EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Rita Cappariello, Vanessa Gunnella, Sebastián Franco-Bedoya, Gianmarco Ottaviano

Rising protectionism
and global value chains:
quantifying the
general equilibrium effects

Abstract

Quantifying the effects of trade policy in the age of 'global value chains' (GVCs) requires an enhanced analytical framework that takes the observed international input-output relations in due account. However, existing quantitative general equilibrium models generally assume that industry-level bilateral final and intermediate trade shares are identical, and that the allocation of imported inputs across sectors is the same as the allocation of domestic inputs. This amounts to applying two proportionality assumptions, one at the border to split final goods and inputs, and another behind the border to allocate inputs across industries. In practice, neither assumption holds in available input-output data sets. To overcome this limitation of existing models, we consider a richer input-output structure across countries and sectors that we can match with the actual structure reported in input-output tables. This allows us to investigate the relation between the effects of changes in trade policies and GVCs. When we apply the enhanced quantitative general equilibrium model to the assessment of the effects of Brexit, we find trade and welfare losses that are substantially larger than those obtained by previous models. This is due to the close integration of UK-EU production networks and implies that denser GVCs amplify the adverse effects of protectionist trade policies.

Non-technical summary

After decades of significant steps towards trade integration at the international level, global trade has been expanding at a slower pace since the Great Recession. At the same time, public opinion and policymakers have started questioning the benefits of free trade. The UK has made the decision to leave the European Union, the US has experienced a return to protectionism while trade barriers have been rising substantially in recent years both in advanced and developing economies contributing to the weakening of global trade. Rising trade barriers have consequences for prices and economic activity. To the extent that higher tariff and non-tariff barriers pass through to the prices of intermediate and final products, higher trade costs can raise consumer prices. This may reduce consumption and investment, weigh negatively on economic activity and ultimately reduce welfare. In the long term, allocative inefficiencies due to relative price distortions could further harm welfare through lower productivity and potential growth.

While the quantification of the impact of trade policy on prices, economic activity and welfare has always been at the core of trade policy analysis, the complexity of today's trade relations raises new unprecedented challenges. In particular, the rise of 'global value chains' (GVCs), through which production processes are organized in multiple stages across several countries, requires the adoption of enhanced analytical frameworks that take the observed international input-output relations in due account.

The aim of this paper is to propose one such framework and show how it can be operationalized for quantitative trade policy analysis. In doing so, we first investigate a simple thought experiment that highlights the importance of allowing for a detailed characterization of GVCs in quantifying the effects of trade policy shocks. The experiment compares the welfare effects of a uniform increase in trade costs across the world in two scenarios that differ in terms of the salience of GVCs. We then apply the proposed framework to the quantitative analysis of the most important trade policy shock currently affecting the European Union: the impending departure of the UK (a.k.a. 'Brexit').

Specifically, we adopt a general equilibrium multi-sector Ricardian trade model of the global economy with trade in both final and intermediate products. By mapping bilateral supply chain linkages and value-added flows, the model provides a rich framework that captures countries' heterogeneity in terms of the composition of their trade flows as well as in terms of their involvement in GVCs. We use the model to understand how cross-border multi-stage production affects

the transmission of trade policy shocks to national welfare. The model is rich enough to predict the impact of trade shocks on each sector within each country for both goods and services. The main caveat is that being based on comparative statics, the model's predictions do not include dynamic effects, such as the short-run effects of increased uncertainty and the transition to a new equilibrium as well as the long-run effects on productivity and growth, unemployment and migration.

In the simple thought experiment, we highlight the crucial role of GVCs in the transmission of trade policy shocks by considering the effects of a uniform 40% increase in trade barriers in all sectors across all world countries and comparing the model's predictions in two scenarios. In the first, we assume the input-output structure observed in 2000. In the second, we assume instead the input-output structure observed in 2014 when GVCs are much more salient. This exercise shows that the negative impact of a 40% increase in trade costs on countries' welfare (measured as real household income) is on average 36% larger in absolute value in 2014 than in 2000, and as much as 219% larger for some countries. Hence, denser GVCs act as an amplifier of the adverse welfare effects of protectionist trade policies.

In the Brexit application, we present results for alternative trade policy scenarios ranging from a EU-UK free trade agreement (FTA) and a reversal to the most favoured nation (MFN) terms prescribed by the WTO in case of 'no deal'. We consider also a variation on the MFN scenario following the schedule of tariffs announced by the UK in March 2019 that involves a drastic and unilateral reduction by the UK of its MFN import tariffs (New MFN scenario). We conclude that properly accounting for GVCs makes a substantial difference. The model with GVCs predicts a fall in bilateral trade between the UK and the EU that would be more severe with no deal. This fall would translate into a decrease in total real exports for the EU and the UK of about -2% and -13% respectively under the FTA scenario, and about -3% and -19% under the MFN scenario. Welfare losses are contained for the EU, from -0.4% with a deal to -0.6% with no deal, but they are much bigger for the UK (from -2.1 to -3.1% respectively). To highlight the role of GVCs, we consider also an alternative version of the model in which we set all sectoral bilateral trade flows in intermediate products to zero and impute their original amounts to final products. Shutting down GVCs in this way weakens the impact of Brexit substantially: on average across the EU the aggregate welfare losses when properly accounting for GVCs are roughly twice as large in absolute value as those without GVCs. Moreover, input-output linkages between the UK and the EU would be considerably disrupted.

1 Introduction

After decades of significant steps towards trade integration at the international level, global trade has been expanding at a slower pace since the Great Recession. At the same time, public opinion and policymakers have started questioning the benefits of free trade. The UK has made the decision to leave the European Union, the US has experienced a return to protectionism (Fajgelbaum et al., 2019) while trade barriers have been rising substantially in recent years both in advanced and developing economies contributing to the weakening of global trade (Evenett, 2019). Rising trade barriers have consequences for prices and economic activity. To the extent that higher tariff and non-tariff barriers pass through to the prices of intermediate and final products, higher trade costs can raise consumer prices. This may reduce consumption and investment, weigh negatively on economic activity and ultimately reduce welfare. In the long term, allocative inefficiencies due to relative price distortions could further harm welfare through lower productivity and potential growth.

While the quantification of the impact of trade policy on prices, economic activity and welfare has always been at the core of trade policy analysis, the complexity of today's trade relations raises new unprecedented challenges. In particular, the rise of 'global value chains' (GVCs), through which production processes are organized in multiple stages across several countries, requires the adoption of enhanced analytical frameworks that take the observed international input-output relations in due account.

The aim of this paper is to propose one such framework and show how it can be operationalized for quantitative trade policy analysis. In doing so, we first investigate a simple thought experiment that highlights the importance of allowing for a detailed characterization of GVCs in quantifying the effects of trade policy shocks. The experiment compares the welfare effects of an uniform increase in trade costs across the world in two scenarios that differ in terms of the salience of GVCs. We then apply the proposed framework to the quantitative analysis of the most important trade policy shock currently affecting the European Union: the impending departure of the UK (a.k.a. 'Brexit').

Specifically, we adopt the general equilibrium multi-sector Ricardian trade model of the global economy with trade in both final and intermediate products designed by Antràs and Chor (2018) in the wake of Eaton and Kortum (2002), Costinot and Rodríguez-Clare (2014) and Caliendo and Parro (2015). By mapping bilateral supply chain linkages and value-added flows, the model

provides a rich framework that captures countries' heterogeneity in terms of the composition of their trade flows as well as in terms of their involvement in GVCs. Antràs and Chor (2018) use their model to study how trade cost changes affect the correlation between the final-use and value-added shares in gross output across countries, as production along GVCs becomes more fragmented across borders. Differently, we use the model to understand how cross-border multi-stage production affects the transmission of trade policy shocks to national welfare. The model is rich enough to predict the impact of trade shocks on each sector within each country for both goods and services. The main caveat is that being based on comparative statics, the model's predictions do not include dynamic effects, such as the short-run effects of increased uncertainty and the transition to a new equilibrium as well as the long-run effects on productivity and growth, unemployment and migration.

Our analysis relates to several recent studies aimed at quantifying the effects of changes in trade policies through the implementation of Ricardian models. Among them, Dhingra et al. (2017) and Felbermayr et al. (2017) analyze the effects of Brexit as we also do. Mayer et al. (2018) look instead at the "cost of non-Europe", *i.e.* the cost of un-doing what the process of European integration has achieved so far by reverting to a shallow regional agreement or to WTO rules. Just like Eaton and Kortum (2002), Costinot and Rodríguez-Clare (2014) and Caliendo and Parro (2015), the multi-country, multi-sector general equilibrium models underlying the aforementioned papers do include realistic input-output linkages. However, they assume that industry-level bilateral final and intermediate trade shares are identical, and that the allocation of imported inputs across sectors is the same as the allocation of domestic inputs. As Johnson (2017) explains, this amounts to applying two proportionality assumptions, one at the border to split final goods and inputs, and another behind the border to allocate inputs across industries. In practice, neither assumption holds in available input-output data sets. Following Antràs and Chor (2018) allows us to implement a richer input-output structure across countries and sectors that we can match with the actual one reported in input-output tables. In doing so, we rely on the value-added decomposition of exports as initially proposed by Koopman et al. (2014) to track cross-country value-added flows and characterize GVC relations. In this respect, an additional important contribution of this paper is the construction of a dataset of sectoral ad-valorem WTO-MFN tariffs for both final and intermediate trade (at the ISIC Rev. 4 classification) that can be combined with the World Input-Output Database (WIOD).[1]

---

[1] See www.wiod.org for additional details.

Accordingly, our analysis also relates to an increasing number of papers that combine information on tariffs with models of trade and value added with the aim of investigating the impacts of protectionist measures and trade wars. Freund et al. (2018) use a computable general equilibrium (CGE) model to assess the implications of higher bilateral tariffs between China and the US for developing countries. In Balistreri et al. (2018) a simulated multi-region multi-sector general-equilibrium model of the global economy is used to evaluate the impacts of tariffs implemented by the US in 2018 and the subsequent retaliation by trade partners. Fajgelbaum et al. (2019) perform a similar analysis within the US using a multi-country general equilibrium model. Berthou et al. (2018) use a 3-region forward-looking DSGE model for the US, the euro area and the rest of the world to assess the impact on global GDP of a global trade war. Felbermayr and Steininger (2019) rely on an input-output gravity approach *à la* Caliendo and Parro (2015) to assess the consequences of an escalation of bilateral tariffs between the US and China on these two countries and the EU. Amiti et al. (2019) explore the implications of the radical change in US trade policy in 2018 on prices and welfare in the US, taking into account the disruption of global value chains. Finally, Bellora and Fontagné (2019) use a general equilibrium framework with intermediate and final products to quantify the effects of detailed tariff changes on value added and welfare. None of these papers, however, zooms in on the actual patterns of GVCs as we do by building on both Koopman et al. (2014) and Antràs and Chor (2018). The only relevant exception we are aware of is Baqaee and Farhi (2019), who nonetheless take a different approach from ours. They quantify gains from trade with non-linear production functions that feature input complementarities. In this sense, their framework also offers a generalization of the input-output models emphasized in Caliendo and Parro (2015). Interestingly, compared with the log-linear production networks common in the literature and in line with our results, Baqaee and Farhi (2019) find that accounting for nonlinear production networks significantly raises the gains from trade and the losses from trade protectionism.

Turning to our findings, in the simple thought experiment, we highlight the crucial role of GVCs in the transmission of trade policy shocks by considering the effects of a uniform 40% increase in trade barriers in all sectors across all world countries and comparing the model's predictions in two scenarios. In the first, we assume the input-output structure observed in 2000. In the second, we assume instead the input-output structure observed in 2014 when GVCs are much more salient. This exercise shows that the negative impact of a 40% increase in trade costs on countries' welfare (measured as real household income) is on average 36% larger in absolute value

in 2014 than in 2000, and as much as 219% larger for some countries.

In the Brexit application, we present results for alternative trade policy scenarios ranging from a EU-UK free trade agreement (FTA) and a reversal to the most favoured nation (MFN) terms prescribed by the WTO in case of 'no deal'. We consider also a variation on the MFN scenario following the schedule of tariffs announced by the UK in March 2019 that involves a drastic and unilateral reduction by the UK of its MFN import tariffs (New MFN scenario). We conclude that properly accounting for GVCs makes a substantial difference. The model with GVCs predicts a fall in bilateral trade between the UK and the EU that would be more severe with no deal. This fall would translate into a decrease in total real exports for the EU and the UK of about -2% and -13% respectively under the FTA scenario, and about -3% and -19% under the MFN scenario. Welfare losses are contained for the EU, from -0.4% with a deal to -0.6% with no deal, but they are much bigger for the UK (from -2.1 to -3.1% respectively). To highlight the role of GVCs, we consider also an alternative version of the model in which we set all sectoral bilateral trade flows in intermediate products to zero and impute their original amounts to final products. Shutting down GVCs in this way weakens the impact of Brexit substantially: on average across the EU the aggregate welfare losses when properly accounting for GVCs are roughly twice as large in absolute value as those without GVCs. Moreover, input-output linkages between the UK and the EU would be considerably disrupted.

The structure of the rest of the paper is as follows. Section 2 provides an illustration of the evolution of GVCs over the years. Section 3 introduces the theoretical framework. Section 4 discusses its properties with the aid of the simple thought experiment described above. Section 5 illustrates the effects of Brexit on aggregate as well as across sectors and countries. Section 6 concludes.

2   The surge of global value chains

Despite recent setbacks, in the last decades economic integration and trade liberalizations at the global level together with profound technological transformations have boosted international trade. Trade openness - defined as the share of trade over GDP - has increased dramatically until the global financial crisis for both advanced and emerging economies (Figure 1).

A crucial development has been what Baldwin (2016) defines "unbundling", *i.e.* the international separation of production stages motivated by cost efficiency considerations and facilitated by

Figure 1: Trade openness in the last three decades
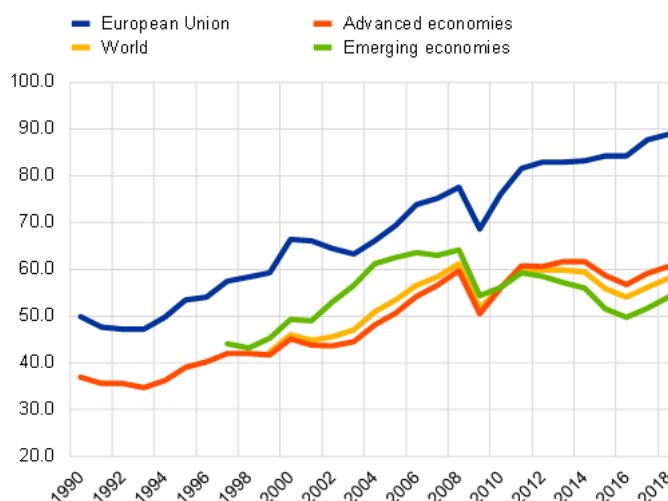
advancements in information and communication technology (ICT). As a result, the complexity of production processes has increased, triggering the so-called "global value chain revolution" whereby the expansion of cross-country production networks has led to a surge in international trade.

Countries and industries across the globe have become more and more interconnected not only via trade in final products but also as firms increasingly source their intermediate inputs from abroad.[2] Figure 2 illustrates the complexity of the global input-output network.[3] It shows that from 2000 to 2014 supply chain linkages have become denser, not only within countries but especially across national borders. It also highlights that over time, sectors have become increasingly interconnected via GVCs, and that the relevance of large emerging economies such as China (in light blue) has grown.

Another way to illustrate the development of GVCs in the last decades is to look at widely used indexes of countries' participation to GVCs in the wake of Koopman et al. (2014) and Wang et al. (2013). A country's GVC participation is computed as the sum of foreign value added

---

[2]See Di Giovanni and Levchenko (2010) and Di Giovanni et al. (2018) who highlight the crucial role of the surge in trade in intermediate inputs in synchronising business cycles across countries.

[3]See also Cerina et al. (2015) for an exploration of the global input-output network from 1995 to 2011 and Carvalho (2014) for a general discussion on input-output linkages.

Figure 2: The evolution of the GVC network
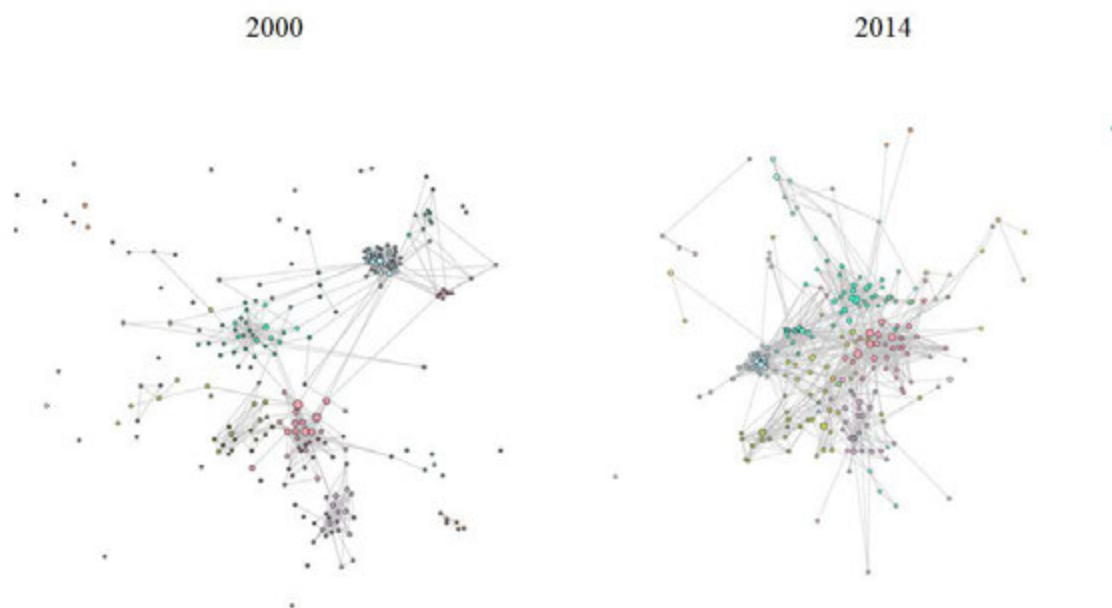
Sources: WIOD (2016 release) and authors' calculations.

Notes: Each dot (node) in the picture represents a sector in a country. Colours distinguish countries. Gray lines (edges) connecting the dots represent trade flows in intermediate inputs between sectors. To reduce complexity, only nodes with betweenness centrality above 3000 and edges representing flows above 1 billion USD are shown. For comparability, these criteria are applied to both figures.
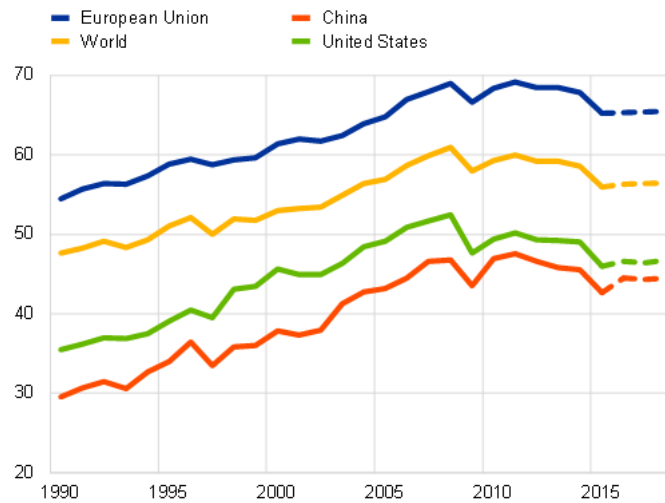
embedded in its exports ('upstream participation') and domestic value added embedded in other countries exports ('downstream participation') as share of the country's total exports. Figure 3 shows that, according to this index, countries' involvement in cross-border supply chains surged remarkably across the globe until the Great Recession. Already integrated regions, such as the European Union, have further expanded their involvement in regional and global supply chains while relatively less open countries, such as the United States and China, have experienced an even more pronounced acceleration of their GVC participation.

However, with the trade slowdown that has materialised starting from the Great Recession, the pace of expansion of GVCs has decreased considerably and GVC participation has receded to pre-crisis levels.[4]

One of the main factors determining the stagnation of GVCs is the recent upsurge in protectionist

---

[4]See Timmer et al. (2016) for an account of the global trade slowdown with insights on GVCs developments.

Figure 3: Global value chain participation over time

measures internationally. Counteracting progress in trade liberalisation, discriminatory measures have been on the rise most notably since 2018, when their increase outpaced liberalising measures (Figure 4). Escalating trade tensions between two major economies such as the United States and China are behind this marked rise. Furthermore, prospects of an exit of the UK from the European Union can be expected to lift trade barriers within the largest integrated trade block in the world.

3 A general equibrium model of global value chains

In a world of GVCs, quantifying the effects of rising protectionism on countries' economic activity, prices and welfare requires the adoption of an enhanced analytical framework that accounts for the actual international input-output relations and the observed differences in trade barriers for final and intermediate products. We thus adopt the model developed by Antràs and Chor (2018), as an extension of Eaton and Kortum (2002), Costinot and Rodríguez-Clare (2014) and Caliendo and Parro (2015), in order to consider the full pattern of intermediate input purchases and final-use expenditures as measured in available World Input-Output Tables (WIOT) as well

Figure 4: Harmful vs liberalising measures
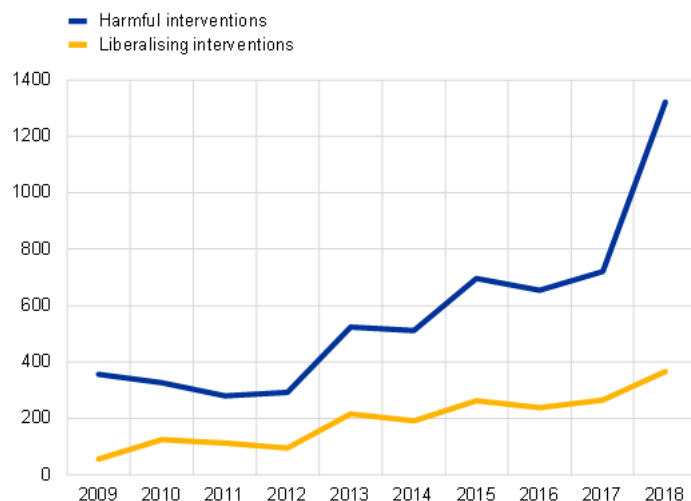
Notes: The figure shows the number of trade interventions. Data are adjusted for reporting lags.

as the corresponding tariffs and non-tariff trade barriers (NTB). This framework will allow us to explore the impacts of trade cost changes on the fortunes of nations through the reorganization of the GVCs they are involved in. Sectoral heterogeneity will be an important dimension in this analysis as impacts of trade cost changes may differ across countries depending on the sectoral composition of their economies and the relative importance of different foreign markets.

Figure 5: Small World Economy with Input-Output structure

Notes: Entries in the table represent exports from sectors/countries in the rows to sectors/countries in the column.

As example of the level of detail needed, Figure 5 shows the input-output table of a simplified world economy. Countries are aggregated in three groups: the UK, the EU (without the UK) and the Rest of the World (RoW). Industries are aggregated in three macro-sectors: manufacturing,

services and the rest (which we call 'non-manufacturing'). The table consists of two blocks for intermediate inputs and final goods. This distinction is crucial for both (i) computing the actual tariff costs and (ii) mapping the observed input-output linkages into the model.

Figure 6 depicts the case of a model in which intermediates are not traded internationally. Such model would not allow one to consider the effect of changes in the trade costs of intermediate products, as illustrated also in Costinot and Rodríguez-Clare (2014).

Figure 6: Input-Output table with no trade in intermediates

Notes: Entries in the table represent exports from sectors/countries in the rows to sectors/countries in the column. Shaded areas indicate non-zero entries.

Differently, Figure 7 illustrates the input-output matrix of the model by Eaton and Kortum (2002) as well as its extension by Caliendo and Parro (2015). These models feature cross-country trade in intermediates. However, they do not allow one to precisely map the input-output structure, as they assume that trade shares and the trade costs for intermediate and final products are identical.

Figure 7: Caliendo and Parro (2015) input-output table

Notes: Entries in the table represent exports from sectors/countries in the rows to sectors/countries in the column. Shaded areas indicate non-zero entries. The row sum of the entries in the intermediate block highlighted in red is equal to the value of the corresponding row entry in the final block. In other words, intermediate exports from a sector-country to another country are equal to final exports to that country.

To be able to work with an input-output matrix like Figure 5, which does not impose unrealistic

constraints on the trade shares and costs of intermediate and final products, we thus build on the model by Antràs and Chor (2018).[5] This model considers a perfectly competitive world economy consisting of J countries, indexed $j = 1, ..., J$, and S sectors, indexed $s = 1, ..., S$. Country j's consumers and firms source sector s's final and intermediate goods from the lowest price supplier across all countries. Consumer preferences in country j are characterized by the utility function:

$$u\left(C_j\right) = \prod_{s=1}^{S} \left(C_j^s\right)^{\alpha_j^s},$$

where C_j^s is the consumption of good j supplied by sector s and α_j^s is the sector's share in expenditure with $\sum_{s=1}^{S} \alpha_j^s = 1$. In sector s of country j, good ω^s is produced according to the Cobb-Douglas production function:

$$y_j^s(\omega^s) = z_j^s(\omega^s) \left(l_j^s(\omega^s)\right)^{1 - \sum_{r=1}^{S} \gamma_j^{rs}} \prod_{r=1}^{S} \left(M_j^{rs}(\omega^s)\right)^{\gamma_j^{rs}}, \tag{1}$$

where $y_j^s(\omega^s)$ is output, $z_j^s(\omega^s)$ is total factor productivity ('technology'), $l_j^s(\omega^s)$ is labour input, and $M_j^{rs}(\omega^s)$ is a Cobb-Douglas composite of intermediates from all sectors with shares γ_j^{rs} for $r = 1, ..., M$ such that $\sum_{r=1}^{S} \gamma_j^{rs} = 1$. Technology $z_j^s(\omega^s)$ is an i.i.d. draw from a Frechet distribution with cumulative density function $exp(-T_j^s z^{-\theta^s})$. In this distribution T_j^s governs the state of technology of country j in sector s, while $\theta^s > 1$ governs (inversely) the dispersion of productivity in sector s across producers, thereby shaping comparative advantage. This randomness makes consumers' and firms' optimal sourcing decisions the solutions to the discrete choice problem with random parameters of choosing the lowest price source country.

Sector s's composite product Q_j^s is a CES aggregate of its goods over the unit interval:

$$Q_j^s = \left(\int_0^1 q_j^s\left(\omega^s\right)^{1 - 1/\sigma^s} d\omega^s\right)^{\sigma^s/(\sigma^s - 1)},$$

where σ^s is the elasticity of substitution between sector s's goods and $q_j^s\left(\omega^s\right)$ denotes the quantity of product ω^s that is ultimately purchased from the lowest price source country. The equilibrium of the model can be found by maximizing utility subject to the unit cost function associated with 1:

$$c_j^s = \Upsilon_j^s w_j^{1 - \sum_{r=1}^{S} \gamma_j^{rs}} \prod_{r=1}^{S} \left(P_j^{rs}\right)^{\gamma_j^{rs}} \tag{2}$$

---

[5]Here we offer a streamlined presentation of the model. See Antràs and Chor (2018) for further details.

where Υ is a constant that depends only on γ_j^{rs} for $r = 1, ..., M$, w_j is the price of labour, and P_j^{rs} is the price index of intermediate inputs:

$$P_j^{rs} = A^r \left[\sum_{i=1}^{J} T_i^r \left(c_i^r \tau_{ij}^{rs} \right)^{-\theta^r} \right]^{-1/\theta^r}. \tag{3}$$

Analogously, the price index of final goods reads:

$$P_j^{rF} = \prod_{s=1}^{S} \frac{1}{\alpha_j^s} A^r \left[\sum_{i=1}^{J} T_i^r \left(c_i^r \tau_{ij}^{rF} \right)^{-\theta^r} \right]^{-\alpha_j^s/\theta^r} \tag{4}$$

These price indexes depend on technologies (T_j^s), unit costs (c_j^s) and trade costs (τ_{ij}^{rs}). Trade costs are of the iceberg type with $\tau_{ij}^{rs} \geq 1$ measuring the number of units of a good produced by sector r for use in sector s that have to be shipped from country i to country j for one unit to reach destination. The fraction $\tau_{ij}^{rs} - 1$ melts away in transit. The price indexes also depend on sector-specific productivity dispersion (θ^r).

In equilibrium, the shares of final and intermediate products sector s in country j buys from sector r in country i are given respectively by:

$$\pi_{ij}^{rs} = \frac{T_i^r (c_i^r \tau_{ij}^{rs})^{-\theta^r}}{\sum_{k=1}^{J} T_r^k (c_r^k \tau_{kj}^{rs})^{-\theta^r}} \tag{5}$$

and

$$\pi_{ij}^{rF} = \frac{T_i^r (c_i^r \tau_{ij}^{rF})^{-\theta^r}}{\sum_{k=1}^{J} T_r^k (c_r^k \tau_{kj}^{rF})^{-\theta^r}}, \tag{6}$$

which themselves depend on technologies (T_j^s), unit costs (c_j^s) and trade costs (τ_{ij}^{rs}). They also depend on the productivity dispersion parameters (θ^r). These can now be interpreted as sector-specific trade elasticities as they measure (in absolute value) the percentage fall in a sector's bilateral trade due to a 1% increase in the bilateral iceberg trade cost. This will allow us to use the trade elasticities that Felbermayr et al. (2017) estimate by Poisson Pseudo-Maximum Likelihood (PPML) structural gravity regressions based on (5) and (6). In particular, they estimate θ^r as the elasticity of trade flows to tariffs controlling for non-tariff barriers through sectoral bilateral EU and other FTA dummies in a model-consistent way. The trade elasticities and NTBs we use are reported in Table 4 in Appendix B.

The solution of the model is closed by two sets of market clearing conditions and a trade balance

condition. The first requires that for each country j total expenditure X_j^s satisfies:

$$X_j^s = \sum_{r=1}^{S} \gamma_j^{sr} Y_j^r + \alpha_j^s \left(\omega_j L_j + D_j \right), \tag{7}$$

where D_j denotes the trade deficit so that the two terms on the right hand side correspond to total expenditures on the country's intermediate and final products respectively. The second market clearing condition requires that total output Y_j^s satisfies:

$$Y_j^s = \sum_{r=1}^{S} \sum_{k=1}^{J} \pi_{jk}^{sr} \gamma_k^{sr} Y_k^r + \sum_{k=1}^{J} \pi_{jk}^{sF} \alpha_k^s \left(\omega_k L_k + D_k \right), \tag{8}$$

where the two terms on the right hand side correspond to the country's total output levels of intermediate and final products respectively.

The trade balance condition requires that country j's aggregate imports equal the aggregate exports plus the trade deficit D_j, as follows:

$$\sum_{i=1}^{J} \sum_{r=1}^{S} \sum_{s=1}^{S} \pi_{ij}^{sr} \gamma_j^{sr} Y_j^r + w_j L_j = \sum_{i=1}^{J} \sum_{r=1}^{S} \sum_{s=1}^{S} \pi_{ji}^{sr} \gamma_i^{sr} Y_i^r + \sum_{s=1}^{J} \sum_{i=1}^{J} \pi_{sFji} \alpha_i^s \left(w_i L_i + D_i \right) \tag{9}$$

Finally, the equilibrium is defined by the following system of equations: $J \times S$ equations in (2), $J \times (J-1) \times S$ equations in (3), $J \times S$ equations in (4), $J \times (J-1) \times S \times S$ equations in (5), $J \times (J-1) \times S$ equations in (6), $J \times S - 1$ equations in (8), and J equations in (9). In this system of equations one seeks to solve for the following unknown variables: $J \times (J-1) \times S \times S$ independent intermediate trade shares π_{ij}^{rs}, $J \times (J-1) \times S$ independent final trade shares π_{ij}^{rF}, $J \times S$ unit production costs c_j^s, $J \times S \times S$ intermediate goods price indices P_j^{rs}, $J \times S$ final goods price indices P_j^{rF}, $J-1$ wage levels w_j (one is a numeraire), and $J \times S$ gross output levels Y_j^s. This is computationally demanding. However, in order to obtain the effects of a change in trade costs on wages, output and prices, the system of equilibrium equations can be solved in differences using the so-called "hat algebra" approach of Dekle et al. (2008) and Caliendo and Parro (2015). By applying goods market-clearing and trade balance conditions, the "hat algebra" allows deriving results for changes in the variables of interest, without knowing the initial levels of the target variables. In particular, in addition to the changes in trade costs, the only pieces of information actually needed are the trade shares (π_{ij}^{rs} and π_{ij}^{rF}), the trade elasticities (θ^r) and the expenditure shares (γ_j^{rs} and α_j^s).

4   Tariff hikes and global value chains

Do GVCs matter in determining the effects of protectionist trade shocks on national economies? To answer this question we use the model detailed in the previous section to compare the effects of a 40% increase in bilateral trade costs between all sector-country pairs in two scenarios: 'sparse' GVCs corresponding to the world input-output structure in 2000 and 'dense' GVCs corresponding to the world input-output structure in 2014. These structures are based on the World Input-Output Database (www.wiod.org), which considers 56 sectors and covers all EU countries as well as other 14 countries individually plus all remaining countries together as 'Rest of the World'. For ease of comparison, in both scenarios we assume the same trade elasticities (equal to 5 for all sectors and countries) so that differences between the effects of the trade shock in the two years will depend solely on changes in the world input-output structure.

To illustrate these changes, Figure 8 contrasts various trade indicators calculated using world input-output tables for 2000 and 2014. Two pieces of evidence are worth noticing. First, with few exceptions, from 2000 to 2014 trade openness - defined as the sum of imports and exports over total production - increases for all countries in the sample. Second, in line with Section 2, during the same period the observed increase in trade openness is mainly driven by GVC-related trade (bottom left panel), which expands by 59% on average across countries, compared with an average 20% increase of value added in final exports (top right panel). Another measure of involvement in GVCs, *i.e.* foreign value added in exports (bottom right panel), delivers similar conclusions with values that are on average 63% higher in 2014.

Against this backdrop, we look at two outcome variables: welfare, as measured by real household income[6], and the Consumer Price Index (CPI). Figure 9 shows that all countries lose welfare from the 40% increase in trade costs and that the welfare losses are on average 36% larger in absolute value with dense GVCs than with sparse ones. For some countries (Bulgaria, Japan, Lithuania and the Slovak Republic) the impact of a 40% increment in trade costs is more than twice larger in 2014 than in 2000. These are indeed the countries experiencing the largest increase in (GVC-driven) trade openness as shown in Figure 8.

In order to investigate the fundamental mechanisms underpinning these results, Table 1 illustrates the relation between the welfare effects of the trade cost shock and the measures of trade openness and GVC participation illustrated in Figure 8 by comparing the absolute

---

[6]In an economy modelled as in Section 3, real Gross Domestic Product (GDP) boils down to real household income, *i.e.* real wages.

Figure 8: Changes in aggregate trade and global value chain participation
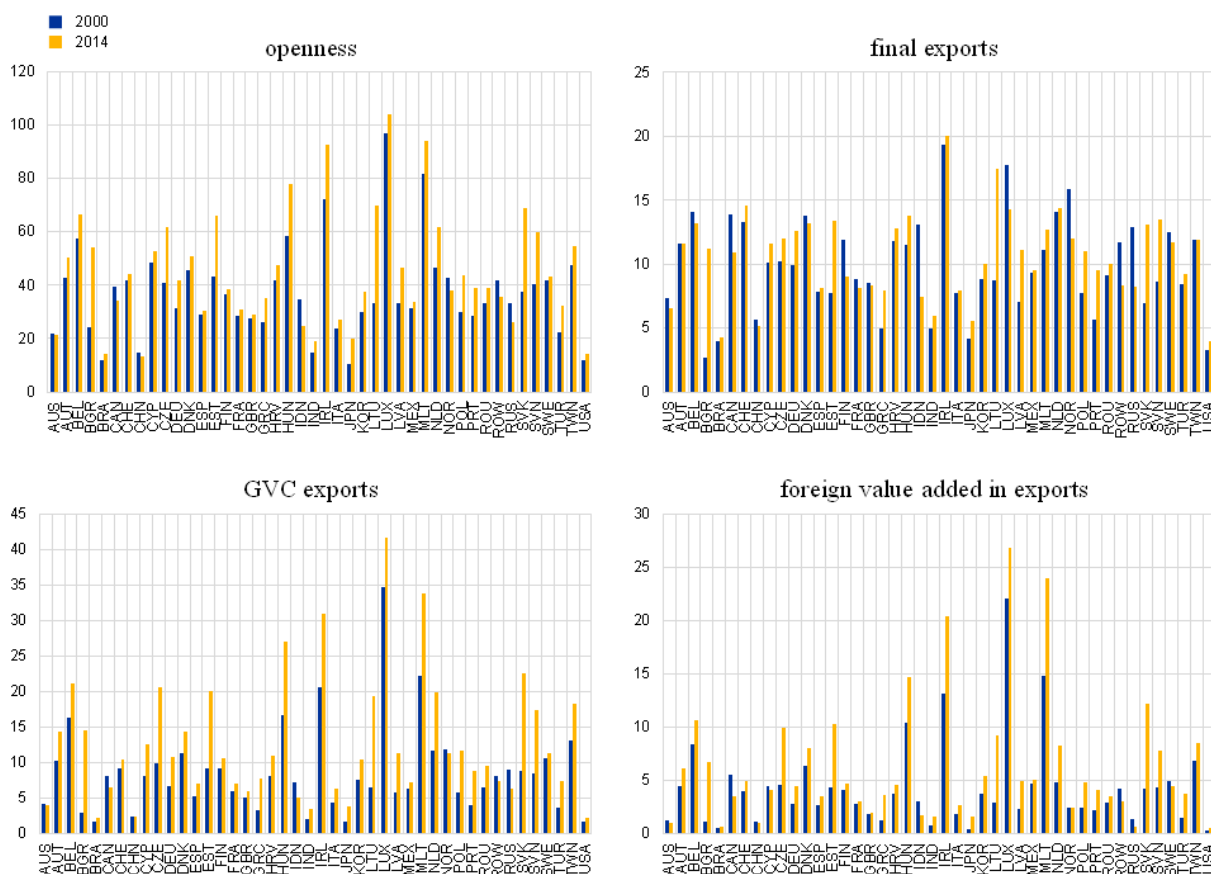
Sources: WIOD (2016 release) and authors' calculations.
Note: The figure shows trade measures as share of total production for each country in the sample.

correlations computed with sparse and dense GVCs. These correlations are quite high in both 2000 and 2014, which is explained by the fact that the larger exports are, the higher are the losses from a surge in trade barriers given that domestic production is more reliant on foreign demand. While this holds in both years, it is interesting to look at how each component of gross exports is related to the magnitude of the trade cost shock. In this respect, Table 1 shows that in both years the welfare effects of the trade cost shock are much more correlated with GVC exports (shipments that cross the borders many times) than with final exports (shipments that cross the border only once). The reason is that the more a country is involved in GVCs, the larger in absolute value is the loss from the protectionist cost shock, as the increase in trade costs cumulates when intermediates repeatedly cross borders. Indeed, the higher is a country's value-added content in its exports that gets re-exported (IV) and the higher is the foreign value added

Figure 9: Welfare effects of a 40% increase in trade costs - 2000 vs 2014
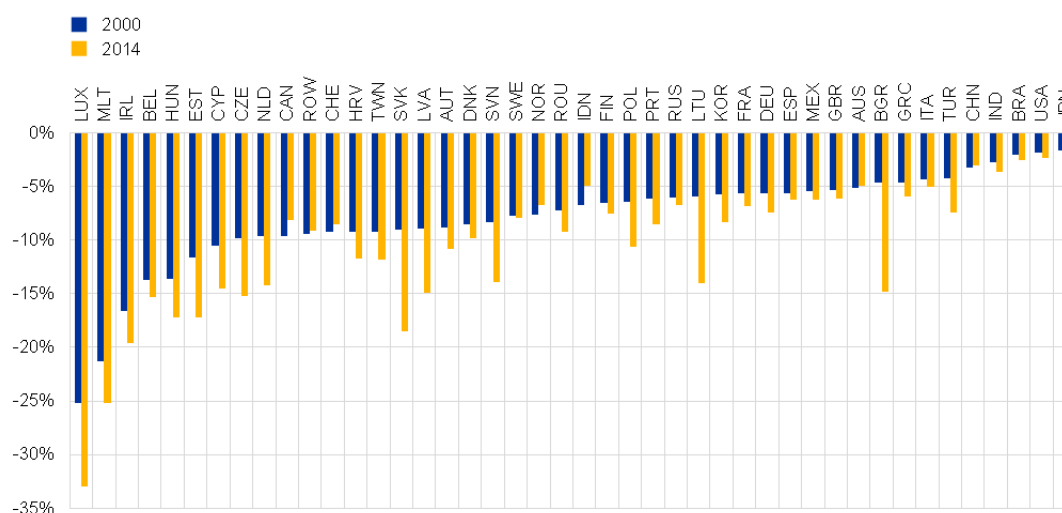
in its exports (FV), the larger in absolute value are its welfare losses. However, the correlation of welfare changes is much larger with IV than with FV.

Table 1: Correlation between trade cost shock effects and trade variables - 2000 vs 2014

		welfare	
		2000	2014
exports		0.90	0.93
of which:	*final exports*	*0.68*	*0.73*
	GVC exports	*0.95*	*0.93*
	IV	*0.94*	*0.95*
	FV	*0.66*	*0.72*

Zooming in on price effects, Figure 10 compares the impacts of a 10% and a 40% increases in trade costs applied to a global economy characterised by the input-output structure existing in 2014.[7] The figure shows that, for most of the countries, the smaller increase in trade costs is inflationary while the larger one is deflationary as it would depress prices in half of the countries in the sample.

[7]Results obtained by using the 2000 input-output structure are qualitatively similar.

With a 10% rise in trade costs, on average prices grow by 0.8% whereas a 40% increase leads to an average drop in prices of -0.3%. Intuitively, this asymmetry arises from the interplay of two opposite forces. On the one hand, higher trade costs make imported intermediate inputs more expensive and this tends to increase prices. On the other hand, more expensive imported inputs depress economic activity and this tends to decrease prices. The former force dominates for a small rise in trade costs, whereas the latter force dominates for a large rise in trade costs. Clearly, the relative strength of the two opposite forces on prices is specific to the composition of trade flows. The larger the amount of imports relative to exports, the stronger the inflationary force; conversely, the larger the weight of exports in a country's production, the stronger the depressing impact of higher trade costs on economic activity. Price effects turn out to be indeed negatively correlated with countries' trade balances with correlation coefficients equal to -0.6 and -0.86 in 2000 and 2014 respectively.

Figure 10: Price effects in 2014 - 10% vs 40% increase in trade costs
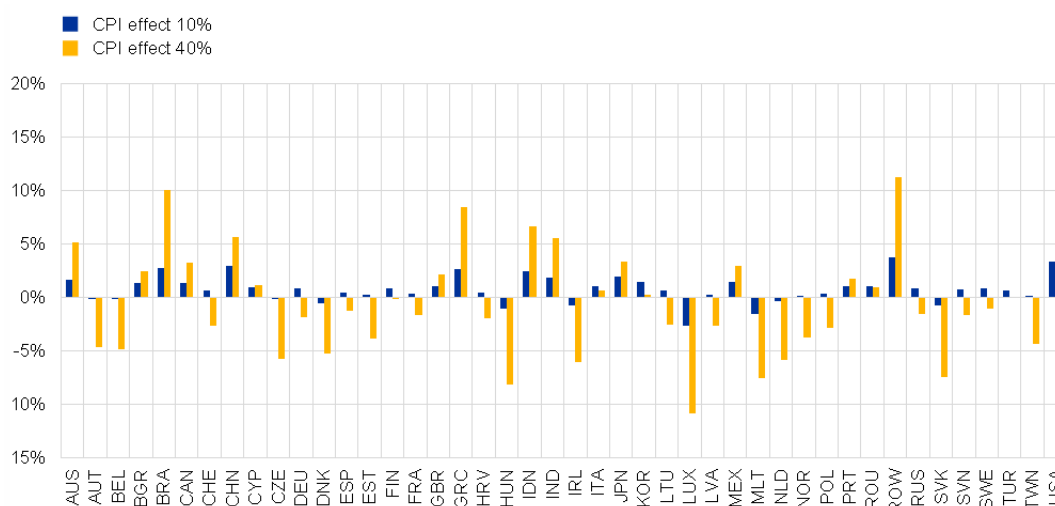
Sources: WIOD (2016 release) and authors' calculations.
Notes: The figure shows the effects on consumer prices (CPI) of a 10% and 40% increase in trade costs between all countries and all sectors calculated using input-output tables for 2014.

5 The impact of Brexit when global value chains matter

The simple thought experiment discussed in the previous section has clearly shown that properly accounting for GVCs can make a sizable difference for the quantification of the impacts of trade

policies on economic activity, prices and welfare. It has also suggested that the impacts can vary substantially both across sectors due to their specific input-output linkages and across countries due their different degree of participation to global production networks. We will now study how these two dimensions of heterogeneity become crucial when one wants to quantify the impacts of more realistic trade policy shocks that are not uniform across tariff lines as was instead the case with the foregoing thought experiment.

The trade policy shock we consider is the one related to the UK's withdrawal from the EU, commonly known as 'Brexit'. We consider three alternative scenarios for the post-Brexit trade regime between the UK and the other EU countries. In our first scenario, we assume that the two parties sign a bilateral Free Trade Agreement (FTA) leading to no variation in tariffs on trade in goods. However, administrative, technical and regulatory barriers for trade in both goods and services (non-tariff barriers - NTBs) are assumed to increase. Moreover, we assume that the UK is able to maintain its current trade agreements with the rest of the world.

In the second scenario, no trade agreement ('no deal') is signed between the UK and the other EU countries. As a result, UK trade in goods with the EU is subject to higher import duties levied on most favoured nation (MFN) terms as prescribed by the WTO rules. Moreover, NTBs on the exchange of goods and services also rise substantially[8].

In the third and last scenario, we consider a variation on the MFN scenario that follows the temporary schedule of duties announced by the UK government in March 2019 for imports from the EU and elsewhere in case of no deal. The announced schedule entails the removal of UK import tariffs on a majority of products, but also the introduction of duties on specific manufacturing goods (such as cars) and on some agricultural products. This scenario, which we call 'New MFN', involves a drastic and unilateral reduction by the UK of its MFN import tariffs, thus increasing the international openness of its economy. It allows us to evaluate the potential ability of the UK to substitute non-EU markets for the European single market.

In the MFN and New MFN scenarios NTBs are higher than the FTA scenario, as the latter is assumed to include provisions aimed at removing non-tariff impediments to trade.

---

[8]The *ad-valorem* equivalent NTBs under the FTA and the MFN scenario are obtained from the coefficients of a bilateral FTA and a EU dummy estimates in the PPML structural equations in Felbermayr et al. (2017), see Table 4 in Appendix B.

5.1 Data and descriptive statistics

While still based on the WIOD, the analysis of the effects of Brexit relies on a richer quantitative implementation of the theoretical model, in which sectors are allowed to feature different trade elasticities as empirically observed (see Imbs and Méjean 2017). We take the values of these elasticities from Felbermayr et al. (2017), who, as already mentioned, estimate them by PPML in structural gravity regressions consistent with our theoretical framework. On the other hand, as there are no off-the-shelf measures of the sectoral trade barriers we need to simulate the MFN and New MFN scenarios, we have devised a detailed crosswalk from WTO product-level tariff lines to WIOD sectors, distinguishing between intermediate and final uses. See Appendix A for details.

Figure 11: Bilateral trade between the EU27 and the UK

*Sources*: WIOD 2016 Release, Wang et al. (2013) and authors' calculations.
Notes: Shares of total nominal trade, for the EU27 this include intra-block and extra-block flows. Direct trade consists of flows that are absorbed by the destination country for final consumption. GVC trade includes value added sourced by third countries and trade flows redirected back or to third countries.

5.1.1 Trade interdependence

The UK and other EU countries are extensively involved in bilateral trade, half of which is due to their integration in common supply chains. While for the UK the rest of the EU ('EU27') represents the biggest trading partner, with more than 45% of UK trade flows involving EU27 countries, the share of EU27 trade with the UK amounts only to about 6% (Figure 11). Moreover, about half of the total UK-EU27 trade flows are related to supply chains, which cross countries' borders several times and involve also value added produced in or directed to third countries.

Among EU27 countries, trade exposure to the UK is quite heterogeneous, ranging from 22% for Malta to 2% for Slovenia (Figure 12).[9]

Figure 12: EU27 countries' bilateral trade with the UK
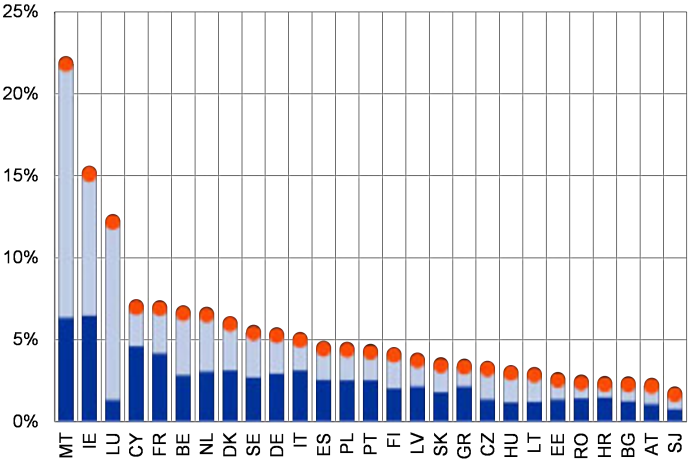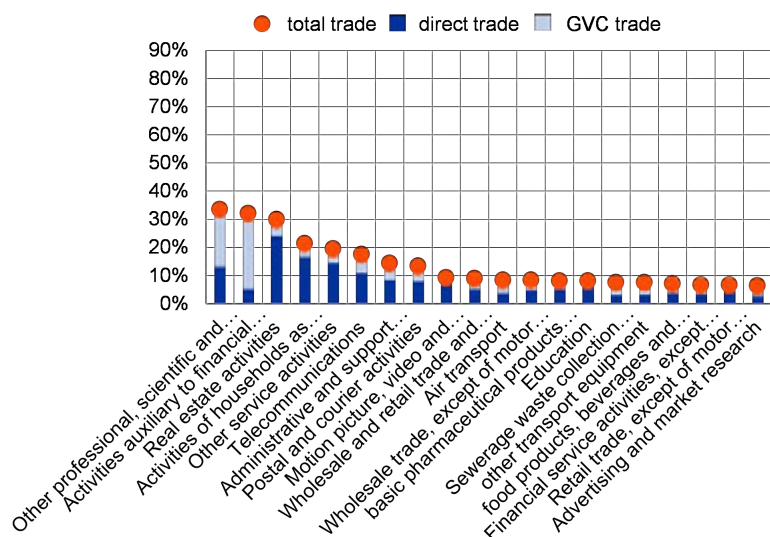

Sources and notes: see Figure 11.

The reciprocal trade exposure of the most exposed sectors in the UK and the EU is substantial. As in the case of aggregate trade, the share of UK sectors' trade with the rest of the EU is much larger than that of EU27 sectors with the UK. In particular, Figures 13 and 14 show that the trade shares of the 20 most exposed UK sectors exceed 50%, with telecommunication and car-related sectors at around 80% and 60%. With the exception of pharmaceutical, non-car vehicles and food, the most exposed sectors in the EU are, instead, service sectors. Although some professional and finance auxiliary services are quite involved in trade with the UK (with a share higher than 30%), those trade flows are mostly GVC-related. This is not the case with bilateral trade flows of real estate services, which mostly consist of intermediate and final products either directly supplied by the UK for final use in the EU or vice versa.

5.1.2 MFN tariffs

In our analysis, the FTA, the MFN and the New MFN scenarios are compared with the status quo. Whereas NTBs will be higher than they currently are in all scenarios, the MFN and New MFN scenarios also imply a generalized increase in tariffs as we assume that, with no deal, the

---

[9]Balance of payment data for the year 2017 might differ from the WIOD data used in the figures. Most notably, Malta's share is overstated in the WIOD data, while Greece's share is understated.
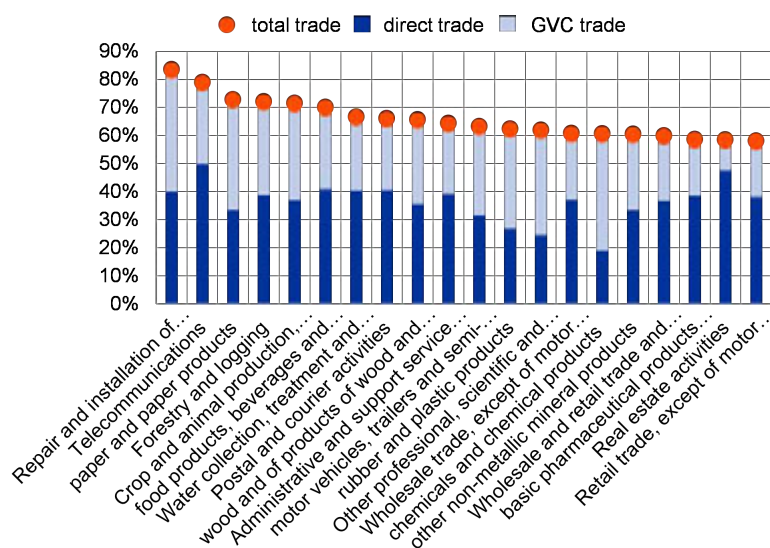
Figure 13: 20 most exposed EU27 sectors to trade with the UK

Notes: share of sectors' total nominal trade. Sectors are defined according to the ISIC Rev. 4 classification. Total number of sectors is 56.

Figure 14: 20 most exposed UK sectors to trade with the rest of the EU

EU and the UK apply to each other's imports the same tariff schedule they currently apply to countries with which they have no FTA in place. There is, however, substantial variation

across sectors and countries. The EU's MFN tariff schedule varies across product categories, with agriculture, textile and transport products facing higher tariffs. Hence, heterogeneity in the product composition of countries' and sectors' trade flows gives rise to considerable variation in their aggregate tariffs. Moreover, within the same broad sector, tariffs on final (e.g. motor vehicles) and intermediate products (e.g. motor vehicles components) can be very different, with the former being generally higher than the latter.[10] Substantial variation characterizes also the estimated *ad-valorem* equivalents of NTBs (see Table 4 in Appendix B).

Figure 15: UK tariffs on imports from EU27 by sector
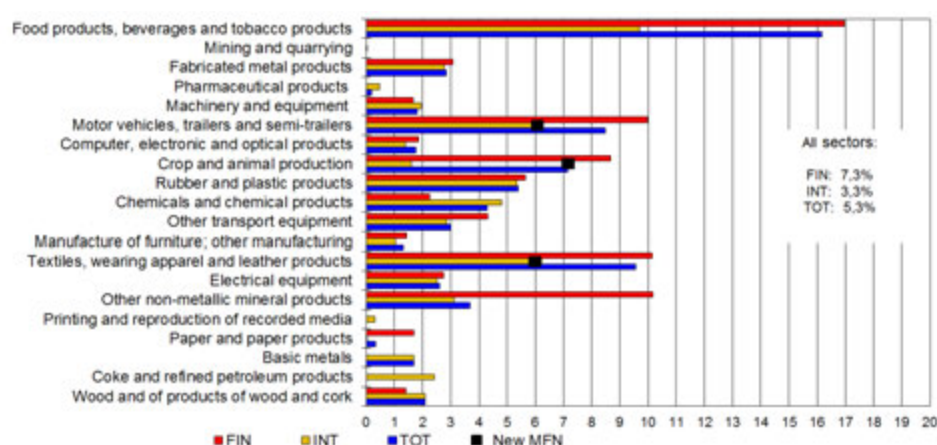
Sources: Calculation on WTO-IDB database, ITC Market Access Map and Comtrade.
Notes: percentage tariff on imports. The figure shows sectors defined according to the ISIC Rev.4 classification and ordered by using sector value added shares in UK's total value added. Total number of sectors for goods is 22.

Figure 15 (Figure 16) shows the average bilateral tariffs that, according to our calculations, the UK (the EU) would apply to imports from the EU (the UK) at the sector level, distinguishing between intermediate and final uses. Given the product composition of bilateral trade flows, the average duty imposed by the UK on goods imported from the EU would be 5.3 per cent whereas the duty imposed by the EU on British goods would be 3.9 per cent.[11]

The UK imports a relatively high share of final goods from the EU: half of the value of UK imports from the EU is constituted by products for final consumption, mainly motor vehicles and food products. On the contrary, the EU imports a relatively high share of intermediate inputs

---

[10]This is consistent with 'tariff escalation' practices, which consist in increasing trade barriers along subsequent stages of a processing chain.

[11]Average tariffs differ slightly from those in Cappariello et al. (2018) whose calculation is based on the sector shares of the WIOD data.

Figure 16: EU27 tariffs on imports from UK by sector
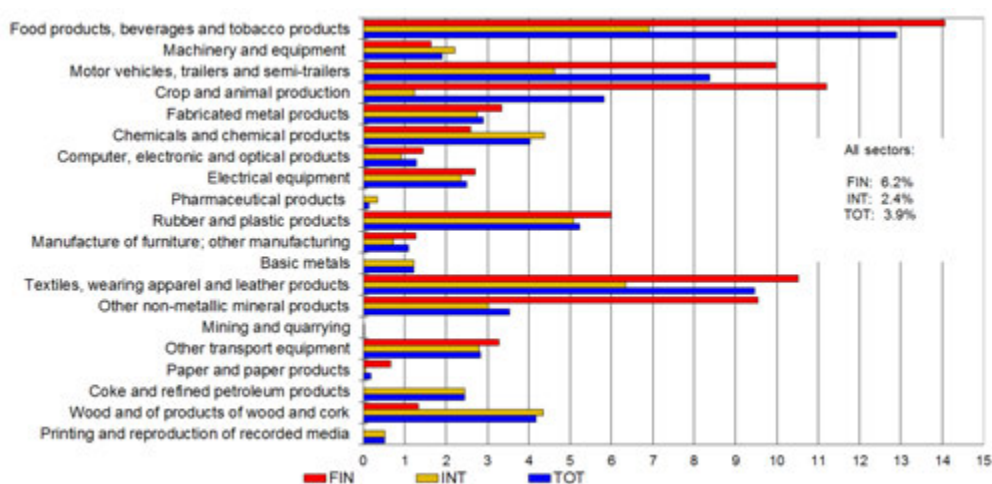
Sources and notes: See Figure 15. Sectors are ordered by using sector value added shares in EU's total value added

from the UK: about 62% of imports from the UK are given by goods subsequently processed in the EU economies especially chemical, mining and metal products. Considering a sectoral disaggregation at the ISIC Rev. 4, in a MFN scenario about 40% of the EU goods delivered to the UK market would face tariffs exceeding 5%. Almost half of these high tariff goods are 'motor vehicles, trailers, and semi-trailers', which would incur a tariff of 8.5% on average. Even 'food products, beverages, and tobacco', which represent a significant share of total UK imports from the EU27 (about 11%), would potentially face an extremely high tariff rate. Turning to EU imports from the UK, the share of products potentially affected by duties exceeding 5% (such as automotive and food) is much lower (24%).

Figure 15 presents also the average duty in sectors (such as motor vehicles, crop and animal production, textile) that would face UK import tariffs in the New MFN scenario. In this case, the average duty imposed by the UK on imports from the EU would be equal to about 1%, much lower than in the MFN scenario.

Figure 29 in Appendix B presents the MFN average tariffs that would be imposed on intermediate, final and total goods imports by the UK from each EU Member States when sectoral tariffs are aggregated at the country level weighted by sectoral import shares. The figure reveals considerable cross-country variation driven by different sectoral specialisation, with 14 countries facing average MFN tariffs higher than 5%. Tariffs potentially applied by the EU to products

imported from the UK would be generally lower (Figure 30, Appendix B).

5.2 Results and robustness checks

In this section we present the effects of Brexit under our three scenarios on trade flows and three outcome variables nominal GDP, welfare and the CPI. We start with an aggregate view distinguishing between the UK and the other EU countries (EU27). We then unpack the EU27 to discuss cross-country and cross-sector heterogeneity. Next, we report the effects of Brexit on countries' GVC linkages. Finally, we conclude with a sensitivity analysis of our results.

5.2.1 Aggregate effects

Under the FTA, the MFN and the New MFN scenarios, bilateral trade between the UK and the EU27 decreases substantially in nominal terms (Table 2). In the FTA scenario, exports from the UK to the EU27 fall by -31.4% and -38.3% for intermediates and final goods respectively. Those from the EU27 to the UK fall by -27.3% and -28.2% respectively. While exports from the Rest of the World increase only towards the UK (by 6.9%) for final goods, they increase towards both the EU and the UK (by 2.1% and 7.4% respectively) for intermediates. The trade effects of Brexit are more pronounced in the MFN scenario. Exports from the UK to the EU27 fall by -45.5% and -53.7% for intermediates and final goods respectively. Those from the EU27 to the UK fall by -40.6% and -43.9% respectively. Again, exports from the Rest of the World increase only towards the UK (by 13.9%) for final goods, but towards both the EU27 and the UK (by 1.7% and 10.7% respectively) for intermediates.

The effects of Brexit on trade flows are not much different in the New MFN scenario, which highlights the difficulty faced by the UK and the EU27 in replacing their single market.

These nominal changes translate into lower real exports for the EU27 and the UK of about -2% and -13% respectively in the FTA scenario, and as much as 3% and 19% respectively in the MFN scenario (Figure 17). They are slightly less marked in the New MFN scenario.

For imports the fall in real flows is more pronounced than for exports in all scenarios, especially for the UK whose imports decrease by more than 15% in the FTA scenario and by more than 20% in the MFN one.[12]

Less trade is associated with lower welfare, with losses that are larger for the UK than the EU27 although with substantial heterogeneity across member countries. UK and EU27 real household

---

[12]Individual country results are reported in Appendix B, Figures 31.

Table 2: Changes in nominal bilateral trade in FTA, MFN and New MFN scenarios

	Intermediates			Final goods		
	EU27	UK	RoW	EU27	UK	RoW
	FTA scenario					
EU27		-27.3	0.8		-28.2	-0.5
UK	-31.4		0.6	-38.3		-0.2
RoW	2.1	7.4		-0.5	6.9	
	MFN scenario					
EU27		-40.6	1.2		-43.9	-0.1
UK	-45.5		0.1	-53.7		-1.1
RoW	1.7	10.7		-0.8	13.9	
	New MFN scenario					
EU27		-39.1	1.1		-41.7	-0.2
UK	-44.7		1.6	-52.6		0.7
RoW	1.8	11.3		-0.7	13.4	

Sources: WIOD 2016, WTO-IDB database, ITC Market Access Map, Comtrade, Felbermayr et al. (2017) and authors' calculations.

Notes: percentage changes. Exporting country/area is reported in table's row. Intermediate and final indicate nominal trade in intermediate and final products, respectively. EU27 refers to EU countries, excluding the UK. Corresponding real changes are broadly similar to the nominal changes reported in the table.

Figure 17: Aggregate effects on real exports and imports
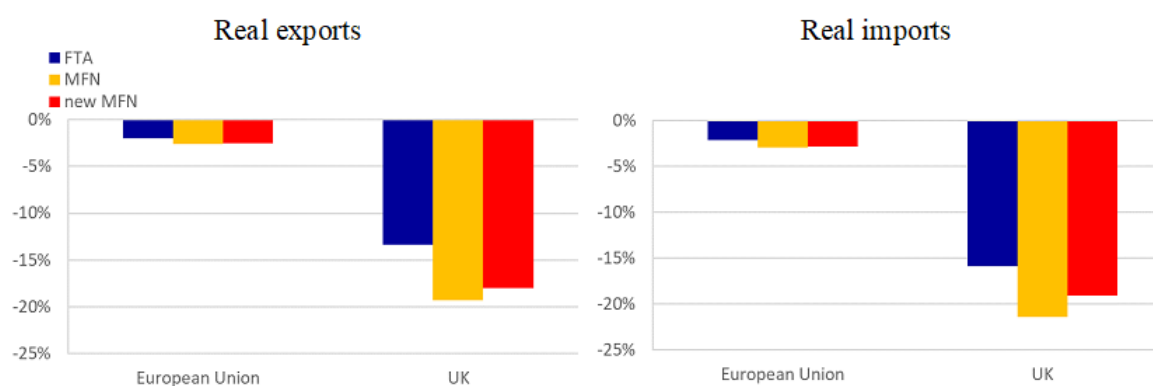
Notes: Changes in total real exports and imports have been aggregated from changes in sector-level real bilateral trade by using shares of corresponding nominal values. Nominal bilateral sector-level trade changes have been deflated with the respective price changes.

income levels decrease respectively by -2.1% and -0.4% in the FTA scenario, and by -3.1% and -0.6% in the MFN scenario (Figure 18).

Figure 18: Aggregate effects on welfare and nominal GDP
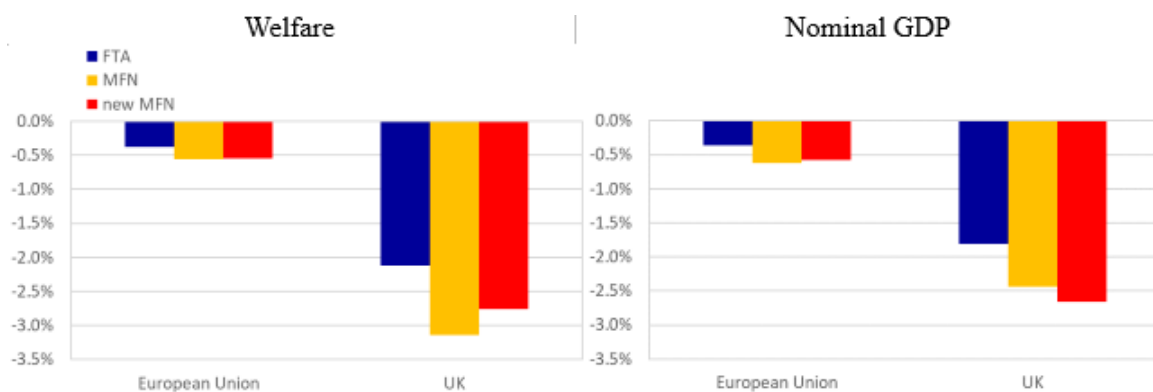
Notes: Welfare is defined as real household income and GDP as the difference between total nominal output and consumption of intermediate products.

For the UK the fall in nominal GDP is slightly less pronounced than in welfare in both the FTA and the MFN scenarios. In the New MFN scenario UK nominal GDP would fall in a similar way than welfare because imports from the rest of world substitute the production of domestic

suppliers.

In addition, in the New MFN scenario the increase in UK import prices is less marked than in the MFN scenario so that consumer prices increase by less and this curtails the negative impact of Brexit on welfare. Indeed, Figure 19 shows that UK prices (as measured by the CPI) rise less in the New MFN scenario not only than in the MFN scenario but also than the FTA one thanks to cheaper imports from the rest of the world. Differently, EU prices levels are essentially unaffected by Brexit in all scenario, with the largest but still neglibile decrease happening in the MFN scenario (-0.06%). As discussed for the simple thought experiment in Section 4, such asymmetry arises from the interplay of two opposite forces. Higher trade costs make imported intermediate inputs more expensive and this tends to increase prices. However, more expensive imported inputs also depress economic activity and this tends to decrease prices. The former force dominates the latter in the UK, whereas the two forces tend to offset each other in the EU27.

Figure 19: Aggregate effects on CPI
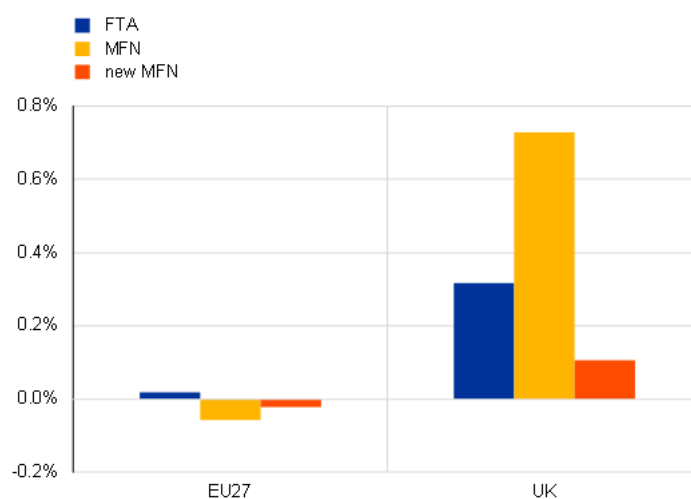
Sources: See Table 2.

Table 3 summarizes our aggregate Brexit effects. The relative magnitudes of our trade and welfare effects are broadly in line with those of previous studies based on the same class of models such as Dhingra et al., 2017 and Felbermayr et al., 2017. They are, however, bigger in absolute terms. There are several reasons for this. First, differently from those studies, our framework fully captures the actual GVC linkages and this leads to stronger reactions to trade cost increases as

Table 3: Aggregate effects of Brexit - Summary

| | EU27 | | | UK | | |
	FTA	MFN	New MFN	FTA	MFN	New MFN
Welfare	-0.38	-0.56	-0.55	-2.12	-3.14	-2.76
Nominal GDP	-0.36	-0.62	-0.57	-1.81	-2.43	-2.66
CPI	0.02	-0.06	-0.02	0.32	0.73	0.11

Sources and notes: See Table 2.

shown in Section 4. Second, both Dhingra et al. (2017) and Felbermayr et al. (2017) rely on an older version of the WIOD input-output tables (2011 vs. 2014), which matters given that, especially in the case of the EU, there has been a remarkable increase in GVC integration in the intervening years (see Figure 3). Third, as the sectoral breakdown of the WIOD input-output tables is less detailed for 2011 than for 2014, previous studies fail to capture the extent of sectoral heterogeneity we exploit. Fourth, the design of the scenarios is different. We assume that the UK will maintain the preferential trade agreements with non-EU trading partners that were signed while in the EU. The other papers assume instead that the UK will be forced to adopt MFN tariffs with all non-EU partners.[13] Finally, also due to different sectoral breakdown, we use different trade elasticities. The sensitivity analysis in Section 5.2.4 shows results with the alternative trade elasticities used in the previous studies that tend to deliver smaller effects.

5.2.2 Country and sector effects

Country-level results show very heterogeneous welfare losses, with Malta, Luxembourg, and Ireland hit the most by Brexit (Figure 20). For these small EU27 countries welfare losses are bigger than for the UK. This is due to their high trade exposure to UK sectors with large trade elasticities, most prominently services.[14] It is also explained by the limited diversification of their trade linkages. Welfare losses for large EU27 countries are much less pronounced and below -0.3% even in the MFN scenario. Welfare effects compound a generalized fall in nominal GDP (Figure 21) with the CPI rising in some countries and falling in others (Figure 22). This depends again

---

[13]The UK government has been working on new preferential trade agreements in case of a no-deal Brexit. Some new agreements have already been signed, while others are still under discussion. See https://www.gov.uk/guidance/uk-trade-agreements-with-non-eu-countries-in-a-no-deal-brexit for updated lists.

[14]The difference with respect to the UK is attenuated when we use other sets of trade elasticities (Figure 28 in Section 5.2.4). Moreover, the welfare losses we compute for Malta, Luxembourg and Ireland could be overstated if services firms currently in the UK relocated to other EU countries.
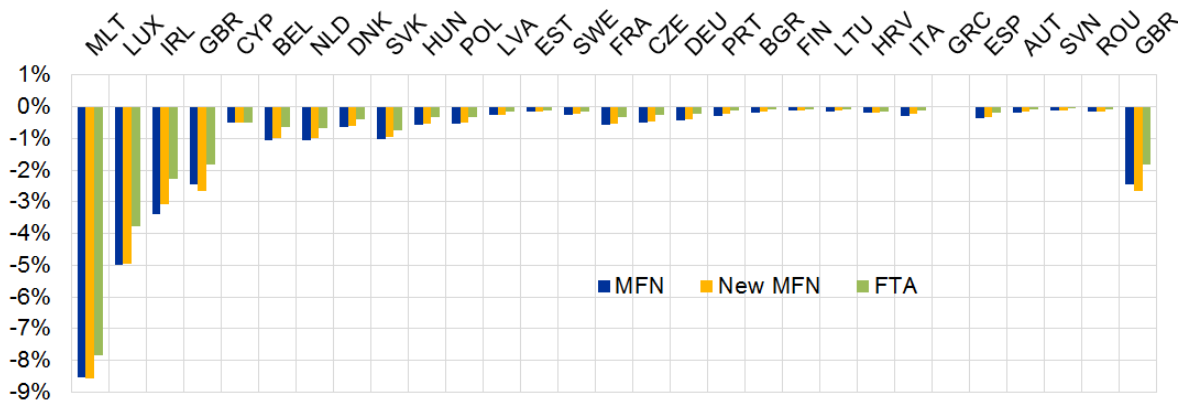
Figure 20: Country-level results - welfare
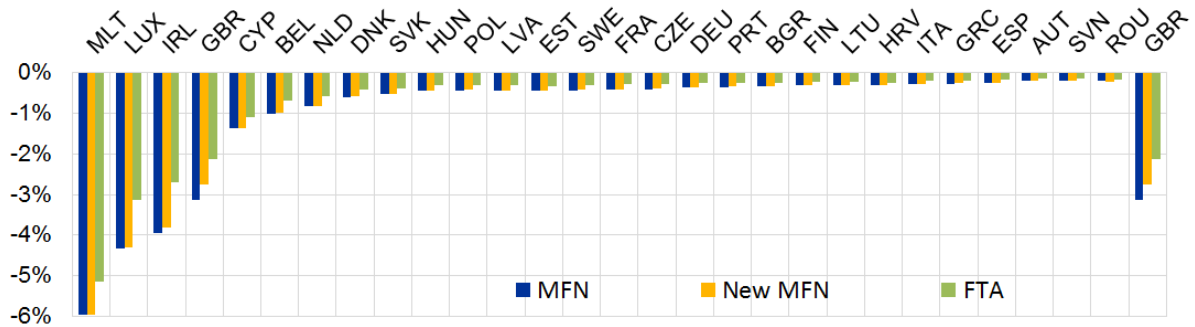
Sources: See Table 2.

Notes: Welfare is defined as real household income.

Figure 21: Country-level results - nominal GDP

Sources: See Table 2.

Notes: Changes in nominal GDP is aggregated from sector-level value added by using sector value added shares in country's total value added.

on whether or not the inflationary impact of more expensive imported intermediates dominates their depressing impact on economic activity. The largest price increases are observed for Ireland and Cyprus, due to their heavy reliance on UK final products and intermediate inputs.

As for sectoral patterns, for parsimony we present here only the results for the MFN scenario, while leaving those for the FTA scenario to Appendix B. The most affected sectors in the EU27 are finance-related sectors, manufacturing of other transport equipment, other professional activities and textiles, with losses in nominal value added ranging from -2.5% to -3% (Figure

Figure 22: Country-level results - Consumer Price Index
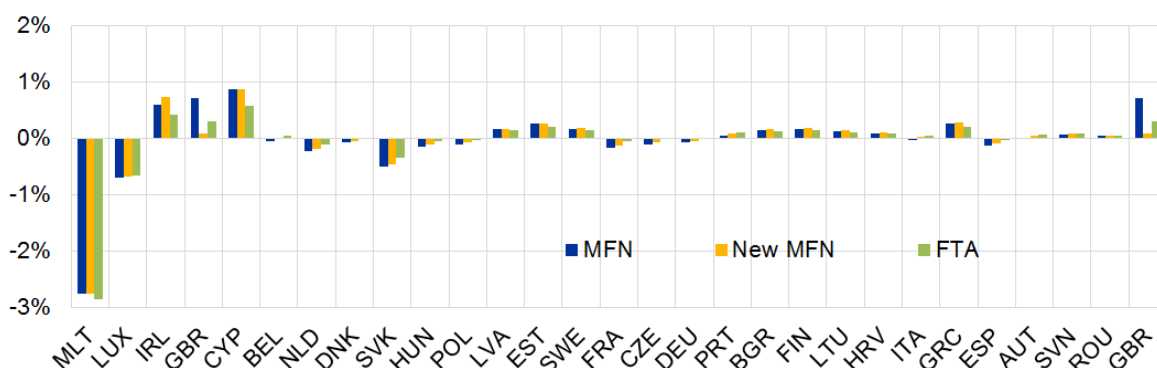
Sources: See Table 2.

23).[15] Differently, in the UK the most affected sectors tend to belong to manufacturing (Figure 24). Notable exceptions are food and car sectors, which see their value added rise. Yet, as we have seen in the previous subsection, the aggregate effects of Brexit are nevertheless significantly negative.

Turning to trade flows, it is interesting to zoom in on the financial sector. In the MFN scenario, the -53% decline of UK finance-related exports to the EU27 in Figure 24 is roughly in line with the aggregate patterns in Table 2. However, for the EU27 the decrease in exports to the UK in the financial sector is much more pronounced than on aggregate (-55% vs around -40%). All non-EU countries also experience reductions in their finance-related exports to the UK. This highlights the disruptive effects of Brexit on finance in the absence of substitution between EU and non-EU countries, which makes UK finance-related imports fall by -29%. As a consequence of the decline in both sectoral and aggregate activity, UK exporters in the financial sector gain some competitiveness as wages are depressed. Accordingly, the fall in UK exports is less pronounced than in UK imports and amounts to -9.2% (with a severe decline in exports to the EU27 and a mild increase in exports to the rest of the world). Within the EU27 there is an overall decline in finance-related exports by -4.7%. However, there is also striking cross-country heterogeneity. Indeed, the average effect is slightly positive and the overall effect is entirely driven by Malta and, most of all, Luxembourg. For other countries, intra-EU exports actually increase, pointing to some substitution within the EU27.

In general, it is clear that sectoral and country results partly depend on exposure to EU-UK

---

[15]Country-specific results are available upon request.

Figure 23: Sectoral effects under the MFN scenario - EU
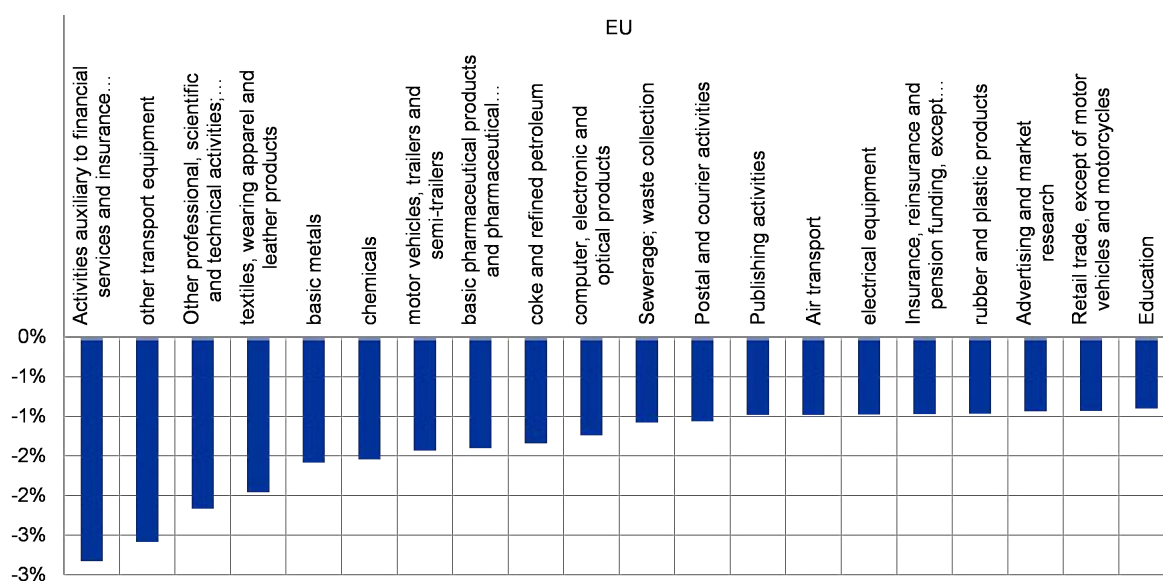
Sources: See Table 2.
Notes: The figure reports the 20 most affected sectors in terms of percentage loss in nominal value added.

trade. Different sector-specific trade elasticities and trade barriers also play a substantial role in determining countries' outcomes. Specifically, countries more exposed to EU-UK trade in more elastic sectors (such as services sectors) suffer the largest welfare losses.[16]

5.2.3 Supply chains effects

In Section 5.1 we have shown that the UK and the rest of the EU are deeply integrated through GVCs. We have also observed that a sizable part of EU trade consists of GVC-related flows. Against this backdrop, we now deepen our investigation of the effects of Brexit in two ways. First, we quantify the extent to which the sheer existence of GVC linkages between the UK and the EU27 affects the transmission of the Brexit trade shock to national welfare. Second, we look at how those GVCs linkages are themselves affected by the Brexit trade shock. In doing so, we leverage the ability of the model to map all the entries of the world input-output tables.

The role of trade in intermediates   How does the existence of GVC linkages affect the welfare effects of Brexit? To answer this question, we compare some key results reported in Section 5.2 with parallel ones obtained in a simplified counterfactual economy in which all bilateral trade

---

[16] See Table 4 in Appendix B for the applied trade elasticities and NTBs.

Figure 24: Sectoral effects under the MFN scenario - UK
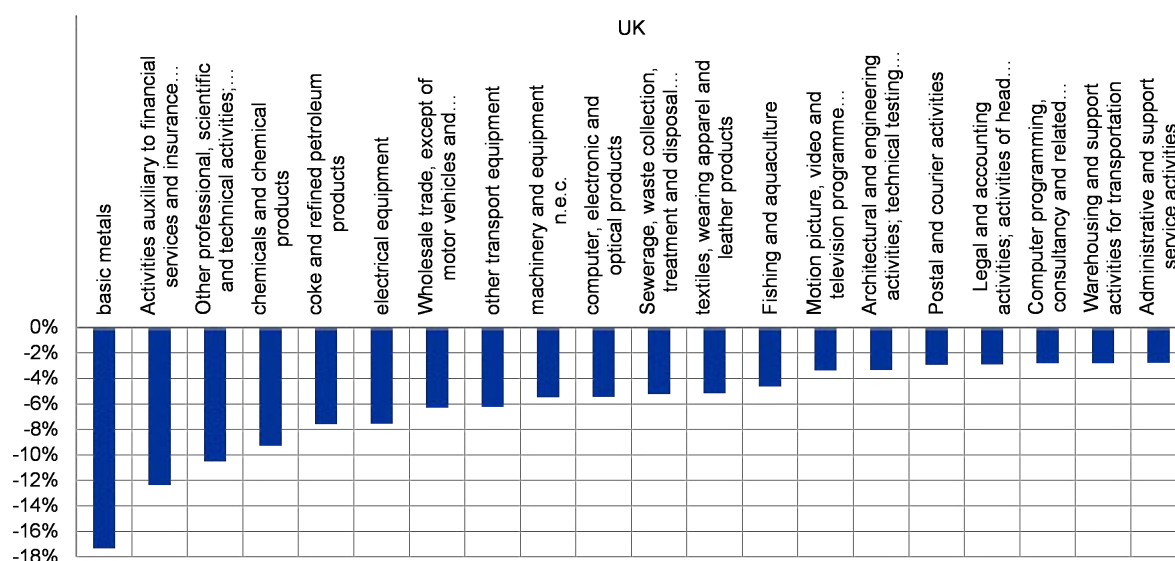
Sources and notes: See Figure 23.

flows in intermediate products are set to zero and the corresponding actual amounts are allocated to final products in the same sector. For parsimony, we focus here on the MFN scenario, while the analysis of the FTA scenario can be found in Appendix B. The results for the MFN scenario are reported in Figure 25, which highlights how GVC linkages greatly magnify the effects of the Brexit trade cost shock on national welfare: by 105% on average within a range from 25% to 176%. Hence, disregarding GVCs would lead to a substantial underestimation of the welfare effects of Brexit in all countries. The reason is that, as captured by the model's equations (2) and (3), when GVCs are properly accounted for, higher trade costs for the intermediate inputs supplied by any given sector translate into higher production costs in all sectors using those inputs, leading to an escalation of production costs as intermediates are shipped back and forth across borders along the value chain.

Figure 25 shows the results also for a simplified one-sector model akin to some of the most frequently used macroeconomic models. The consequences of such simplification are ambiguous with welfare losses that are more pronounced than in the multi-sector case for some countries and less pronounced for others.

These findings on the comparisons of results with or without GVCs and with one or many sectors are consistent with Costinot and Rodríguez-Clare (2014), who conduct a comparative analysis

Figure 25: The role of GVCs in the model - MFN scenario
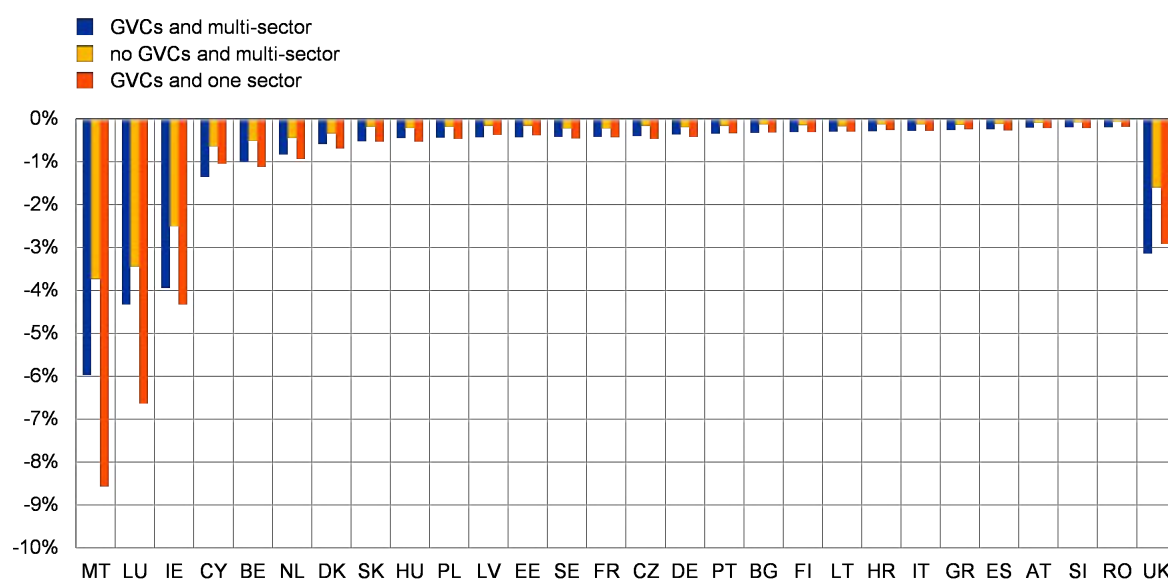
Notes: Welfare is defined as real household income. "GVCs and multi-sector" corresponds to the full model results for the MFN scenario reported in Figure 20. "GVCs and one sector" reports the results a model in which both intermediate and final trade flows have been aggregated to country level and weighted averages for the tariff changes and the elasticities have been used. "no GVCs and multi-sector" reports the results of a model in which bilateral intermediate entries have been attributed to bilateral final entries.

of general equilibrium models under several alternative modeling assumptions.

The effects of Brexit on UK-EU27 GVCs How will European GVCs reorganize after Brexit? To answer this question, we first take the most recent international input-output table (those for 2014 in the WIOD) and decompose UK and EU27 bilateral exports into direct flows between country pairs and indirect flows through third countries (GVC-related trade). We then simulate the changes in trade costs (tariff and non-tariff barriers) implied by Brexit under the FTA and MFN scenarios to obtain the counterfactual post-Brexit international input-output tables. Finally, we use these tables to decompose the simulated post-Brexit exports into direct and indirect flows.

The results of this exercise are depicted in Figures 26 and 27 for direct and indirect exports respectively. Figure 26 shows that after Brexit direct bilateral exports between the UK and the EU27 shrink in both scenarios. In the FTA scenario, direct exports decrease by -24% from the EU27 to the UK and -16% from the UK to the EU27. In the MFN scenario, the decline of direct

exports is -40% from the EU27 to the UK and -33% from the UK to the EU27.

Figure 26: Changes in direct bilateral trade
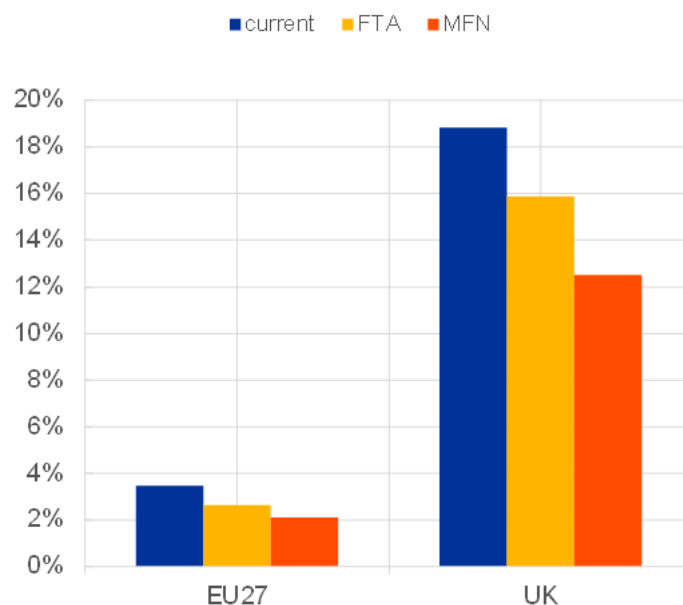
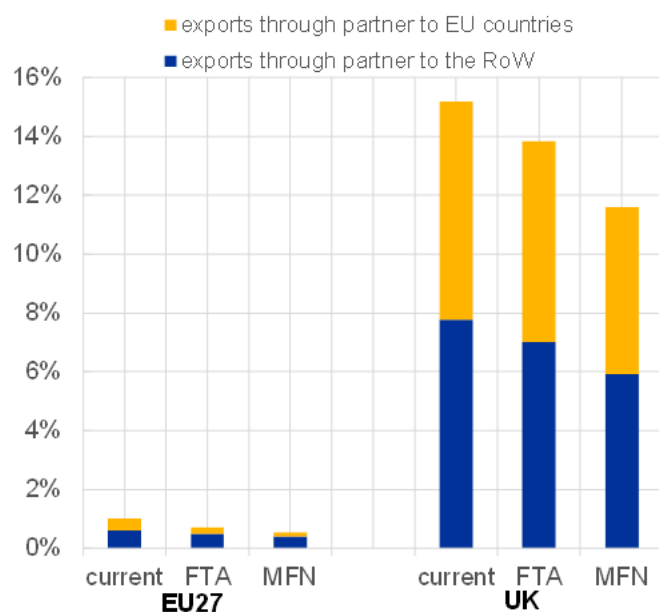*Sources*: See Table 2 and Wang et al. (2013).
Notes: : Percentage of total exports. Pure bilateral trade (direct value added in exports) is the domestic value added that is produced in the economy and finally consumed in the trade partner.

Turning to GVC-related trade, two things are worth noticing in Figure 27. First, the UK is significantly reliant on supply chains with the other EU countries. A considerable share of UK's exports is used as input in the EU27 for the production of products destined for other countries in the EU (7.4% of total exports) or in the rest of the world (7.8% of total exports). This is not the case for the EU27, for which just 1% of its total exports are channeled through the UK. Second, especially for the EU27, the decline in GVC-related trade is quite substantial, especially in trade flows redirected by the UK to other EU countries: -46% in the FTA scenario and -66% in the MFN one.[17] Conversely, for the UK, the decline of indirect trade via the rest of the EU to other EU countries is much lower: -8% in the FTA scenario and -23% in the MFN one.[18] This suggests that other EU countries can more easily substitute the UK with other trading partners, most likely within the EU.

---

[17]The decline of EU27's exports through the UK towards the non-EU countries is -21% and -35% in the FTA and MFN scenarios respectively.

[18]The decline of the UK's exports through the EU27 towards the rest of the world (non-EU countries) is -10% and -24% in the FTA and MFN scenario, respectively.

Figure 27: Changes in GVC-related bilateral trade

Notes: Percentage of total exports. Exports through partner are the value added of exports which are originated in the economy, exported to the partner (either UK for the LHS or EU27 for the RHS) where they are re-elaborated and exported further.

5.2.4 Sensitivity analysis

Our results on the effects of tariff hikes and Brexit are obtained by feeding the computations derived from the theoretical model with observable parameter values calculated from the input-output tables as well as consistently estimated trade elasticities and NTBs (obtained from the observed effects of trade agreements). In particular, the estimates of elasticities and NTBs are obtained from structural gravity regressions that are fully consistent with a wide range of trade models, including the model by Antràs and Chor (2018) on which we build.

Nonetheless, it is interesting to assess the sensitivity of our results to the alternative choices of elasticities and NTBs. As a first alternative, we set the trade elasticity to 5 for all sectors in all countries. This choice is consistent with the average elasticities estimated for advanced economies by Imbs and Méjean (2017), although it is somewhat higher than the average sector elasticities estimated by Felbermayr et al. (2017) that we use (see Table 4). As a second alternative, we adopt the same elasticities and NTBs as Dhingra et al. (2017). For manufacturing sectors, these authors use the sectoral elasticities estimated by Caliendo and Parro (2015). These range from

0.4 to 51.1. For services, however, they also impose the same elasticity equal to 5 in all sectors. As for NTBs, Dhingra et al. (2017) adopt estimates from Berden et al. (2013) based on econometric and survey-based calculations.

Figure 28: Sensitivity analysis - MFN scenario
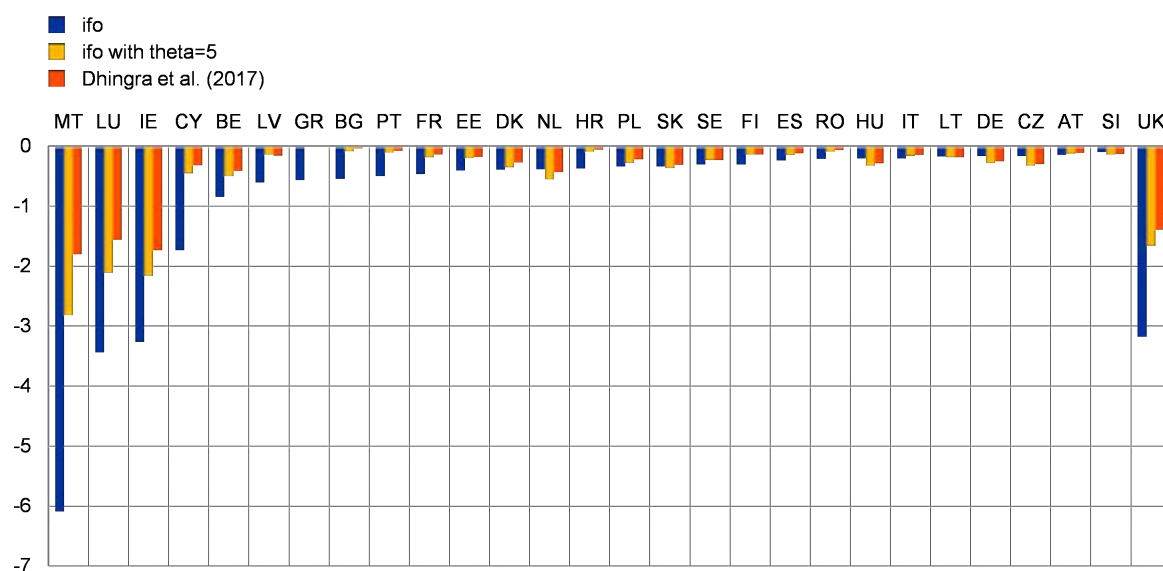
Compared with our baseline results, in the MFN scenario aggregate welfare losses from Brexit are smaller with both sets of alternative parameter values. This holds for both the EU27 and the UK. When the trade elasticity is set to 5 in all sectors, welfare falls by -0.28% for the EU27 and -1.66% for the UK. For the parameter values used by Dhingra et al. (2017), the welfare loss is -0.24% for the EU27 and -1.4% for the UK. Figure 28 shows that the most notable deviations from our previous results concern small countries, in particular Malta, Luxembourg and Ireland. Among the largest countries, deviations are larger for France and Spain, for which the impact of Brexit is weaker with a uniform elasticity equal to 5. Deviations are smaller for Germany, but in this case a uniform elasticity equal to 5 generates a stronger impact. These patterns are explained by the fact that countries differ in terms of the sectoral composition of their trade flows and sectors differ in terms of the trade elasticities we use.

6 Conclusions

This paper has investigated the long-term effects of trade cost shocks in a world in which GVCs play a crucial role. After reporting a set of stylized facts on the emergence and the development of cross-country production networks, we have introduced a multi-country multi-sector quantitative general equilibrium model. By mapping bilateral supply chain linkages and value-added flows, the model has allowed us to capture the magnifying effect of multi-stage production on the transmission of international trade policy shocks to national welfare.

To highlight the quantitatively relevant role GVCs play in the transmission of trade shocks, we have first analyzed a simple thought experiment in which bilateral trade costs rise uniformly by 40% between all country pairs in the world. We have shown that, for almost all countries, the welfare effects are considerably larger in a world characterized by the more developed GVCs existing in 2014 than by the less developed GVCs existing in 2000. On average, welfare effects in 2014 are 36% larger (and as much as 219% larger for some countries) than in 2000.

We have then applied our model to the quantification of the effects of Brexit under alternative trade policy scenarios. The model predicts a fall in bilateral trade between the UK and the EU that would be more severe in the case in which trade between the two parties fell back to MFN terms ('no deal'). To reveal the importance of GVCs for these results, we have considered also an alternative version of the model in which we have set all sectoral bilateral trade flows of intermediate products to zero and imputed their original amounts to final products. On average, the aggregate welfare losses with GVCs are roughly twice as large as those without GVCs.

Being based on comparative statics, our model's predictions do not include dynamic effects, such as the short-run effects of increased uncertainty and the transition to a new equilibrium as well as the long-run welfare effects through productivity growth, unemployment and migration. They show, however, that properly accounting for observed GVC linkages makes a substantial difference for the quantification of the general equilibrium effects of protectionist trade policies.

Appendices

A   Methodology to estimate tariffs by sector and end-use

This appendix describes the data sources and the procedures that have been used to construct a framework of *ad-valorem* WTO-MFN tariffs for both final and intermediate trade at the ISIC Rev. 4 classification, a framework suitable to be combined with the WIOD Input-Output database.

A.1   Tariff and trade data

We obtain the average tariffs that would be imposed on goods imported by each Member State from the UK (and vice versa) by using information from the WTO-IDB database on the EU MFN tariffs. Data have been retrieved through the WITS, a platform developed by the World Bank that gives access to information on trade and tariffs compiled by various international organizations (https://wits.worldbank.org/). The WTO-IDB database provides *ad-valorem* tariffs (*i.e.* charged as a percentage of the value of the good imported) for about 5,000 product lines defined according to a 6-digits HS Combined classification. However, since almost 200 products, mostly in "food and live animals" industry, are charged by quantity or by weight allowing a minimum and maximum ranges of tariffs, their *ad-valorem* MFN tariffs are missing in the WTO-IDB database. For these products we use the estimated *ad-valorem* equivalent tariffs drawn from the International Trade Centre Market Access Map (ITC MAP) based on the weight-based tariffs taken at the minimum rate. Finally, for products for which the WTO arrangements envisage tariff rate quotas - a combination of an import tariff and an import quota by which imports below a specified quantity is charged at a lower tariff (Inside Quota Tariff Rate, IQRT) and imports above that quantity at a higher one (Outside Quota Tariff Rate, OQRT) - we adopt the IQRTs from the same data source. Given this approach, our estimates of tariffs, especially for an industry like "food and live animals", may be considered as a lower bound of the tariffs that could be potentially applied. These *ad-valorem* tariff data are matched with trade statistics for year 2014 from the UN ComTrade database, which contains annual bilateral trade flows at the HS 2012-6 digits classification.

A.2 From the HS 2012 to the ISIC Rev.4 classification

We construct our dataset of MFN tariffs and bilateral good flows, classified according to both their end-use category and ISIC Rev. 4 industry classification, through a process that requires many steps. First of all, we assign to each product-level tariff and its corresponding bilateral flow a classification according to their final and intermediate use. To this aim, we use the correspondence table between HS (2012 Revision) 6-digit commodities and the BEC classifications drawn from WIITS. In general, these correspondences provide a clean mapping to classify trade according the end-use category. Next steps present some complications. We transpose our data from the Harmonized System 2012 (HS 2012) to the Central Product Classification, Version 2.1 (CPC Ver. 2.1) by using a correspondence table from Ramon (`http://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL`). The reason for this step is that a direct correspondence table from the HS 2012 classification to the ISIC Rev. 4 is not available. That said, the correspondence among the HS 2012 and the CPC 2.1 sectors is not univocal. In the simple case when to one HS 2012 sector correspond many CPC 2.1 sectors, we split in equal shares the import values to the different CPC 2.1 sectors attributing them the same *ad-valorem* MFN tariff and the same end-use category. In the opposite case when to different HS 2012 sectors corresponds only a CPC 2.1 sector (this is the case for about 500 observations), we sum the HS 2012 tariff and import values that correspond to the same CPC 2.1 sector and attribute to it the prevailing (in terms of number of HS 2012 sectors) end-use category. Finally, we convert data from the CPC 2.1 to the ISIC Rev. 4 classification. Even in this case when to one CPC 2.1 sector correspond many different ISIC groups, we split in equal shares the import values to the different ISIC Rev. 4 groups attributing them the same *ad-valorem* MFN tariff and the same end-use category. In the case when many CPC 2.1 sectors correspond to just a single ISIC 4 sector, we calculate the value of tariff and imports of that sector as the sum of tariffs and imports of the corresponding CPC 2.1 sectors by end-use category. Finally, tariff and import values are aggregated from the ISIC classification at 4 digits (238 sectors) to the 3 digits one (32 sectors) and the average tariff are calculated.

B   Other Data and Results

Table 4: Estimated trade elasticities and non-tariff barriers under FTA and MFN scenarios

goods

	θ	MFN NTBs	FTA NTBs
Crops & Animals	1.96	47%	4%
Forestry & Logging	1.87	30%	4%
Fishing & Aquaculture	3.58	3%	2%
Mining & Quarrying	3.58	3%	2%
Food, Beverages & Tobacco	1.63	34%	7%
Textiles, Apparel,Leather	3.58	10%	2%
Wood & Cork	3.58	8%	4%
Paper	1.04	33%	7%
Recorded Media Reproduction	2.04	3%	4%
Coke, Refined Petroleum	6.04	6%	0%
Chemicals	3.78	19%	2%
Pharmaceuticals	7.63	17%	7%
Rubber & Plastics	2.82	28%	9%
Other non-Metallic Mineral	1.42	35%	10%
Basic Metals	4.72	14%	6%
Fabricated Metal	1.84	35%	15%
Electronics & Optical Products	5.73	8%	1%
Electrical Equipment	6.42	14%	5%
Machinery & Equipment	7.51	8%	2%
Motor Vehicles	4.39	19%	8%
Other Transport Equipment	5.17	9%	7%
Furniture & Other Manufacturing	3.42	2%	2%
average	*3.81*	*17.6%*	*5%*

services

|	θ	MFN NTBs	FTA NTBs
Repair and installation of machinery and equipment	1.56	117%	39%
Electricity & Gas	1.56	68%	39%
Water Supply	1.56	3%	5%
Sewerage & Waste	1.56	56%	22%
Construction	1.56	74%	27%
Trade & Repair of Motor Vehicles	1.56	113%	31%
Wholesale Trade	1.56	94%	27%
Retail Trade	1.56	117%	39%
Land Transport	1.56	50%	5%
Water Transport	1.56	74%	15%
Air Transport	1.56	29%	5%
Aux. Transportation Services	1.56	18%	5%
Postal and Courier	1.56	44%	48%
Accommodation and Food	1.56	45%	5%
Publishing	1.56	21%	5%
Media Services	1.56	21%	5%
Telecommunications	1.56	15%	5%
Computer & Information Services	1.56	72%	5%
Financial Services	1.56	65%	5%
Insurance	1.56	45%	5%
Activities auxiliary to financial services and insurance activities	1.56	55%	5%
Real Estate	1.56	41%	2%
Legal and Accounting	1.56	23%	7%
Business Services	1.56	99%	48%
Research and Development	1.56	37%	4%
Admin. & Support Services	1.56	18%	5%
Other professional, scientific and technical activities, veterinary activities	1.56	57%	26%
Administrative and support service activities	1.56	28%	13%
Public & Social Services	1.56	28%	13%
Education	1.56	58%	13%
Human Health and Social Work	1.56	32%	5%
Other Services, Households	1.56	119%	5%
Activities of households	1.56	45%	13%
Activities of extraterritorial organizations and bodies	1.56	28%	13%
average	*1.56*	*53.2%*	*15%*

Sources: WIOD and Felbermayr et al. (2017).

Notes: Trade elasticities are obtained by Felbermayr et al. (2017) by estimating the coefficient of a bilateral (sector-to-country), time-variant tariff variable in a sector-level gravity model with Poisson Pseudo Maximum Likelihood (PPML). As service products are not subject to tariffs, an average trade elasticity is imposed and calculated from estimated average elasticity in goods sectors. The *ad–valorem* equivalent NTBs under the FTA and the MFN scenario are obtained in the same regression as coefficients of a bilateral, time-variant FTA and a EU dummy as $exp(\beta/\theta) - 1$, where β is the mentioned coefficient. Missing elasticities for some sectors in Felbermayr et al. (2017) have been proxied with the elasticities of similar sectors.

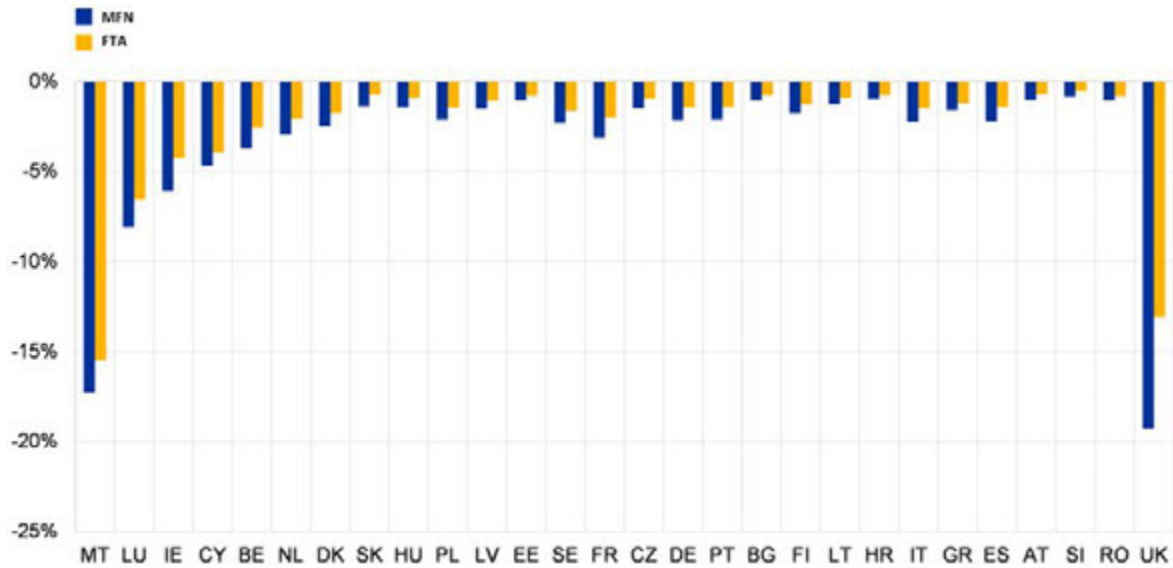Figure 29: UK tariffs on imports from EU27 countries
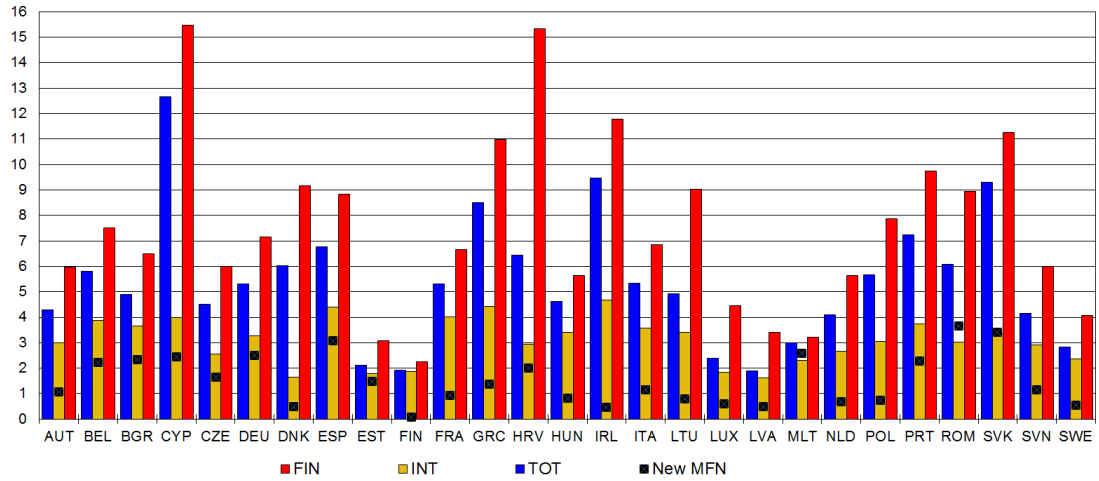
Sources and notes: See Figure 15.

Figure 30: EU27 countries tariffs on imports from UK
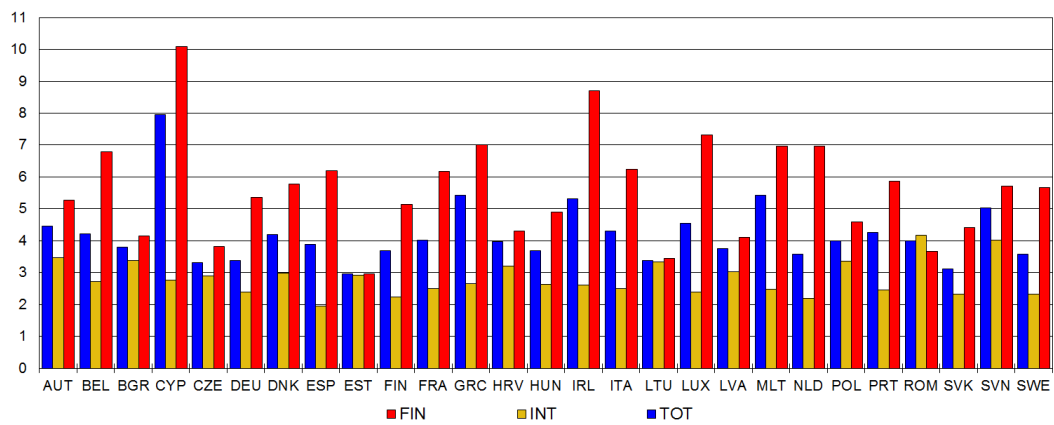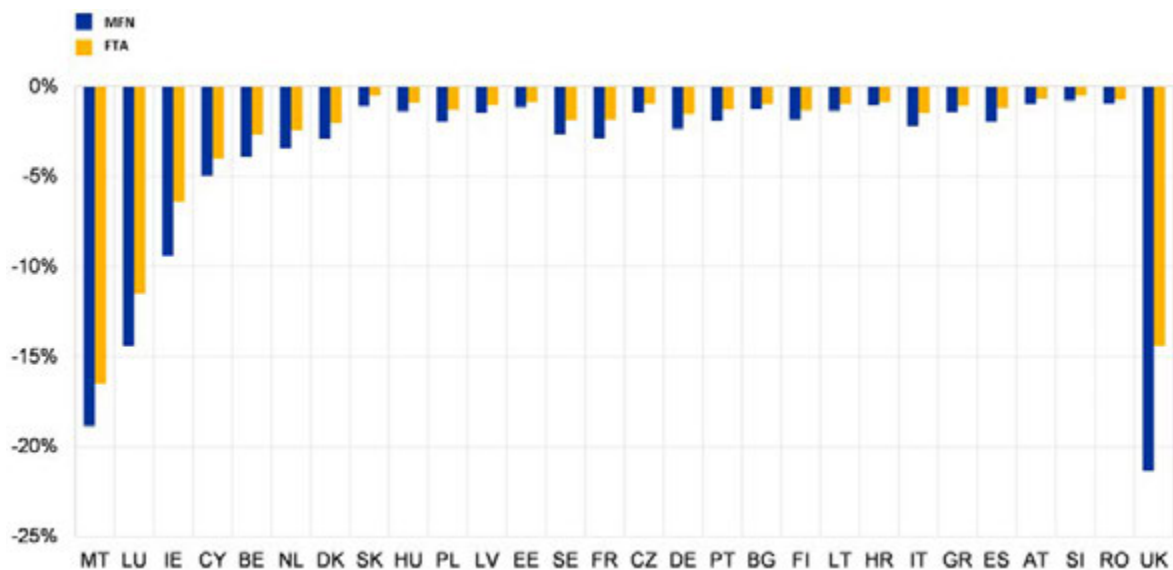

Sources and notes: See Figure 15.

Figure 31: Country-level results - real exports

Sources: WIOD 2016, WTO-IDB database, ITC Market Access Map, Comtrade, Felbermayr et al. (2017) and authors' calculations.

Notes: Changes in total real exports and imports have been aggregated from changes in sector-level real bilateral exports by using shares of corresponding nominal values. Nominal bilateral sector-level export changes have been deflated with the respective price changes.

Figure 32: Country-level results - real imports

Sources and notes: See Figure 31.

References

Amiti, M., Redding, S. J., and Weinstein, D. E. (2019). The impact of the 2018 tariffs on prices and welfare. *Journal of Economic Perspectives*, 33(4):187–210.

Antràs, P. and Chor, D. (2018). On the measurement of upstreamness and downstreamness in global value chains. In *World Trade Evolution: Growth, Productivity and Employment*, pages 126–194. Taylor & Francis Group.

Auer, R. A., Levchenko, A. A., and Sauré, P. (2017). International inflation spillovers through input linkages. NBER Working Paper 23246, National Bureau of Economic Research.

Baldwin, R. (2016). *The great convergence*. Harvard University Press.

Balistreri, E. J., Böhringer, C., and Rutherford, T. (2018). Quantifying disruptive trade policies. CESifo Working Paper 7382.

Baqaee, D. and Farhi, E. (2019). Networks, barriers, and trade. *mimeo*.

Bellora, C. and Fontagné, L. (2019). Shooting oneself in the foot? trade war and global value chains. GTAP resource 5733.

Berden, K., Francois, J., Tamminen, K., Thelle, M., and Wymenga, P. (2013). Non-tariff barriers in EU-US trade and investment: An economic analysis. IIDE Discussion Papers 23246, Institute for International and Development Economis.

Berthou, A., Jardet, C., Siena, D., and Szczerbowicz, U. (2018). Quantifying the losses from a global trade war. *Banque de France ECO Notepad*, 19.

Caliendo, L. and Parro, F. (2015). Estimates of the trade and welfare effects of NAFTA. *The Review of Economic Studies*, 82(1):1–44.

Cappariello, R., Damjanovic, M., Mancini, M., and Vergara Caffarelli, F. (2018). EU - UK global value chain trade and the indirect costs of brexit. Bank of Italy Occasional Papers (Questioni di economia e Finanza) No. 468, Bank of Italy.

Carvalho, V. M. (2014). From micro to macro via production networks. *Journal of Economic Perspectives*, 28(4):23–48.

Cerina, F., Zhu, Z., Chessa, A., and Riccaboni, M. (2015). World input-output network. *PloS one*, 10(7).

Costinot, A. and Rodríguez-Clare, A. (2014). Chapter 4 - Trade theory with numbers: Quantifying the consequences of globalization. In Gopinath, G., Helpman, E., and Rogoff, K., editors, *Handbook of International Economics*, volume 4 of *Handbook of International Economics*, pages 197 – 261. Elsevier.

Dekle, R., Eaton, J., and Kortum, S. (2008). Global rebalancing with gravity: Measuring the burden of adjustment. *IMF Economic Review 55(3): 511-540.*

Dhingra, S., Huang, H., Ottaviano, G., Paulo Pessoa, J., Sampson, T., and Van Reenen, J. (2017). The costs and benefits of leaving the EU: trade effects. *Economic Policy*, 32(92):651–705.

Di Giovanni, J. and Levchenko, A. A. (2010). Putting the parts together: trade, vertical linkages, and business cycle comovement. *American Economic Journal: Macroeconomics*, 2(2):95–124.

Di Giovanni, J., Levchenko, A. A., and Mejean, I. (2018). The micro origins of international business-cycle comovement. *American Economic Review*, 108(1):82–108.

Eaton, J. and Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, 70(5):1741–1779.

Evenett, S. J. (2019). Protectionism, state discrimination, and international business since the onset of the global financial crisis. *Journal of International Business Policy*, 2(1):9–36.

Fajgelbaum, P., Goldberg, P., Kennedy, P., and Khandelwal, A. (2019). The return to protectionism. NBER Working Paper 25638, National Bureau of Economic Research.

Felbermayr, G., Groeschl, J., and Heiland, I. (2017). The European Union in turmoil: a general equilibrium analysis of trade and welfare. *mimeo.*

Felbermayr, G. and Steininger, M. (2019). Trump's trade attack on China- who will have the last laugh? In *CESifo Forum*, volume 20, pages 27–32. München: Ifo Institute for Economic Research.

Francois, J., Berden, K., Tamminen, S., Thelle, M., Wymenga, P., et al. (2013). Non-tariff measures in EU-US trade and investment: An economic analysis. Technical report, Institute for International and Development Economics.

Freund, C., Ferrantino, M., Maliszewska, M., and Ruta, M. (2018). Impacts on global trade and income of current trade disputes. *Macroeconomics, Trade Investment (MTI) Practice Notes, July*, 2.

Imbs, J. and Méjean, I. (2017). Trade elasticities. *Review of International Economics*, 25(2):383–402.

Johnson, R. C. (2017). Measuring global value chains. NBER Working Paper 24027, National Bureau of Economic Research.

Johnson, R. C. and Noguera, G. (2017). A portrait of trade in value-added over four decades. *The Review of Economics and Statistics*, 99(5):896–911.

Koopman, R., Wang, Z., and Wei, S.-J. (2014). Tracing value-added and double counting in gross exports. *American Economic Review*, 104(2):459–94.

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *The American Economic Review*, 70(5):950–959.

Mayer, T., Vicard, V., and Zignago, S. (2018). The cost of non-Europe, revisited. CEPR Discussion Papers No. 12844.

Miroudot, S., Rouzet, D., and Spinelli, F. (2013). *Trade Policy Implications of Global Value Chains*. Oecd Publishing.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., and de Vries, G. J. (2015). An illustrated user guide to the world input-output database: the case of global automotive production. *Review of International Economics*, 23(3):575–605.

Timmer, M. P., Los, B., Stehrer, R., and de Vries, G. J. (2016). An anatomy of the global trade slowdown based on the wiod 2016 release. *Available as GGDC research memorandum number 162*.

Wang, Z., Wei, S.-J., and Zhu, K. (2013). Quantifying international production sharing at the bilateral and sector levels. NBER Working Paper 19677, National Bureau of Economic Research.

Rita Cappariello
Banca d'Italia, Rome, Italy; email: rita.cappariello@bancaditalia.it

Vanessa Gunnella
European Central Bank, Frankfurt am Main, Germany; email: vanessa.gunnella@ecb.europa.eu

Sebastián Franco-Bedoya
The World Bank, Washington, D.C., United States; email: sfranco2@worldbank.org

Gianmarco Ottaviano
Bocconi University, Milan, Italy; email: gianmarco.ottaviano@unibocconi.it