Can Brexit be overturned with other trade and FDI agreements? A quantitative assessment

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Abstract

We conduct a general equilibrium analysis including a state-of-the-art Melitz structure in manufactures and the operations of foreign multinationals in services. We study different policy alternatives for UK and the Rest of the European Union (REU) to counteract the harmful impact of Brexit. In particular, we analyze a unilateral tariff elimination in the UK, different FDI agreements of this economic with China, Japan and India and a comprehensive trade and FDI agreement with the US (similar to TTIP). While the FDI agreements have a negligible impact on the UK, we find some scope in the unilateral tariff elimination to raise wages and capital remuneration in that economy. When analyzing a UK-US TTIP agreement we find it insufficient to compensate the negative impacts of Brexit. By contrast, in most of the possible Brexit and TTIP joint scenarios TTIP could be useful for the REU to overturn the limited negative effects it experiences with Brexit.

Keywords: Multinationals, CGE, Melitz, monopolistic competition, trade in services.

JEL codes: C68, F14, F15, F17, F21

Introduction

UK's decision to exit the EU has been one of the most important economic events in recent years. While the conditions of the withdrawal agreement are still being negotiated, it is clear that UK will try to strike trade and foreign direct investment (FDI) agreements with third nations. On the other hand, the EU has always advocated to expand trade and FDI relationships and will continue to do so. What can both regions expect from other potential trade and FDI agreements?

This paper uses an innovative general equilibrium approach to analyze different potential policies that both regions could undertake. For UK, we analyze a unilateral trade liberalization policy, simultaneous FDI agreements with big countries, such as, China, Japan and India, as well as a comprehensive trade and FDI agreement with the US similar to the Transatlantic Trade and Investment Partnership (TTIP). For the rest of the European Union (henceforth REU, i.e., EU28 excluding UK), we concentrate on the potential for TTIP to counteract the negative effects of Brexit.

Several papers have analyzed the negative and asymmetric impact of Brexit (see Busch and Matthes, 2016; Latorre et al., 2018PIIE for reviews). However, the analyses of different policy alternatives after Brexit are scarcer. What is more, very few of them have taken into account the effects of foreign multinationals and FDI in the context of Brexit. We include this component in our approach, which, therefore, contrasts with most of the previous analyses, which have focused on the impact of trade.

Our model also has a state-of-the-art approach to study trade itself. It incorporates a Melitz structure with differences in productivity and firms' selection in manufacturing sectors. In addition, our model has many features of real economies, such as, multiple sectors, regions and factors of production; trade imbalances; intermediates with demand structures reflecting actual data; sector-specific tariffs as well as Non-Tariff Barriers (NTBs) to trade and FDI. The simultaneous combination of all these characteristics together with FDI and a Melitz setting, extends more stylized mainstream economic analysis in international economics (e.g., Costinot and Rodríguez-Clare, 2014; Arkolakis et al., 2012).

We find that UK would not be able to compensate the harmful impacts of Brexit with any of the policies we analyze. As we explain later, it is hard to believe that UK will be able to strike other trade agreements with regions that are very distant culturally and which have very different legislative regimes.

By contrast, the REU could use an agreement like TTIP to more than counteract the negative impact of Brexit. Even though US President Donald Trump has stopped the TTIP negotiations, he could change his mind or his successors could well resume them. Our quantitative evidence shows that TTIP would be beneficial to the US, particularly, due to the FDI component that has been neglected in other previous analyses of TTIP.

The rest of the paper is organized as follows. In section 2, we provide an overview of the feasibility and importance of doing business with different trade and FDI partners for the REU and UK. In section 3, we explain the model, while in Section 4 we present the data and different scenarios that are analyzed. In section 5, we analyze macro and microeconomic results, while the main conclusions close the paper. The algebraic description of the model is offered in an appendix.

Trade relationships

Figure 1 shows the shares in aggregate exports and imports of all trade partners of the UK, the REU and the US. What stands out from that figure is the huge amount of trade flows that the REU conducts within its own region (i.e., intra-REU imports and exports) and the weight of the REU in UK's trade. The REU is also an important trade partner for the US.

On the other hand, for the REU, the UK and the US trade with other advanced regions is also very remarkable[1]. There are many trade agreements already between all these advanced regions, so it does not include many partners with which the UK can substantially enhance its trade or FDI relationships, even though it will probably have to revise them after Brexit (see Fernández-Pacheco et al., 2018 for details). The Middle-East is also an important trade partner for the REU, the UK and the US and not only due to oil imports but also as an exporting destination. However, it is composed of countries with a very different culture, compared to the anglosaxon or European, and this complicates doing business there. The same applies to China, India, and also to the group of countries which constitute the Southeast Asia region, which a priori may look like important targets for the REU and the UK. Note that the REU itself does not have any special trade agreement with China, while it has been since 2013 trying to reach a comprehensive one for FDI. The relationships with China are problematic. Despite more flexible approaches taking recently by the Chinese government (e.g., Latorre et al. 2018 CER) important barriers to trade and FDI remain. Japan is also a potential more friendly target than other Asian partners. However, note that given its size it seems far from being able to compensate UK losses of preferential access to the REU market. The US looks like a big and culturally close potential target. Trump has shown willingness to strike a comprehensive trade agreement with the UK, much in contrast with other protectionist movements undertaken by the US president. It seems worth exploring, therefore, what could be the benefits of a potential agreement with the US for the UK. We will also analyze its effects for the REU.

[1] This region includes Hong Kong SAR, Iceland, Israel, Korea, New Zealand, Norway, Singapore, San Marino, Switzerland, Taiwan Province of China, Australia, Canada, Albania, Rest of North America, and Rest of the World.

Table 1 offers more details on the bilateral shares in exports and imports between the main partners we will consider (i.e., the REU, the UK and the US). We now display the shares across all sectors in the model, as well as some summarizing totals for all manufactures and all services. This highlights that there is a lot of sectoral heterogeneity which will be an important factor to explain different sectoral outcomes below. In the case of REU we also include the weight of intra-EU trade given its importance and particular free trade and FDI regime. The figures for the total shown in the last row of Table 1 match the ones in Figure 1.

For the UK the REU is by far a much more important trade partner than the US is. On the other hand, the US is a more important trade partner for the UK economy than for the REU. The US is behind 11.0% and 12.4% of UK's imports and exports, respectively, while the US explains only 6.5% and 7% of REU imports and exports. This makes us expect that the impact of an agreement with the US would be more important for the UK economy than for the REU.

For the REU the US is a slightly more important partner than UK is. Indeed, US accounts for 6.5% and 7.0% of total REU imports and exports, respectively, while the UK accounts for 5.3% and 6.3% for the same respective shares. This suggests that TTIP has the potential to compensate the harmful impact of Brexit for the REU. This initial descriptive analysis gives us some hints about the potential impact of other policies to counteract the harmful effects of Brexit. However, it is hard to tell a priori the size of their respective effects. What would be the impact on GDP, or on wages and on exports or imports of Brexit or TTIP? What is more, what would be the effects for the different sectors. We offer the quantitative impact of these policies.

In addition, the story may be different depending on the sector, given the heterogeneity in bilateral trade shares. In addition, other factors are at play, such as, the size of trade barriers, the dependency on exports (i.e., the shares of output devoted to exports) or the type of imports (intermediates or final). All these elements differ across sectors and will underlie our general equilibrium analysis.

The model

We use a computable general equilibrium (CGE) approach. Our model extends the path-breaking approach of Balistreri et al. (2011), which were the first to introduce a Melitz structure in several sectors of a multi-regional CGE model. To be more precise, we combine the Melitz structure present in manufacturing sectors in the approach of Olekseyuk (2016) with a setting in which multinationals run in imperfect competition in all of the regions of the model, following Latorre and Yonezawa (2018) and Latorre et al. (2018CER). Our methodological approach can also be considered and extension of the model of Olekseyuk and Balistreri (2017), who run Melitz, Krugman and Armington structures in a multiregional and multisector setting, but do not include the

operations of multinationals in services. A detailed description of the model is included as an algebraic formulation in an appendix.

Figure 1 depicts the production function in each sector of the model. Sector specific capital enters the top nest together with an aggregate of all other inputs with an elasticity of substitution eta_sub_{ir}. We calibrate this elasticity according to the econometric estimates provided by Schiff and Wang (2006). Thus, the model reproduces elasticities of supply that depend on the stage of development of the different regions and on the technological complexities of goods and services produced across sectors. At the next lower level, we find a combination of intermediate inputs and a sophisticated value added nest. The latter includes an aggregation of business services and a more standard value added bundle. The intuition behind for the combination of business services and value added is that firms can use services provided by, e.g. accounting or legal firms instead of hiring accountants or lawyers as employees. It follows the original approach of Markusen et al. (2005), which has been implemented in a few CGE models that consider the presence of multinationals (e.g., Jensen et al., 2010; Jensen et al., 2007; Jensen and Tarr (2012), Balistreri et al., 2009; Balistreri et al., 2015; Latorre, 2016). The standard value added next combines, labor, mobile capital, natural resources and land. 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. Due to the presence of these fixed factors variations in output are, to some extent, limited in the sectors in which they operate.

As is common in models focusing on trade, ours includes two agents, namely, the government and a single representative household. Public consumption remains constant in real terms to avoid the distortions that its variation could produce. Consumption of final goods is modelled as a Cobb-Douglas utility function over sectoral commodity bundles. Final and intermediate demands are composed of the same composite of domestic and foreign goods. We differentiate between domestic and foreign products at the firm level due to the presence of imperfect competition and increasing returns to scale (IRTS) in some selected manufacturing sectors and business services. This requires an assumption of the same substitution elasticity between firms and products. This inter-variety elasticity of substitution sig_i is set at 3.8, which is consistent with the plant-level empirical analysis of Bernard et al. (2003). Therefore, the composite of the firm level goods is modelled by a single-level CES function with all domestic and imported varieties competing directly, which is what we see at the bottom of Figure 1 in the structure of good 20 and in the structure of business services. Following Olekseyuk and Balistreri (2017) manufacturing sectors with a higher share of intra-industry trade (over 60%) are assumed to produce under IRTS technology within a Melitz structure (i.e., the good 20 structure). This allows us to capture the trade-policy induced changes in aggregate productivity due to a within industry reallocation of factors from more to less productive plants (including entry firms with the lowest productivity).

With FDI in business services we allow for the existence of two types of firms: (i) domestic firms producing in the host country for the local and foreign markets and (ii) multinational firms producing in the host economy for the local market with FDI from other regions. These FDI firms (or multinational firms) produce a specific variety in the host economy, which is differentiated from domestic, imported and other home region varieties.

In these FDI sectors we implement large-group monopolistic competition among symmetric firms producing under the same IRTS technology, following Krugman (1980). The costs of domestic firms are defined by the costs of local primary factors and intermediate inputs. For FDI firms, the cost structure differs as in addition to the host production factors and intermediates, they import specialized foreign inputs (e.g., technology or management expertise developed in other countries). The barriers to FDI raise the costs of multinational firms and, consequently, affect their profitability and entry. Larger barriers reduce foreign entry and lead to productivity losses due to reduced number of available varieties, according to the Dixit and Stiglitz (1977) variety effect. Our model differentiates the impact of FDI flows according to the sector to which they accrue, which is in accordance with the fact that the effects of multinationals vary across sectors (e.g., Smarzynska, 2004; Latorre and Hosoe, 2016; Zhou and Latorre, 2014a,b)

Data and simulations

We use the latest available GTAP 9 Database (Aguiar et al., 2016). Since this database resembles the world economy in 2011, we use IMF projections for 2020 to conduct a forward calibration following Böhringer et al. (2009). 2020 seems a reasonable year to assess the impact of Brexit and will be used as a reference for our simulations. Our model has 11 regions ((i.e., RE, UK, US, China, India, Japan, other advanced economies, South East Asia, Latin America, Middle East and Sub-Saharan Africa), 21 sectors (shown in Table 1) and four types of factors (land, natural resources, labor and capital).

Table 2 offers the overall trade barriers of Brexit and TTIP that we model following the literature. Obviously, Brexit implies increases in trade costs between the UK and the REU. These are larger with a hard Brexit than with a soft one. A hard Brexit has been modelled usually (e.g., Dhingra et al., 2017; Latorre et al., 2018SRRN) as a reversion to WTO rules for the UK, while a soft Brexit would capture an agreement similar to the one that Norway has with the EU.

By contrast, trade barriers related to TTIP would go down between the REU and US or between the UK and US, depending on the simulation. That is why the information displayed in Table 2 appears in red indicating reductions in trade costs. The latter would be larger with an ambitious TTIP than with a modest one. Again our approach to those

barriers is the one adopted in general in the available literature on the impact of TTIP (e.g., Francois et al. 2013; Fontagne et al., 2013; Latorre and Yonezawa, 2018).

Several lessons can be drawn from Table 2. First, there is a lot of heterogeneity in barriers across sectors. As mentioned above, this will be a force inducing different sectors' adjustments in contrast with other analyses that assume homogenous NTBs (e.g., Dhingra et al, 2017, Ottaviano et al., 2014). The second lesson is that a hard Brexit would imply much larger trade costs increases than any possible TTIP agreement. Third, a soft Brexit would imply, however, smaller trade costs than savings emerging from any TTIP agreement. This suggests that TTIP may be a tool to counteract the harmful impact of Brexit. However, the impact of TTIP and Brexit does not depend only on the size of (increasing or decreasing) trade barriers, but also on the share of overall trade flows affected by those barriers, i.e., on the information displayed in Table 1. This implies that the UK will be much more affected by Brexit than the EU because similar barriers across sectors are applied to a much larger share in trade in the UK than in the EU.

Table 3 provides further detail on the components of all TTIP barriers[2]. Note that in general NTBs barriers are larger than tariffs. However, for some sectors, such as, food, textiles and motor vehicles tariffs are can also be considerable particularly in REU and UK.

Results

Macroeconomic impact

The first rows in Table 4 show the asymmetric impact of Brexit, which is much more harmful for the UK than for the REU. This is the general consensus of the economic literature (Fernández-Pacheco et al., 2018; Latorre et al., 2018 PIIE). The contributions of trade (NTBs and tariffs) and FDI components of Brexit have been deeply analyzed in Latorre et al. (2018ssrn). Therefore, in this paper we keep the overall impact of a Brexit shock (composed of both trade and FDI effects) and expand the number of policy alternatives that the UK and the EU could adopt after Brexit.

The UK could consider a policy of unilateral tariff elimination (i.e., removal of all sectoral tariffs against all possible trade partners[3]). The impact of such a policy would expand aggregate exports and imports by 4.01% and 3.09%, respectively. It would also

[2] The interested reader can find all the details on the different components Brexit barriers and their corresponding effects in Latorre et al. (2018srrn). Although we update the shares of multinationals sales in telecommunications and business services, we found its impact is rather small, so we omit this analysis here to extend the analysis to trade and FDI alternatives following Brexit. Latorre and Yonezawa provide a detailed analysis of TTIP including barriers to trade and FDI and their effects. However, in that analysis UK was part of the EU and although their barriers agains the US are, in general, very similar we provide their exact values in this paper.

[3] Note that with respect to the EU these tariffs are already null.

reduce prices (the CPI contracts by -1.19%). Wages and capital remuneration go up[4] by 0.51% and 0.63% despite a rather moderate GDP increase by 0.12%. The impact on welfare is negligible (0.03%).

The UK could also lower its barriers to FDI faced by the multinationals coming from the largest countries of the world, namely, China, Japan and India[5]. We do this for the three countries simultaneously including modest reductions (10%) of total existing barriers in the UK or more ambitious ones (25% decreases). The effects of such a policy turn out to be minimal. However, we are probably underestimating them since our data on affiliates sales are from Fukui and Lakatos (2012)[6]. In these data, the shares of UK multinationals coming from China, Japan and India in the UK are probably lower than current trends, particularly in the case of China. It is hard to find the real shares since data for foreign multinationals' sales are elusive. A larger weight of foreign multinationals in the UK would amplify the impact of reductions in barriers to their entry and operations. The UK has always played an important role as origin and destination of foreign multinationals. For example, in the analysis of Latorre et al. (2018CER) UK stands out compared to the EU average in its capacity to profit from the reduction in barriers to FDI in services in China that the government has been recently promoting. However, still UK does not derive much impact from its increase in FDI in the Chinese economy, in terms of GDP and other macroeconomic variables. Although this effect may also be affected by the problems with the data we have just mentioned since the paper also uses the Fukui and Lakatos (2012) database.

The next rows show the impact of an agreement similar to TTIP between the UK and the US, while the bottom rows of the table analyze the impact of TTIP between the REU and the US. Note that these scenarios consider the impact of TTIP itself without Brexit. The different possible combinations between Brexit and TTIP will be analyzed in Table 5 below. As already noted, we run two types of TTIP agreements (modest and ambitious) in line with the literature[7].

The impact of a modest TTIP between the EU and the US brings about the same overall outcomes for both regions. GDP would increase by 0.22% and 0.53% after a modest

[4] The analyses in Dhingra et al. (2017) and Ortiz and Latorre (2018) have found that the impact of a unilateral tariff elimination would bring about a very small positive impact incapable of compensating the large losses arising from Brexit. Because we cover a larger set of macro variables we can identify that, in terms of factors' remuneration, this policy would still be able to have a positive impact on them.

[5] The US will be considered later in the context of TTIP results.

[6] We have updated the shares in sales in telecommunications and business services between the UK, the UK and the US to the year 2015 using Eurostat (2018) data. For the rest of regions the information was unavailable to the best of our knowledge, therefore we have kept the very low shares they had in the Fukui and Lakatos (2012) dataset.

[7] Latorre and Yonezaya (2018) offer a deep analysis of TTIP between Europe (including the UK) and the US. In addition, several manufactures run in an imperfect competition setting à la Krugman (1980), without including a Melitz structure as in this paper. Latorre and Yonezaya (2018), however, expand the number of TTIP scenarios analyzed, including more inclusive ones. The latter consist of scenarios in which reductions in trade and FDI barriers between the EU and the US would lead to reductions in these barriers also for other regions' exports and FDI going to the TTIP partners.

and ambitious TTIP, respectively, in both regions. While for the EU the component that contributes more to the positive effect is the NTBs, for the US the reduction in barriers to FDI would be the most important element. This is because barriers to FDI are in general larger in the US so that lowering them brings about important increases in US production in services sectors, which are the ones hosting multinationals.

A TTIP agreement with the US (again without considering the impact of Brexit) would be more positive for the UK than for the EU. An ambitious TTIP would increase GDP in the REU by 0.53%, while for the UK it would be 0.66%. This is because the US is a more important trade partner for UK than for the EU. By contrast, for the US the impact of TTIP with the UK would be very small. Even with an ambitious UK-US TTIP, GDP would increase by 0.10%, which is five times smaller than the 0.53% it would obtain after an ambitious TTIP with the REU.

Table 5 displays the joint macroeconomic impact of *full implementation* of (hard and soft) Brexit and a (modest or ambitious) TTIP. When a full implementation of Brexit comes into play (thus, simultaneously including all trade and FDI barriers[8]), the UK is severely harmed, while the REU is harmed to a much lesser extent. Table 5 shows that TTIP becomes a compensating force of the negative impact of Brexit for both regions. It would also allow them to counteract trade and FDI losses expanding their flows to a relatively large region as the US is. We have seen that TTIP causes a larger impact on the UK than on the REU. Despite this fact TTIP alone is not able to overturn the losses from Brexit in any possible scenario in the UK. However, in the EU, TTIP unleashes, in general, forces that are strong enough to make up the negative impact of Brexit. This positive impact from TTIP for the REU arises in all Brexit and TTIP combinations except the one that consists of a hard Brexit and a modest TTIP. In this latter scenario, the EU would still suffer a small contraction in its GDP of -0.14%. This is because the US is a much larger region than UK is and a more important trade and FDI partner for the EU than the UK is.

As noted above, positive or negative outcomes may hide considerable variations for individual sectors. We turn now to this sectoral analysis

Microeconomic impact

We offer an analysis of producer-side impacts and consumer-side variety effects, which have received less attention, to the best of our knowledge, in previous studies. These results are characteristic of models including a Melitz setting and imperfect competition (e.g., Krugman, 1980). To that aim we analyze average productivity for firms operating in domestic markets and industry-wide average productivity which also accounts for

[8] As already noted, the impact of this full implementation of Brexit is what appears in Table 4 in the hard and soft Brexit scenarios.

firms' exit and entry to/from domestic markets. We also study the evolution of the number of varieties. The results are for the UK and the REU region, depending on which region undertakes the particular policy measure analyzed from now onwards. This is because the impact mainly concentrates in that region, as can be seen in the macroeconomic outcomes above. In addition, this helps us to keep the analysis manageable[9].

The first two upper sets of results in Table 6 offer the evolution of average domestic productivity and of industry-wide average productivity. Brexit would harm productivity in both the UK and the REU. However, its impact is much more harmful for the UK than for REU. As analyzed in detail in Latorre et al. (2018srrn), productivity is falling due to the domestic entry of less productive firms (due to increased protectionism) and not because of the exit from export markets. The last block of results in Table 6 presents the reduction in the number of varieties available for consumption that Brexit brings about. This consumer-side variety effects are measured using the Feenstra (2010) ratio, which takes into account firm level prices and quantities of heterogeneous firms. This ratio discriminates between varities that are cheap (i.e., produced in big quantities by more productive firms) and those that are expensive (i.e., produced in small quantities by less productive firms). An increase in the former brings about more positive consumer-side variety effects than an increase in the latter does.

Producer-side gains from unilateral UK trade liberalization tend to concentrate more on the average productivity for firms operating in domestic markets. These used to be sheltered from foreign competition through high tariffs faced by imports coming from outside Europe. When these tariffs are eliminated, the most productive domestic firms survive but less productive ones shut down. As a result, average domestic productivity increases. The sectors whose domestic productivity increases more are textiles, other transport and motor vehicles. These sectors are characterized by a combination of rather high tariffs for most of the partners (particularly textiles and motor vehicles) and a strong trade integration with third countries (particularly for textiles and other transport), rather than from the REU. Increases in average domestic productivity are, however, dampened when we consider industry-wide average productivity. This is because tariffs are only lowered in UK's markets, so that UK's exporters do not experience substantial increases in their productivity. The reduction in tariffs results, however, in sizeable consumer-side variety effects only in two sectors, namely, food and textiles. In these two sectors, third countries (i.e., countries coming outside the EU) are quite competitive, faced sizeable tariffs and a large share of imports is oriented to private consumption. For the rest of sectors increases in the number of varieties are very small, since the UK loses the varieties that were previously produced by highly productive European exports. The latter are crowded out by exports from other areas that enjoy increases in competitiveness only due to tariffs' elimination.

[9] We also omit the impact of the reductions of barriers in the UK to FDI with China, Japan and India, since as shown in the macroeconomic results, it is negligible.

The next columns in Table 6 show the impact of TTIP without taking into account Brexit. Because domestic firms lose shelter after TTIP liberalization only the most productive ones survive, thus, increasing average domestic productivity. The only exception to this average domestic productivity increases is construction that has nearly no barriers and is hardly traded, so that TTIP would not affect domestic productivity. Increases in average domestic productivity across the board result, in general, in average industry-wide productivity rises that are slightly more positive for the UK than for the REU. In the same line, increases in the number of varieties available for consumption are slightly more pronounced in the UK than in the REU. All these trends are expected since the US is a more important trade partner for the UK than for the REU (Figure 1 and Table 1). However, we do find some sectoral variation in these impacts. For example, in sectors like food and textiles the impact on industry-wide average productivity is the opposite than the one experienced in the rest of sectors in the UK and in the REU. As noted above, food and textiles' production is less oriented to exports so they tend to benefit less from the reduction in barriers when TTIP lowers them. In addition, in these sectors exports and imports to/from the US are rather small, so that barriers reductions are applied to a small share of their exports. Thus, the increases in production due to more exports in these sectors are considerably smaller than in the rest of sectors. What is more, barriers in these two sectors are larger in the European side (both for REU and UK) than in the US side, so that imports coming from US would tend to expand more than European (UK and REU) exports going to the US side. TTIP would thus not result in a particularly strong expansion of EU and UK exporters.

Table 7 turns to the analysis of the simultaneous impact of Brexit and TTIP. We thus present different combinations of a hard and soft Brexit and a modest and ambitious TTIP. In addition we do it for a UK-US TTIP (which appears on the left of the table) and a REU-US TTIP which appears on the right. Again our results focus on the region undertaking the policy shock, so that results on the left are for the UK and the ones on the right are for the REU. In general, the fall due to Brexit of average productivity of REU domestic firms could be overturned by a TTIP agreement. The only exception would be the least favorable scenario of a hard Brexit and a modest EU-US TTIP. By contrast, in the UK the impact of TTIP would never be strong enough to make up for the reductions in productivity induced by Brexit, independently of the scenario considered. These patterns also hold for the average industry-wide productivity for which TTIP in general could overturn decreases in productivity in the EU but not in the UK[10]. They match, in general, the outcomes we have described in the macroeconomic results. Note, however, that in the UK there are some exceptions of increases of productivity or nearly no changes in productivity in sectors like other machinery and construction. These exceptional patterns can be explained by the fact that these sectors have nearly no barriers to trade, so when changes arise for these barriers in other sectors due to either TTIP or Brexit, the difference with respect to the initial situation in construction and other machinery is negligible.

[10] The exceptional patterns of decreases in average industry-wide productivity described above for food and textiles after TTIP (with no Brexit) scenario again hold here.

We also analyze the evolution of the number of varieties available for consumption (using again the Feenstra ratio explained above). The results are analogous to the ones we have just described in relationship with the impact on productivity. Varieties for consumption would tend to increase in the REU thanks to TTIP after Brexit. The only exception would arise again in the combination of a hard Brexit and a modest TTIP in which there would be very small reductions in the number of varieties. By contrast, in the UK, there is no TTIP agreement that can compensate the losses in varieties caused by Brexit.

Conclusions

We use a general equilibrium analysis including a state-of-the-art Melitz structure in manufactures and the operations of foreign multinationals in services. We study different policy alternatives for UK and the Rest of the European Union (REU) to counteract the harmful impact of Brexit. Given cultural distance and differences in legislative regimes not all possible trade or FDI partners are desirable targets to do business with. In this sense the US appears as a rather close economy to the European partners with a very attractive size.

The paper analyzes a unilateral tariff elimination in the UK, different FDI agreements of this economic with China, Japan and India and a comprehensive trade and FDI agreement with the US (similar to TTIP). While the FDI agreements have a negligible impact on the UK, we find some scope in the unilateral tariff elimination to raise wages and capital remuneration in that economy. When analyzing a UK-US TTIP agreement we find it insufficient to compensate the negative impacts of Brexit. By contrast, in most of the possible Brexit and TTIP joint scenarios TTIP could be useful for the REU to overturn the limited negative effects it experiences with Brexit.

Brexit tends to lower productivity in manufactures since it shelters firms from healthy competition, while TTIP tends to raise competition. In the same line, Brexit lowers the number of manufacturing and services varieties, whereas TTIP increases them. All these results are very asymmetric, with the UK being much more negatively affected by Brexit than the REU. The same can be said about the macroeconomic impacts. However, all these results hide considerable variation across sectors, not only in the depth of the adjustment but also in some cases in its direction. In sectors, in which the level of barriers is small, such as, other machinery the adjustment is also very small. In sectors in which the partners affected by the policy measured analyzed tend to be less integrated the impact is also limited.

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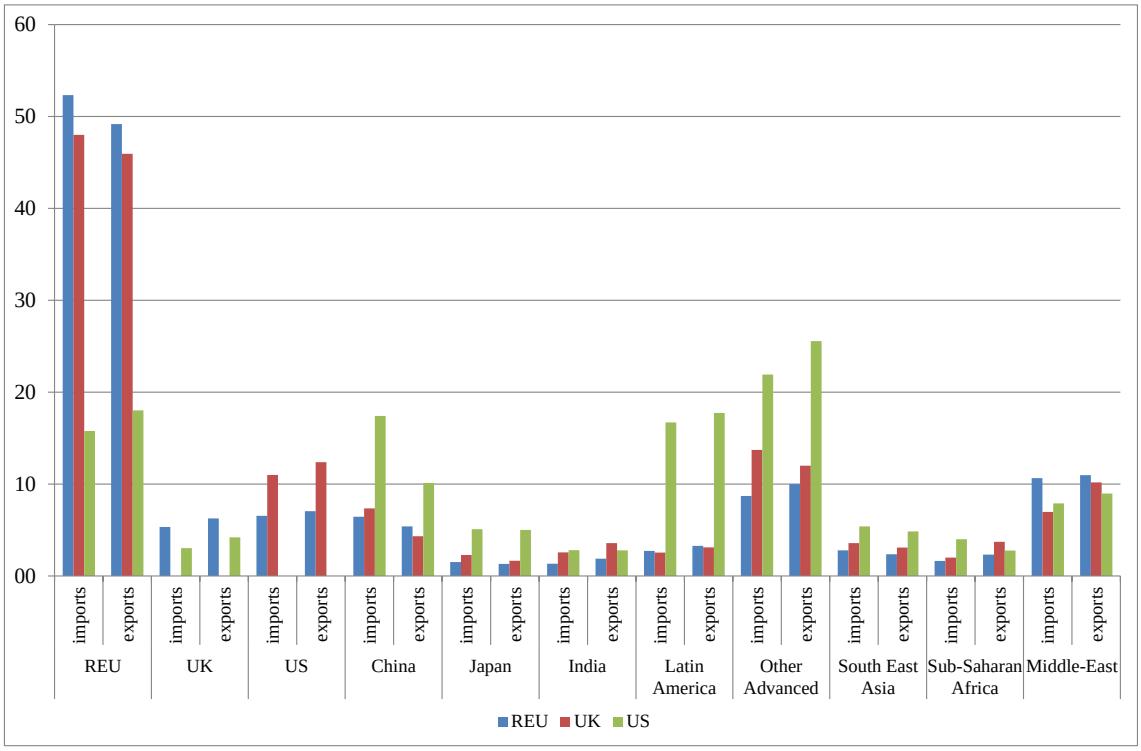
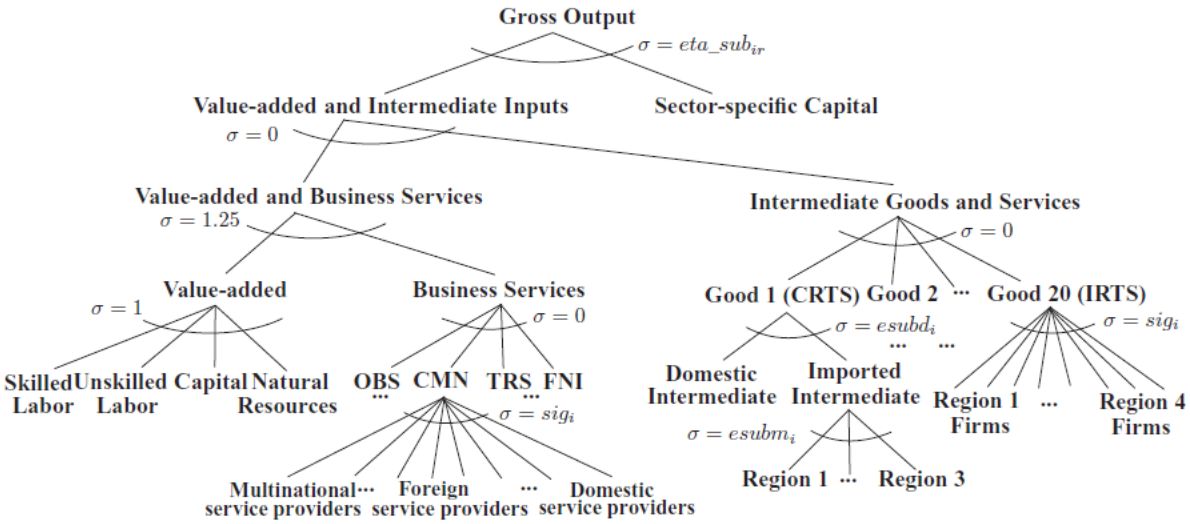
Figure 1. Regions' shares in aggregate imports and exports of the UK, the Rest of the European Union (REU) and the US in 2020



Source: Authors' estimations based on Aguiar et al. (2016) and IMF (2015) for the projections.

Figure 2. Production structure



Source: Authors' elaboration.

Table 1. UK, the Rest of the European Union (REU) and US bilateral shares in their respective trade flows

	Sectors	REU imports from:				UK imports from:			US imports from:			REU exports to:				UK exports to:			US exports to:		
		GBR	USA	ROW	REU	REU	USA	ROW	REU	GBR	ROW	GBR	USA	ROW	REU	REU	USA	REU	REU	GBR	ROW
CRTS sectors	Agriculture	2.4	4.1	93.5	55.8	48.7	4.0	47.3	3.8	0.4	95.8	6.4	1.3	92.3	65.3	71.3	3.7	25.0	5.7	0.6	93.7
	Other primary	3.4	1.3	95.3	4.0	11.4	1.5	87.1	0.1	0.3	99.6	12.4	0.5	87.1	38.8	68.0	4.7	27.3	21.0	2.8	76.3
	Wood and paper	3.4	2.7	93.9	75.1	62.0	7.3	30.7	9.4	1.5	89.1	7.1	3.1	89.9	59.3	48.7	9.0	42.3	9.0	3.5	87.4
	Personal services	7.2	10.7	82.2	50.6	46.6	25.0	28.4	30.0	7.3	62.7	7.4	5.9	86.7	43.5	44.4	10.4	45.2	17.7	7.7	74.7
	Other services	3.2	9.6	87.1	48.9	43.9	17.1	39.0	25.8	5.2	68.9	5.2	8.3	86.5	43.0	33.4	19.9	46.7	21.9	5.3	72.8
IRTS sectors with Melitz structure	Food	5.0	1.8	93.2	72.5	74.7	3.0	22.3	19.7	2.6	77.7	9.5	4.9	85.6	59.1	57.9	9.2	32.8	6.5	1.7	91.8
	Textiles	2.6	0.8	96.6	42.6	30.3	1.4	68.3	5.6	0.4	94.0	6.3	4.3	89.4	58.9	62.3	4.7	33.0	9.5	2.5	88.0
	Chemicals	6.3	9.1	84.6	58.9	57.9	10.5	31.6	28.0	4.7	67.3	5.9	9.0	85.1	52.5	55.1	14.8	30.2	20.9	2.8	76.3
	Metals	3.8	2.4	93.8	66.1	35.2	17.3	47.5	12.6	1.8	85.6	5.5	3.9	90.6	58.6	40.1	6.8	53.1	8.4	10.5	81.2
	Motor vehicles	5.4	2.5	92.1	79.0	84.3	1.6	14.1	16.6	2.0	81.4	8.7	6.0	85.3	53.3	47.8	9.4	42.7	8.0	0.8	91.2
	Other transport	6.0	19.2	74.8	44.5	36.6	32.6	30.8	37.4	7.5	55.0	5.0	12.4	82.6	37.4	32.7	16.1	51.2	25.9	7.2	67.0
	Electronics	3.8	4.6	91.6	37.4	41.5	7.6	50.9	2.7	0.4	96.9	7.6	3.8	88.6	52.4	58.5	6.6	34.9	13.3	2.9	83.8
	Other machinery	4.0	7.3	88.7	60.1	54.7	13.6	31.7	20.8	3.0	76.1	4.6	7.7	87.7	42.0	35.6	14.4	50.0	14.6	3.3	82.1
	Other manufactures	4.1	4.4	91.5	53.0	36.9	17.5	45.6	14.5	2.1	83.4	6.2	10.1	83.7	47.9	38.0	15.2	46.7	14.9	11.0	74.1
	Construction	2.5	5.2	92.3	48.0	37.6	2.7	59.7	24.7	1.7	73.6	1.5	1.6	96.9	31.5	34.0	2.3	63.7	21.5	0.7	77.9
IRTS services with multinationas	Water transport	3.4	0.9	95.8	46.3	55.6	2.7	41.7	14.8	1.5	83.7	4.5	0.8	94.7	34.4	40.4	1.3	58.3	12.6	4.4	83.1
	Air transport	7.6	12.7	79.6	38.0	51.5	9.6	38.9	34.0	7.3	58.7	9.3	12.1	78.6	28.1	33.7	15.5	50.8	30.3	5.6	64.0
	Communications	11.1	9.9	79.0	43.6	46.0	13.2	40.7	32.9	4.2	62.9	9.5	9.6	80.9	43.7	58.6	6.4	35.0	30.5	8.4	61.1
	Finance	16.4	21.1	62.4	36.0	29.3	33.2	37.5	26.5	28.8	44.7	8.0	13.7	78.3	47.7	34.5	23.5	42.0	35.6	11.5	52.9
	Insurance	9.8	19.5	70.8	43.5	52.2	19.7	28.1	45.3	14.3	40.4	2.6	32.0	65.4	20.8	18.7	40.5	40.7	21.4	2.2	76.3
	Business services	12.7	13.1	74.2	43.0	35.6	11.7	52.7	21.5	3.4	75.0	4.7	5.8	89.5	42.2	51.6	3.9	44.5	39.1	4.7	56.2
Aggregates	Total Manufacturing	4.6	5.2	90.2	54.2	49.9	9.6	40.5	13.9	2.1	84.0	6.4	6.7	86.9	51.1	48.2	11.6	40.3	15.5	3.9	80.7
	Total services	8.7	12.1	79.1	44.5	41.3	16.7	42.0	28.0	8.4	63.6	5.8	8.9	85.3	40.3	41.5	14.0	44.5	28.9	6.1	65.0
	Total	5.3	6.5	88.1	52.3	48.0	11.0	41.0	15.8	3.0	81.2	6.3	7.0	86.7	49.2	45.9	12.4	41.7	18.0	4.2	77.8

Source: Authors' estimations based on Aguiar et al. (2016) and IMF (2015) for the projections.

Table 2. Total trade costs increases of Brexit and trade cost decreases of TTIP arising from joint reductions in tariffs and NTBs to trade

Sectors		Total Brexit trade costs increases EU-UK			Total TTIP trade costs reductions							
		Hard Brexit		Soft Brexit	Ambitious				Modest			
		In REU	In UK	In REU and UK	In EU	In UK	In US for EU	In US for UK	In EU	In UK	In US for EU	In US for UK
CRTS sectors	Agriculture	38.6	39.2	14.2	-17.5	-18.1	-20.6	-19.0	-9.0	-9.6	-9.7	-8.0
	Other primary	28.4	28.5	14.2	-14.2	-14.2	-18.4	-18.4	-5.7	-5.7	-7.4	-7.4
	Wood and paper	6.1	6.6	2.8	-3.1	-3.1	-2.1	-2.0	-1.4	-1.4	-1.0	-0.8
	Personal services	2.2	2.2	1.1	-1.1	-1.1	-0.6	-0.6	-0.4	-0.4	-0.3	-0.3
	Other services	2.2	2.2	1.1	-1.1	-1.1	-0.6	-0.6	-0.4	-0.4	-0.3	-0.3
IRTS sectors with Melitz structure	Food	48.2	50.4	14.2	-27.7	-25.3	-20.9	-19.5	-19.2	-16.8	-10.0	-8.5
	Textiles	19.6	19.1	4.8	-11.1	-12.9	-11.9	-10.6	-8.3	-10.0	-9.4	-8.1
	Chemicals	9.6	9.5	3.4	-5.4	-5.5	-6.1	-6.2	-3.4	-3.5	-3.3	-3.4
	Metals	7.8	8.0	3.0	-4.9	-4.7	-5.5	-5.2	-3.2	-2.9	-3.0	-2.7
	Motor vehicles	20.8	21.5	6.4	-14.6	-10.4	-7.8	-7.9	-10.8	-6.6	-3.8	-3.9
	Other transport	11.1	11.0	4.7	-5.9	-5.7	-4.9	-4.8	-3.1	-2.8	-2.1	-2.0
	Electronics	7.3	7.9	3.2	-3.7	-3.9	-4.0	-4.1	-1.8	-2.0	-1.8	-1.9
	Other machinery	1.7	1.8	0.0	-1.2	-1.6	-0.9	-0.8	-1.2	-1.6	-0.9	-0.8
	Other manufactures	8.2	7.8	2.8	-4.7	-3.6	-3.8	-2.6	-3.0	-1.9	-2.6	-1.5
	Construction	2.3	2.3	1.2	-1.2	-1.2	-0.6	-0.6	-0.5	-0.5	-0.3	-0.3
IRTS services with multinationas	Water transport	4.0	4.0	2.0	-2.0	-2.0	-2.0	-2.0	-0.8	-0.8	-0.8	-0.8
	Air transport	1.0	1.0	0.5	-0.5	-0.5	-0.5	-0.5	-0.2	-0.2	-0.2	-0.2
	Communications	5.9	5.9	2.9	-2.9	-2.9	-0.4	-0.4	-1.2	-1.2	-0.2	-0.2
	Finance	5.7	5.7	2.8	-2.8	-2.8	-7.9	-7.9	-1.1	-1.1	-3.2	-3.2
	Insurance	5.4	5.4	2.7	-2.7	-2.7	-4.8	-4.8	-1.1	-1.1	-1.9	-1.9
	Business services	7.5	7.5	3.7	-3.7	-3.7	-1.0	-1.0	-1.5	-1.5	-0.4	-0.4

Source: Latorre et al. (2018srrn) and Latorre and Yonezawa (2018) for TTIP barriers.

Table 3. Detailed cost decreases related to NTBs to trade and Tariffs of TTIP

	Sectors	TTIP NTBs costs reductions				TTIP 100% Tariffs Elimination			
		Ambitious		Modest		In EU	In UK	In US	In US
		In EU&UK	In US	In EU&UK	In US	for US		for EU	for UK
CRTS sectors	Agriculture	-14.2	-18.3	-5.7	-7.3	-3.3	-3.9	-2.3	-0.6
	Other primary	-14.2	-18.3	-5.7	-7.3	0.0	0.0	-0.1	-0.1
	Wood and paper	-2.8	-1.9	-1.1	-0.8	-0.2	-0.3	-0.2	0.0
	Personal services	-1.1	-0.6	-0.4	-0.3	0.0	0.0	0.0	0.0
	Other services	-1.1	-0.6	-0.4	-0.3	0.0	0.0	0.0	0.0
IRTS sectors with Melitz structure	Food	-14.2	-18.3	-5.7	-7.3	-13.5	-11.1	-2.6	-1.2
	Textiles	-4.8	-4.2	-1.9	-1.7	-6.3	-8.1	-7.7	-6.4
	Chemicals	-3.4	-4.8	-1.4	-1.9	-2.0	-2.1	-1.4	-1.5
	Metals	-3.0	-4.3	-1.2	-1.7	-2.0	-1.7	-1.3	-1.0
	Motor vehicles	-6.4	-6.7	-2.6	-2.7	-8.2	-4.1	-1.1	-1.2
	Other transport	-4.7	-4.8	-1.9	-1.9	-1.2	-1.0	-0.1	-0.1
	Electronics	-3.2	-3.7	-1.3	-1.5	-0.5	-0.7	-0.3	-0.4
	Other machinery	0.0	0.0	0.0	0.0	-1.2	-1.6	-0.9	-0.8
	Other manufactures	-2.8	-1.9	-1.1	-0.8	-1.9	-0.8	-1.9	-0.7
	Construction	-1.2	-0.6	-0.5	-0.3	0.0	0.0	0.0	0.0
IRTS services with multinationas	Water transport	-2.0	-2.0	-0.8	-0.8	0.0	0.0	0.0	0.0
	Air transport	-0.5	-0.5	-0.2	-0.2	0.0	0.0	0.0	0.0
	Communications	-2.9	-0.4	-1.2	-0.2	0.0	0.0	0.0	0.0
	Finance	-2.8	-7.9	-1.1	-3.2	0.0	0.0	0.0	0.0
	Insurance	-2.7	-4.8	-1.1	-1.9	0.0	0.0	0.0	0.0
	Business services	-3.7	-1.0	-1.5	-0.4	0.0	0.0	0.0	0.0

Source: Latorre and Yonezawa (2018).

Table 4. Macroeconomic impact of Brexit, UK unilateral tariff elimination, UK FDI agreements, a UK-US TTIP and a REU-US TTIP (% changes with respect to the initial data)

		GDP			Welfare			Wages			Capital remuneration			Exports			Imports			CPI	
		UK	REU	US	UK	REU	US	UK	REU	US	UK	REU	US	UK	REU	US	UK	REU	US	UK	REU
Soft Brexit		-1.24	-0.17	0.01	-1.57	-0.29	0.01	-1.25	-0.18	0.00	-1.66	-0.22	0.01	-7.39	-1.57	0.05	-6.48	-1.68	0.04	0.28	-0.06
Hard Brexit		-2.55	-0.38	0.01	-3.19	-0.63	0.02	-2.80	-0.41	0.01	-3.47	-0.45	0.02	-16.69	-3.53	0.12	-14.30	-3.81	0.10	1.06	-0.19
UK Unilateral Tariff Elimination		0.12	-0.01	0.02	0.03	-0.04	0.04	0.51	-0.01	0.01	0.63	-0.01	0.02	4.01	-0.09	0.48	3.09	-0.09	0.36	-1.19	-0.23
UK modest FDI agreement		0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
UK ambitious FDI agreement		0.02	0.00	0.00	0.04	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	-0.02	0.00
UK-US modest TTIP	fdi	0.08	0.00	0.02	0.10	0.00	0.02	0.03	0.00	0.02	0.17	0.00	0.01	-0.17	0.00	0.07	0.07	0.00	-0.01	1.14	-0.17
	ntb	0.13	0.00	0.02	0.18	0.00	0.02	0.11	0.00	0.01	0.13	0.00	0.01	0.64	-0.02	0.23	0.50	-0.02	0.17	1.12	-0.20
	tar	0.05	0.00	0.01	0.06	-0.01	0.01	0.08	0.00	0.01	0.07	0.00	0.01	0.59	-0.02	0.20	0.48	-0.02	0.15	0.95	-0.22
	total	0.26	0.00	0.04	0.34	-0.01	0.05	0.23	0.00	0.04	0.37	-0.01	0.03	1.13	-0.04	0.52	1.11	-0.05	0.32	1.08	-0.21
UK-US ambitious TTIP	fdi	0.22	0.00	0.04	0.30	0.00	0.06	0.09	0.00	0.05	0.48	-0.01	0.02	-0.48	-0.01	0.20	0.21	-0.01	-0.02	0.29	-0.09
	ntb	0.37	0.00	0.05	0.50	0.00	0.06	0.30	0.00	0.05	0.34	0.00	0.04	1.89	-0.06	0.67	1.49	-0.07	0.49	0.42	0.28
	tar	0.05	0.00	0.01	0.06	-0.01	0.01	0.08	0.00	0.01	0.07	0.00	0.01	0.59	-0.02	0.20	0.48	-0.02	0.15	0.04	-0.15
	total	0.66	-0.01	0.10	0.87	-0.01	0.13	0.49	0.00	0.10	0.92	-0.01	0.08	2.22	-0.09	1.13	2.35	-0.11	0.66	0.14	0.10
REU-US modest TTIP	fdi	-0.01	0.06	0.11	-0.01	0.11	0.15	-0.01	0.03	0.09	-0.02	0.10	0.16	0.02	0.13	-0.02	0.00	0.03	0.10	-0.01	-0.02
	ntb	0.00	0.10	0.07	-0.01	0.18	0.08	0.00	0.08	0.07	0.00	0.10	0.01	-0.07	0.67	1.23	-0.06	0.78	0.90	0.06	0.10
	tar	-0.01	0.04	0.04	-0.01	0.05	0.05	0.00	0.06	0.06	0.00	0.07	0.05	-0.06	0.93	1.21	-0.03	1.02	0.89	-0.09	-0.11
	total	-0.02	0.22	0.22	-0.03	0.34	0.29	-0.01	0.18	0.22	-0.03	0.29	0.23	-0.12	1.86	2.58	-0.09	1.96	2.00	-0.06	-0.05
REU-US ambitious TTIP	fdi	-0.03	0.17	0.29	-0.04	0.30	0.39	-0.02	0.07	0.24	-0.04	0.29	0.42	0.04	0.29	0.02	-0.01	0.10	0.25	0.01	-0.03
	ntb	-0.01	0.30	0.19	-0.02	0.51	0.22	0.01	0.24	0.20	-0.01	0.30	0.02	-0.20	1.85	3.62	-0.17	2.19	2.64	0.19	0.33
	tar	-0.01	0.04	0.04	-0.01	0.05	0.05	0.00	0.06	0.06	0.00	0.07	0.05	-0.06	0.93	1.21	-0.03	1.02	0.89	-0.09	-0.11
	total	-0.04	0.53	0.53	-0.06	0.88	0.69	-0.01	0.40	0.51	-0.06	0.69	0.52	-0.23	3.44	5.31	-0.21	3.71	4.11	0.06	0.13

Source: Authors' estimations.

Table 5. Macroeconomic impact of joint Brexit and TTIP agreements (% changes with respect to the initial data)

	Impact on UK's						
	GDP	Welfare	Wages	Capital Remuneration	Exports	Imports	CPI
UK-US modest TTIP & soft Brexit	**-1.19**	**-1.23**	**-1.01**	**-1.29**	**-6.17**	**-5.29**	**0.35**
UK-US ambitious TTIP & soft Brexit	**-0.58**	**-0.70**	**-0.76**	**-0.76**	**-4.92**	**-3.92**	**0.59**
UK-US modest TTIP & hard Brexit	**-2.28**	**-2.84**	**-2.56**	**-3.10**	**-15.38**	**-13.23**	**1.08**
UK-US ambitious TTIP & hard Brexit	**-1.89**	**-2.32**	**-2.32**	**-2.57**	**-14.00**	**-11.76**	**1.30**

	Impact on REU's						
	GDP	Welfare	Wages	Capital Remuneration	Exports	Imports	CPI
REU-US modest TTIP & soft Brexit	**0.06**	**0.08**	**0.03**	**0.09**	**0.63**	**0.67**	**-0.08**
REU-US ambitious TTIP & soft Brexit	**0.37**	**0.62**	**0.25**	**0.50**	**2.32**	**2.53**	**0.10**
REU-US modest TTIP & hard Brexit	**-0.14**	**-0.25**	**-0.19**	**-0.14**	**-1.30**	**-1.43**	**-0.20**
REU-US ambitious TTIP & hard Brexit	**0.19**	**0.30**	**0.03**	**0.27**	**0.42**	**0.46**	**0.00**

Source: Authors' estimations.

Table 6. Impact on productivity in Melitz sectors and on consumption varieties of Brexit, a UK unilateral tariff elimination, a UK-US TTIP and a REU-US TTIP (% changes with respect to the initial data)

			Soft Brexit		Hard Brexit		UK Unilateral Tariff Elimination	UK-US modest TTIP	UK-US ambitious TTIP	REU-US modest TTIP	REU-US ambitious TTIP
			UK	REU	UK	REU	UK	UK	UK	REU	REU
			Domestic productivity								
FPR	IRTS sectors with Melitz structure	Food	-1.22	-0.21	-2.12	-0.41	0.48	0.17	0.47	0.16	0.40
T_A		Textiles	-0.77	-0.09	-2.27	-0.28	1.26	0.13	0.14	0.19	0.23
CHM		Chemicals	-0.99	-0.10	-2.27	-0.24	0.41	0.30	0.52	0.20	0.37
MMP		Metals	-0.65	-0.05	-1.60	-0.11	0.44	0.23	0.42	0.05	0.08
MVH		Motor vehicles	-2.27	-0.21	-2.27	-0.62	0.60	0.25	0.49	0.23	0.42
OTN		Other transport	-0.91	-0.14	-1.89	-0.28	0.99	0.43	0.98	0.29	0.64
EEQ		Electronics	-1.39	-0.12	-2.27	-0.26	0.58	0.13	0.26	0.06	0.12
OME		Other machinery	0.06	0.01	-0.59	-0.01	0.34	0.13	0.10	0.06	0.03
OMF		Other manufactures	-0.22	-0.03	-0.66	-0.08	0.25	0.05	0.07	0.08	0.09
CNS		Construction	0.00	0.00	0.00	0.01	0.01	0.00	-0.01	0.00	-0.01
			Industry productivity								
FPR	IRTS sectors with Melitz structure	Food	-1.13	-0.26	-2.75	-1.10	-0.01	-0.09	-0.76	-0.14	-0.79
T_A		Textiles	-0.72	-0.08	-2.37	-0.45	0.38	-0.14	-0.25	-0.11	-0.20
CHM		Chemicals	-0.91	-0.07	-2.18	-0.22	0.28	0.22	0.35	0.12	0.20
MMP		Metals	-0.57	-0.03	-1.48	-0.12	0.28	0.13	0.20	0.00	-0.02
MVH		Motor vehicles	-2.08	-0.18	-2.33	-0.65	0.45	0.17	0.27	0.13	0.18
OTN		Other transport	-0.84	-0.10	-1.83	-0.28	0.69	0.33	0.71	0.20	0.42
EEQ		Electronics	-1.29	-0.09	-2.15	-0.24	0.43	0.09	0.16	0.02	0.03
OME		Other machinery	0.05	0.01	-0.54	-0.01	0.26	0.11	0.08	0.04	0.02
OMF		Other manufactures	-0.20	-0.02	-0.63	-0.09	0.09	0.03	0.04	0.03	0.04
CNS		Construction	-0.05	0.00	-0.07	-0.01	-0.10	0.02	0.05	0.00	0.02
			Consumption varieties								
FPR	IRTS sectors with Melitz structure	Food	-1.75	-0.10	-2.88	-0.16	0.40	0.19	0.45	0.12	0.27
T_A		Textiles	-0.76	-0.09	-1.49	-0.20	0.84	0.14	0.35	0.07	0.19
CHM		Chemicals	-0.52	-0.08	-1.24	-0.16	0.02	0.10	0.22	0.08	0.21
MMP		Metals	-0.26	-0.03	-0.39	-0.08	0.14	0.07	0.12	0.02	0.05
MVH		Motor vehicles	-2.37	-0.15	-6.47	-0.33	0.00	0.13	0.31	0.11	0.27
OTN		Other transport	-0.39	-0.07	-0.73	-0.13	0.04	0.15	0.40	0.11	0.29
EEQ		Electronics	-0.50	-0.06	-1.22	-0.12	0.03	0.06	0.13	0.04	0.10
OME		Other machinery	-0.11	-0.02	-0.18	-0.06	0.02	0.04	0.07	0.02	0.05
OMF		Other manufactures	-0.41	-0.05	-0.73	-0.11	-0.01	0.13	0.32	0.04	0.12
CNS		Construction	-0.04	-0.01	-0.07	-0.02	0.00	0.01	0.02	0.01	0.02

Source: Authors' estimations.

Table 7. Impact on productivity in Melitz sectors and on consumption varieties of joint Brexit and TTIP agreements (% changes with respect to the initial data)

	UK-US modest TTIP & soft Brexit			UK-US ambitious TTIP & soft Brexit			REU-US modest TTIP & soft Brexit			REU-US ambitious TTIP & soft Brexit		
	Impact on UK's			Impact on UK's			Impact on REU's			Impact on REU's		
	Domestic productivity	Industry productivity	Consumption varieties	Domestic productivity	Industry productivity	Consumption varieties	Domestic productivity	Industry productivity	Consumption varieties	Domestic productivity	Industry productivity	Consumption varieties
FPR	-1.06	-1.16	-1.54	-0.77	-1.72	-1.27	0.01	-0.30	0.01	0.26	-0.95	0.17
T_A	-0.64	-0.84	-0.62	-0.62	-0.96	-0.41	0.13	-0.16	-0.01	0.18	-0.24	0.11
CHM	-0.70	-0.69	-0.43	-0.48	-0.56	-0.32	0.13	0.07	0.00	0.30	0.15	0.13
MMP	-0.42	-0.43	-0.19	-0.23	-0.36	-0.14	0.01	-0.02	-0.01	0.05	-0.05	0.02
mvh	-2.27	-2.12	-2.13	-2.27	-2.21	-1.84	0.10	0.03	-0.02	0.31	0.10	0.14
otn	-0.48	-0.50	-0.24	0.06	-0.11	0.01	0.17	0.12	0.04	0.52	0.35	0.21
EEQ	-1.26	-1.20	-0.45	-1.13	-1.12	-0.37	-0.05	-0.06	-0.02	0.02	-0.05	0.04
ome	0.20	0.15	-0.07	0.16	0.13	-0.04	0.08	0.05	0.00	0.05	0.04	0.03
omf	-0.16	-0.17	-0.28	-0.15	-0.16	-0.09	0.05	0.02	-0.01	0.07	0.02	0.07
cns	0.00	-0.03	-0.03	-0.01	0.01	-0.02	0.00	0.01	0.00	0.00	0.02	0.01
	UK-US modest TTIP & hard Brexit			UK-US ambitious TTIP & hard Brexit			REU-US modest TTIP & hard Brexit			REU-US ambitious TTIP & hard Brexit		
	Impact on UK's			Impact on UK's			Impact on REU's			Impact on REU's		
	Domestic productivity	Industry productivity	Consumption varieties	Domestic productivity	Industry productivity	Consumption varieties	Domestic productivity	Industry productivity	Consumption varieties	Domestic productivity	Industry productivity	Consumption varieties
FPR	-1.97	-2.66	-2.64	-1.71	-3.03	-2.35	-0.23	-1.09	-0.05	0.02	-1.73	0.11
T_A	-2.22	-2.53	-1.32	-2.19	-2.63	-1.12	-0.06	-0.47	-0.11	-0.01	-0.55	0.01
CHM	-2.26	-2.21	-0.97	-2.06	-2.07	-0.87	-0.01	-0.06	-0.07	0.17	0.03	0.05
MMP	-1.37	-1.32	-0.33	-1.19	-1.24	-0.28	-0.05	-0.09	-0.05	-0.01	-0.11	-0.02
mvh	-2.27	-2.36	-6.22	-2.27	-2.44	-5.92	-0.27	-0.36	-0.20	-0.06	-0.27	-0.03
otn	-1.46	-1.47	-0.57	-0.93	-1.07	-0.32	0.03	-0.03	-0.02	0.39	0.21	0.16
EEQ	-2.27	-2.18	-1.12	-2.27	-2.22	-1.00	-0.19	-0.20	-0.08	-0.12	-0.18	-0.02
ome	-0.46	-0.42	-0.15	-0.49	-0.45	-0.12	0.06	0.04	-0.03	0.03	0.02	0.00
omf	-0.60	-0.60	-0.61	-0.59	-0.59	-0.42	0.01	-0.04	-0.06	0.03	-0.03	0.02
cns	0.00	-0.05	-0.07	-0.01	-0.01	-0.05	0.00	0.00	-0.01	0.00	0.01	0.00

Source: Authors' estimations.

Online Appendix: The Algebraic Description of the Model

This document presents the algebraic formulation of a computable general equilibrium (CGE) model of the global economy, which is a numerical simulation model. This model has the similar structure to the models in Balistreri et al. (2014) and Balistreri and Tarr (2011). The model is what is called a mixed complementarity system in mathematics (for an explanation see the technical Appendices in Markusen (2002)). This model description is based on the Appendix F in Balistreri and Tarr (2011); however, the important distinctions include:

(i) this model is a multi-region model, whereas the model in Balistreri and Tarr (2011) is a single country model;

(ii) it incorporates both Krugman (1980) and Melitz (2003) model structures for Increasing Returns To Scale (IRTS) production following Balistreri and Rutherford (2013) and Olekseyuk and Balistreri (2017).

The model includes n commodities (goods and services), which are purchased by households, firms, and the government. Let the commodities be indexed by $g \in G$. Divide these commodities into the following three categories that define their treatment in the model formulation:

(a.) Business Services including foreign direct investment (FDI), characterized by monopolistic competition under Krugman structure, indexed by $i \in I \subset G$;

(b.) IRTS manufacturing sectors, characterized by monopolistic competition under Melitz structure, indexed by $j \in J \subset G$;

(c.) Constant Returns To Scale (CRTS) goods indexed by $k \in K \subset G$.

Commodities are also classified by their associated region, indexed by $r \in R$ where O indicates own region. The accounts track the incomes of the representative household in each region decomposed by the primary mobile factors of production as well as sector-specific inputs for the monopolistic competition sectors and business service sectors with FDI.

Table 1 summarizes the equilibrium conditions and associated variables, and Tables 2 and 3 summarizes the parameters. To reduce the notation burden, we consider the perspective from one country so that we can suppress the index of own region r in Table 1 and the following equations, although the model is a multi-region model. The non-linear system is formulated in GAMS/MPSGE and solved using the PATH algorithm. We proceed with a description and algebraic representation of each of the conditions itemized in Table 1.

Table 1: General equilibrium conditions

Equilibrium Conditions	**(Equation)**		**Associated Variables**
Dual representation of preferences and technologies:			
Armington-like unit-cost functions	(1)	$\forall i \in I$	A^g : Armington-like activity
	(2)	$\forall j \in J$	
	(3)	$\forall k \in K$	
Dixit-Stiglitz price indexes (Krugman)	(4)	$\forall i \in I$	Q_r^i : D-S Activity by region
Zero profits for Dixit-Stiglitz firms (Krugman)	(5)	$\forall i \in I$	N_r^i : Number of firms
Dixit-Stiglitz price indexes for FDI firms	(6)	$\forall i \in I$	Q_r^{FDI} : D-S FDI Activity by region
Zero Profits for Dixit-Stiglitz FDI firms	(7)	$\forall i \in I$	N_r^{FDI} : Number of FDI firms
Dixit-Stiglitz price indexes (Melitz)	(8)	$\forall j \in J$	Q_r^j : D-S Activity by region
Zero cutoff profits for Melitz firms	(9)	$\forall j \in J$	N_{rm}^j : Number of operating firms
Expected zero profits for Dixit-Stiglitz firms (Melitz)	(10)	$\forall j \in J$	M_r^j : Number of entered firms
Firm-level productivity for average firm (Melitz)	(11)	$\forall j \in J$	$\tilde{\varphi}_{rm}^j$: Productivity
Price including sector-specific capital	(12)	$\forall g \in (I \cup J)$ and $r = O$	$Z_r^j(Q_r^i)$: Sector-specific capital use
	(13)	$\forall g \in (I \cup J)$ and $r \neq O$	
	(14)	$\forall i \in I$ and $r \neq O$	Q_r^{FDI} : Sector-specific capital use for FDI
Input-output technologies for non primary energy	(18)	$\forall g \in G$ but $g = ene$	Y^g: Production level
Input-output technologies for primary energy	(20)		Y^{ene}: Production level
Unit expenditure function	(21)		U: Household utility index
Unit cost of public purchase	(22)		PUB: Government activity
Unit cost of investment	(23)		INV: Investment activity
Market clearance conditions:			
Composite goods and services	(24)	$\forall g \in G$	PA^g : Composite price indexes
D-S composites	(26)	$\forall j \in J$ and $r \neq O$	P_r^g: Prices of D-S composites
	(27)	$\forall j \in J$ and $r = O$	
Markets for IRTS composite input (Krugman)	(28)	$\forall j \in J$	PMC^j: Composite input prices
Markets for IRTS composite input (Melitz)	(29)	$\forall j \in J$	PMC^j: Composite input prices
Markets for output	(30)	$\forall k \in K$	PY^g: Output prices
	(31)	$\forall i \in I$	
	(34)	$\forall j \in J$	
Markets for imports	(35)	$\forall i \in I$ and $r \neq O$	PM_r^g: Import prices
	(36)	$\forall j \in J$ and $r \neq O$	
	(37)	$\forall k \in K$ and $r \neq O$	
Factor markets	(38)	$\forall f \in F$	PF_f: Factor prices
Specific factors	(39)	$\forall g \in (I \cup J)$	PZ_r^g: Sector-specific capital price
Fixed real investment	(40)		$PINV$: Unit cost of investment
Fixed real public spending	(41)		PG: Unit cost of public good
Nominal utility equals Income	(42)		PC: Unit expenditure index
Balance of payments	(43)		PFX: Price of foreign exchange
Income balance:			
Domestic agent income	(44)		RA_h: Household Income
Government budget	(45)		$GOVT$: Government spending
Foreign Entrepreneur	(46)		FE: External agent income
Auxiliary Conditions:			
Fixed real public spending	(47)		T: Index on direct taxes

Table 2: Model parameters

Symbol	Description
Elasticity of substitution parameters	
σ_{va}	Value added composite
σ_{vas}	Value added vs. business services composite
σ_{srv}	Business services composite
ϵ_r^g	Elasticity of substitution between sector specific capital and others
σ_F^i	Dixit-Stiglitz elasticity of substitution on business services
σ_F^j	Dixit-Stiglitz elasticity of substitution on IRTS goods
σ_{DM}^k	Armington elasticity of substitution on CRTS goods (Domestic vs. foreign)
σ_{MM}^k	Armington elasticity of substitution on CRTS goods (among foreign)
Other parameters	
$\overline{sav}$	Reference saving
$\overline{pub}$	Reference level of government spending
$\overline{dtax}$	Reference level of direct tax from household to government
$\overline{ftrn}$	Reference capital account surplus
ϕ_r^i	Share of Dixit-Stiglitz component in Armington-like activity of business services i
ϕ_r^{FDI}	Share of FDI component in Armington-like activity of business services i
ϕ_r^j	Share of Dixit-Stiglitz component in Armington-like activity of manufacturing sectors j
ϕ_r^k	Share of domestic or import component in Armington activity of CRTS goods k
θ_{Zr}^g	Share of specific capital component in marginal cost
θ_{rr}^g	Share of all other components in marginal cost
θ_{VAS}	Share of value-added/business service cost in marginal cost without sector specific capital
θ_g	Share of non-business service commodity in marginal cost without sector specific capital
θ^{VAB}	Share of value-added cost in value-added/business-services cost bundle
θ_f	Share of each factor cost in value added cost bundle
θ_i	Share of each intermediate business service cost in aggregate business service cost bundle
μ_C^g	Expenditure share commodity g in private consumption
μ_G^g	Expenditure share commodity g in public consumption
μ_{INV}^g	Expenditure share commodity g in investment consumption
a	Shape parameter of the Pareto distribution for Melitz structure
b	Minimum productivity determined by the Pareto distribution

Table 3: Parameter values for elasticities

Parameter	Description	Value
σ_{va}	Value-added bundle	1
σ_{vas}	Value-added vs. business services	1.25
σ_{srv}	Business services bundle	1.25
ϵ_r^g	Sector specific capital vs. others	See notes.
σ_F^i	Dixit-Stiglitz elasticity on business services	3
σ_F^j	Dixit-Stiglitz elasticity on IRTS goods	3.8
σ_{DM}^k	Armington elasticity (Domestic vs. foreign)	GTAP values
σ_{MM}^k	Armington elasticity (among foreign)	GTAP values
s_{ene}	Price elasticity of primary energy production	1

Notes: This elasticity is calibrated, instead of being chosen explicitly, to the supply elasticities based on the estimates of Schiff (2006). Also, the Dixit-Sitiglitz elasticity for IRTS goods is based on the plant-level empirical analysis by Bernard et al. (2003). For Armington elasticities see Hummels (2001) and Hertel et al. (2007).

1 Dual representation of technologies and preferences

Technologies and preferences are represented through value functions that embed the optimizing behavior of agents. Any linearly-homogeneous transformation of inputs into outputs is fully characterized by a unit-cost (or expenditure) function. Generally, setting the output price equal to optimized unit cost yields the equilibrium condition for the activity level of the transformation. That is, a competitive constant-returns activity will increase up to the point that marginal benefit (unit revenue) equals marginal cost. In the case of this model not all transformations are constant returns, so there are exceptions. In general, however, we will use the convention of setting unit revenues (left-hand side) equal to unit cost (right-hand side) and associating this equilibrium condition with a transformation activity level.

Agents in each region wishing to purchase a particular good or service g face an aggregate price PA^g. In constructing the aggregate prices, we will rely on the following notation for the component prices:

PY^k Price of output for CRTS sectors,

PM^k Price of import composite of CRTS goods,

P_r^g Dixit-Stiglitz price index on region-r varieties for IRTS sectors ($\forall g \in (I \cup J)$),

P_r^{FDI} Dixit-Stiglitz price index on region-r varieties for FDI firms ($r \neq O$).

Assuming a Constant Elasticity of Substitution (CES) aggregation of the components we equate the prices to the CES unit-cost functions:

$$PA^i = \left(\sum_r \phi_r^i (P_r^i)^{1-\sigma_F^i} + \sum_{r \neq O} \phi_r^{FDI} (P_r^{FDI})^{1-\sigma_F^i} \right)^{1/(1-\sigma_F^i)} \quad (1)$$

$$PA^j = \left(\sum_r \phi_r^j (P_r^j)^{1-\sigma_F^j} \right)^{1/(1-\sigma_F^j)} \quad (2)$$

$$PA^k = \left(\phi_D^k (PY^k)^{1-\sigma_{DM}^k} + \phi_M^k (PM^k)^{1-\sigma_{DM}^k} \right)^{1/(1-\sigma_{DM}^k)}, \quad (3)$$

where σ_F^i and σ_F^j are the Dixit-Stiglitz elasticity of substitution, σ_{DM}^k is the Armington elasticity of substitution on CRTS goods, and PM^k is the composite of imports from all other countries by using the Armington elasticities σ_{MM}^k. Thus, Armington trade is considered for CRTS goods, whereas trade with monopolistic competition (proposed by Krugman (1980)) and with endogenous entry (as extension to Krugman (1980)) is considered for business service sectors. The arguments of these functions are the component prices. The ϕ parameters are CES distribution parameters that indicate scale and weighting of the arguments. These are calibrated to the social accounts such that the accounts are replicated in the benchmark equilibrium.

For the business service sectors, we have the Dixit-Stiglitz price indexes following the Krugman structure. These are functions of the number of varieties, firm-level costs, and the optimal markup. Assuming each firm is small relative to the size of the market the demand elasticity for a firm's variety is σ_F^i and the optimal markup over marginal cost is given by $1/(1-\frac{1}{\sigma_F^i})$. Let marginal cost equal PMC_r^i, which is the price of a composite input to the Dixit-Stiglitz firms associated with region-r, and let the number of varieties by region equal N_r^i. The price indexes for the Dixit-Stiglitz goods are thus given by

$$P_r^i = \left[N_r^i \left(\frac{PMC_r^i}{1-\frac{1}{\sigma_F^i}} \right)^{1-\sigma_F^i} \right]^{1/(1-\sigma_F^i)}. \tag{4}$$

In equilibrium, the number of varieties by region adjusts such that we have zero profits. Denote the Dixit-Stiglitz composite activity level associated with equation (4) by Q_r^i. Given the Dixit-Stiglitz aggregation of varieties each firm produces a quantity $Q_r^i (N_r^i)^{\sigma_F^i/(1-\sigma_F^i)}$. Following the literature (e.g., Krugman (1980) and Helpman and Krugman (1985)), we assume a firm-level fixed cost of f_r^i (in composite input units) and also assume that fixed and variable costs are satisfied using the same input technology. Then, we have the zero profit condition

$$f_r^i - \frac{Q_r^i (N_r^i)^{\sigma_F^i/(1-\sigma_F^i)}}{\sigma_F^i - 1} = 0. \tag{5}$$

This same structure is assumed for FDI firms. The price indexes for the Dixit-Stiglitz FDI goods are given by

$$P_r^{FDI} = \left[N_r^{FDI} \left(\frac{PFDI_r}{1-\frac{1}{\sigma_F^i}} \right)^{1-\sigma_F^i} \right]^{1/(1-\sigma_F^i)}. \tag{6}$$

The zero profit condition is following:

$$f_r^{FDI} - \frac{Q_r^{FDI} (N_r^{FDI})^{\sigma_F^i/(1-\sigma_F^i)}}{\sigma_F^i - 1} = 0. \tag{7}$$

Regarding the IRTS manufacturing sectors, we adopt the competitive selection model of heterogeneous firms consistent with Melitz (2003) for the IRTS goods j. We modify the Krugman equations (4) and (5) with the equations (8) and (9) and include further equations (10) and (11) which determine firm's selection to different bilateral markets. To account for firm operation on

a particular bilateral link, we now have to add another country index $m \in R$ which identifies the destination (or importing) country. As firms are heterogeneous in this setup and have market power over their unique varieties, there is a continuum of firm-level prices, quantities and productivities. Following the initial Melitz representation, we simplify this by using a representative (or average) firm with the CES weighted average productivity $\tilde{\varphi}^j_{rm}$. Considering this we get a Dixit-Stiglitz price index for a composite commodity j in region m similar to the Krugman specification:

$$P^j_m = \left[\sum_r N^j_{rm} \left(\frac{PMC^j_r}{\tilde{\varphi}^j_{rm}(1 - \frac{1}{\sigma^j_F})} \right)^{1-\sigma^j_F} \right]^{1/(1-\sigma^j_F)}, \tag{8}$$

where N^j_{rm} is the number of firms operating on the r to m link.

Let M^j_r denote the number of entered firms in region r. Each of the entered firms pays the fixed entry cost f^s_{jr} and receives a firm-specific productivity draw φ from a Pareto distribution. Taking the fixed cost of operation on the r to m link (f^j_{rm}) into account, there will be a marginal firm with a level of productivity such that operating profits are zero. Linking this marginal firm in a given bilateral market to a representative firm earning positive profits, we can specify a zero-cutoff-profit condition in terms of average firm revenues:

$$f^j_{rm} - \frac{Q^j_r (N^j_{rm})^{\sigma^j_F/(1-\sigma^j_F)}}{\tilde{\varphi}^j_{rm}(1 - 1/\sigma^j_F)} \cdot \frac{(a + 1 - \sigma^j_F)}{a\sigma^j_F} = 0, \tag{9}$$

where a is the shape parameter of the Pareto distribution.[1] This condition is associated with the number of operating firms (N^j_{rm}) meaning that the average-firm revenues fall with more firms shipping from r to m.

The free entry condition or expected zero profits are given by the difference of the firm-level annualized flow of entry payments δf^s_{jr} and the expected profits from each potential market:

$$\delta f^s_{jr} - \sum_s \frac{Q^j_r (N^j_{rm})^{\sigma^j_F/(1-\sigma^j_F)}}{a\tilde{\varphi}^j_{rm}} \cdot \frac{N^j_{rm}}{M^j_r} = 0, \tag{10}$$

where δ denotes a probability of a negative shock that forces exit in each future period and N^j_{rm}/M^j_r indicates the probability that a firm from M^j_r will operate in the market m. Given the last one and applying the Pareto distribution we get the productivity of the average firm:

$$\tilde{\varphi}^j_{rm} = b \left(\frac{a}{a + 1 - \sigma^j_F} \right)^{\frac{1}{\sigma^j_F - 1}} \left(\frac{N^j_{rm}}{M^j_r} \right)^{-\frac{1}{a}}, \tag{11}$$

where b is the minimum productivity determined by the Pareto distribution.

The technologies for producing the composite inputs for use in the Dixit-Stiglitz sectors

[1] We assume a value for the Pareto shape parameter of 4.582, which is the central value estimated by Balistreri et al. (2011).

depend on the type of sector. For the IRTS manufacturing sectors and business service sectors (including FDI) there is a sector-specific capital input from the respective source region. Let $PZ_r^g \ \forall g \in (I \cup J)$ be the price of this sector-specific capital input. Domestic firms (producing goods or services) use domestic inputs, so the unit cost function is given by

$$PMC_r^g = \left[\theta_{Zr}^g (PZ_r^g)^{1-\epsilon_r^g} + \theta_{Dr}^g (PY^g)^{1-\epsilon_r^g}\right]^{1/(1-\epsilon_r^g)}, \quad \text{for} \quad r = O \ and \ \forall g \in (I \cup J) \quad (12)$$

where ϵ_r^g is the elasticity of substitution between the sector-specific capital input and other inputs, and the θ's are the CES distribution parameters. Imports of these sectors embody the gross of tariff imported inputs:

$$PMC_r^g = \left[\theta_{Zr}^g (PZ_r^g)^{1-\epsilon_r^g} + \theta_{Mr}^g (PM_r^g)^{1-\epsilon_r^g}\right]^{1/(1-\epsilon_r^g)}, \quad \text{for} \quad r \neq O \ and \ \forall g \in (I \cup J). \quad (13)$$

FDI firms, on the other hand, use domestic inputs as well as a specialized imported service from the sources region. The price of the specialized imports equals the price of foreign exchange (denoted PFX). The unit cost for FDI firms ($PFDI$) is thus given by the following:

$$PFDI_r = \left[\theta_{Zr}^i (PZ_r^i)^{1-\epsilon_r^i} + (\theta_{Dr}^i PY^i + \theta_{Mr}^i PFX)^{1-\epsilon_r^i}\right]^{1/(1-\epsilon_r^i)}, \quad \text{for} \quad r \neq O. \quad (14)$$

Note that the price of domestic inputs used for FDI firms (PY) is inclusive of the iceberg trade cost. In the counterfactual simulations, we reduce the iceberg trade cost component. Also, import tariff (t_{gr}^{imp}) and export tax (t_g^{exp}) create the wedge between the import price and foreign output price or between the domestic output price and import price of foreign countries.

For the CRTS sectors and upstream of the other technologies, we have domestic production in accordance with the input output data. Denote the price of this output PY^s, for $s \in G$. The technology includes an upstream CES value-added nest which then combines business services and ultimately then this composite combines with other intermediates in fixed proportions. Let PF_f indicate the price of primary factor of production $f \in F$ and let P_s^{vas} be the value-added business-services composite price for sector s. The composite of business services and value added, P_s^{vas}, is the CES aggregate of two CES aggregates (P_s^{srv} and P_s^{va}) as follows:

$$P_s^{vas} = \left[(1-\theta^{VAB})(P_s^{srv})^{1-\sigma_{vas}} + \theta^{VAB}(P_s^{va})^{1-\sigma_{vas}}\right]^{1/(1-\sigma_{vas})}, \quad (15)$$

$$P_s^{srv} = \left(\sum_i \theta_i^s [(1+t_{is}^{int})PA_i]^{1-\sigma_{srv}}\right)^{1/(1-\sigma_{srv})}, \quad (16)$$

$$P_s^{va} = \left(\sum_f \theta_f^s [(1+t_{fs})PF_f]^{1-\sigma_{va}}\right)^{1/(1-\sigma_{va})}, \quad (17)$$

where t_{gs}^{int} is the tax in sector s on purchases of good g and t_{fs} is the factor tax. The substitution elasticity between value added and the business services composite is given by σ_{vas}, whereas the substitution between business services and between factors are given by σ_{srv} and σ_{va}. With

P_s^{vas} established, the top-level Leontief unit cost function for sector s is given by

$$PY^s = \theta_{vas}^s P_s^{vas} + \sum_{g \neq I} \theta_g^s (1 + t_{gs}^{int}) PA^g, \tag{18}$$

where the θ is share parameters determined in the calibration to the input-output accounts.

Regarding the primary energy production sector, it includes the resource factor that is sector-specific, and thus this sector is subject to decreasing returns to scale. We calibrate the elasticity of substitution betweeen the resource factor and the rest of inputs to match the given price elasticities of supply, denoted s_{ene}. As Rutherford (2002) shows, the calibrated substution elasticitiy σ_{ene} is given by

$$\sigma_{ene} = s_{ene} \frac{\theta_{res}}{1 - \theta_{res}}, \tag{19}$$

where θ_{res} is the value share of resource factor input. Then, instead of equation (18), the top-level unit cost function of the primary energy production sector becomes

$$PY^{ene} = \left[\theta^{res} (PF_{res})^{1-\sigma_{ene}} + (1 - \theta^{res}) (\theta_{vas}^s P_s^{vas} + \sum_{g \neq I} \theta_g^s (1 + t_{gs}^{int}) PA^g)^{1-\sigma_{ene}} \right]^{1/(1-\sigma_{ene})}. \tag{20}$$

Final demand includes three categories: household demand, government demand, and investment. The representative agents for each household h are assumed to have identical Cobb-Douglas preferences over the aggregated goods and services. The preferences are specified via a unit expenditure function associated with an economy-wide utility index (U). Let PC be the true-cost-of-living index indicated by the following unit expenditure function:

$$PC = \prod_g [(1 + t_g^{cons}) PA^g]^{\mu_C^g}, \tag{21}$$

where the μ are value shares. The government faces a Leontief price index, PG, for government purchases:

$$PG = \sum_g \mu_G^g (1 + t_g^{gov}) PA^g. \tag{22}$$

Similarly the price of investment, $PINV$ is a Leontief aggregation of commodity purchases:

$$PINV = \sum_g \mu_{INV}^g (1 + t_g^{inv}) PA^g. \tag{23}$$

Equations (1) through (23) define all of the transformation technologies for the model. Next we turn to a specification of the market clearance conditions for each price.

2 Market clearance conditions

For each good or service there is a market, and, for any non-zero equilibrium price, supply will equal demand. We will use the convention of equating supply, on the left-hand side, to demand, on the right-hand side. The unit-value functions presented above are quite useful in deriving the appropriate compensated demand functions, by the envelope theorem (Shephard's Lemma).

Supply of the composite goods and services, trading at PA^g, is given by the activity level, A^g, and demand is derived from each production or final demand activity that uses the good or service. The market clearance condition is given by

$$A^g = \sum_s h_{gs}(Y^s, \boldsymbol{p}) + \mu_C^g U \frac{PC}{(1+t_g^{cons})PA^g} + \mu_G^g PUB + \mu_{INV}^g INV, \tag{24}$$

where $h_{gs}(Y^s, \boldsymbol{p})$ are the conditional input demands (as a function of output and the price vector). These are found by taking the partial derivative of the unit cost function for sector s with respect to the gross of tax price of input g. For inputs that are not business services input demands are proportional to output: $h_{gs}(Y^s, \boldsymbol{p}) = \theta_g^s Y^s \ \ \forall g \in (J \cup K)$. The input demands for business services are, however, more complex:

$$h_{is}(Y^s, \boldsymbol{p}) = \theta_i^s \theta_{vas}^s Y^s \left(\frac{P_s^{srv}}{(1+t_{is}^{int})PA_i} \right) \left(\frac{P_s^{vas}}{P_s^{srv}} \right)^{\sigma_{vas}} \tag{25}$$

where P_s^{srv} is the composite price of business services inputs as defined in equation (16).

For the IRTS sectors we have market clearance for the Dixit-Stiglitz regional composites:

$$Q_r^j = A^j \left(\frac{PA^j}{P_r^j} \right)^{\sigma_F^j} \quad r \neq O; \tag{26}$$

and for domestic firms we include demand for the Dixit-Stiglitz exports (or import demand of other countries)

$$Q_D^j = A^j \left(\frac{PA^j}{P_D^j} \right)^{\sigma_F^j} + \sum_r FORIM_r^j. \tag{27}$$

Since we consider the perspective from one country for reducing the notation burden in this document of model equations, here we simply call the foreign import demand as $FORIM_r^j$. The IRTS composite input (trading at PMC_r^j) is supplied by an activity, denoted Z_r^j, and is demanded by the firms:

$$Z_r^j = f_r^j N_r^j + Q_r^j (N_r^j)^{1/(1-\sigma_F^j)}. \tag{28}$$

To derive (28) recall that firm-level output is $Q_r^j (N_r^j)^{\sigma_F^j/(1-\sigma_F^j)}$ so the use of the input across all firms is $Q_r^j (N_r^j)^{1/(1-\sigma_F^j)}$ plus the total input use on fixed costs, $f_r^j N_r^j$.

Under the Melitz structure, demand includes three components: the use of inputs for fixed entry costs, $\delta f_{jr}^s M_r^j$; for operating fixed costs, $\sum_m f_{rm}^j N_{rm}^j$; as well as operating inputs, $\sum_m [Q_r^j (N_{rm}^j)^{1/(1-\sigma_F^j)}]/\tilde{\varphi}_{rm}^j$.

$$Z_r^j = \delta f_{jr}^s M_r^j + \sum_m f_{rm}^j N_{rm}^j + \sum_m \frac{Q_r^j (N_{rm}^j)^{1/(1-\sigma_F^j)}}{\tilde{\varphi}_{rm}^j}. \tag{29}$$

Market clearance for the output of CRTS sectors depends on supply (simply given as an

activity of production) and domestic and foreign demand from the Armington activity:

$$Y^k = \phi_D^k A^k \left(\frac{PA^k}{PY^k}\right)^{\sigma_{DM}^k} + \sum_r FORIM_r^k. \tag{30}$$

While the supply of business service sectors is simply the activity of production, the demand is either from the domestic or FDI firms (on top of the demand from foreign countries):

$$\begin{aligned} Y^i &= \theta_{DD}^i Q_O^i \left(\frac{PMC_O^i}{PY^i}\right)^{\epsilon_O^i} + \sum_{r \neq O} \theta_{Dr}^i Q_r^{FDI} \left(\frac{PFDI_r}{\theta_{Dr}^i PY^i + \theta_{Mr}^i PFX}\right)^{\epsilon_r^i} \\ &+ \sum_r FORIM_r^i, \end{aligned} \tag{31}$$

$$Q_r^i = A^i \left(\frac{PA^i}{PMC_r^i}\right)^{\sigma_F^i}, \tag{32}$$

$$Q_r^{FDI} = A^i \left(\frac{PA^i}{PFDI_O^i}\right)^{\sigma_F^j} \quad r \neq O. \tag{33}$$

For IRTS sectors, supply is simply given by the production activity. Output is then demanded by the domestic and foreign firms. The market clearance conditions are given by

$$Y^j = \theta_{DD}^j Z_D^j \left(\frac{PMC_D^j}{PY^j}\right)^{\epsilon_D^j} + \sum_r FORIM_r^j. \tag{34}$$

Import demand is derived from the Armington activities or embodied in the foreign Dixit-Stiglitz firm's inputs. For $r \neq O$, we have the following:

$$IM_r^i = \phi_r^i Q_r^i \left(\frac{PMC^i}{PM_r^i}\right)^{\sigma_F^i} \tag{35}$$

$$IM_r^j = \theta_{Mr}^j Z_r^j \left(\frac{PMC_r^j}{PM_r^j}\right)^{\epsilon_r^j} \tag{36}$$

$$IM_r^k = \phi_r^k A^k \left(\frac{PA^k}{PM_r^k}\right)^{\sigma_{DM}^k}. \tag{37}$$

Factor markets clear, where factor supply is given by the exogenous endowments to households, denoted $\overline{S}_f$, and input demands are derived from the cost functions:

$$\overline{S}_f = \sum_s \theta_f^s \theta_{vas}^s Y^s \left(\frac{P_s^{va}}{(1+t_{fs})PF_f}\right) \left(\frac{P_s^{vas}}{P_s^{va}}\right)^{\sigma_{vas}}, \tag{38}$$

where P_s^{va} is the composite value-added price as defined in equaiton (17). In addition, we have the market for the specific factor used in the IRTS sectors. Denoting the regional endowments of the specific factors $\overline{SF}_r^g \ \forall g \in (I \cup J)$, we have:

$$\overline{SF}_r^g = \theta_{Zr}^g (Z_r^j + Q_r^i) \left(\frac{PMC_r^g}{PZ_r^g} \right)^{\epsilon_r^g} \quad \forall g \in (I \cup J). \tag{39}$$

Real investment equals real savings by households:

$$INV = \overline{sav}. \tag{40}$$

Real government purchases equal the nominal government budget scaled by the government price index:

$$PUB = \frac{GOVT}{PG}. \tag{41}$$

Household utility (U) equals nominal income across households scaled by the true-cost-of-living index. That is, in each region we have an aggregate activity U, which supplies utility to the representative household of that region, and its nominal income is RA. The corresponding market clearance condition is thus

$$U = \frac{RA}{PC}. \tag{42}$$

The final market clearance condition reconciles the balance of payments. The supply of foreign exchange includes its generation in the export activities and net borrowing from the rest of the world (net capital account surpluses). The real capital account surplus is held fixed at the exogenous benchmark observation, denoted $\overline{ftrn}$. Foreign exchange is demanded for direct import purchases as well as the payments to foreign agents for their contribution to production.

$$\begin{aligned} \sum_{r \neq O} \sum_g FORIM_r^g + \overline{ftrn} &= \sum_{r \neq O} \sum_g IM_r^g \\ &+ \sum_{r \neq O} \sum_i \theta_{Mr}^i Z_r^i \left(\frac{PMC_r^i}{\theta_{Dr}^i PY^i + \theta_{Mr}^i PFX} \right)^{\epsilon_r^i} \\ &+ \frac{FE}{PFX}, \end{aligned} \tag{43}$$

where FE equals the nominal claims that the foreign entrepreneurs have on specific factor rents in the Dixit-Stiglitz service sectors.

3 Income Balance Conditions

The representative agent (household) earns income from factor endowments, but disposable income nets out savings and a direct tax transfer to the government. Real savings is held fixed (by the coefficient $\overline{sav}_h$). We also hold fixed the real level of government spending, but this requires an adjustment in direct taxes on households. Removal of tariffs, for example, impact the government budget and the shortfall is made up for by an endogenous increase in the direct

taxes on households. We use the auxiliary variable T to scale the direct taxes appropriately. In addition, the household is assumed to hold any benchmark net international capital flows. The household's budget is given by

$$\begin{aligned} RA &= \sum_f PF_f \overline{S}_f \\ &+ \sum_g PZ^g \overline{SF}^g \\ &- \overline{sav} PINV \\ &- \overline{dtax} PG \times T \\ &+ \overline{ftrn} PFX \end{aligned} \tag{44}$$

The government budget is given by net direct and indirect taxes on domestic and international transactions. The full nominal government budget is

$$\begin{aligned} GOVT &= \overline{dtax}_h PG \times T \\ &+ \sum_g t_g^{cons} PA^g \mu_C^g U \frac{PC}{(1+t_g^{cons})PA^g} \\ &+ \sum_g t_g^{inv} PA^g \mu_{INV}^g INV \\ &+ \sum_g t_g^{gov} PA^g \mu_G^g PUB \\ &+ \sum_s \sum_i t_{is}^{int} PA_i \theta_i^s \theta_{vas}^s Y^s \left(\frac{P_s^{srv}}{(1+t_{is}^{int})PA_i} \right) \left(\frac{P_s^{vas}}{P_s^{srv}} \right)^{\sigma_{vas}} \\ &+ \sum_s \sum_j t_{js}^{int} PA_j \theta_j^s Y^s \\ &+ \sum_s \sum_k t_{ks}^{int} PA_k \theta_k^s Y^s \\ &+ \sum_s \sum_f t_{fs} PF_f \theta_f^s \theta_{vas}^s Y^s \left(\frac{P_s^{va}}{(1+t_{fs})PF_f} \right) \left(\frac{P_s^{vas}}{P_s^{va}} \right)^{\sigma_{vas}} \\ &+ \sum_{r \neq O} \sum_g t_{gr}^{imp} (PFX) IM_r^g \\ &+ \sum_{r \neq O} \sum_i t_i^{exp} \frac{PMC^i}{1 - \frac{1}{\sigma_F^i}} FORIM_r^i \\ &+ \sum_{r \neq O} \sum_j t_j^{exp} \frac{PMC^j}{1 - \frac{1}{\sigma_F^j}} FORIM_r^j \\ &+ \sum_{r \neq O} \sum_k t_k^{exp} PX_r^k FORIM_r^k \end{aligned} \tag{45}$$

Again, the index T is adjusted endogenously to hold the real level of public spending fixed. In addition to the household and government agents we need an agent representing the foreign entrepreneurs who own the specific factors associated with Dixit-Stiglitz service goods. The

foreign entrepreneur's nominal income is FE, which is spent on foreign exchange:

$$FE = \sum_{r \neq O} \sum_{g} PZ_r^g \overline{SF}_r^g \quad \forall g \in I. \tag{46}$$

4 Auxiliary Conditions

In addition to the three sets of standard conditions presented above, we use an auxiliary condition to fix the real size of the government. Specifically, we need to determine the index which scales direct taxes on households. Associated with the variable T is the following condition:

$$PUB = \overline{pub}. \tag{47}$$

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