \widehat{M}_r V D_\mu \left(D'_\mu V \widehat{M}_r D_\mu\right)^{-1} D'_\mu V \widehat{M}_r \\
\widehat{G}_r &= W'_\phi \widehat{Q}_{\mu,r} W_\phi,\ W_\phi = [Z, D_\phi] \\
\widehat{F}_r &= D'_\phi \widehat{Q}_{\mu,r} W_\phi
\end{aligned}
$$

where $\widehat{G}_r$ is assumed to be non-singular. D_μ denotes the dummy design matrix for the country-pair effects, while D_ϕ comprises the dummies for the multilateral resistance terms. V is a diagonal matrix with ones for observed trade flows and zero for missing ones.

CPPMLE formally II

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Given the results of iteration step r, step $r+1$ proceeds with the following calculations:

1. $$\widehat{\phi}_{r+1} = \widehat{\phi}_r + \left(\widehat{G}_r^{-1} - \widehat{G}_r^{-1} \widehat{F}_r' \left(\widehat{F}_r \widehat{G}_r^{-1} \widehat{F}_r' \right)^{-1} \widehat{F}_r \widehat{G}_r^{-1} \right) W_\phi' V (s - \widehat{m}_r)$$
   $$+ \widehat{G}_r^{-1} \widehat{F}_r' \left(\widehat{F}_r \widehat{G}_r \widehat{F}_r' \right)^{-1} \left[\theta_C - D_\phi' \widehat{m}_r \right]$$
   $$\widehat{m}_{ijt,\phi,r+1} = e^{z_{ijt}' \widehat{\alpha}_{r+1} + \beta_{it}(\widehat{\alpha}_{r+1}, \widehat{\mu}_r) + \gamma_{jt}(\widehat{\alpha}_{r+1}, \widehat{\mu}_r)}$$
2. $$\widehat{\mu}_{r+1} = \ln \left(\left(diag(D_\mu' V \widehat{m}_{\phi,r+1}) \right)^{-1} \theta_\mu \right)$$
   $$\widehat{m}_{ijt,\mu,r+1} = e^{\widehat{\mu}_{ij,r+1}}$$
3. $$\widehat{m}_{ijt,r+1} = \widehat{m}_{ijt,\phi,r+1} \widehat{m}_{ijt,\mu,r+1}$$
4. Iterate until convergence of $\widehat{\phi}_r$ and $\widehat{\mu}_r$.

Step 2 of the procedure shows that the country-pair fixed effects (μ_{ij}) are fully determined by the country-pair means of the bilateral trade flows θ_μ and the other structural parameters and do not need to be estimated explicitly. Hence, the inference is conditional on θ_μ.

Country coverage

Albania, Australia, Austria, Brazil, Bulgaria, Canada, China, Colombia, Costa Rica, Cyprus, Czech Republic, Denmark, Egypt, Estonia, Ethiopia, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Kazakstan, Kenya, Korea, Kyrgyzstan, Latvia, Lithuania, Macedonia, Malawi, Malaysia, Mauritius, Mexico, Moldova, Morocco, Netherlands, New Zealand, Norway, Panama, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Tanzania, Turkey, Ukraine, United kingdom, United States of America and Uruguay.

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