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This paper is from the
GTAP Annual Conference on Global Economic Analysis
https://www.gtap.agecon.purdue.edu/events/conferences/default.asp

A CGE analysis of Boris Johnson's Brexit including Melitz, multinationals and unemployment effects

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Abstract

The role of multinationals in services sectors in the British economy has received little attention in the context of Brexit, even though foreign affiliates sales constitute the most important way of provision of services. We simulate Boris Johnson's proposal for Brexit to illustrate the effects of barriers to the operations of foreign multinationals in services sectors (both EU multinationals in the UK and UK multinationals operating in the EU). These multinationals operate in a climate of monopolistic competition à la Krugman (1980), which is important to grasp scale economies and variety effects. We also include the impact of barriers to trade across goods and services. The majority of manufacturing sectors include a Melitz (2003) structure, which allows us to grasp the effects along the extensive margin of trade, together with productivity impacts. In addition, we include a specific characterization of unemployment, using a wage curve à la Blanchflower and Oswald (1994a; 1994b, 2005), with which we can estimate the effects of Brexit for employment, for which very few estimates exist. Our model uses the latest GTAP10 database, although we have conducted a forward calibration following Böhringer et al. (2009) to the year 2021, in which the Brexit shock would be implemented. While we offer several macroeconomic results for the UK, the Rest of the European Union, the US and the Rest of the World, we focus on the macro and microeconomic results for the Spanish economy. Beyond Boris Johnson's proposal, we also analyze other UK alternatives for Brexit to try to illustrate the effects of different policy options. They include not only a soft and hard Brexit but also a Customs Union arrangement, together with an ambitious or modest agreement between the UK and the US, and between the entire EU (including the UK) and the US. Finally, our analysis covers the short run impact together with a steady state simulation following the approach of Francois et al. (2013).

Introduction

Many economic studies of Brexit have concentrated on the analysis of trade. Other papers have studied different effects, such as, migration, uncertainty, exchange rate and Foreign Direct Investment (FDI) flows at the macroeconomic levels (see Latorre et al., 2019a, 2019b; Bisciari, 2019; Fernández-Pacheco et al., 2018a; 2018b, for reviews).

The UK economy stands out among European economies and even at the global level in terms of the prominent role that multinationals play in it. The British economy has always been an important center for the operations of foreign multinationals. Around a third of all the firms' sales that take place in the UK territory are in the hands of foreign affiliates, according to Eurostat (2019) data. Moreover, UK has always been a world champion as a home economy of multinationals operating worldwide.

On the other hand, the world is nowadays a services economy. This trend is even more pronounced among developed countries among which the UK stands out as a particularly extreme case. For this reason, the impact on services should be a very important channel for the transmission of Brexit effects.

The role of multinationals in services sectors in the British economy has received little attention in the context of Brexit. According to some statistics (e.g., Fetzer, 2018; Mann, 2017; Rueda Cantuche et al., 2016) foreign affiliates sales constitutes the most important way of provision of services. Even though, services are becoming more tradable, they remain much less tradable than goods. Physical presence is often needed for services provision. We are, then, arguing that for the most important share in the British economy (and many other economies), the effects of obstacles to the operations of foreign affiliates that may arise with Brexit are worth exploring. As with many other economic phenomena, a general equilibrium analysis seems mandatory to properly assess their impact.

However, very few CGE analysis include the operations of foreign affiliates. A few of them have analyzed the impact of (FDI) flows. In those models, FDI is an extra source of (foreign) investment in the economy, but no account is taken on the number of workers multinationals hire or their contribution to production in the sectors in which they operate. In other words, some CGE models analyze FDI by looking at flows or stocks at the macroeconomic level, while others focus on the operations of multinationals at the sectoral level. In this paper, we focus on this latter approach to study the impact of services multinationals in the UK after Brexit.

We simulate Boris Johnson's proposal for Brexit to illustrate the effects of barriers to the operations of foreign multinationals in services sectors (both EU multinationals in the UK and UK multinationals operating in the EU). These multinationals operate in a climate of monopolistic competition à la Krugman (1980), which is important to grasp scale economies and variety effects. We also include the impact of barriers to trade across goods and services. The majority of manufacturing sectors include a Melitz (2003) structure, which allows us to grasp the effects along the extensive margin of trade, together with productivity impacts. In addition, we include a specific characterization of unemployment, using a wage curve à la Blanchflower and Oswald (1994a; 1994b, 2005)

with which we can estimate the effects of Brexit for the number of workers, for which very few estimates exist.

We use a CGE model which has 22 sectors, 5 regions (UK, Spain, the rest of the European Union), the US and the rest of the world and four factors of production (land, natural resources, capital, labor). Our model uses the data from the latest GTAP10 database although we have conducted a forward calibration following Böhringer et al. (2009) to the year 2021, in which the Brexit shock would be implemented.

Beyond Boris Johnson's proposal, we also analyze other UK alternatives for Brexit to try to illustrate the effects of different policy options. Our analysis covers the short run impact together with a steady state simulation following the approach of Francois et al. (2013).

While we offer several macroeconomic results for the UK, the Rest of the European Union, the US and the Rest of the World, we focus on the macro and microeconomic results for the Spanish economy. Spain is the fourth largest economy in the European Union, when measured in GDP terms and excluding the UK. Although Spanish exporters and, even more, its multinationals play a considerable role at the world stage, the impact of Brexit on this economy has received very little attention.

We find that, although the overall damage to the Spanish economy is limited, estimates vary depending on the final agreement on the future relationship after Brexit. Hence, the importance of trying to negotiate a Brexit that will raise as few barriers as possible. However, the big market for Spanish exports is the European one, even if the UK has left. The single European market (not including the UK) accounts for 49.9% of our exports and 46.5% of our imports of goods and services. In addition, multinationals from the rest of the EU, without the UK, operating in the services sectors account for 14.73% of total final sales in these sectors in Spain, while Spanish multinationals in Europe account for approximately 0.45% of total sales in the advanced services sectors.

Therefore, if negotiations with the British were to jeopardize the European project, there is much more at stake in maintaining barrier-free access to the single market than in the barriers that may arise with the UK.

The rest of the paper is organized as follows. The next section briefly describes Spanish economic ties with the UK. Section 2 presents the model and the simulations. Section 3 offers the main results. In section 3.1 we display the macroeconomic results for all regions in the model, section 3.2 concentrates on macroeconomic results for Spain while section 3.3. shows the sectoral results for Spain. Finally, section 4 concludes. An appendix with an algebraic description of the model closes the paper.

1. Spanish economic ties with the UK

Brexit will have consequences for the flows of trade and Foreign Direct Investment (FDI) that the Spanish economy sends and receives. It will put obstacles in the way of these flows, which in turn will influence many macro and microeconomic variables in Spain.

Spain directs approximately 8% of its aggregate exports towards the United Kingdom (UK) and imports approximately 5% of its total imports from this country (calculations

for total goods and services). In turn, Spanish multinationals operating in service sectors in the UK account for approximately 2% of total sales in the UK service sectors[1], while British multinationals account for approximately 5.14% of sales in Spain in the service sectors. These figures vary considerably depending on the particular sector analyzed in the Spanish economy and require further important nuances.

Spanish exporters will find it more difficult to access the UK market and the aggregate volume of exports will contract. At the sectorial level, the reductions in exports are very heterogeneous depending mainly on: 1) The size of the barriers that arise with Brexit, which are different by sector; 2) The climate of competition in the sector; 3) The importance of the UK in the total of destinations of sectoral exports; and 4) The weight of exports in the total of the possible uses of the sectorial production.

Likewise, Spanish imports are dominated by intermediate goods and services (inputs). This implies that it is more a question of imports necessary for the production of our economy and not so much competition for Spanish companies. With Brexit, they will experience more obstacles than in the past, which will make them more expensive, generating an increase in costs for companies that depend on them, if they are not easily substituted by domestic products or imports from other countries.

Foreign multinationals operating in advanced service sectors are suppliers of intermediaries needed for production in other sectors and of different varieties of final services for consumers that have not received well-deserved attention in other previous studies about Brexit.

Brexit will reduce the flows of Spanish exports to and imports from the UK, as well as the operations of Spanish multinationals in the UK and British multinationals in Spain. This reduction in economic activity will cause a contraction in production, value added and employment in Spain.

2. Model and simulations

To estimate the impact of Brexit we use a computable general equilibrium (CGE) model. This model expands a previous model used for the analysis of Brexit (Latorre, Olekseyuk and Yonezawa, 2019a; Latorre, Olekseyuk, Yonezawa and Robinson, 2019b, Latorre, Olekseyuk, Yonezawa and Robinson, 2019c) and we could say that it is at the frontier of science because of its unique combination of two advanced features. These two characteristics are: 1) The modelling of a climate of competition à la Melitz (2003) in several manufacturing sectors; and 2) The presence of foreign multinationals in advanced service sectors, operating in a climate of imperfect competition à la Krugman (1980). A complete algebraic description of the model appears in the Appendix.

[1] These calculations are based on the weight of multinationals in what is often referred to in the literature as “advanced services”. Our model includes multinationals only in these “advanced services”. The specific percentages of multinational weights cited here, for various reasons, do not include utilities, various network services such as energy supply, wholesale and retail trade, and financial services.

By including a climate of monopolistic competition à la Melitz (2003), the model makes it possible to capture two real-world effects: (1) the existence of firms with different sizes, costs, productivities and prices within each sector, which generates endogenous variations in productivity when barriers to trade arise; and (2) the ability to attract firms to open or close, or to stop serving one foreign market and move on to another. In other words, Melitz captures variations not only in the intensive margin of international trade (variations in its intensity for a given origin or destination), but also in the extensive margin (or changes in the number of countries of destination or origin of trade flows).

Additionally, for the modelling of the Spanish economy we have introduced other extensions by incorporating a dynamic specification with endogenous variations in aggregate investment (gross fixed capital formation) and in the capital stock following the approach of Francois et al. (2013), together with the presence of unemployment (following previous works, Latorre, Yonezawa and Zhou, 2015), as well as, frictions in the mobility of the labor force.

It is important to note that the results of the general equilibrium model isolate and quantify the impact of the specific shock being analyzed. In other words, the model estimates the effects of the Brexit, while in the real world, the Brexit will interact with many other economic forces that will take place at the same time (such as, fiscal, monetary, trade policies...) that lead to other simultaneous impacts. Our results focus on what can be expected from the Brexit itself, regardless of other forces that are at work when it takes place. They cannot be interpreted as projections.

We estimate the impact of four possible central Brexit scenarios:

- “Hard” Brexit scenario: UK exit from the EU without agreement, where trade would be subject to World Trade Organisation rules. It would involve the adoption of Most Favoured Nation tariffs between the EU and the UK, and the higher non-tariff barriers to trade and FDI that may occur in the future relationship between the UK and Spain, on the one hand, and between the UK and the rest of the EU (EU28 excluding Spain and the UK), on the other. If no agreement is reached during the transition period, which in principle will last until 31 December 2020, there is a possibility of falling into this "no deal" scenario. In addition, it is an important reference for considering the higher losses that could be expected from Brexit, according to most economic studies.

- Customs Union Scenario: UK exits the European Single Market but remains in the Customs Union. This would imply maintaining tariffs between the two parties at zero and common external tariffs, but increases in high non-tariff barriers to trade and FDI. Since the customs union would force the UK to adopt the common tariff that the EU would dictate to the outside world in the different sectors, it seems unlikely that the UK would want to give up autonomy to set trade policies vis-à-vis other countries. This ability to pursue new trade policies outside the EU has been one of the arguments put forward by Brexit supporters. Note that when we talk about tariffs, for example in this context vis-à-vis third countries, it goes without saying that we also take quotas into account, which are also included in the calculation of tariffs in our model.

- Boris Johnson's Brexit Scenario: ratio based on the "revised policy statement" (Gov UK, 2019). This is broadly a proposal for a UK exit from the Customs Union[2], to move to a future free trade agreement with the EU. Tariffs would be zero but non-tariff barriers would arise between the UK and the EU. This setting involves higher barriers than those in the political declaration agreed by Prime Minister Theresa May.

- "Soft" Brexit Scenario: In all the previous scenarios the increases in non-tariff barriers to both trade and FDI will be high. For this reason, it seems appropriate to also provide estimates for a closer relationship agreement with the EU. The relationship with the lowest possible barriers for third countries is that of the European Economic Area, which has usually been modelled on Norway's situation vis-à-vis the EU. The definitive future relationship between the United Kingdom and the European Union has yet to be defined and, although it seems unlikely that the United Kingdom will seek a very close relationship, especially with the obligations of accepting immigrants, applying European regulations, without being able to vote for them, and contributions to the budget assumed by Norway, this scenario is usually a reference for the minimum damage that Brexit could cause.

We also analyze the impact of Boris Johnson's Brexit combined with a treaty that further reduces barriers to trade and FDI with the United States. We explore both an ambitious agreement and modest agreement with the United States, with big or small cuts in non-tariff barriers, respectively. We envisage that the agreement with the US could be signed by the UK alone or simultaneously by the rest of the EU (including Spain, of course) on similar terms.

3. Results

3.1 The macroeconomic impact of Brexit: An international comparison

Table 1 provides the macroeconomic impact of Brexit on Spain, the UK, the European Union, the USA and the rest of the world. These are the five regions into which we have divided the world economy in our model. We will focus on the effects of Prime Minister Boris Johnson's Brexit. On the top of the table we present the results obtained with our core or reference scenario. At the bottom, we present the results derived when we implement a dynamic closure in the model à la Francois et al. (2013), which allows to derive the steady state results.

In line with most empirical studies, the Brexit is a force that tends to reduce GDP and private consumption in the countries directly involved (UK, Spain and the rest of the EU). By contrast, it has virtually no effect for the US and the rest of the world.

[2] Only Northern Ireland, which accounts for only 2% of UK GDP in 2017 (ONS, 2019) and 2.63% and 1.63% of UK exports and imports respectively in 2018 (HM Revenue & Customs, 2019), would remain in the Customs Union, during the transitional period until a new relationship was agreed.

Table 1 clearly shows that the United Kingdom is the most negatively affected region, as most studies derive. This is because it will see the emergence of barriers to its economic transactions, losing preferential access to a huge market, with which it negotiates approximately half of its foreign trade, such as that of the European Union. No matter how many trade agreements it manages to sign, the United Kingdom will not be able to find a way to access any other market in the world as it did in the European single market. It is difficult for any of the treaties that the UK can do with third countries to remove as many barriers as the single market of the EU has. As a result, UK's foreign trade is contracting by around 10% (-11.29% and -9.36% for aggregate exports and imports, respectively) in the core scenario.

The EU also loses a partner with whom it exchanged trade and investment flows (among others) with the least possible obstacles. However, the EU will still have the rest of the large European market to seek new business opportunities without frictions or barriers. Table 1 shows that GDP, private consumption, exports and imports in aggregate contract much less than the macro variables in the United Kingdom.

Certainly, the relatively small percentages of contraction experienced by the large EU region may hide a substantial impact in absolute value, since the initial values are very high. Moreover, the small percentage changes in the EU may appear very limited for the whole region, but they may also hide more important impacts for individual countries in the region. However, it is hard to believe that any individual EU country's losses would be greater than those of the UK. This is because, as already mentioned, the Brexit will put obstacles in the way of almost half of the aggregate imports and exports that the British Isles make with the EU. None of the other countries in the EU are so dependent on trade with the UK alone, not even Ireland. Therefore, the impact on individual countries in the rest of the EU is likely to be less intense than in the UK. This is indicated by studies analyzing the effects for several individual countries such as Dhingra et al (2017) and Felbermayr et al (2018).

The Spanish economy has much less to lose than the UK itself and is experiencing a similar contraction to the rest of the EU, as Table 1 indicates. We will return shortly to these results for further discussion. It is precisely the fact that the EU is not greatly affected by Brexit that explains why the impact beyond EU borders (for the US and the rest of the world) is almost non-existent. The EU is a major player in global imports and exports. It would therefore have the capacity to produce significant trade diversion or creation effects. However, the latter effects are small in the rest of the world because the aggregate trade of the large EU region as a bloc only contracts by 2% (-2.13% and -2.33% for aggregate exports and imports, respectively) in the core scenario.

At the bottom of Table 1 a drop in the capital stock due to the fall in investment underlies the results for the version of the model with a dynamic closure (steady state). Not all trade models incorporate these possible impacts on the capital stock, for example HM Government (2018a, 2018b) does not include it among its core scenarios either. With the dynamic closure the model reflects the results of a "Steady state" equilibrium. This is a long-term situation in which the direct impact of Brexit would have disappeared and the falls in the remuneration of the capital factor would return to their pre-Brexit level. To return to that pre-Brexit level, if there has been a fall in the capital remuneration, as we

will see shortly in the results of Table 2, the aggregate capital stock of the economy has to be reduced. Note that in the central specification of the model we include certain dynamic characteristics, such as the effects of productivity in response to a trade shock, which are characteristic of a climate of competition à la Melitz (2003). However, in our core specification we have not included the "steady state" simulation we have just explained because we consider, as other authors have done (HM Government, 2018a, 2018b), that a scenario of capital stock reduction after Brexit is not the most likely, at least outside of the UK. Nevertheless, in order to encourage public policies that favor an investment climate in Spain that compensates for these possible contractionary forces, we offer the estimates in the event of capital reductions.

The steady state results, at the bottom of Table 1, show that the United Kingdom is the territory that is most affected, by far, in all macroeconomic variables. However, the increase in the negative effect in relation to the reference model is not the same for all variables. In GDP and private consumption there is a significant deterioration, much greater in relative terms than that occurring in trade flows. The fall in the capital stock affects the GDP in such a way that it goes from a 2.57% drop in the reference model to a 5.11% drop. The fall in private consumption is in the same vein, going from a fall of 3.37% to a fall of 6.17%. This latter result is in line with the estimations of the few studies have looked at the dynamic effects of Brexit (Dhingra et al., 2017; Aichele and Felbermayr, 2015), based on a reduced form approach. Dhingra et al. (2017) derive reductions in GDP per capita in the UK in a range of 6.3–9.4%. Aichele and Felbermayr (2015) report that GDP per capita could fall between 6 and 26% in the UK. However, "we must warn readers here not to take the results too seriously because they always apply the average effect of openness (determined for many countries) to the specific case of a Brexit" (Aichele and Felbermayr, 2015, p. 50).

The effects for Spain also have a qualitative change in relation to the rest of the European Union. If in the reference model the GDP fell by 0.47% for Spain and 0.45% for the rest of the European Union, the differences widen when the capital stock falls. In Spain the GDP would fall by 1.49%, while in the rest of the European Union it would fall by 1.30%. Something similar happens with private consumption. In the reference model it would fall by 0.80% in Spain and by 0.77% in the rest of the European Union. With the fall of the capital stock, in Spain private consumption would fall by 2.08%, while in the rest of the European Union it would fall by 1.88%.

The previous effects necessarily imply a lower demand of imports to satisfy private consumption or to the productive process (imports of intermediate goods) in the European area, which negatively affects the Spanish exporters, who see the demand of exports contracting. For trade flows, the negative effects are accentuated for Spain. The fall in aggregate exports reaches 1.67%, compared to 0.83% in the reference model. The fall in aggregate imports is 1.78%, compared to 0.92% in the reference model. It seems that the fall in capital would be affecting especially the sectors most related to tradable goods. In fact, it is very remarkable that this negative effect for Spain is not so marked for the rest of the European Union countries. In this case, the fall in aggregate exports reaches 2.83%, in relation to the 2.13% in the reference model, and the fall in aggregate imports is 2.99%, in relation to the 2.33% in the reference model.

The effects for the rest of the world and the USA are also very small, as in the reference model. After this international comparison, we will now analyze in more detail the macroeconomic impact of Brexit on the Spanish economy.

3.2 The macroeconomic impact in Spain: different Brexit scenarios

Table 2 reproduces the same results for GDP, private consumption, exports and aggregate imports or our core scenario in the previous section. We now extend them to a greater number of scenarios and variables. With respect to the variables, we now add wages, employment, remuneration of capital and the Consumer Price Index (CPI). The columns show the impact for each of the variables. This is a very detailed analysis that few studies offer.

The rows in Table 2 display the four blocks of Brexit scenarios: hard, customs union, Johnson's Brexit and soft, together with an additional final block that combines Johnson's Brexit with the effects of a trade agreement with the US, of the whole EU (including the UK and Spain).

For all the scenarios, we analyze the impact of each of Brexit components, along with their total effect when all components interact simultaneously. Thus, for each of these scenarios, we present separately the impact of the emergence of tariffs ("Tariffs" row), non-tariff barriers (NTBs) to trade ("NTBs" row) and NTBs to the operations of the multinationals that, to differentiate them from the previous NTBs to trade, are labelled "FDI" in the tables. We also present a row showing the "Total" with the impact of all barriers operating simultaneously. In the Brexit scenarios, only the hard Brexit and the customs union incorporate tariffs whose effects are included in the "Total" impact.

Brexit represents a contractionary force in economic activity, which will tend to reduce the growth of GDP, private consumption, wages, employment and international trade. In this paper we quantify the main mechanisms that cause Spanish GDP to fall, taking into account each of the ways in which it is traditionally calculated. As we know, there are three ways of estimating an economy's GDP (demand side, supply side and income side). GDP on the demand side is dragged down by a significant reduction in private consumption, which is the component of final demand that has by far the greatest weight on the GDP calculated in this way. Although foreign trade (aggregate exports and imports) is also declining, its direct contribution to GDP from the demand side is offset in real net terms in our results[3]. Likewise, both the public expenditure and investment components are kept constant in our simulations in the central reference model. This is to avoid introducing biases and to focus the adjustments on the mechanisms derived from international trade in all sectors and those from the operations of multinationals in the services sectors. This treatment of the demand side of GDP is common in the CGE models that analyze shocks related to foreign trade.

[3] We shall see, however, how exports and imports affect production in the different sectors of the economy, which, in turn, sets in motion another series of effects via production and income.

Private consumption falls due to the contraction experienced by wages, capital remuneration and the number of employees. All these results for the main macroeconomic aggregates that drag GDP into negative territory (private consumption, wages, employment and capital remuneration) are shown in the macroeconomic results of Table 2.

The evolution of the demand for labor and its wages, together with the remuneration of capital, is consistent with the GDP on the supply side. Our analysis offers the detail of the production for each of the 22 sectors of the model together with a total for the aggregate of manufacturing, another for the aggregate of services, as well as the aggregate of the production of the total sectors of the economy. We analyze below the results at the sectoral level that show the evolution of GDP, viewed from the supply side of the economy. Table 4, which offers the impact on production in the reference framework shows an evolution totally in line with the evolution of GDP in Table 2.

Going back to Table 2, the falls in macroeconomic variables are more intense the higher the barriers to trade and FDI that arise with the Brexit. If Brexit were to represent the lowest possible barriers (soft Brexit), GDP would fall by 0.32 per cent. At the opposite end, the most intense fall of 0.64% would arise with the highest barriers typical of a hard Brexit (without agreement). If in the end Brexit has remarkable regulatory convergence in goods and somewhat less in services and no tariffs with the rest of the EU (which is what we modeled in Boris Johnson's Brexit) the fall could be of 0.47%. As a reference, if there were low tariffs in agriculture and food and savings in customs procedures and costs, in the hypothetical case that the United Kingdom remained in the customs union with the EU, the fall in GDP would be 0.52%.

As already mentioned, these falls in GDP are caused by the forces that Brexit would set in motion, all else being equal. The forces of Brexit are contractive and will subtract those percentages of growth that Table 2 reflects from the growth of around 2% or 3%, perhaps a little below or a little above those figures, that the Spanish economy will experience from 2021.

It is important to consider that we model the different Brexit scenarios with the maximum barriers that could be expected in each of them. The UK is currently compliant with European legislation, so some of the NTBs, both for trade and FDI, will occur over time. However, tariffs and customs inspections along with declarations in the customs union, would arise from the outset, if the UK leaves the customs union, which seems very likely.

Certain NTBs linked to new tax, accounting, data protection, intellectual property rights procedures as well as the need for obtaining certificates, licences and authorisations, etc. will arise from the outset. In addition, companies, administrations and other economic agents along are experiencing the costs related to the need to draw up contingency plans and to familiarize with the new environment. A whole new web of possibly affected relationships will emerge for companies (and many administrations) related to customers, suppliers, competitors, employees, advisors, regulatory agencies or competent authorities. The time frame in which all these factors develop is not simple to determine

and will follow a different course depending on the type of sector involved. Our estimates should therefore be interpreted as the largest negative effect when all the contractionary forces of Brexit are in place.

The results in Table 2, in line with most Brexit studies, indicate that tariffs are the element with the least quantitative impact. The impact of tariffs, if finally implemented, would be automatic and in the case of the Most Favored Nation, they have not negligible effects on the aggregate of exports and imports.

The most important element is the NTBs applied to trade, although in the case of Spain it is noteworthy that the impact of FDI follows at a short distance. Of course, both components are modulated according to the type of agreement reached and the consequent size of the barriers that may arise. The higher the barriers, the more intense the contraction in the various macroeconomic variables. Although few studies have quantified its effects, the strength of FDI in the services sectors alone explains almost half of the contraction in GDP in most of Brexit scenarios in Table 2.

Taking a further step, the truly significant impact on the Spanish economy of the different policies we combine with Boris Johnson's Brexit comes, on the one hand, from Brexit itself and, on the other, from the fact that the EU (including Spain and the UK) could sign a treaty with the US (fifth and sixth blocks of results in Table 1). On the other hand, the policies that the United Kingdom could undertake in isolation, whether it be tariff elimination or the signing of a trade treaty only between the United Kingdom and a large isolated trading partner such as the United States, seem to lack sufficient substance to affect the Spanish economy intensely. For this reason, we have not added the impacts of UK policies in Table 2, because their impact would not change at the aggregate level that of Boris Johnson's own Brexit.

Table 2 shows the impact of an ambitious and modest EU treaty (including Spain and the UK) with the US combined with Johnson's Brexit (i.e., with Johnson's Brexit total impact, including both its NTBs and its barriers to FDI). It is important that in these two scenarios the starting point is the impact of Johnson's Brexit itself and that the results for the last two blocks of results in Table 1 indicate to what extent an EU-wide (including Spain and the UK) treaty with the US can offset the negative impact of Johnson's Brexit. Such a treaty with the US, if ambitious, would offset the negative effects of Brexit, and, if modest, it would soften them considerably. Table 2 shows that the isolated influence of the NTB component of an ambitious treaty with the US would largely compensate for the fall in GDP caused by Boris Johnson's Brexit (-0.47%), leaving GDP at -0.10% (see row NTBs of Johnson's Brexit scenario+UK and EU ambitious treaty with the US). The tariffs and FDI of this ambitious treaty with the US, in isolation, have less impact, and would only soften somewhat the fall in GDP from -0.47% of Johnson's Brexit to -0.43% (after tariffs) and to -0.40% (after reduction of FDI barriers). When all components (NTBs, tariffs and FDI) come into play simultaneously, the Johnson GDP impact goes from -0.47% to 0.03% (row "Total" of Johnson's Brexit scenario+UK and EU ambitious deal with US). The patterns are similar, although less intense, for a moderate treaty with the US, following Johnson's Brexit. The NTBs would be the ones that would most smooth the fall from -0.47% to -0.35%, which together with the lower contributions of tariffs and

FDI, would end up leaving the GDP, when all components interact simultaneously, at -0.27%.

Table 2 reflects that the impact of Brexit is limited, and even more so if we combine it with other trade agreements in which Spain is involved. However, as shown in Table 1, we have also analyzed a scenario in the dynamic framework of the model that we consider unlikely but that, if it were to occur, could considerably aggravate the negative impact. If Brexit were to trigger sharp falls in investment (domestic or FDI) in the economy, which would eventually lead to a reduction in the stock of capital in the Spanish economy, the contraction experienced in Spain would be approximately double for trade flows, compared with that of Table 2, and about triple for the rest of the macroeconomic variables. This should alert us to the importance of fostering a favorable investment climate.

3.3 Sectoral effects in the Spanish Economy

Table 3 shows the impact on Spanish exports of the same scenarios that we have considered in Table 2. After Brexit, several sectors increase their exports and the maximum drop that sectorial exports experience is 5.25% in the hard Brexit in the agricultural sector. This is a sector in which the United Kingdom has notable importance as a destination (11.1% of its exports go to the islands), and in which the expected barriers, both in the form of tariffs and NTBs, are among the highest (only surpassed by tariffs on food, as both record the highest NTBs to trade). However, behind the evolution of the total agricultural sector there are hundreds of companies, which will be more or less affected by Brexit depending on their particular dependence on the UK market and their export orientation.

The agricultural contractions are followed by food and automotive companies and, at some distance, by textile companies. The sector with the greatest weight, both in aggregate exports and in imports in Spain, namely chemicals, is in the group of those experiencing the least contractions. Exports from another sector of great importance, namely, business services, register only a very small reduction. In contrast, other machinery, which is also very important in the panorama of Spanish aggregate exports, increases, although slightly, its exports. Other sectors that would increase their exports are: construction, air transport and communications and, after the hard Brexit, other services, personal services and mining.

Let us have a look at the last row of Table 3 ("All sectors"), whose results coincide with the aggregate exports shown in Tables 1 and 2 above. The combination of Johnson's Brexit with an ambitious trade agreement with the US signed with the entire EU (including Spain and the UK) would move Spanish exports into positive territory (with an increase of 0.18%) if it were ambitious. If the treaty with the US were modest it will still leave Spanish aggregate exports in the negative territory (-0.37%), but would largely offset the contractionary effect of Brexit (-0.83%). After this agreement, most sectors would improve their exports. The sectors that would benefit most from this treaty would

be food, textiles, chemicals, metals and automobiles. As they are all among the most important sectors for Spanish aggregate exports, the net impact would clearly be positive. It is true that there are sectors that experience a greater contraction in exports than those generated by Brexit itself, as is the case with other transport and construction and, to a lesser extent, with business services, personal services and other services. Construction and other transport are small sectors in overall exports. Of the three service sectors, business services and other services are of considerable export size. However, total service exports experience small variations compared to Johnson's Brexit, as other service sectors improve their exports compared to Johnson's Brexit.

Table 4 shows the evolution of production in all sectors. A good group of sectors maintain positive production rates, following the different Brexit scenarios.

Agriculture leads the contraction in all Brexit scenarios, followed by the automobile, and at a greater distance are the falls in the food sector. It should be noted that none of these falls, of the most negatively affected sectors, exceed 2%. The production of the agricultural sector is remarkably oriented to the foreign market (32.8% is exported) and, as we have already pointed out, it has an important dependence on the United Kingdom. The automobile sector leads the export orientation of the sectors of the Spanish economy, no less than 78.5% of its production is destined for this purpose. Furthermore, it is also among those sectors that are most dependent on the British market, since 13% of its exports go there. It experiences the emergence of very high barriers (tariffs and NTBs), although the highest are those of agriculture and food.

The evolution of exports is a force that, depending on its sign, tends to boost or slow down sectoral production. However, it is not the only force behind Brexit. This is because the evolution of private consumption and of production itself in the other sectors of the economy, together with the barriers to productive investment linked to FDI, tend to contract sectoral production. The service sectors had not been greatly affected in their exports, since their production is generally more oriented towards private consumption and the provision of intermediate services (inputs) for other sectors. However, production in services is more negatively affected by Brexit than manufacturing itself, as we can see by comparing the evolution of "Total manufacturing" versus "Total services" in Table 4. In fact, the evolution of services, which contribute much more to Spanish production and value added than manufacturing itself, drags the "Total sectors" into a fall that is more in line with the evolution of services and more in line, too, with the evolution of GDP itself in Table 2.

When Johnson's Brexit is combined with an ambitious EU treaty (including Spain and the UK) with the US, production improves in most sectors. The exception would be other transport and agriculture, which would be affected more negatively than after Brexit itself. Other transport is a small sector in the national picture, but agriculture is larger. A similar process occurs, to a much lesser extent, in electronics and other machinery. For all of them we had seen exports fall in comparison to Johnson's Brexit. In sum, the aggregate output of the economy improves from a fall with Johnson's Brexit of 0.39% to

0.02%. A modest trade agreement with the US softens the decline caused by Johnson's Brexit, leaving it at a contraction of 0.24%.

Finally, we should not forget that the recent crisis has shown the great export capacity of Spanish companies (De Lucio et al., 2019). This is an example to be extended to an even greater number of firms. The aim of Spanish companies should be to replace the exports and operations of UK multinationals in the EU, or for Spanish domestic companies themselves to replace the imports of our economy from the British Isles or their multinationals in our territory, as UK companies will find it more difficult to export and carry out operations within their multinationals in the EU. However, it is important to differentiate between the productivity of domestic companies (we are referring to those that only sell in the domestic market) as opposed to exporting companies or multinationals, not only in Spain but in the global economy. There is solid empirical evidence supporting the idea that, in general, the highest productivity occurs in multinationals, followed by exporting companies which, in turn, precede domestic companies. Therefore, perhaps the opportunity lies more in trying to replace the trade and FDI that the UK did in the rest of the EU, than in replacing British exporters and multinationals in the Spanish economy.

Although we do not present the detail here, Spain's bilateral trade with the EU is expanding after Brexit, except in the unlikely scenario of a large drop in aggregate investment, which would lead to a reduction in capital stock. However, the expansion of Spanish trade towards the EU does not offset the contraction of our bilateral trade flows with the UK. The EU (including Spain) can find a way to compensate for Brexit by effectively negotiating and implementing new trade and FDI agreements and by finally putting into place those that have already been signed. As the results with the US illustrate, these treaties offer numerous possibilities for growth, job creation and wage improvements.

Conclusions

This study derives that the negative impact of Brexit on the Spanish economy is limited. However, its estimates vary depending on the type of future relationship between the UK and the EU, for which there is only a non-binding political declaration (Gov UK, 2019).

The use of a Computable General Equilibrium (CGE) model has allowed us to present a very detailed analysis for different micro and macroeconomic variables. Our model extends previous work (Latorre, Olekseyuk and Yonezawa, 2019a; Latorre, Olekseyuk, Yonezawa and Robinson, 2019d). It is inherited from the analysis of the introduction of Melitz (2003) in the general equilibrium models (Balisteri, Hillbery and Rutherford, 2011) that we have extended to model the multinationals following the model of Latorre and Yonezawa (2018). This is therefore an advanced model that includes not only monopolistic competition à la Krugman (1980) for service sectors where there are

multinationals, but also a climate of monopolistic competition à la Melitz (2003) in most manufacturing sectors.

Additionally, for the modelling of the Spanish economy we have introduced other extensions by incorporating a dynamic specification with endogenous variations in aggregate investment and capital stock, the presence of unemployment (following previous works, Latorre, Yonezawa and Zhou, 2015 and Latorre and Yonezawa, 2018), as well as, frictions in the mobility of labour.

The higher the barriers between the EU and the UK, the greater the negative impact. Therefore, the most damaging would be the hard Brexit, followed by the unlikely case of the UK remaining in the Customs Union with the EU. Next would come Johnson's Brexit proposal (with notable regulatory convergence in goods and somewhat less in services and no tariffs with the rest of the EU), and the least impact would follow a soft Brexit.

It is important to try to negotiate a future relationship that brings about the lowest possible barriers. Although it is good to bear in mind that the big market for Spanish trade and FDI is the European one, even in the absence of the United Kingdom. Therefore, if the negotiation with the British were to endanger the European project, there is much more at stake in maintaining barrier-free access to the single market than in the barriers that may arise with the United Kingdom.

Although it may seem the opposite, Brexit ends up being a protectionist movement when it comes to trade and FDI. The barriers that would emerge may not be tariffs, but that is of little consequence. Today, tariffs are among the smallest barriers to trade.

The European single market has succeeded in making trade and FDI regimes between different European countries as similar as one can find on the face of the earth to operating within the same country. No other area of the world has such similar regimes between countries, neither the North American Free Trade Agreement (NAFTA, slightly modified and renamed the United States-Mexico-Canada Agreement, USMCA), nor the Trans-Pacific Partnership (TPP, renamed the Comprehensive and Progressive Agreement for Trans-Pacific Partnership, CPTPP, after the departure of the US), nor a treaty such as the Global Economic and Trade Agreement between the EU and Canada, nor any other treaty that establishes a regime between countries with such low barriers as the EU.

Brexit also means that imports from the UK, among which intermediate goods predominate, are hindered. These are complementary to the productive process in Spain and will most likely become more expensive with the Brexit obstacles. The barriers will also arise for the operations of Spanish multinationals in the United Kingdom and British ones in Spain. All this reduction in economic activity, together with that caused by the fall in exports, will lead to a contraction in production, added value and employment in Spain.

Non-tariff barriers (NTBs) to trade are the main focus of post-Brexit contractionary trends. This is a result in line with most of the Brexit studies. We therefore argued that if the treaty to be agreed between the UK and the EU focuses only on the elimination of tariffs (and quotas that are also included in the tariff calculation in our model), it can be expected that over time significant NTBs will emerge, related to the regulatory divergences between the EU and the UK.

However, the impact of FDI barriers is very important in the Spanish economy as well. Foreign multinationals operating in advanced service sectors are suppliers of intermediates needed for production in other sectors and of different varieties of final services for consumers that have gone almost unnoticed in the Brexit literature. In the case of Spain, this single FDI-related force, not counting the contractions linked to international trade, explains almost half of the negative impact of Brexit at the macroeconomic level. The effect of multinationals in Spain after Brexit is greater than in the United Kingdom itself (Latorre et al., 2019a; Latorre et al., 2019d). Modern economies are increasingly a productive system of goods and services that are interrelated in increasingly complex ways (Baldwin, 2016; Baldwin and Evenett, 2015).

We also find that an ambitious EU treaty (including Spain and the UK) with the US would offset the negative effects of the Brexit on the Spanish economy, and if it were modest, would soften them considerably.

We have also analyzed a scenario with a dynamic closing of the model, simulating falls in capital stock, which we consider unlikely, but which if it occurred could considerably aggravate the negative impact of Brexit. If Brexit were to trigger sharp falls in investment in the economy (domestic or FDI) that ended up reducing the stock of capital in the Spanish and European economy, it would become a serious obstacle to economic growth and welfare. The damage would, of course, be much greater in the UK itself. This should alert us to the importance of fostering a favorable investment climate in the wake of the Brexit.

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Table 1. International Comparison: Macroeconomic impact of Johnson's Brexit in the Reference model and in the capital stock reductions' framework (% change from baseline)

	GDP	Private consumption	Aggregate exports	Aggregate imports
	Reference model			
Spain	-0.47	-0.80	-0.83	-0.92
European Union	-0.45	-0.77	-2.13	-2.33
United Kingdom	-2.57	-3.37	-11.29	-9.36
Rest of the world	0.02	0.03	0.26	0.28
United States	0.01	0.02	0.08	0.06
	Steady state: Capital stock reductions' framework			
Spain	-1.49	-2.08	-1.67	-1.78
European Union	-1.30	-1.88	-2.83	-2.99
United Kingdom	-5.11	-6.17	-13.55	-11.10
Rest of the world	0.00	0.01	0.05	-0.03
United States	0.01	0.01	0.02	-0.03

Source: Authors' estimations.

Table 2. Macroeconomic impact on Spain of different Brexit scenarios and components and of an EU-UK agreement with the US after Johnson's Brexit in the reference model (% change from baseline)

	GDP	Private consumption	Wages	Employment	Aggregate exports	Aggregate imports
	Hard Brexit					
Total	**-0.64**	**-1.08**	**-0.55**	**-0.36**	**-1.31**	**-1.42**
Tariffs	-0.11	-0.19	-0.17	-0.08	-0.52	-0.54
NTBs	-0.31	-0.52	-0.38	-0.20	-0.94	-0.97
FDI	-0.25	-0.43	-0.04	-0.11	-0.06	-0.14
	Customs Union					
Total	**-0.52**	**-0.87**	**-0.38**	**-0.28**	**-0.92**	**-1.02**
Tariffs	-0.02	-0.03	-0.04	-0.01	-0.12	-0.12
NTBs	-0.27	-0.45	-0.31	-0.17	-0.82	-0.84
FDI	-0.25	-0.43	-0.04	-0.11	-0.06	-0.14
	Johnson's Brexit					
Total	**-0.47**	**-0.80**	**-0.33**	**-0.26**	**-0.83**	**-0.92**
NTBs	-0.25	-0.42	-0.30	-0.16	-0.77	-0.80
FDI	-0.23	-0.39	-0.04	-0.10	-0.05	-0.13
	Soft Brexit					
Total	**-0.32**	**-0.54**	**-0.23**	**-0.17**	**-0.56**	**-0.63**
BNAs	-0.17	-0.28	-0.20	-0.11	-0.53	-0.55
IED	-0.16	-0.26	-0.03	-0.06	-0.03	-0.08
	Johnson's Brexit & Ambitious agreement between the US and EU&UK block					
Total	**0.03**	**0.04**	**0.09**	**-0.04**	**0.18**	**0.08**
Tariffs	-0.43	-0.73	-0.30	-0.23	-0.66	-0.74
NTBs	-0.10	-0.17	0.05	-0.10	-0.17	-0.22
FDI	-0.40	-0.67	-0.32	-0.24	-0.74	-0.90
	Johnson's Brexit & Modest agreement between the US and EU&UK block					
Total	**-0.27**	**-0.46**	**-0.18**	**-0.17**	**-0.37**	**-0.45**
Tariffs	-0.43	-0.73	-0.30	-0.23	-0.66	-0.74
NTBs	-0.35	-0.59	-0.20	-0.20	-0.60	-0.68
FDI	-0.44	-0.74	-0.33	-0.25	-0.79	-0.91

Source: Authors' estimations.

Table 3. Impact on total exports by sector in Spain of the different Brexit scenarios and an EU-UK agreement with the US after Johnson's Brexit in the reference model (% change from baseline)

	Brexit				**Johnson+Agreement with the US**	
	Soft	Johnson's	Customs Union	Hard	Ambitious	Modest
	Total	Total	Total	Total	Total	Total
Agriculture	-2.35	-3.43	-4.39	-5.25	-3.78	-3.60
Other primary	-0.12	-0.06	0.00	0.24	8.62	1.47
Food	-2.22	-3.03	-4.12	-4.48	4.78	-0.19
Textiles	-0.57	-0.87	-0.86	-1.78	0.68	0.30
Wood and Paper	-0.06	-0.17	-0.05	-0.05	0.06	0.01
Chemicals	-0.30	-0.47	-0.40	-0.69	1.07	0.29
Metals	-0.48	-0.72	-0.56	-1.02	-0.36	-0.45
Motor vehicles	-0.97	-1.49	-1.63	-3.37	-1.21	-1.46
Other transport	-0.91	-1.32	-1.31	-1.77	-2.08	-1.63
Electronics	-0.35	-0.56	-0.44	-0.56	-0.76	-0.55
Other machinery	0.13	0.17	0.22	0.17	-0.02	0.23
Other manufactures	-0.45	-0.69	-0.50	-0.92	0.30	0.29
Construction	0.30	0.37	0.74	0.99	-0.47	0.10
Water transport	-0.31	-0.52	-0.51	-0.48	0.16	-0.19
Air transport	0.50	1.95	2.33	2.50	2.30	2.14
Communications	0.13	0.20	0.26	0.35	0.80	0.55
Finance	-0.58	-1.01	-1.05	-0.92	-1.00	-0.98
Insurance	-0.22	-0.41	-0.39	-0.21	1.88	0.55
Business services	-0.14	-0.32	-0.30	-0.10	-0.72	-0.42
Hotels+Restaurants	-0.20	-0.45	-0.33	-0.12	-0.03	-0.25
Personal services	-0.07	-0.24	-0.19	0.08	-0.52	-0.28
Other services	-0.02	-0.16	-0.11	0.22	-0.47	-0.22
All Manufatures	-0.65	-0.96	-1.05	-1.65	0.59	-0.27
All Services	-0.05	-0.08	-0.01	0.23	-0.22	-0.08
Total	**-0.56**	**-0.83**	**-0.92**	**-1.31**	**0.18**	**-0.37**

Source: Authors' estimations.

Table 4. Impact on output by sector in Spain of the different Brexit scenarios and an EU-UK agreement with the US after Johnson's Brexit in the reference model (% change from baseline)

	Brexit				**Johnson+Agreement with the US**	
	Soft	Johnson's	Customs Union	Hard	Ambitious	Modest
	Total	Total	Total	Total	Total	Total
Agriculture	-0.88	-1.31	-1.68	-1.98	-2.07	-1.62
Other primary	0.26	0.32	0.37	0.60	0.44	0.28
Food	-0.45	-0.69	-0.91	-1.02	0.78	-0.20
Textiles	-0.26	-0.41	-0.39	-0.68	0.34	0.15
Wood and Paper	-0.11	-0.20	-0.20	-0.19	0.04	-0.07
Chemicals	0.04	0.02	0.03	0.21	0.07	0.02
Metals	0.02	0.01	0.05	0.07	-0.04	0.02
Motor vehicles	-0.47	-0.77	-0.84	-1.97	-0.67	-0.83
Other transport	-0.06	-0.10	-0.06	-0.01	-1.30	-0.67
Electronics	0.14	0.17	0.21	0.41	-0.37	-0.03
Other machinery	0.07	0.08	0.11	0.19	-0.11	0.04
Other manufactures	-0.05	-0.09	-0.06	-0.02	0.11	0.14
Construction	-0.04	-0.06	-0.05	-0.06	0.00	-0.03
Water transport	-0.36	-0.55	-0.57	-0.67	0.18	-0.23
Air transport	0.05	0.76	0.96	0.98	1.32	1.02
Communications	-0.26	-0.39	-0.42	-0.53	-0.04	-0.24
Finance	-0.26	-0.38	-0.39	-0.51	-0.01	-0.21
Insurance	-0.42	-0.63	-0.69	-0.82	0.14	-0.31
Business services	-0.27	-0.41	-0.44	-0.51	-0.11	-0.28
Hotels+Restaurants	-0.47	-0.70	-0.76	-0.93	0.03	-0.41
Personal services	-0.36	-0.55	-0.60	-0.70	-0.06	-0.34
Other services	-0.32	-0.48	-0.52	-0.63	-0.01	-0.29
All Manufatures	-0.12	-0.20	-0.23	-0.29	0.08	-0.09
All Services	-0.32	-0.47	-0.51	-0.61	-0.01	-0.28
Total	**-0.25**	**-0.39**	**-0.43**	**-0.52**	**-0.02**	**-0.24**

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	(19)	$\forall g \in G$ but $g = ene$	Y^g: Production level
Input-output technologies for primary energy	(21)		Y^{ene}: Production level
Unit expenditure function	(22)		U: Household utility index
Unit cost of public purchase	(23)		PUB: Government activity
Unit cost of investment	(24)		INV: Investment activity
Market clearance conditions:			
Composite goods and services	(25)	$\forall g \in G$	PA^g : Composite price indexes
D-S composites	(27)	$\forall j \in J$ and $r \neq O$	P_r^g: Prices of D-S composites
	(28)	$\forall j \in J$ and $r = O$	
Markets for IRTS composite input (Krugman)	(29)	$\forall j \in J$	PMC^j: Composite input prices
Markets for IRTS composite input (Melitz)	(30)	$\forall j \in J$	PMC^j: Composite input prices
Markets for output	(31)	$\forall k \in K$	PY^g: Output prices
	(32)	$\forall i \in I$	
	(35)	$\forall j \in J$	
Markets for imports	(36)	$\forall i \in I$ and $r \neq O$	PM_r^g: Import prices
	(37)	$\forall j \in J$ and $r \neq O$	
	(38)	$\forall k \in K$ and $r \neq O$	
Factor markets	(39)	$\forall f \in F$	PF_f: Factor prices
Mobile labor	(40)		PL_{mob}: Mobile labor price
Sector specific labor	(42)	$\forall g \in G$	PL_g: Sector-specific labor price
Sector specific capital	(43)	$\forall g \in (I \cup J)$	PZ_r^g: Sector-specific capital price
Fixed real investment	(44)		$PINV$: Unit cost of investment
Fixed real public spending	(45)		PG: Unit cost of public good
Nominal utility equals Income	(46)		PC: Unit expenditure index
Balance of payments	(47)		PFX: Price of foreign exchange
Income balance:			
Domestic agent income	(48)		RA_h: Household Income
Government budget	(49)		$GOVT$: Government spending
Foreign Entrepreneur	(50)		FE: External agent income
Auxiliary Conditions:			
Fixed real public spending	(51)		T: Index on direct taxes
Capital in steady state	(52)		S_{CAP}: Capital stock
Investment in the steady state	(53)		INV: Investment activity
Unemployment rate	(54)		UNE: Unemployment

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
σ_{lab}	Mobile labor vs. sector specific labor
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_{ML}^s	Share of mobile labor component in labor composite
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
σ_{lab}	Mobile labor vs. sector specific labor	2
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
ϵ_{emp}	Elasticity of unemployment with respect to real wage	0.1

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

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

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

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

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

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

The zero profit condition is following:

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

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.

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

The technologies for producing the composite inputs for use in the Dixit-Stiglitz sectors 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. Note that the half of labor is mobile among sectors, while the other half of labor is sector specific, and thus PF_{Lab} is the price of the composite of mobile labor and sector-specific labor, and thus it is sector-specific, although PF_{Lab} does not include s index for reducing the notation burden. Let PL^s and PL_{mob} indicate the price of the sector specific labor and mobile labor, respectively. 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:

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

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

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

$$PF_{Lab} = \left[(1-\theta_s^{ML})(PL^s)^{1-\sigma_{lab}} + \theta_s^{ML}(PL_{mob})^{1-\sigma_{lab}} \right]^{1/(1-\sigma_{lab})}, \tag{18}$$

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}, and σ_{lab} is the substitution elasticity between mobile and sector specific labor. With P_s^{vas} established, the top-level Leontief unit cost function for sector s is given by

$$PY^s = \theta_{vas}^s P_s^{vas} + \sum_{g \neq I} \theta_g^s (1+t_{gs}^{int}) PA^g, \tag{19}$$

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

$$\sigma_{ene} = s_{ene} \frac{\theta_{res}}{1-\theta_{res}}, \tag{20}$$

where θ_{res} is the value share of resource factor input. Then, instead of equation (19), the top-level unit cost function of the primary energy production sector becomes

$$PY^{ene} = \left[\theta^{res} (PF_{res})^{1-\sigma_{ene}} + (1-\theta^{res}) (\theta_{vas}^s P_s^{vas} + \sum_{g \neq I} \theta_g^s (1+t_{gs}^{int}) PA^g)^{1-\sigma_{ene}} \right]^{1/(1-\sigma_{ene})}. \tag{21}$$

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:

$$PC = \prod_g [(1+t_g^{cons}) PA^g]^{\mu_C^g}, \tag{22}$$

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

$$PG = \sum_g \mu_G^g (1+t_g^{gov}) PA^g. \tag{23}$$

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

$$PINV = \sum_g \mu_{INV}^g (1+t_g^{inv}) PA^g. \tag{24}$$

Equations (1) through (24) 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

$$A^g = \sum_s h_{gs}(Y^s, \boldsymbol{p}) + \mu_C^g U \frac{PC}{(1+t_g^{cons})PA^g} + \mu_G^g PUB + \mu_{INV}^g INV, \tag{25}$$

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:

$$h_{is}(Y^s, \boldsymbol{p}) = \theta_i^s \theta_{vas}^s Y^s \left(\frac{P_s^{srv}}{(1+t_{is}^{int})PA_i} \right) \left(\frac{P_s^{vas}}{P_s^{srv}} \right)^{\sigma_{vas}} \tag{26}$$

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:

$$Q_r^j = A^j \left(\frac{PA^j}{P_r^j} \right)^{\sigma_F^j} \quad r \neq O; \tag{27}$$

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

$$Q_D^j = A^j \left(\frac{PA^j}{P_D^j} \right)^{\sigma_F^j} + \sum_r FORIM_r^j. \tag{28}$$

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:

$$Z_r^j = f_r^j N_r^j + Q_r^j (N_r^j)^{1/(1-\sigma_F^j)}. \tag{29}$$

To derive (29) 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, $\delta f^s_{jr} M^j_r$; for operating fixed costs, $\sum_m f^j_{rm} N^j_{rm}$; as well as operating inputs, $\sum_m [Q^j_r (N^j_{rm})^{1/(1-\sigma^j_F)}]/\tilde{\varphi}^j_{rm}$.

$$Z^j_r = \delta f^s_{jr} M^j_r + \sum_m f^j_{rm} N^j_{rm} + \sum_m \frac{Q^j_r (N^j_{rm})^{1/(1-\sigma^j_F)}}{\tilde{\varphi}^j_{rm}}. \tag{30}$$

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:

$$Y^k = \phi^k_D A^k \left(\frac{PA^k}{PY^k} \right)^{\sigma^k_{DM}} + \sum_r FORIM^k_r. \tag{31}$$

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):

$$\begin{aligned} Y^i &= \theta^i_{DD} Q^i_O \left(\frac{PMC^i_O}{PY^i} \right)^{\epsilon^i_O} + \sum_{r \neq O} \theta^i_{Dr} Q^{FDI}_r \left(\frac{PFDI_r}{\theta^i_{Dr} PY^i + \theta^i_{Mr} PFX} \right)^{\epsilon^i_r} \\ &+ \sum_r FORIM^i_r, \end{aligned} \tag{32}$$

$$Q^i_r = A^i \left(\frac{PA^i}{PMC^i_r} \right)^{\sigma^i_F}, \tag{33}$$

$$Q^{FDI}_r = A^i \left(\frac{PA^i}{PFDI^i_O} \right)^{\sigma^j_F} \quad r \neq O. \tag{34}$$

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

$$Y^j = \theta^j_{DD} Z^j_D \left(\frac{PMC^j_D}{PY^j} \right)^{\epsilon^j_D} + \sum_r FORIM^j_r. \tag{35}$$

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:

$$IM^i_r = \phi^i_r Q^i_r \left(\frac{PMC^i}{PM^i_r} \right)^{\sigma^i_F} \tag{36}$$

$$IM^j_r = \theta^j_{Mr} Z^j_r \left(\frac{PMC^j_r}{PM^j_r} \right)^{\epsilon^j_r} \tag{37}$$

$$IM_r^k = \phi_r^k A^k \left(\frac{PA^k}{PM_r^k} \right)^{\sigma_{DM}^k}. \quad (38)$$

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:

$$\overline{S}_f = \sum_s \theta_f^s \theta_{vas}^s Y^s \left(\frac{P_s^{va}}{(1+t_{fs})PF_f} \right) \left(\frac{P_s^{vas}}{P_s^{va}} \right)^{\sigma_{vas}}, \quad (39)$$

where P_s^{va} is the composite value-added price as defined in equaiton (17). Regarding the labor endowment, $\overline{S}_{Lab}$ is the total labor endowment including both mobile and sector specific labor. Denoting the endowment of mobile labor $\overline{SL}^{mob}$, we have

$$\overline{SL}^{mob} = \sum_s \theta_s^{ML} DL_s^{com} \left(\frac{PF_{Lab}}{PL_{mob}} \right)^{\sigma_{lab}}, \quad (40)$$

where DL_s^{com} is the sectoral demand of composite labor, and it is specified as following:

$$DL_s^{com} = \theta_{Lab}^s \theta_{vas}^s Y^s \left(\frac{P_s^{va}}{(1+t_{fs})PF_{Lab}} \right) \left(\frac{P_s^{vas}}{P_s^{va}} \right)^{\sigma_{vas}}. \quad (41)$$

Denoting the endowment of sector specific labor $\overline{SL}_s^{sec}$, we have

$$\overline{SL}_s^{sec} = (1-\theta_s^{ML}) DL_s^{com} \left(\frac{PF_{Lab}}{PL^s} \right)^{\sigma_{lab}}. \quad (42)$$

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:

$$\overline{SF}_r^g = \theta_{Zr}^g (Z_r^j + Q_r^i) \left(\frac{PMC_r^g}{PZ_r^g} \right)^{\epsilon_r^g} \quad \forall g \in (I \cup J). \quad (43)$$

Real investment equals real savings by households:

$$INV = \overline{sav}. \quad (44)$$

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

$$PUB = \frac{GOVT}{PG}. \quad (45)$$

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

$$U = \frac{RA}{PC}. \quad (46)$$

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.

$$\begin{aligned}\sum_{r\neq O}\sum_{g} FORIM_r^g + \overline{ftrn} &= \sum_{r\neq O}\sum_{g} IM_r^g \\ &+ \sum_{r\neq O}\sum_{i} \theta_{Mr}^i Z_r^i \left(\frac{PMC_r^i}{\theta_{Dr}^i PY^i + \theta_{Mr}^i PFX}\right)^{\epsilon_r^i} \\ &+ \frac{FE}{PFX}, \end{aligned} \tag{47}$$

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

$$\begin{aligned} RA &= \sum_{f} PF_f \overline{S}_f \\ &+ \sum_{g} PZ^g \overline{SF}^g \\ &- \overline{sav} PINV \\ &- \overline{dtax} PG \times T \\ &+ \overline{ftrn} PFX \end{aligned} \tag{48}$$

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

$$\begin{aligned} GOVT &= \overline{dtax}_h PG \times T \\ &+ \sum_{g} t_g^{cons} PA^g \mu_C^g U \frac{PC}{(1+t_g^{cons})PA^g} \\ &+ \sum_{g} t_g^{inv} PA^g \mu_{INV}^g INV \\ &+ \sum_{g} t_g^{gov} PA^g \mu_G^g PUB \end{aligned}$$

$$
\begin{aligned}
&+ \sum_s \sum_i t_{is}^{int} PA_i \theta_i^s \theta_{vas}^s Y^s \left(\frac{P_s^{srv}}{(1+t_{is}^{int})PA_i} \right) \left(\frac{P_s^{vas}}{P_s^{srv}} \right)^{\sigma_{vas}} \\
&+ \sum_s \sum_j t_{js}^{int} PA_j \theta_j^s Y^s \\
&+ \sum_s \sum_k t_{ks}^{int} PA_k \theta_k^s Y^s \\
&+ \sum_s \sum_f t_{fs} PF_f \theta_f^s \theta_{vas}^s Y^s \left(\frac{P_s^{va}}{(1+t_{fs})PF_f} \right) \left(\frac{P_s^{vas}}{P_s^{va}} \right)^{\sigma_{vas}} \\
&+ \sum_{r \neq O} \sum_g t_{gr}^{imp} (PFX) IM_r^g \\
&+ \sum_{r \neq O} \sum_i t_i^{exp} \frac{PMC^i}{1 - \frac{1}{\sigma_F^i}} FORIM_r^i \\
&+ \sum_{r \neq O} \sum_j t_j^{exp} \frac{PMC^j}{1 - \frac{1}{\sigma_F^j}} FORIM_r^j \\
&+ \sum_{r \neq O} \sum_k t_k^{exp} PX_r^k FORIM_r^k
\end{aligned} \tag{49}
$$

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:

$$
FE = \sum_{r \neq O} \sum_g PZ_r^g \overline{SF}_r^g \quad \forall g \in I. \tag{50}
$$

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:

$$
PUB = \overline{pub}. \tag{51}
$$

Second, we use auxiliary conditions to consider the steady state simulation instead of the static simulation. While the capital stock is exogenous with the endogenous capital return in the static simulation, the capital stock is endogenous with the exogenous capital return (demanded by investors) in the steady state simulation as modelled in Balistreri et al. (2009). The capital return is determined by the following equation with the associate variable of capital stock S_{CAP}:

$$
PF_{CAP} = PINV. \tag{52}
$$

We assume that the real investment is decreased as the capital stock shrinks. Specifically, we assume that the percentage change in investment equals the percentage change in capital supply

as Francois et al. (2013) does.

$$\frac{\Delta INV}{INV_0} = \frac{\Delta K}{K_0}, \tag{53}$$

where INV_0 and K_0 are the benchmark value of investment and capital supply, respectively. In the steady state simulation, we replace the capital market clearance condition of (39) with the equation (52), and we also replace the fixed investment condition (44) with endogenous investment condition (53).

Lastly, we use the following auxiliary condition to model the unemployment. As suggested by Blanchflower and Oswald (1994), we characterize the unemployment by a wage curve. With the unemployment feature in the model, we modify the labor endowment by following the equation:

$$log\frac{PF_{LAB}}{PC} = \epsilon_{emp}\, log\frac{UNE}{UNE_0}, \tag{54}$$

where UNE is the unemployment rate in the counterfactual simulation, UNE_0 is the unemployment rate at the benchmark, and ϵ_{emp} is the elasticity of the unemployment with respect to real wage.

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