

# Trade and foreign direct investment-related impacts of Brexit

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## 1 | INTRODUCTION

The potential impact of Brexit has attracted much attention since the referendum in 2016. UK's departure from the EU was due in March 2019, two years after invoking article 50 of the Lisbon Treaty. However, the UK's Parliament has rejected the Withdrawal Agreement negotiated by the then-prime minister of UK Theresa May, who has ended up resigning. As a result, much uncertainty still surrounds what the future relationship between the UK and the EU will be. With this background, we address the following questions in this paper: Which side (UK or EU) will be more harmed? Will the UK or EU be able to recover much of its lost trade after Brexit in other regions of the world? Who wins in that trade with third nations? What is the role of UK and European multinationals as well as multinationals in UK and EU?

Modelling a disintegration process constitutes a rather uncommon analysis.<sup>1</sup> However, the economic effects of Brexit have been broadly studied and reviewed (e.g. Busch & Matthes, 2016; Chang, 2018; Fernández-Pacheco, Lopez, & Latorre, 2018; and Latorre, Olekseyuk, Yonezawa, & Robinson, 2019). The consensus is that it will generate an asymmetric negative outcome in which UK will lose more than

<sup>1</sup>As the last decades are characterised by the deepening of economic integration and the fall in barriers to trade and FDI, studies tend to investigate integration processes (e.g. Latorre et al., 2018; Ortiz and Latorre, 2017; Latorre and Yonezawa, 2018). Some scarce exceptions, however, can be found in the analysis of disinvestments (Gómez-Plana and Latorre, 2014), of FDI decreases during the crisis (Latorre and Hosoe, 2016) and of Crimea's annexation from Ukraine (Olekseyuk and Schuerenberg-Frosch, 2018).

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the Rest of the European Union (REU, henceforth). This paper analyses the impact of two dimensions of Brexit, namely trade and foreign direct investment (FDI). It aims at quantifying its effects on a sectoral and aggregate level for several regions, with a focus on potential effects on foreign multinationals in services and productivity impacts in manufacturing. We use a numerical simulation model with 21 sectors, 11 regions and 4 factors of production, which incorporates a Melitz (2003) structure in manufactures and foreign multinationals operating under imperfect competition in services. This combination has not been previously attained in a multiregional framework, to the best of our knowledge.

Our analysis provides original estimations of Brexit impact and contributes to the literature along three broad fronts. First, with respect to the mainstream analysis in international economics (e.g. Costinot & Rodríguez-Clare, 2014), we incorporate more simultaneous features of real economies. These include multiple sectors, regions and factors of production; trade imbalances; intermediates with demand structures reflecting actual data; sector-specific tariffs as well as nontariff barriers (NTBs) to trade and FDI; multinationals operating in services' sectors; and a competitive selection of heterogeneous manufacturing firms.

Second, modelling productivity differences across firms within sectors and firms' selection to bilateral markets is an appropriate approach accounting for the features of real economies (e.g. Bernard, Jensen, Redding, & Schott, 2007). Most of the previous studies on Brexit neglect this point by applying an Armington perfect competition setting (e.g. Aichele & Felbermayr, 2015; Ciuriak et al., 2015; Dhingra et al., 2017; Ottaviano, Pessoa, Sampson, & Reenen, 2014). Since the debated equivalence of welfare impacts of trade among Armington and Melitz structures suggested by Arkolakis, Costinot, and Rodríguez-Clare (2012) holds only in a very restrictive setting (see, e.g. Akgul, 2017; Balistreri & Tarr, 2017; Costinot & Rodríguez-Clare, 2014), most of the analyses of Brexit with the Armington setting could be considered as a lower bound impact.

Third, we additionally incorporate multinationals in services into the path-breaking numerical simulation model of Balistreri, Hillberry, and Rutherford (2011) with the full Melitz structure in several sectors. Given the particularly intense specialisation of UK economy in services, such as finance, insurance, telecommunications and business services, an analysis of mode 3 provision of services (i.e. through foreign affiliates sales) is of high relevance. Moreover, our sensitivity analysis illustrates that dropping the FDI barriers and monopolistic competition among heterogeneous firms (i.e. similar setting to Ottaviano et al., 2014 and Dhingra et al., 2017) would generate an underestimated Brexit impact by approximately 50%.<sup>2</sup>

Our results suggest that the UK experiences much more sizeable losses in its welfare, foreign trade, production, average industry productivity, wages and capital remuneration than the REU does. A hard Brexit (i.e. reversion to WTO rules) would reduce welfare in the UK by  $-3.17\%$  (in REU by  $-0.59\%$ ), while the impact of a soft Brexit (e.g. a post-Brexit arrangement similar to Norway) would be about a half of the negative impact of the hard one in both regions. We also observe higher welfare losses along the extensive margin for the UK illustrating the fact that the UK loses many imported varieties (produced by highly productive European firms) with low prices and high quantities, while the new domestic varieties are produced by firms with lower productivity and therefore at high prices and small quantities. Indeed, the results for average productivity of domestic firms in the UK confirm this with a decline by up to  $-2.27\%$  in several manufacturing sectors such as textiles, chemicals, motor vehicles and electronics. Thus, less productive firms enter the British market due to increased protectionism and reduced import competition. Moreover, our

<sup>2</sup>While the magnitude of Brexit impact quantified by Ottaviano et al. (2014) and Dhingra et al. (2017) is comparable with our results, note that their policy assumptions of Brexit are different from ours. Specifically, they incorporate missed future opportunities of further EU integration, which generates the lion's share of losses accounting for more than half of the total effect. In contrast, we incorporate the FDI barriers, which lead to one third of the welfare loss.

inclusion of FDI in services also constitutes an extra source for losses since an increase in FDI barriers explains approximately one third of the overall fall in GDP, welfare and wages in the UK and REU. Concerning outsiders (i.e. the United States, China, India, Japan, other advanced economies, South-East Asia, Latin America, Middle East and sub-Saharan Africa), the impact is negligible at the aggregate level.<sup>3</sup>

Our study has the following structure. In Section 2, we provide an overview of the production and trade structure of the REU and UK. In Section 3, we explain the model structure and scenarios. In Section 4, we analyse sectoral and aggregate outcomes, while Section 5 offers a sensitivity analysis for our results. Main conclusions are presented in Section 6. The algebraic description of the model is offered in online Appendix S1.

## 2 | TRADE AND PRODUCTION STRUCTURE OF THE UK AND THE REST OF THE EUROPEAN UNION (REU)

Tables 1 and 2 offer data on capital and labour intensity, value added, as well as several indicators related to exports and imports for the REU and UK, respectively. The information is available for the 21 sectors included in the model.<sup>4</sup> The bottom rows of the table also show some summarising aggregates for manufacturing, services and all the sectors.

The information refers to 2020, which is the base year in our modelling application.<sup>5</sup> The first two columns present information on capital and labour intensity across sectors. In particular, we offer each sector's share of labour and capital remuneration in total costs.<sup>6</sup> The structure of value added (i.e. the shares of all the sectors in total value added of the economy) appears in the third column. The next columns display the weight of each sector in aggregate exports and imports and the shares of each of the Brexit partners (i.e. the UK and REU) in exports and imports of the other partner. In the case of REU, we also present the share of intra-EU imports and exports in separate columns, given its importance for trade within the REU.

We can see that in the REU and in UK services' sectors are more labour intensive and tend to generate a larger share of value added per unit of production than manufactures (i.e. the sum of labour and capital remuneration shares in total costs is larger in services than in manufactures). 31.4% and 36.7% of total costs in services' sectors go to labour remuneration in the REU and in UK, respectively. On the other hand, the services' specialisation of the UK is more intense than the one in the REU. Their respective shares in total value added are of 75.9% versus 67.2%. However, looking at the next columns, we see that contrasting with the structure of value added the bulk of trade is concentrated in manufacturing. This reflects a global tendency, which has been analysed in detail in Latorre and Yonezawa (2018) and Latorre, Yonezawa, and Zhou (2018).

<sup>3</sup>Our negative results are lower than the ones obtained in macroeconomic models that include uncertainty (e.g. HM Treasury, 2016a,2016b; OECD 2016). See Latorre et al. (2019) and Fernández-Pacheco et al. (2018) for a comprehensive comparison of Brexit studies including ours.

<sup>4</sup>Table A1 presents sectors' description and their mapping between different sectoral classifications.

<sup>5</sup>We update the initial data for 2011, which is the latest version available of the database GTAP 9 (Aguiar et al., 2016), using IMF (2016) projections. See Section 3 for details.

<sup>6</sup>The total costs of production include expenses not only for labour and capital, but also for intermediate inputs, for land in agriculture and for natural resources in agriculture and other primary goods. Therefore, reported labour and capital shares in Tables 1 and 2 represent just a part of total costs.

**TABLE 1** Trade and GDP structure of the Rest of the European Union in 2020 (in percentage)

Sectors	% Share in total costs of remuneration of		% Shares in total			% Share going to (coming from) UK		% Share of Intra-EU trade		
	Labor	Capital	Value added	Exports	Imports	In exports	In imports	In exports	In imports	
CRTS sectors	Agriculture	31.9	13.2	2.8	1.4	2.4	6.4	2.4	65.3	55.8
	Other primary	17.9	20.5	0.7	1.0	17.1	12.4	3.4	38.8	4.0
	Wood and paper	21.1	14.5	2.3	3.2	1.7	7.1	3.4	59.3	75.1
	Personal services	30.3	26.9	3.4	1.4	1.2	7.4	7.2	43.5	50.6
	Other services	33.1	24.7	39.3	7.9	6.9	5.2	3.2	43.0	48.9
IRTS sectors with Melitz structure	Food	15.4	14.6	3.3	5.0	3.1	9.5	5.0	59.1	72.5
	Textiles	21.5	10.7	1.2	2.7	5.9	6.3	2.6	58.9	42.6
	Chemicals	11.7	10.1	3.7	17.7	15.3	5.9	6.3	52.5	58.9
	Metals	21.1	11.0	3.0	6.8	5.5	5.5	3.8	58.6	66.1
	Motor vehicles	15.4	6.9	1.7	9.8	3.3	8.7	5.4	53.3	79.0
	Other transport	19.3	6.3	0.6	3.4	2.9	5.0	6.0	37.4	44.5
	Electronics	15.6	11.5	0.8	3.5	7.2	7.6	3.8	52.4	37.4
	Other machinery	24.2	10.2	4.4	19.2	10.3	4.6	4.0	42.0	60.1
	Other manufactures	22.3	13.4	1.7	2.7	2.4	6.2	4.1	47.9	53.0
	Construction	24.1	18.3	6.7	1.3	0.7	1.5	2.5	31.5	48.0
IRTS services with multinationas	Water transport	6.5	6.0	0.4	1.1	0.8	4.5	3.4	34.4	46.3
	Air transport	11.8	3.0	0.4	2.7	2.0	9.3	7.6	28.1	38.0
	Communications	29.1	15.5	2.7	0.5	0.8	9.5	11.1	43.7	43.6
	Finance	32.6	12.9	4.1	0.9	2.4	8.0	16.4	47.7	36.0
	Insurance	25.2	7.3	1.2	1.0	0.4	2.6	9.8	20.8	43.5
Business services	30.7	16.5	15.7	6.8	7.6	4.7	12.7	42.2	43.0	
Aggre-gates	Total manufacturing	19.0	12.3	30.0	76.3	75.5	6.4	4.6	51.1	54.2
	Total services	31.4	21.2	67.2	22.3	22.1	5.8	8.7	40.3	44.5
	Total	25.7	17.0	100.0	100.0	100.0	6.3	5.3	49.2	52.3

*Note:* Table A1 presents sectors' description and their mapping between different sectoral classifications. The share of intra-EU trade excludes trade with the UK.

*Source:* Authors' estimations based on Aguiar et al. (2016) and in IMF (2016) for the projections.

Table 2 shows that the REU is a crucial trade partner for UK. 46.9% and 48.4% of UK's aggregate exports and imports, respectively, take place with the REU. This dependency is of much relevance in general across all the sectors. The UK, by contrast, explains only around 6.3% (of exports) or 5.3% (of imports) of REU trade, once intra-EU trade has been taken into account (see Table 1). The bulk of REU trade within the EU-27 is very high with 49.2% and 52.3% of its total exports and imports, respectively. However, intra-REU trade is more important for manufactures than for services. Similarly, the UK is more integrated in services than in manufactures with third nations. In other words, within the former EU-28 trade integration was stronger in manufacturing than in services.

**TABLE 2** Trade and GDP structure of the UK in 2020 (in percentage)

Sectors		% Share in total costs of remuneration of		% Shares in total			% Share going to (coming from) REU	
		Labor	Capital	Value added	Exports	Imports	In exports	In imports
CRTS sectors	Agriculture	30.4	9.8	1.1	0.8	2.1	71.3	48.7
	Other primary	7.0	44.2	2.1	3.8	7.0	68.0	11.4
	Wood and paper	31.2	12.4	2.0	2.1	3.5	48.7	62.0
	Personal services	32.4	21.0	3.3	1.7	1.5	44.4	46.6
	Other services	39.3	21.7	46.6	5.5	6.3	33.4	43.9
IRTS sectors with Melitz structure	Food	23.3	13.0	2.7	4.1	6.1	57.9	74.7
	Textiles	36.2	9.2	0.9	1.8	5.4	62.3	30.3
	Chemicals	17.3	6.7	2.5	18.2	14.8	55.1	57.9
	Metals	27.0	5.6	1.5	6.5	9.9	40.1	35.2
	Motor vehicles	21.8	4.5	1.0	7.7	8.4	47.8	84.3
	Other transport	27.3	8.6	0.9	4.1	2.9	32.7	36.6
	Electronics	22.2	11.9	0.5	3.1	5.2	58.5	41.5
	Other machinery	29.8	10.0	2.6	12.3	10.7	35.6	54.7
	Other manufactures	26.6	12.1	1.2	2.3	3.3	38.0	36.9
	Construction	22.1	18.2	5.2	0.4	0.3	34.0	37.6
IRTS services with multinationas	Water transport	23.8	3.2	0.5	0.5	0.6	42.0	56.7
	Air transport	12.7	4.7	0.4	3.0	2.7	34.4	51.2
	Communications	38.1	14.0	3.5	0.7	1.0	72.9	50.0
	Finance	21.2	6.6	4.3	5.8	2.2	44.2	37.0
	Insurance	20.5	4.6	1.6	1.5	0.3	16.9	52.6
	Business services	39.3	12.7	15.6	14.0	5.7	50.7	35.3
Aggre-gates	Total manufacturing	23.4	12.4	23.0	66.4	77.5	48.2	49.9
	Total services	36.7	17.8	75.9	32.8	20.4	43.7	42.7
	Total	32.1	15.9	100.0	100.0	100.0	46.9	48.4

Note: Table A1 presents sectors' description and their mapping between different sectoral classifications.

Source: Authors' estimations based on Aguiar et al. (2016) and in IMF (2016) for the projections.

### 3 | MODEL AND SIMULATIONS

This study applies an original multiregion, multisector and multifactor general-equilibrium numerical simulation model to evaluate the impact of Brexit.<sup>7</sup> One of the innovations is that our model is among the few numerical models incorporating the operations of foreign multinationals (Tarr, 2013; Latorre, 2009) in advanced services' sectors.<sup>8</sup> The impact of FDI varies depending on the services' sector to which they accrue, which is in accordance with the fact that the effects of multinationals vary across sectors (Latorre, 2012, 2013; Zhou & Latorre, 2014a, 2014b). Data on the sales of foreign

<sup>7</sup>The complete algebraic description of the model can be found in the Appendix S1.

<sup>8</sup>The advanced services' sectors include water transport, air transport, communication, finance, insurance and business services.



multinationals across different regions and services stem from the US International Trade Commission Database (Fukui & Lakatos, 2012).<sup>9</sup>

Moreover, we apply a competitive selection model of heterogeneous firms consistent with Melitz (2003) in manufactures and construction.<sup>10</sup> Simultaneously, services' sectors with multinationals operate under monopolistic competition à la Krugman (1980) which, therefore, implies firm-level product differentiation of symmetric varieties. The rest of sectors in the model exhibit a climate of perfect competition and constant returns to scale.

Our model is innovative as it applies Melitz structure to more than one manufacturing sector and jointly allows for the presence of multinational firms supplying business services in the host country. While each of the aforementioned characteristics is already included in previous studies, their combination has not been previously implemented, to the best of our knowledge.

Let us put these characteristics in perspective with other numerical models. Several models include a Melitz structure but it tends to be constrained to one sector only (e.g. Akgul, Hertel, & Villoria, 2016; Dixon, Jerie, & Rimmer, 2016; Oyamada, Nabeshima, & Michida, 2015), while in the present paper we include it in ten manufacturing sectors. Others include Melitz structure in several sectors of their models (Hosoe, 2018; Petri & Plummer, 2016; Petri, Plummer, & Zhai, 2012). Petri and Plummer (2016) and Petri et al. (2012) omit firms' entry and exit in their approach.<sup>11</sup> That is a crucial feature in a Melitz setting, which is included in our model. In this sense, the present model follows the path-breaking approach of introducing Melitz in a numerical model by Balistreri et al. (2011) to which we add the presence of foreign multinationals in services. In contrast to other models that include multinationals, which are scarce, our specification incorporates imperfect competition, which seems to be more appropriate for sectors where multinationals operate. Some models, reviewed by Tarr (2013) and Latorre (2009), adopt a Dixit–Stiglitz monopolistic competition framework only in manufactures (e.g. Balistreri, Tarr, & Yonezawa, 2015).<sup>12</sup> In contrast, the present model extends monopolistic competition to business services following Latorre and Yonezawa (2018) and Latorre et al. (2018), while additionally incorporating Melitz structure in manufacturing. Thus, our present model is closer to the one of Olekseyuk (2016), who already had Melitz in manufacturing with imperfect competition and multinationals in services, but multinationals with imperfect competition were modelled only in one of the regions of the multiregional setting. In our model, FDI and multinationals are present in all considered regions. The present study can be also considered as an extension of the work by Olekseyuk and Balistreri (2018), who run Melitz, Krugman and Armington version of the model in a multiregional and multisector setting, but do not include the operations of multinationals in services.

The initial database for the majority of micro and macroeconomic variables, as well as the input–output data of the model, comes from the latest version of the GTAP Database

<sup>9</sup>We include FDI only in advanced services' sectors due to the data availability of NTBs for the operations of multinationals.

<sup>10</sup>We model a Melitz structure in manufacturing sectors with the share of intraindustry trade over 60% of total trade following Olekseyuk and Balistreri (2018). This is the case for food, textiles, chemicals, metals, motor vehicles, other transport, electronics, other machinery, other manufactures and construction; that is, all manufacturing sectors except for wood and paper as well as other primary products. This matches the idea that a climate of monopolistic competition is related to trade in different varieties of the same product. Also, note that since the important parameter of Melitz structure (namely the shape parameter of Pareto distribution) is estimated for manufacturing sectors in Balistreri et al. (2011), we do not apply this structure to service sectors.

<sup>11</sup>To be more precise, there is no firm entry or exit in Melitz sectors in the studies of Petri & Plummer (2016) and Petri et al. (2012). Therefore, the total number of firms is exogenous and fixed. However, Melitz sectors still exhibit endogenous firm selection into bilateral markets.

<sup>12</sup>Balistreri et al. (2015), in turn, are the first to develop a multiregional numerical simulation model in a literature of 'FDI in services', which had been previously constrained to single country models (e.g. Latorre, 2016).

(GTAP 9, Aguiar, Narayanan, & McDougall, 2016). Our model includes 11 regions, 21 sectors<sup>13</sup> and four types of production factors, namely land, capital, labour and natural resources.<sup>14</sup> GTAP 9 resembles the world economy in 2011, and we conduct the forward calibration using IMF (2016) GDP projections for 2020 (following the technique described in Böhringer, Löschel, Moslener, & Rutherford, 2009). This year seems to be a reasonable benchmark for estimation of the initial impact of Brexit. Therefore, it will be our reference year for the simulations.

To quantify the impact of Brexit, we simulate two different scenarios: hard and soft Brexit (following Ottaviano et al., 2014; Dhingra et al., 2017 and Chang, 2018). In the case of hard Brexit (i.e. a "no deal" reversion to WTO rules), we increase import tariffs between the REU and UK to the trade weighted average MFN level calculated using the external tariff rates of the REU and UK's bilateral trade flows with the rest of the EU. Moreover, the UK and REU will face an increase in their respective bilateral NTBs equivalent to 50% of NTBs that the United States faces on EU markets.<sup>15</sup> We also assume an increase in existent FDI barriers between the UK and REU by 50%. In the case of soft Brexit (i.e. a post-Brexit arrangement similar to the one that Norway has with the EU, in line with UK's current proposal), we remain zero import tariffs, but increase the NTBs and FDI barriers by 25%.<sup>16</sup>

The scenarios seem to be a good choice to illustrate the potential outcomes of Brexit given no significant progress in the negotiations between the REU and UK. The MFN treatment is a possible scenario if the REU and UK are not able to negotiate a trade deal. It also represents the worst scenario for the Brexit partners. However, it seems reasonable that the UK will get an agreement with low tariffs or even a comprehensive free trade agreement with the EU, which could be closer to the soft Brexit or to the NTBs' components of the hard Brexit scenario.

For calculation of the potential tariff rates between the REU and UK, we use the external applied MFN tariffs of the EU from TRAINS for 2015 as well as trade flows for 2014. As the raw data are available on a disaggregated level only, we applied several correspondence tables from WITS to calculate both:

1. trade-weighted MFN tariff rates that the UK might apply against the EU (weighted with UK's imports from the EU); and
2. trade-weighted MFN tariff rates that the EU might apply against the UK (weighted with UK's exports to the EU).

<sup>13</sup>Recall that Table A1 presents description of sectors and their mapping between different sectoral classifications. Table A2 offers the regional composition.

<sup>14</sup>As commonly done in the literature, we model natural resources as a fixed factor of production in agriculture and other primary sector, which includes the extraction of coal, crude oil and natural gas. Land is also a fixed production factor in agriculture. Therefore, the output change as such is, to some extent, limited.

<sup>15</sup>The NTBs to trade stem from Ecorys (2009) who additionally estimated the share of rents and efficiency losses that were behind the NTBs between Europe and the United States. On average, 60% of the costs of the NTBs were found to be efficiency losses, while 40% would create rents. Additionally, they calculated that 2/3 of the rents were earned by importers and 1/3 by exporters. The 60% of efficiency losses are modelled as iceberg costs, using a common approach. Ecorys (2009) did not provide the barriers for 'Agriculture', 'Other manufacturing' and 'Other services'. For those sectors, we take the estimations used by Latorre and Yonezawa (2018).

<sup>16</sup>The UK faces less barriers (and, therefore, costs) in the European markets than the United States does. Therefore, we increase UK-REU barriers by a fraction of the total barrier. It is hard to know the percentage costs, so we follow the approach of Ottaviano et al. (2014) and Dhingra et al. (2017).

**TABLE 3** Cost increases due to MFN tariffs, NTBs to trade and NTBs to FDI that the Brexit would imply

Sectors		MFN tariffs		NTBs to trade		NTBs to FDI			
		Hard Brexit		Soft Brexit	Hard Brexit	Soft Brexit		Hard Brexit	
		In REU	In UK	In REU and UK	In REU and UK	In REU	In UK	In REU	In UK
CRTS sectors	Agriculture	10.2	10.8	14.2	28.4				
	Other primary	0.0	0.1	14.2	28.4				
	Wood and paper	0.5	1.0	2.8	5.7				
	Personal services			1.1	2.2				
	Other services			1.1	2.2				
IRTS sectors with Melitz structure	Food	19.8	22.0	14.2	28.4				
	Textiles	10.0	9.5	4.8	9.6				
	Chemicals	2.8	2.7	3.4	6.8				
	Metals	1.9	2.0	3.0	6.0				
	Motor vehicles	8.0	8.8	6.4	12.8				
	Other transport	1.7	1.6	4.7	9.4				
	Electronics	0.9	1.5	3.2	6.4				
	Other machinery	1.7	1.8	0.0	0.0				
	Other manufactures	2.6	2.2	2.8	5.7				
	Construction			1.2	2.3				
IRTS services with multinationas	Water transport			2.0	4.0	2.8	0.0	5.6	0.0
	Air transport			0.5	1.0	4.6	4.7	9.1	9.3
	Communications			2.9	5.9	0.2	0.2	0.5	0.4
	Finance			2.8	5.7	0.5	0.6	0.9	1.1
	Insurance			2.7	5.4	2.7	2.8	5.5	5.6
	Business services			3.7	7.5	7.9	4.8	15.8	9.7

Note: See note in Table 2.

Source: for the NTBs Ecorys (2009), Latorre and Yonezawa (2018) and Latorre et al. (2018); TRAINS and WITS for tariffs and Jafari and Tarr (2017) and Koske et al. (2015) for barriers to FDI.

Our calculations of FDI barriers between the UK and REU are based on the product market regulation (PMR) indicators derived by the OECD (Koske, Wanner, Bitetti, & Barbiero, 2015). They are appropriate to deal with the EU internal market (ECSIP Consortium, 2014) and should be a good indicator to capture the differences among EU regulations.<sup>17</sup> Due to the common market, we cannot think of a more integrated region comprising different countries as the EU. However, it is also true that particularly in services, foreign multinationals from other EU countries do face barriers in their operations within the EU (Monteagudo, Rutkowski, & Lorenzani, 2012; Mustilli & Pelkmans, 2013). Indeed, Jafari and Tarr (2017) provide different barriers to FDI in services across European countries. Therefore, we take outward sales of UK

<sup>17</sup>The OECD PMR Indicators represent a comprehensive and internationally comparable set of indicators that measure the degree to which policies promote or inhibit competition. We work with the recently updated 'trade and investment indicator' since there is no estimation separating trade versus FDI.

multinationals in different EU countries and use them as weights to derive the total FDI barrier in the EU in each services' sector.<sup>18</sup>

Table 3 shows the increases in trade costs related to the barriers that will emerge between the EU and UK after Brexit. The first two columns show the resulting MFN tariffs that we model as an element of the hard Brexit. The next two columns present the NTBs related to trade and the final four columns the NTBs related to FDI in services. For both types of NTBs, we have a soft and hard version with the above mentioned 25% and 50% shares of the total values of the NTBs, respectively.

Table 3 shows that barriers are heterogeneous across sectors. With respect to trade barriers, they tend to be larger in agriculture, other primary (although only in the case of NTBs since tariffs are nearly zero), food, textiles, motor vehicles and other transport. For barriers to FDI, they tend to be particularly high in business services and to a lesser extent in air transport. These sectors with high barriers are likely to be the most affected by Brexit.

Our modelling strategy consists of introducing what at first sight could be considered as rather high barriers related to trade and FDI.<sup>19</sup> We do this on purpose for two reasons: first, in order to provide an upper bound (or strongest impact) that Brexit could imply for both the REU and UK, and second, to better grasp whether Brexit could have any effects for outsiders. In any case, it is important to note, that after the initial assessment of barriers made by Ecorys (2009), Egger, Francois, Manchin, and Nelson (2015) have updated the estimations including even larger barriers to trade than the ones applied here, which tends to magnify the impact of the shock analysed.

## 4 | RESULTS

### 4.1 | Microeconomic impact

#### 4.1.1 | Bilateral trade within the Brexit block, intra-REU trade and trade with third nations

The direct impact of the emergence of trade and FDI barriers caused by Brexit will occur for bilateral trade flows between the UK and REU (Rest of the European Union). This shock will be later spread to trade flows with other regions. Table 4 displays three blocks of results: (a) trade within the Brexit block where we consider both REU imports from the UK (or UK exports to REU) and REU exports to the UK (or UK imports from the REU); (b) trade of the Brexit block with third nations where we show the results of the REU and UK joint exports to the ROW (Rest of the World) and their joint imports from the ROW; and (c) intra-REU trade which presents imports or exports within the EU-27. We illustrate the impact of the soft and hard Brexit for all the sectors of the model as well as for the selected aggregates.

<sup>18</sup>We first take the FDI barriers as provided by Jafari and Tarr (2017). They provide estimations for 20 countries (instead of 28). Since the UK is one of the 20 countries, we use the estimates of the other 19 to proxy the FDI barriers for the REU. Second, we weight each country's barrier with the share of outward sales of UK multinationals in that country in overall UK outward sales going to the REU (using Eurostat, 2016 data). The FDI barrier that UK multinationals face is high (small) in sectors with large UK sales in the EU countries with tight (flexible) regulations.

<sup>19</sup>UK is currently in compliance with the EU regulations, so most of the barriers will tend to grow as time passes by and regulations drift apart. However, depending on the type of trade relationship stemming from the negotiations, controls on the borders and other delays may arise automatically when Brexit is applied.

**TABLE 4** Impact on bilateral trade within the Brexit block, trade with third nations and intra-REU trade (% changes with respect to the initial data)

Sectors	Trade within the Brexit block						Trade of the Brexit block with third nations					
	REU imports from UK			REU exports to UK			REU&UK joint exports to ROW			REU&UK joint imports from ROW		
	UK exports to REU		UK imports from REU	UK exports to REU		UK imports from REU	REU&UK joint exports to ROW		REU&UK joint imports from ROW	REU&UK joint imports from ROW		
	Soft	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft	Hard
CRTS sectors	Agriculture	-43.68	-79.43	-32.95	-70.20	0.66	1.61	1.93	4.12	0.57	1.06	
	Other primary	-66.21	-90.16	-74.11	-93.20	12.57	18.17	1.28	1.60	5.00	6.84	
	Wood and paper	-13.55	-28.73	-9.81	-21.44	0.56	1.37	0.62	1.38	0.22	0.54	
	Personal services	-2.94	-7.04	-3.57	-6.34	0.45	1.01	-0.51	-1.17	0.03	0.14	
	Other services	-2.88	-7.04	-3.76	-6.64	0.48	1.12	-0.52	-1.21	0.00	0.07	
	Food	-53.76	-92.48	-43.81	-88.92	0.82	1.95	1.09	2.58	0.34	0.51	
IRTS sectors with Meltiz structure	Textiles	-21.24	-65.03	-20.22	-61.13	0.67	1.81	-0.18	0.07	0.19	0.73	
	Chemicals	-14.83	-39.19	-13.85	-34.63	0.25	0.58	0.52	1.48	0.39	1.11	
	Metals	-14.22	-35.03	-11.83	-29.37	0.43	1.06	0.44	1.23	0.22	0.53	
	Motor vehicles	-28.90	-67.83	-15.45	-48.25	-0.05	0.10	2.80	9.28	0.70	1.48	
	Other transport	-20.68	-43.29	-19.33	-40.31	0.30	0.64	0.75	1.54	0.66	1.50	
	Electronics	-14.97	-32.23	-11.66	-26.99	0.31	0.84	0.56	1.23	0.43	1.06	
	Other machinery	-0.10	-11.01	-0.40	-7.83	0.23	0.65	-0.36	-0.39	-0.01	0.22	
	Other manufactures	-13.20	-36.59	-13.22	-32.18	0.53	1.23	-0.39	-0.62	0.05	0.21	
	Construction	-5.08	-11.76	-7.33	-12.50	0.66	1.62	-0.76	-1.84	-0.05	-0.10	
	Water transport	-5.07	-11.06	-4.48	-8.25	0.09	0.27	-0.16	-0.44	-0.08	-0.17	
	Air transport	-2.40	-5.91	-0.46	3.29	-0.02	0.00	0.24	1.15	0.18	0.31	
	Communications	-4.62	-9.79	-6.90	-12.54	0.06	0.17	-0.47	-1.05	-0.09	-0.22	
IRTS services with multinationas	Finance	-6.88	-14.40	-7.05	-12.83	-0.17	-0.65	-0.43	-0.99	-0.06	-0.15	
	Insurance	-5.58	-13.33	-7.14	-13.95	0.05	0.13	0.08	0.26	0.35	0.96	
	Business services	-8.72	-17.91	-9.46	-17.70	0.39	0.79	-0.05	-0.30	0.29	0.53	
	Total manufacturing	-21.77	-46.52	-16.72	-40.17	0.49	1.05	0.59	1.31	0.35	0.85	
	Total services	-6.62	-13.97	-5.27	-9.01	0.28	0.60	-0.26	-0.61	0.11	0.23	
	Total	-17.15	-36.44	-14.91	-34.94	0.43	0.94	0.43	0.95	0.32	0.75	

Source: Authors' estimations.

**TABLE 5** Estimations for the capacity to recover in other markets the lost trade within the Brexit block (% changes with respect to the initial data)

	% of REU exports to the UK which is recovered				% of UK exports to REU which is	
	With REU exports to the rest of partners		With intra-REU exports		Recovered: with UK exports to third nations	
	Soft	Hard	Soft	Hard	Soft	Hard
All manufactures	31.5	33.9	16.8	16.9	7.7	2.8
All services	68.0	106.9	14.0	17.5	3.2	-6.6
Total	33.7	37.1	16.7	16.8	6.9	1.6

Source: Authors' estimations.

The reductions of trade flows between the UK and REU are pervasive.<sup>20</sup> The patterns of sectoral adjustments are parallel in percentage changes for exports and imports. This reflects the importance of the depth of the barriers that emerge with Brexit and vary across sectors, as shown in Table 3. The larger the increase in barriers is, the stronger the contraction in trade is. That is why hard Brexit brings about stronger reductions in trade than the soft one, as the aggregate results for all the sectors show. It also explains why contractions of trade in manufactures are larger than in services. Table 3 clearly shows that barriers in services tend to be smaller than the ones in manufactures. As a consequence, trade in services is less affected than trade in manufacturing.

Looking at the Brexit block in detail, REU imports from the UK decrease by  $-21.77\%$  and  $-46.52\%$  for aggregated manufacturing sectors and by  $-6.62\%$  and  $-13.97\%$  for aggregated services in the soft and hard Brexit simulation, respectively. For REU exports to the UK, in manufacturing they fall by  $-16.72\%$  and  $-40.17\%$  in the soft and hard Brexit case, while in services the respective figures are  $-5.27\%$  and  $-9.01\%$ . Overall, aggregate bilateral trade flows would shrink considerably with REU imports diminishing by  $-17.15\%$  or  $-36.44\%$  in the soft and hard Brexit scenario, respectively, while REU exports would decrease by  $-14.91\%$  and  $-34.94\%$ . In general, sectors with the strongest reductions of trade flows are those with the largest barriers such as agriculture, other primary and food products, textiles and motor vehicles. The only sector with increased exports from the REU to UK is air transport in the hard Brexit scenario. Due to high FDI barrier in this sector (over 9%) and low NTB to trade (only 1%), European multinationals will switch from local supply in the UK (FDI case) to cross-border supply, that is export of services.

The results on trade flows with third nations illustrate that after the emergence of trade and FDI barriers between the UK and REU, exporters in both regions lose sales opportunities within the Brexit region and look for new export destinations. In particular, total REU and UK exports to the ROW increase by 0.43% or 0.94% in the soft and hard Brexit simulation, respectively. The overall increase looks rather moderate, although we have to consider that this percentage changes apply to trade flows that are very large in absolute terms. On the sectoral level, other primary goods, food products, textiles and agriculture tend to experience a stronger increase in exports to third nations. These are, in general, the sectors in which exports between the Brexit partners contract the most. Due to a trade diversion effect, exports to third regions in these sectors expand stronger than in the rest. The joint REU and UK imports of manufactures from third nations tend to exhibit a similar pattern as for exports: total

<sup>20</sup>Red-shaded cells indicate reductions.

**TABLE 6** Impact on productivity in Melitz sectors and Feenstra ratio (% changes with respect to the initial data)

Sectors	Domestic productivity				Industry productivity				Feenstra ratio			
	Soft		Hard		Soft		Hard		Soft		Hard	
	REU	UK	REU	UK	REU	UK	REU	UK	REU	UK	REU	UK
Food	-0.21	-1.22	-0.41	-2.12	-0.26	-1.14	-1.10	-2.76	-0.10	-1.74	-0.15	-2.87
Textiles	-0.09	-0.77	-0.28	-2.27	-0.08	-0.72	-0.45	-2.37	-0.08	-0.75	-0.19	-1.47
Chemicals	-0.10	-0.99	-0.24	-2.27	-0.07	-0.92	-0.22	-2.18	-0.08	-0.53	-0.15	-1.26
Metals	-0.05	-0.64	-0.12	-1.59	-0.03	-0.57	-0.12	-1.48	-0.03	-0.28	-0.07	-0.43
Motor vehicles	-0.21	-2.27	-0.62	-2.27	-0.18	-2.08	-0.65	-2.34	-0.14	-2.37	-0.32	-6.46
Other transport	-0.14	-0.92	-0.28	-1.90	-0.10	-0.84	-0.28	-1.83	-0.07	-0.40	-0.13	-0.74
Electronics	-0.11	-1.40	-0.26	-2.27	-0.09	-1.29	-0.24	-2.15	-0.06	-0.51	-0.11	-1.24
Other machinery	0.01	0.06	-0.01	-0.60	0.01	0.04	-0.01	-0.54	-0.02	-0.11	-0.05	-0.19
Other manufactures	-0.03	-0.22	-0.08	-0.67	-0.02	-0.20	-0.09	-0.64	-0.05	-0.40	-0.10	-0.72
Construction	0.00	0.00	0.01	0.00	0.00	-0.04	-0.01	-0.06	-0.01	-0.04	-0.01	-0.08

Source: Authors' estimations.

**TABLE 7** Variety impact: weighted number of firms in services' sectors (% change with respect to the initial data)

Sector	Soft Brexit		Hard Brexit	
	REU	UK	REU	UK
Water transport	-0.16	-0.22	-0.28	-0.86
Air transport	-0.49	-3.83	-0.66	-15.37
Communications	-0.18	-0.64	-0.37	-1.41
Finance	-0.07	-0.82	-0.13	-1.76
Insurance	-0.37	-0.99	-0.85	-2.11
Business services	-0.15	-1.63	-0.30	-3.24

Source: Authors' estimations.

manufacturing imports increase by up to 1.31% in the hard Brexit case. In particular, motor vehicles, food industry, other primary, metals, chemicals, other transport and agriculture extend their imports from the ROW strongly. This evolution largely explains the increase in aggregate imports from the ROW: the soft (hard) Brexit brings an increase of 0.43% (0.95%).

The trend of joint REU and UK services' imports from third nations is somewhat different at first sight: while total manufacturing imports increase, total imports of services decline by up to 0.61% in the hard Brexit case (see Table 4). In the soft Brexit simulation, both the REU and UK experience a small reduction in services imports from third countries by approximately -0.2%. However, in the case of hard Brexit it holds only for the REU: European services' imports decline by -0.79%, while the UK increases its services' imports by 0.38%.<sup>21</sup> Therefore, in the UK we observe increased services' imports from the ROW with higher trade barriers in the hard Brexit case, meaning that there is trade diversion towards third countries in order to satisfy domestic demand for services. In contrast, the

<sup>21</sup>The separate results for trade flows of UK and REU to third countries are not reported in Table 4 due to space limitations.

**TABLE 8** Variety impacts in Melitz sectors (% change with respect to the initial data)

Sectors	British firms supplying REU market	Domestic firms in UK	Raw varieties consumed in UK	European firms supplying UK market	Domestic firms in REU	Raw varieties consumed in REU
Hard Brexit						
Chemicals	-38.08	9.50	6.50	-34.71	0.98	-1.28
Construction	-10.31	-0.15	-2.15	-12.42	-0.02	-1.39
Electronics	-30.97	7.63	7.09	-27.00	1.05	-1.12
Food	-92.63	13.65	17.73	-88.86	1.08	-5.73
Metals	-34.20	7.41	5.16	-29.35	0.55	-1.95
Motor vehicles	-68.08	19.61	36.42	-48.23	1.52	-2.42
Other machinery	-9.80	2.62	1.65	-7.87	0.18	-0.73
Other manufacturing	-35.72	3.15	0.58	-32.14	0.27	-2.35
Other transport	-42.34	7.92	4.27	-40.38	1.37	-1.25
Textiles	-64.37	9.94	4.67	-61.04	0.96	-3.51
Soft Brexit						
Chemicals	-14.28	4.45	2.57	-13.89	0.34	-0.47
Construction	-4.43	-0.08	-1.46	-7.29	-0.01	-0.55
Electronics	-14.34	4.99	3.61	-11.65	0.43	-0.50
Food	-54.11	6.93	7.18	-43.67	0.59	-3.05
Metals	-13.84	3.06	1.92	-11.82	0.23	-0.75
Motor vehicles	-28.83	10.56	12.32	-15.47	0.68	-0.93
Other machinery	0.32	-0.08	-0.38	-0.41	-0.01	-0.13
Other manufacturing	-12.75	1.26	-0.17	-13.19	0.08	-0.86
Other transport	-20.21	3.89	2.02	-19.36	0.63	-0.59
Textiles	-20.70	3.31	1.15	-20.15	0.29	-1.18

Source: Authors' estimations.

REU is able to replace a part of lost imports via increased intra-REU trade, which is seen in the last two columns of Table 4. Thus, there is no need to increase services' imports from the ROW. Furthermore, European demand for services seems to drop strongly in the hard Brexit scenario, so that the REU do not increase services' imports from the ROW. This is consistent with the overall result for the REU that even with reduced domestic output and total imports, exports of services are slightly increased.

Intra-EU trade reflects similar patterns as trade with third nations. After experiencing the emergence of significant barriers with the UK, REU firms will have strong incentives to search for markets or providers within the REU area, where no barriers exist. Therefore, after the soft Brexit intra-REU trade grows by 0.32%, while for the hard Brexit it rises by 0.75%.

#### 4.1.2 | Capacity to recover in other markets the lost trade within the Brexit block, productivity and variety losses

As mentioned in the introduction, we aim at answering the following questions: Will the UK or REU be able to recover much of its lost trade after Brexit in other regions of the world? Who wins in that trade with third nations? Table 5 presents at its left the results for the percentage of REU lost exports to the UK that is recovered via REU exports to the rest of partners and separately via intra-REU

TABLE 9 Impact on sectoral trade and output (% changes with respect to the initial data)

Sectors	Exports						Imports						Output											
	Soft			Hard			Soft			Hard			Soft			Hard								
	REU	UK	REU	UK	REU	UK	REU	UK	REU	UK	REU	UK	REU	UK	REU	UK	REU	UK						
CRTS sectors	Agriculture	-5.47	-31.17	-11.43	-57.17	-2.49	-7.33	-4.96	-14.19	-0.51	-0.55	-1.12	-0.14	-12.40	-31.64	-15.45	-41.53	-8.98	-13.92	-0.45	-6.15	-0.31	-9.07	
	Other primary	-1.30	-5.89	-2.58	-13.43	-2.12	-4.62	-4.73	-9.93	-0.18	-0.54	-0.34	-1.48	-0.13	-0.82	0.10	-2.78	-2.36	-4.64	-0.19	-1.32	-0.39	-2.89	
	Wood and paper	0.02	-0.20	0.41	-1.65	-0.56	-2.38	-1.36	-4.59	-0.17	-1.19	-0.36	-2.58	0.02	-9.20	-33.15	-18.17	-59.21	-10.47	-18.90	-0.62	1.82	-1.38	5.04
	Food	-2.58	-12.78	-7.89	-39.96	-1.35	-5.50	-3.89	-14.84	-0.22	-0.98	-0.57	-3.01	-1.60	-7.62	-3.84	-7.30	-5.27	-17.66	-0.05	-0.86	0.02	-3.57	
	Textiles	-1.18	-5.55	-2.76	-14.48	-1.72	-3.00	-4.36	-7.10	-0.01	-0.38	0.00	-1.47	-2.77	-14.79	-8.63	-34.23	-6.94	-16.55	-0.27	-1.42	-1.35	2.06	
IRTS sectors with Melitz structure	Chemicals	-1.34	-6.31	-2.61	-13.87	-1.81	-5.82	-3.81	-12.29	0.04	-1.00	0.21	-2.79	-1.60	-8.65	-3.50	-19.12	-0.72	-2.86	-0.10	-2.29	-0.12	-5.66	
	Metals	0.19	0.06	0.09	-4.30	-0.19	-0.90	-1.44	-4.72	0.06	-0.22	0.18	-1.50	-1.15	-4.49	-2.62	-13.92	-1.47	-5.29	-0.10	-0.29	-0.15	-1.35	
	Motor vehicles	0.45	-0.75	1.33	-3.21	-0.79	-4.45	-1.99	-7.67	-0.04	-0.76	-0.08	-1.79	-1.15	-4.49	-2.62	-13.92	-1.47	-5.29	-0.10	-0.29	-0.15	-1.35	
	Other transport	-0.23	-2.26	-0.24	-5.57	-0.41	-2.89	-0.94	-5.69	0.03	-0.39	0.16	-1.29	-0.23	-4.93	-2.83	-10.60	-1.23	-4.93	-0.23	-1.41	-0.49	-3.20	
	Electronics	0.07	-1.19	1.05	-3.43	-0.05	-0.01	-0.38	4.56	-0.17	-1.97	-0.11	-7.62	-1.69	-4.93	-2.83	-10.60	-1.23	-4.93	-0.23	-1.41	-0.49	-3.20	
IRTS services with multinationas	Communications	-1.47	-3.59	-2.42	-8.12	-1.97	-3.51	-4.19	-6.65	-0.11	-1.46	-0.24	-3.37	-1.47	-3.59	-2.42	-8.12	-1.97	-3.51	-0.11	-1.46	-0.24	-3.37	
	Finance	-0.06	-1.52	0.28	-3.74	-0.76	-4.07	-1.51	-7.23	-0.12	-1.28	-0.35	-2.96	-0.06	-1.52	0.28	-3.74	-0.76	-4.07	-0.12	-1.28	-0.35	-2.96	
	Insurance	-0.25	-3.83	-0.17	-8.32	-1.76	-3.05	-3.68	-5.88	-0.10	-1.84	-0.24	-4.08	-0.25	-3.83	-0.17	-8.32	-1.76	-3.05	-0.10	-1.84	-0.24	-4.08	
	Business services	-1.87	-9.68	-4.36	-21.77	-1.83	-7.44	-4.19	-17.11	-0.13	-0.67	-0.30	-1.46	-1.87	-9.68	-4.36	-21.77	-1.83	-7.44	-0.13	-0.67	-0.30	-1.46	
	Total manufacturing	-0.18	-2.68	0.07	-6.23	-1.11	-2.54	-2.43	-4.25	-0.15	-1.35	-0.32	-3.02	-0.18	-2.68	0.07	-6.23	-1.11	-2.54	-0.15	-1.35	-0.32	-3.02	
Aggre-gates	-1.54	-7.54	-3.48	-16.94	-1.69	-6.44	-3.82	-14.42	-0.15	-1.11	-0.33	-2.46	-1.54	-7.54	-3.48	-16.94	-1.69	-6.44	-0.15	-1.11	-0.33	-2.46		

Source: Authors' estimations.

exports. Note that trade with the 'rest of partners' includes trade within the REU (i.e. intra-REU trade) and trade with third nations. In the right part of Table 5, we present the results for the percentage of UK lost exports to the REU that is recovered with UK exports to third nations.

Let us begin with the capacity of REU to recover the exports it loses with the UK by conducting more trade with all partners.<sup>22</sup> We can see that the percentages of total trade recovered are approximately one third (33.7% and 37.1% after a soft and hard Brexit, respectively). Around half of the trade recovered is via intra-REU trade, while the other half is via trade with nations outside the Brexit block. In contrast, UK's capacity to recover its lost exports with the REU by trading with other partners is considerably smaller. The UK could recover as much as 6.9% in the soft Brexit scenario and virtually nothing (just 1.6%) in the case of hard Brexit.<sup>23</sup>

Looking at the trade in services, the story is very different for the two Brexit partners. In particular, the REU recovers much of the services' exports lost with the UK by exporting more services to third nations rather than via intra-REU trade expansion. The REU is also more successful in recovering exports in services than in manufacturing. In the UK, the situation is opposite – it is able to recover more trade in manufacturing than in services. Moreover, while in the soft Brexit scenario at least 3.2% of UK exports to the REU can be recovered by increased trade with third countries, there are even further losses in the hard Brexit case.<sup>24</sup> This illustrates that UK's services' sectors will be suffering from Brexit most, which is consistent with the impact on sectoral output in Table 9.

The fact that the REU outperforms the export capacity of the UK is intuitive given that the REU still has access to the huge common market, while the UK has lost that preferential access to the REU. This implies that European exporters should be able to retain important economies of scale after Brexit, while UK exporters should be more harmed. With implemented Melitz structure, we can capture the evolution of (a) average productivity for firms operating in domestic markets (domestic productivity) and (b) industry-wide average productivity which also accounts for firms' exit and entry to/from third markets (see Table 6). The results indicate a reduction in both domestic-wide productivity and industry-wide productivity for the Brexit partners in almost all the sectors.<sup>25</sup> However, the magnitude is much lower in the case of the REU. While the maximal decline of domestic productivity in the REU occurs in motor vehicle sector with  $-0.63\%$  in the hard Brexit scenario, in the UK this value amounts to  $-2.27\%$  in several sectors such as textiles, chemicals, motor vehicles and electronics. This decrease in average productivity indicates entry of less productive firms due to increased protectionism and therefore less import competition. The fall of industry-wide productivity is even more pronounced in the UK with the maximum of  $-2.76\%$  in food processing for the hard Brexit case. Comparing both productivity measures, we see that productivity is generally falling due to domestic entry of less productive firms and not because of exit from export markets, as the domestic firms' productivity decrease is relatively large.

In addition to the negative producer-side impacts of Brexit, there are also negative consumer-side variety effects. Looking at the changes in the weighted average number of varieties in services,

<sup>22</sup>For all the values reflecting the 'capacity to recover lost trade due to Brexit' in Table 5, we take the absolute values of trade with third nations (or intra-EU trade) in the numerator and divide them by the absolute values of trade lost by one of the Brexit partners in trading with the other Brexit partner. Trade between the Brexit partners falls in most of the cases, so we take its absolute value (without the minus).

<sup>23</sup>This result occurs without taking into account possible FTAs between the UK and third countries that might be negotiated and adopted after Brexit.

<sup>24</sup>In this negative case ( $-6.6\%$ ), UK does not increase its exports to other partners as it does in the rest of scenarios. Instead, the UK decreases them, thus, losing not only exports going to the EU but also UK's exports going to third partners.

<sup>25</sup>The only slightly positive changes are observed in other machinery and construction.

TABLE 10 Aggregate results (% changes with respect to the initial data)

Scenario	Soft Brexit										Hard Brexit												
	REU	UK	USA	CHN	JPN	IND	LAC	OAC	SEA	SSA	MEN	REU	UK	USA	CHN	JPN	IND	LAC	OAC	SEA	SSA	MEN	
<b>GDP</b>																							
NTBs	-0.10	-0.82	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.03	-0.18	-1.47	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.03	0.05	0.05
FDI barriers	-0.06	-0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.12	-0.83	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Tariffs	-0.16	-1.23	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.03	-0.35	-2.53	0.01	0.00	0.01	0.02	0.01	0.03	0.02	0.03	0.06	0.06
<b>Welfare</b>																							
NTBs	-0.16	-0.96	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.03	0.07	-0.29	-1.75	0.01	0.00	0.01	0.02	0.01	0.03	0.02	0.05	0.10	0.10
FDI barriers	-0.11	-0.60	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	-0.21	-1.19	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	-0.01
Tariffs	-0.27	-1.56	0.01	0.00	0.01	0.02	0.01	0.02	0.01	0.03	0.06	-0.59	-3.17	0.02	0.01	0.03	0.04	0.02	0.06	0.04	0.06	0.11	0.11
<b>Welfare (in \$billions of 2020)</b>																							
NTBs	-15.616	-18.950	0.580	-0.231	0.157	0.237	0.398	0.915	0.220	0.478	3.179	-29.016	-34.741	1.189	-0.053	0.427	0.409	0.651	1.673	0.432	0.740	4.819	4.819
FDI barriers	-10.585	-11.915	0.476	0.055	0.097	0.121	0.034	0.215	0.042	-0.021	-0.201	-20.309	-23.485	0.986	0.112	0.187	0.242	0.112	0.462	0.127	-0.021	-0.295	-0.295
Tariffs	-26.178	-30.818	1.051	-0.176	0.252	0.357	0.434	1.129	0.263	0.457	2.980	-57.977	-62.701	2.695	0.630	1.091	0.851	0.944	2.760	0.813	0.846	5.144	5.144
<b>Wages</b>																							
NTBs	-0.12	-0.97	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.02	0.01	-0.22	-1.75	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	0.04	0.02	0.02
FDI barriers	-0.05	-0.29	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	-0.09	-0.63	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Tariffs	-0.17	-1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	-0.39	-2.83	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.04	0.02	0.02
<b>Capital remuneration</b>																							
NTBs	-0.14	-0.98	0.00	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	-0.24	-1.76	0.00	-0.02	0.01	0.00	0.00	0.02	0.00	-0.01	0.01	0.01

(Continues)

TABLE 10 (Continued)

Scenario	Hard Brexit																						
	Soft Brexit							Hard Brexit															
GDP	REU	UK	USA	CHN	JPN	IND	LAC	OAC	SEA	SSA	MEN	REU	UK	USA	CHN	JPN	IND	LAC	OAC	SEA	SSA	MEN	
FDI barriers	-0.07	-0.61	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	-0.13	-1.11	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Tariffs	-0.21	-1.59	0.00	-0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.01	-0.43	-0.93	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.01	0.00	0.01
Consumer price index																							
NTBs	-0.08	0.31	0.00	0.00	0.00	0.01	0.01	-0.01	0.01	0.02	0.02	-0.16	0.57	0.00	0.00	0.01	0.01	0.02	-0.01	0.01	0.01	0.03	0.01
FDI barriers	0.02	0.02	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01	-0.01	0.04	0.08	0.00	-0.01	0.00	0.00	-0.01	0.00	-0.01	-0.01	-0.02	-0.02
Tariffs	-0.06	0.33	0.00	-0.01	0.00	0.01	0.01	-0.01	0.00	0.02	0.01	-0.20	0.89	0.00	0.00	0.02	0.01	0.01	-0.01	0.01	0.01	0.01	-0.01
Total	-0.06	0.33	0.00	-0.01	0.00	0.01	0.01	-0.01	0.00	0.02	0.01	-0.20	1.14	0.00	-0.01	0.03	0.02	0.01	-0.02	0.00	0.01	0.01	-0.01

Notes: LAC, Latin America; MEN, Middle East and north of Africa; OAC, other advanced countries; SEA, South-East Asia; SSA, sub-Saharan Africa. There is no change in the CPI for USA as this is the numeraire of the model.

Source: Authors' estimations.

**TABLE 11** Piecemeal sensitivity analysis: impact of the hard Brexit on the UK and REU

Parameter	Parameter value			Equivalent variation as a % of consumption					
				UK			REU		
	Lower	Central	Upper	Lower	Central	Upper	Lower	Central	Upper
$\sigma(q_i, q_j)$ – services	2.5	3	3.5	-3.65	-3.17	-2.93	-0.69	-0.59	-0.54
$\sigma(q_i, q_j)$ – goods	3	3.8	4.6	-3.33	-3.17	-3.07	-0.62	-0.59	-0.57
$\sigma(va, bs)$	0.625	1.25	1.875	-2.77	-3.17	-3.68	-0.46	-0.59	-0.77
$\sigma(D, M)$	×0.5	×1	×1.5	-3.11	-3.17	-3.21	-0.59	-0.59	-0.59
$\sigma(M, M)$	×0.5	×1	×1.5	-3.27	-3.17	-3.11	-0.61	-0.59	-0.58
$\sigma(L, K)$	0.5	1	1.5	-3.17	-3.17	-3.17	-0.59	-0.59	-0.59
$\sigma(A_1, \dots, A_n)$	0	0	0.25	NA	-3.17	-3.22	NA	-0.59	-0.60
$\varepsilon(fi)$	×0.75	×1	×1.25	-3.08	-3.17	-3.23	-0.58	-0.59	-0.59
$\theta_m$	0.025	0.05	0.075	-3.13	-3.17	-3.21	-0.58	-0.59	-0.60
$\pi$	0.25	0.5	0.75	-3.69	-3.17	-3.08	-0.79	-0.59	-0.59
$\alpha$	3.924	4.582	5.171	-3.19	-3.17	-3.14	-0.59	-0.59	-0.58

Notes:  $\sigma(q_i, q_j)$ : Elasticity of substitution between firm varieties in imperfectly competitive sectors.  $\sigma(va, bs)$ : Elasticity of substitution between value-added and business services.  $\sigma(D, M)$ : Elasticity of substitution between domestic goods and imports in CRTS sectors.  $\sigma(M, M)$ : Elasticity of substitution between imports from different regions in CRTS sectors.  $\sigma(L, K)$ : Elasticity of substitution between primary factors of production in value added.  $\sigma(A_1, \dots, A_n)$ : Elasticity of substitution in intermediate production between composite Armington aggregate goods.  $\varepsilon(fi)$ : Elasticities of imperfectly competitive firms' supply with respect to the price of their outputs.  $\theta_m$ : Shares of value added in multinational firms due to specialised primary factor imports.  $\pi$ : Share of capital remuneration of multinational firms.  $\alpha$ : Shape parameter for the Pareto distribution (Melitz). Note that the assumed values here are estimated by Balistreri et al. (2011).

Source: Authors' estimates.

which includes both domestic and FDI firms weighted with their market shares, we observe a decline across all services' sectors for both Brexit partners with stronger reductions in the UK (see Table 7). Moreover, increased protectionism forces highly productive REU firms to exit from British market in all Melitz sectors with the highest reduction in supplied varieties by 88.86% in food processing in the case of hard Brexit (see Table 8). British firms are also forced to exit the REU market and to switch to domestic supply in order to replace the lost imports. In general, we observe an increase in the number of domestic varieties for both sides but with much higher changes in the case of the UK. And while the total number of consumed varieties in the REU is negative across all the sectors, it is positive for the UK, providing a misleading impression of a positive result. It turns to be a negative effect once firm-level prices and quantities of heterogeneous firms are taken into account. To evaluate the variety impact in Melitz sectors, we calculate the Feenstra ratio – an index of the consumption-side variety impacts on welfare suggested by Feenstra (2010), which accounts for differentiated firm-level prices in the context of Melitz model. Table 6 illustrates the percentage changes (relative to unity) in the Feenstra ratio for all Melitz sectors and indicates welfare losses along the extensive margin for both the UK and REU. Thus, UK's losses are much higher illustrating the fact that the UK loses many imported varieties (produced by highly productive European firms) with low prices and high quantities, while the new domestic varieties are produced by firms with lower productivity and therefore at high prices and small quantities.

### 4.1.3 | Total exports, imports and production in a sector by sector analysis

The aforementioned reductions in bilateral trade flows translate into overall reductions in exports and imports across the board in both the REU and UK. However, they are more intense for trade flows of the UK than for REU, as the REU accounts for a larger share of UK's trade than vice versa (see Tables 1 and 2). This is what we see in Table 9, which offers the evolution of total exports and imports of each sector in the UK and REU after the soft and hard Brexit. In particular, aggregate exports shrink by  $-7.54\%$  and  $-16.94\%$  in the UK after the soft and hard Brexit, respectively, while in the REU they go down only by  $-1.54\%$  and  $-3.48\%$ , respectively. Similarly, aggregate imports of the UK decrease by  $-6.44\%$  and  $-14.42\%$  in the UK, whereas in the REU they decline only by  $-1.69\%$  and  $-3.82\%$  after the soft and hard Brexit, respectively. The strongest reductions in trade flows occur in sectors such as food, agriculture, motor vehicles, other primary and textiles, thus in the sectors with the highest barriers to trade.<sup>26</sup> While imports decline in all sectors of both regions<sup>27</sup> as well as British exports fall in all sectors, the REU is able to increase its exports of services such as construction, air transport, insurance, other and personal services in the case of hard Brexit.<sup>28</sup> These developments even lead to a small increase in total European services exports by  $0.07\%$  in the hard Brexit scenario, mainly due to increased trade with the rest of the world.

The contraction of foreign trade is associated with the more sizeable output reductions in the UK compared to the REU (see Table 9). Aggregate output in the REU is nearly unaffected after both the soft ( $-0.15\%$ ) and hard Brexit ( $-0.33\%$ ). However, in the UK the overall contraction constitutes  $-1.11\%$  and  $-2.46\%$  for the soft and hard Brexit, respectively. Moreover, UK's total output of services goes down by  $-1.35\%$  versus  $-0.67\%$  in manufactures in the soft Brexit scenario, while in the hard Brexit case these figures amount to  $-3.02\%$  versus  $-1.46\%$ , respectively.

In general, output contractions are more intense in the sectors that experience stronger reductions in trade due to the emergence of larger barriers to trade and FDI. Thus, in the REU production falls stronger in food processing, motor vehicles and agriculture, while slightly positive changes occur in other transport, machinery and water transport mainly to satisfy domestic demand. In the UK, the strongest reductions in output are observed in sectors such as other primary, electronics, air transport and business services. The evolution of food and motor vehicles in the UK is exceptional, however, because their output rises. These sectors are the most dependent on imports coming from the REU. As shown in Table 2,  $74.7\%$  and  $84.3\%$  of their imports come from the REU, while the average across manufactures is  $49.9\%$ . This fact combined with rather large NTBs and tariffs bring about a very remarkable reduction in its overall imports. Although their exports also fall, the need to saturate domestic demand for motor vehicles and food products leads to increases in their production.<sup>29</sup> The number

<sup>26</sup>This confirms that sector-specific NTBs are very important for measurement of Brexit impact. However, this aspect has been neglected in some analyses of Brexit, which use homogeneous NTBs across sectors (e.g. Ottaviano et al., 2014; Dhingra et al., 2017).

<sup>27</sup>Except the imports of air transport services in the UK for hard Brexit case, which has been already described above.

<sup>28</sup>Note that these sectors, in general, tend to face the smallest NTBs to trade across all the sectors and no tariffs.

<sup>29</sup>We additionally performed a sensitivity analysis to further analyse the evolution of motor vehicle sector as example. For this purpose, we redistributed UK's total imports by the region of origin: we reduced the share of imports from the REU to  $19\%$  and doubled the one from other regions. The results indicate that being less dependent on REU imports, sector's output would also go down just like in the rest of sectors. Note also that only a small share of imports of this sector is used as intermediates ( $18.28\%$ ). The same applies for food industry where only  $26.12\%$  of imports are intermediates, in contrast to the rest of sectors with an average of  $56\%$ . The particular use of imports for intermediates and (different types of) final demand plays a significant role to explain the differential behaviour of sectors, as has been deeply analysed in Zhou & Latorre (2014a, 2014b).



of domestic firms confirms this development as it increases strongly in these sectors with the highest value of 19.61% in the motor vehicle production, followed by 13.65% in food processing (Table 8). Thus, less productive British firms enter the local market to supply products at high prices and low quantities (i.e. losses along the extensive margin are the highest in motor vehicles and food processing, see Feenstra ratio in Table 6).

In sum, the microeconomic results reflect a much stronger impact of Brexit in the UK than in REU for exports, imports and output on a sector by sector basis. The two regions are, of course, quite different in size. This implies that small percentage changes in the REU may seem very limited for the entire region, but may also hide more sizeable impacts for the individual countries. This is certainly an issue for future research. However, two important conclusions can be derived from our outcomes so far. First, the damage derived for the UK is sizeable because nearly half of its aggregate imports and exports will experience the emergence of barriers. None of the countries within REU will have such a strong relationship with the UK alone. Therefore, in all likelihood the impact for all the countries within the REU would be less intense than the one for the UK.

A second important conclusion from these results is that the REU as a whole is not much affected by Brexit. This region is an important player in world imports and exports. Therefore, it would have had the capacity to bring about important trade diversion or creation effects. However, because the REU is not much affected, the latter effects are small. We will confirm this now by looking at the macroeconomic impact for all the regions included in our model.

## 4.2 | Macroeconomic impact

Table 10 offers the impact for GDP, welfare, wages, capital remuneration and the Consumer Price Index (CPI) for all the regions considered. For these aggregate variables, we present the effects of the different components of Brexit separately as well as the 'total' impact for both soft Brexit and hard Brexit. Thus, for the soft Brexit, which appears on the left, we include increases in NTBs to trade (labelled as "NTBs" in the table) and increases in NTBs to FDI (labelled as "FDI barriers") and their joint impact ("Total"). For the hard Brexit, we add the impact of MFN tariffs (labelled as "Tariffs") to the two former components, which now imply larger increases than in the case of the soft Brexit (as reflected in Table 3).

In line with the evolution of trade and output results on sectoral level, we observe a much stronger reduction in UK's GDP, welfare, wages and capital remuneration than in the REU. GDP in the UK could experience a contraction between  $-1.23\%$  and  $-2.53\%$  in the case of soft and hard Brexit, respectively. In contrast, for the REU the fall in GDP is only between  $-0.16\%$  and  $-0.35\%$ . Welfare reductions, measured as Hicks equivalent variation of consumption, are more pronounced than the ones of GDP: UK's welfare loss reaches  $-3.17\%$  in the hard Brexit scenario, while the one for the REU amounts to  $-0.59\%$ . Translating the percentage changes in welfare into billions of US dollars in 2020 (which is the base year of our simulations), the value of maximal consumption loss after the hard Brexit constitutes 62.701 \$billions for the UK and 57.977 \$billions for the REU. In the case of soft Brexit, the drain would be of 30.818 \$billions ( $-1.56\%$ ) in the UK and of 26.178 \$billions ( $-0.27\%$ ) in the REU.

Concerning factor remuneration, British workers and capital owners would suffer more from Brexit than the ones in the REU. In particular, the maximal reduction in wages and capital remuneration in the hard Brexit scenario amounts to  $-2.83\%$  and  $-3.34\%$  in the UK, while in the REU it takes only  $-0.39\%$  and  $-0.43\%$ , respectively. Moreover, in the UK the decline in wages is lower than in capital returns indicating a relatively lower demand for capital that occurs due to a reallocation of production to the labour-intensive sectors (e.g. food processing and motor vehicles with the share of labour in

value added of 60% and 80%, respectively). Capital owners lose stronger from FDI barriers as a part of capital in services is sector-specific and cannot reallocate due to emergence of new inefficiencies.

Looking at the distribution of the negative impact among the different types of barriers, NTBs to trade account for the largest share of the total negative impact. More precisely, in the hard Brexit simulation the rise of NTBs constitutes over one half of the total negative effect for both the UK and REU across macroeconomic variables such as GDP and welfare. FDI barriers also play a significant role, since they explain approximately one third of the decrease in GDP and welfare in the two regions. The results for wages and capital remuneration also run in parallel to the ones for GDP and welfare implying that NTBs to trade account for the largest reduction in factor remunerations.

Generally, higher barriers after Brexit increase prices for imported products in the UK and REU. In addition, entry of less productive producers due to increased protectionism also raises prices. This leads to a higher Consumer Price Index (CPI) in the UK with the maximal increase of 1.28% in the case of hard Brexit (see Table 10), which reduces the demand and consumption of goods and services. This in turn drives production and trade down, which is associated with lower demand for inputs and therefore lower factor earnings, as described previously. Additionally, there is a considerable welfare loss along the extensive margin of trade as indicated previously by the Feenstra ratio. In the case of the REU, the impact is not that strong as it is not dependent on the British market as much as the UK on the European one. Moreover, as mentioned before, the REU is able to recover much of its trade by increasing the unrestricted intra-REU trade as well as trade with third countries. Therefore, the CPI in the REU is almost unaffected or even slightly reduced, while the overall negative Brexit impact is quite limited with the highest welfare loss of 0.59%.

Considering other regions of the world, they are nearly unaffected by Brexit. We estimate a small percentage variation in welfare for the Middle East region (MEN), other advanced economies (OAC) and the United States, which implies a few billions of extra dollars. This even holds for the hard Brexit which could result in more intense trade diversion or creation effects. However, since the UK accounts for a small share of the world GDP and trade, the potential spillovers from Brexit for outsiders seem to be quite damped.

## 5 | SENSITIVITY ANALYSIS

As a robustness check of our results, we assess the impact of the key model parameter values in our piecemeal sensitivity analysis where we change each parameter one by one, while we keep all other parameters unchanged. Table 11 shows how the welfare impacts of the hard Brexit on the UK and REU are affected by each parameter. In addition, we re-run the model with an Armington structure, which is the most common and standard specification of trade in the literature and has been widely used in previous studies on Brexit.

We see that our welfare results are generally quite robust to the parameters here. The parameter that has the strongest impact on the welfare results is the elasticity of substitution between value-added and business services,  $\sigma(va, bs)$ . Table 11 shows that the welfare impact of the UK (REU) ranges from  $-2.77\%$  ( $-0.46\%$ ) to  $-3.68\%$  ( $-0.77\%$ ). This implies 87% (78%) to 116% (130%) relative to the central result. When this elasticity is higher, firms can substitute the business services for value-added input more easily, which leads to the larger decrease in the business services from multinational firms and cross-border firms after the Brexit. This is because the latter become more expensive due to Brexit barriers. As a result, the production of services is reduced stronger, the business services will be more costly, and welfare loss of the economy becomes larger due to reduced number of available varieties in the love-of-variety setting.



The elasticities of substitution between firm varieties have modest impact on the welfare results. Especially, when the substitution elasticity between firm varieties of service sectors is lower, the welfare impact is not small:  $-3.65\%$  ( $-0.69\%$ ) for the UK (REU) or  $115\%$  ( $117\%$ ) for the UK (REU) relative to the central results. When this elasticity (for both service sectors and good sectors) is lower, the welfare loss becomes larger because lower values of this elasticity imply that varieties are less close to each other, and thus, fewer varieties are more damaging.

Other than the elasticities of substitution, the share of capital remuneration of multinational firms is important. We assume that some portion of the capital remuneration is sent back to the source countries. When this share is low, more multinational firms leave because they have smaller incentive to stay in the host countries in the case of the increased barriers, and thus, the welfare loss becomes larger:  $-3.69\%$  ( $-0.79\%$ ) for the UK (REU) or  $117\%$  ( $134\%$ ) for the UK (REU) relative to the central results.<sup>30</sup> Since the central value (0.5) is already high enough to keep the multinationals, the higher share of capital remuneration (0.75) weakens the welfare loss only in a limited way.

The impact of all other parameters on our central welfare results is quite limited. In sum, our welfare results are robust with respect to the key parameters. Especially, the direction of the impact of each parameter is always the same for the UK and REU, and thus, the welfare loss of the UK is always much larger than that of the REU.

In the simulation with the trade structure of perfect competition for all the sectors, namely Armington trade structure, the welfare impact on the UK (REU) is  $-2.04\%$  ( $-0.39\%$ ) or  $64\%$  ( $66\%$ ) relative to the central results. Furthermore, if we exclude the FDI barriers, which is basically the same setting as Ottaviano et al. (2014) and Dhingra et al. (2017), the welfare impact on the UK (REU) is  $-1.60\%$  ( $-0.31\%$ ) or  $51\%$  ( $52\%$ ) relative to the central results. Thus, without the Melitz structure and FDI barriers, the welfare impacts would be underestimated significantly.<sup>31</sup> A similar pattern is illustrated by Balistreri, Olekseyuk, and Tarr (2017) in a single-country CGE model for the WTO accession of Belarus. In particular, they show that an approach limited to the analysis of services cross-border trade under perfect competition would suggest gains more than ten times smaller than their findings.

## 6 | CONCLUSIONS

In this paper, we quantify the trade and FDI-related impact of Brexit using an innovative numerical simulation model that splits the world economy into 11 regions, 21 sectors and four factors of production. Contrasting with other previous analyses of Brexit, our model incorporates many simultaneous features of real economies. Moreover, to the best of our knowledge, it is the first model combining the Melitz (2003) structure in manufactures with the presence of multinationals operating under monopolistic competition à la Krugman (1980) in services in all the regions of the multiregional framework. To be more precise, the present model is based on the path-breaking approach of Balistreri et al. (2011) and extends the FDI approach of Olekseyuk (2016) to a multiregional setting. In comparison with Latorre and Yonezawa (2018) and Latorre et al. (2018), it additionally incorporates the Melitz structure in manufacturing.

<sup>30</sup>Latorre and Yonezawa (2018) demonstrate the same mechanism (but the direction is opposite because they analyse it in a context of decreasing barriers to FDI related to TTIP). When this share is high, the removal of FDI barriers leads to more multinationals (they have larger incentive to come to the host countries) and thus larger welfare gain.

<sup>31</sup>Trade parameters for the Armington structure are taken from GTAP 9.

Our results suggest that the UK experiences much more sizeable losses in its welfare, foreign trade, production, average industry productivity, wages and capital remuneration than the REU does. In particular, UK's welfare loss reaches  $-3.17\%$  in the hard Brexit (i.e. a 'no deal') scenario, while the one for the REU amounts to  $-0.59\%$  only. Hereby, the inclusion of FDI in services generates an important source for losses, which has often been neglected in other numerical simulation assessments. More precisely, an increase in FDI barriers explains approximately one third of the overall fall in GDP, welfare and wages in the UK and REU. Our sensitivity analysis additionally illustrates that dropping the FDI barriers and monopolistic competition among heterogeneous firms (i.e. similar setting to Ottaviano et al., 2014 and Dhingra et al., 2017) would generate an underestimated Brexit impact by approximately 50%.

The emergence of barriers between the Brexit partners also leads to a reduction in the number of available varieties in services, which is more intense in the UK than in the REU. We also observe higher welfare losses along the extensive margin for the UK. This illustrates the fact that the UK loses many imported varieties (produced by highly productive European firms) with low prices and high quantities, while the new domestic varieties are produced by firms with lower productivity and therefore at high prices and small quantities. Indeed, the results for average productivity of domestic firms in the UK confirm this with a decline by up to  $-2.27\%$  in several manufacturing sectors such as textiles, chemicals, motor vehicles and electronics. Thus, less productive firms enter the British market due to increased protectionism and reduced import competition.

Brexit implies a shrinking of the EU market and, in that sense, is not good news for both the UK and REU since firms lose sales opportunities. However, given the much larger size of the REU, the process is much more harmful for the trade of UK firms. REU firms are better in recovering the lost exports in the UK through intra-EU trade but also by trading more with third nations. In particular, the REU recovers around one third of the exports lost in the UK with half of it recovered via an expansion of intra-EU trade. The UK manages to recover less of its exports lost in the REU: while after the soft Brexit (i.e. Norway agreement in line with UK's current negotiating position) it may recover around 7% of lost exports, in the hard Brexit case this number amounts to 1.6% only. Indeed, the hard Brexit hurts the UK disproportionately more than the REU.

Assuming no changes in the trade policy against third countries, our assessment suggests that GDP and welfare remain nearly unaffected for the outsiders (the US, China, India, Japan, other advanced economies, South-East Asia, Latin America, Middle East and sub-Saharan Africa). Although Brexit may offer good prospects for some manufacturing firms coming from outside the Brexit block, at a more aggregate level benefits for outsiders seem quite limited. Thus, Brexit's scope is mainly confined to the EU landscape.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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## APPENDIX

TABLE A1 Mapping of model sectors to Nace Rev 2, Isic Rev 3.1 and GTAP classifications

Sectors	Nace Rev 2	Isic Rev 3.1	GTAP
1. Agriculture	A Agriculture, forestry and fishery products	ISIC 01–05	1–14
2. Other primary	B Mining and quarrying	ISIC 10–14	15–18
3. Food	C10 Manufacture of food products C11 Manufacture of beverage C12 Manufacture of tobacco products	ISIC 15–16	19–26
4. Textiles	C13 Manufacture of textiles C14 Manufacture of wearing apparel C15 Manufacture of leather and related products		27–29
5. Wood and paper	C16 Manufacture of wood and products of wood, cork, straw and plaiting materials C17 Manufacture of paper and paper products C18 Printing and reproduction of recorded media	ISIC 20–22	30–31
6. Chemicals	C19 Manufacture of coke and refined petroleum products C20 Manufacture of chemicals and chemical products C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations C22 Manufacture of rubber and plastic products	ISIC 24–25	32–33
12. Other manufactures	C23 Manufacture of other non-metallic mineral products	ISIC 23,26	34,42
7. Metals	C24 Manufacture of basic metals C25 Manufacture of fabricated metal products, except machinery and equipment	ISIC 27–28	35,36,37
10. Electronics	C26 Manufacture of computer, electronic and optical products C27 Manufacture of electrical equipment	ISIC 30,32	40
11. Other machinery	C28 Manufacture of machinery and equipment n.e.c.	ISIC 29,31,33	41
8. Motor vehicles	C29 Manufacture of motor vehicles, trailers and semi-trailers	ISIC 34	38
9. Other Transport	C30 Manufacture of other transport equipment	ISIC 35	39
12. Other manufactures	C31 Manufacture of furniture C32 Other manufacturing	ISIC 23,26	34,42

(Continues)

TABLE A1 (Continued)

Sectors	Nace Rev 2	Isic Rev 3.1	GTAP
11. Other machinery	C33 Repair and installation of machinery and equipment	ISIC 29,31,33	41
21. Other services	D Electricity, gas, steam and air conditioning supply D35 Electricity, gas, steam and air conditioning supply E Water supply; sewerage, waste management and remediation activities E36 Water collection, treatment and supply E37 Sewerage E38 Waste collection, treatment and disposal activities; materials recovery E39 Remediation activities and other waste management services	ISIC 40,41,50,51,52,63,75,80,85,90	43,44,45,47,48,56,57
13. Construction	F Construction F41 Construction of buildings F42 Civil engineering F43 Specialised construction activities	ISIC 45	46
21. Other services	G Wholesale and retail trade; repair of motor vehicles and motorcycles G45 Wholesale and retail trade and repair of motor vehicles and motorcycles G454 Sale, maintenance and repair of motorcycles and related parts and accessories G47 Retail trade, except of motor vehicles and motorcycles H49 Land transport and transport via pipelines	ISIC 40,41,50,51,52,63,75,80,85,90	43,44,45,47,48,56,57
14. Water transport	H50 Water transport	ISIC 61	49
15. Air transport	H51 Air transport	ISIC 62	50
21. Other services	H52 Warehousing and support activities for transportation	ISIC 40,41,50,51,52,63,75,80,85,90	43,44,45,47,48,56
16. Communications	H53 Postal and courier activities	ISIC 70–74	51
21. Other services	I55 Accommodation I56 Food and beverage service activities	ISIC 40,41,50,51,52,63,75,80,85,90	43,44,45,47,48,56,57
19. Business services	J582 Software publishing	ISIC 91–93	54
20. Personal services	J59 Motion picture, video and television programme production, sound recording J60 Programming and broadcasting activities	ISIC 91–93	55
16. Communications	J61 Telecommunications	ISIC 70–74	51
19. Business services	J62 Computer programming, consultancy and related activities J63 Information service activities	ISIC 91–93	54

(Continues)

TABLE A1 (Continued)

Sectors	Nace Rev 2	Isic Rev 3.1	GTAP
17. Finance	K64 Financial service activities, except insurance and pension funding	ISIC 65,67	52
18. Insurance	K65 Insurance, reinsurance and pension funding, except compulsory social security	ISIC 66	53
17. Finance	K66 Activities auxiliary to financial services and insurance activities	ISIC 65,67	52
19. Business services	L68 Real estate activities M69 Legal and accounting activities M70 Activities of head offices; management consultancy activities M71 Architectural and engineering activities; technical testing and analysis M72 Scientific research and development M73 Advertising and market research M74 Other professional, scientific and technical activities M75 Veterinary activities N77 Rental and leasing activities N78 Employment activities	ISIC 91–93	54
21. Other services	N79 Travel agency, tour operator reservation service and related activities	ISIC 40,41,50,51,52,63,75,80,85,90	43,44,45,47,48,56,57
19. Business services	N80 Security and investigation activities N81 Services to buildings and landscape activities N82 Office administrative, office support and other business support activities	ISIC 91–93	54
21. Other services	O – Public administration and defence; compulsory social security P – Education Q – Human health and social work activities	ISIC 40,41,50,51,52,63,75,80,85,90	43,44,45,47,48,56,57
20. Personal services	R – Arts, entertainment and recreation S – Other services activities S95 Repair of computers and personal and household goods T – Activities of households as employers; undifferentiated goods and services	ISIC 91–93	55

TABLE A2 Mapping of model regions

Latin America and the Caribbean	Middle East, North Africa, Afghanistan and Pakistan	Sub-Saharan Africa	Emerging and Developing Asia	Other advanced countries
(Latin America, LAC)	(Middle-East, MEN)	(Sub-Saharan A., SSA)	(Southeast Asia, SEA)	OAC
Antigua and Barbuda	Afghanistan	Angola	Bangladesh	Australia
Argentina	Algeria	Benin	Bhutan	Canada
The Bahamas	Armenia	Botswana	Brunei Darussalam	Hong Kong SAR
Barbados	Azerbaijan	Burkina Faso	Cambodia	Iceland
Belize	Bahrain	Burundi	Fiji	Israel
Bolivia	Belarus	Cameroon	Indonesia	Korea
Brazil	Djibouti	Cape Verde	Kiribati	New Zealand
Chile	Egypt	Central African Republic	Lao P.D.R.	Norway
Colombia	Georgia	Chad	Malaysia	Singapore
Costa Rica	Iran	Comoros	Maldives	San Marino
Dominica	Iraq	Dem. Rep. of the Congo	Marshall Islands	Switzerland
Dominican Republic	Jordan	Republic of Congo	Micronesia	Taiwan Province of China
Ecuador	Kazakhstan	Côte d'Ivoire	Mongolia	
El Salvador	Kyrgyzstan	Equatorial Guinea	Myanmar	
Grenada	Kuwait	Eritrea	Nepal	
Guatemala	Lebanon	Ethiopia	Palau	
Guyana	Libya	Gabon	Papua New Guinea	
Haiti	Mauritania	The Gambia	Philippines	
Honduras	Morocco	Ghana	Samoa	
Jamaica	Oman	Guinea	Solomon Islands	
Mexico	Pakistan	Guinea-Bissau	Sri Lanka	
Nicaragua	Qatar	Kenya	Thailand	
Panama	Rest of Eastern Europe	Lesotho	Timor-Leste	
Paraguay	Rest of Former Soviet Union	Liberia	Tonga	
Peru	Russia	Madagascar	Tuvalu	
St. Kitts and Nevis	Saudi Arabia	Malawi	Vanuatu	
St. Lucia	Sudan	Mali	Vietnam	
St. Vincent & the Grenadines	Syria	Mauritius		
Suriname	Tunisia	Mozambique		

(Continues)

TABLE A2 (Continued)

Latin America and the Caribbean	Middle East, North Africa, Afghanistan and Pakistan	Sub-Saharan Africa	Emerging and Developing Asia	Other advanced countries
(Latin America, LAC)	(Middle-East, MEN)	(Sub-Saharan A., SSA)	(Southeast Asia, SEA)	OAC
Trinidad and Tobago	Turkey	Namibia		
Uruguay	Ukraine	Niger		
Venezuela	United Arab Emirates	Nigeria		
	Yemen	Rwanda		
		São Tomé and Príncipe		
		Senegal		
		Seychelles		
		Sierra Leone		
		South Africa		
		South Sudan		
		Swaziland		
		Tanzania		
		Togo		
		Uganda		
		Zambia		
		Zimbabwe		

Note: The classification follows the one of the IMF World Economic Outlook.