POTENTIAL ECONOMIC EFFECTS OF A GLOBAL TRADE CONFLICT

Projecting the medium-run effects with the WTO Global Trade Model

Eddy Bekkers and Robert Teh♣

Economic Research and Statistics Division

World Trade Organization♦

ABSTRACT

The WTO Global Trade Model is employed to project the medium-run economic effects of a global trade conflict. The trade conflict scenario is based on recent estimates in the literature of the difference between cooperative and non-cooperative tariffs. The study provides three main insights. First, the projected macroeconomic effects in the medium run are considerable. A global trade conflict started in 2019 would lead to a reduction in global GDP in 2022 of about 1.96% and a reduction in global trade of about 17% compared to the baseline. For context global GDP fell about 2.1% and global trade 12.4% in the global financial crisis of 2009. Second, behind the single-digit aggregate production effects there are much larger, double-digit sectoral production effects in many countries, leading to a painful adjustment process. In general, a global trade conflict leads to a reallocation of resources away from the most efficient allocation based on comparative advantage. Third, the large swings in sectoral production lead to substantial labour displacement. On average 1.15% and 1.74% of high-skilled and low-skilled workers respectively would leave their initial sector of employment.

♣ Address for correspondence: Rue de Lausanne 154, 1211 Geneva, Switzerland. email: eddy.bekkers@wto.org. Robert.teh@wto.org. We want to thank Lionel Fontagne, Jean Fouré, Joseph Francois, Bernard Hoekman, Robert Koopman, Douglas Nelson, Alessandro Nicita, and Marcelo Olarreaga for useful comments and suggestions on earlier versions of this paper.

1 INTRODUCTION

The US announced the imposition or increase of import tariffs in a series of statements, both on steel and aluminium against all trading partners (invoked under Section 232 of the Trade Expansion Act), on other products against imports from China (invoked under Section 301 of the Trade Act of 1974), and recently also on motor vehicles. In response, various trading partners have announced tariffs measures against products from the United States. These events could be the start of a series of retaliatory tariff increases between different countries with one possible outcome being a global trade conflict.

In this paper we determine the potential effects of global trade conflict on trade, real income and GDP employing the WTO Global Trade Model, a recursive-dynamic CGE model. The trade conflict scenario is based on estimates of the difference between cooperative and non-cooperative tariffs by Nicita et al. (2018a, 2018b). Trade conflict refers to the "worst case" scenario where international trade cooperation breaks down and countries set tariffs non-cooperatively. For WTO members, this would mean not honouring their tariff commitments and setting tariffs that will exceed WTO bindings. With our recursive-dynamic model we can focus on the projected medium-run effects, taking a reallocation of investment across countries into account.

Section 2 discusses the literature on trade conflicts in a succinct way. Section 3 briefly describes the employed CGE-model and the construction of the baseline of the global economy. Section 4 introduces and motivates the trade conflict scenario employed. Section 5 presents the economic effects of a potential trade conflict. Section 6 concludes.

2 LITERATURE REVIEW

Johnson (1953) is probably the beginning of the modern economic analysis of trade conflict. A trade conflict is modelled as a two-person non-cooperative game in which countries choose their optimal tariffs knowing that they would be subject to retaliation. The main result from his analysis is that it is possible for a country to gain from increasing its tariffs even if the action leads to retaliatory tariffs from its partner. Although it was not possible to derive the general conditions under which the result holds, in the special case where the reciprocal demand curves have constant elasticities Johnson was able to use (relatively crude) numerical methods to determine the values of the elasticities under which one country will be better off in a trade conflict.

The use of numerical or computational methods to determine non-cooperative Nash tariffs has since been a feature of the trade conflict literature. These include papers by Abrego et al (2006), Baldwin and Clarke (1987) on the Tokyo round negotiations, Cronshaw (1997) where a trade conflict is modelled as a repeated game, Deardorff and Stern (1987), Foreman-Peck et al (2007) to explain optimal tariffs during the inter-conflict years, Hamilton and Whalley (1982), Harrison and Rutstrom (1991), Markusen and Wigle (1989) on optimal tariffs between Canada and the US, and He et al (2017).

The terms-of-trade theory of trade agreements by Bagwell and Staiger (2002) is closely linked to the trade conflict literature since in their framework the outside option to a trade agreement is a trade conflict in which countries choose optimal political tariffs (which differ from standard Nash tariffs). The idea of politically optimal tariffs follows from the argument that governments do not necessarily maximize social welfare since they may receive contributions from interest groups (Grossman and Helpman, 1995). In Grossman and Helpman's model, political incumbers maximize a function that is a weighted average of social welfare and campaign contributions.

Going beyond the traditional terms-of-trade argument, Ossa (2011) proposes an additional reason for trade agreements based on the new trade theory (Krugman, 1980). Trade agreements help governments internalize a production relocation externality in which countries use import tariffs to gain at the expense of other countries by attracting a larger share of manufacturing production. Using this new theory of trade agreements, he uses computational methods to calculate Nash tariffs in case of a trade conflict. He calculates the median Nash tariff across all countries to be 58.1 percent – levels last seen during the Great Depression (Ossa, 2014).

The election of Donald Trump who campaigned on an anti-trade platform has spurred interest in knowing what the likely magnitude of U.S. tariffs and the retaliatory tariffs by its major trading partners would be and comparing actual tariffs with the Nash tariffs predicted by models of trade conflicts (Balisteri and Hillberry, 2017; Bouet and Laborde, 2018). More recently, Nicita et al (2018a, 2018b) have calculated politically optimal tariffs in the case where multilateral cooperation breaks down and countries choose optimal tariffs. Since the optimal tariffs depend on the inverse of the export supply elasticity, they use the estimated elasticities from Kee et al. (2008) to calculate these tariffs. They find that the optimal tariffs would represent a 32-percentage point increase over current levels of tariff protection faced by the average world exporter. Their study provides the latest and most comprehensive estimates of non-cooperative tariffs in the trade literature, available at the HS 6-digit line and for almost all WTO members.

3 WTO GLOBAL TRADE MODEL: THEORETICAL FRAMEWORK AND CONSTRUCTION OF BASELINE

We employ the WTO Global Trade Model (GTM) for the baseline projections and policy simulations. The GTM is a recursive dynamic CGE model, extending the facelift version of the GTAP model (Version 7). This means that the model features multiple sectors, multiple factors of production, intermediate linkages, multiple types of demand (private demand, government demand, investment demand, and intermediate demand by firms), non-homothetic preferences for private households, a host of taxes, and a global transport sector. Each region features a representative agent collecting factor income and tax revenues and spending this under utility maximization on private consumption, government consumption, and savings. Firms display profit maximizing behaviour, choosing the optimal mix of factor inputs and intermediate inputs. Savings are allocated to investment in different regions according to changes in the rate of return.

Compared to the standard GTAP model, the GTM contains six additional features. First, the model is recursive dynamic, thus featuring endogenous capital accumulation. Second, the model allows for isoelastic factor supply of land and natural resources. Third, the twist-parameter approach developed by Dixon and Rimmer (2002) is included, allowing for changes in spending shares (for example changes in import shares or the share of labour income in total factor income). Fourth, price and quantity indices in the model are defined using the "ideal" index approach. Fifth, the model contains various options for the allocation of global savings, in particular rate-of-return sensitive investment allocation, investment allocation based on initial capital shares, fixed foreign savings, and fixed relative foreign savings. In this paper we apply the rate-of-return sensitive investment allocation. Sixth and finally, the model is flexible in its trade structure, allowing for a perfect competition setting with Armington preferences, but also for a setting with monopolistic competition, either with homogeneous firms (Ethier-Krugman) or with heterogeneous firms (Melitz). The model follows the approach in Bekkers and Francois (2018) to nest the different structures in a general model. This paper follows most of the literature, employing Armington preferences.

In this paper we focus on the medium-run effects of a possible global trade conflict. In concrete terms we project the medium-run impact of a potential trade conflict over a 4-year period, starting in 2019. This means that we first generate a baseline, a projection of how the global economy would develop without policy changes. The baseline is constructed with three main ingredients. First, the global economy is calibrated to the latest version of GTAP, a global trade and production database, version 10P2 in 2014. We aggregate the GTAP-database to 27 regions, 39 sectors, and 5 factors of production.[1] To project the potential effects of a global trade conflict between 2019 and 2022 this baseline first has to be projected to 2018. Therefore, as a second ingredient external data from other international agencies are employed to project population growth, employment growth, and GDP per capita growth until 2022. Population and employment growth projections from the UN are imposed on the model, medium variant for 2015 (UN 2015). Projections on GDP per capita growth from the OECD (Shared Socio-economic Pathways Middle-of-the-Road Scenario or SSP2, Dellink et al., 2017) are targeted by endogenizing non-capital augmenting productivity growth.

[1] An overview of the aggregation is included in the appendix.

Second, three types of structural change are included in the baseline: differential productivity growth across sectors, changing savings rates, and changing preference parameters. Differential productivity growth is based on estimates of sectoral productivity growth relative to average productivity growth in both EUKLEMS and OECD-STAN. Adjusting savings rates are based on the estimating framework in Fouré et al. (2013) in which savings rates adjust in response to changes in GDP per capita growth and demographic factors. Adjusting preferences are modelled based on regressing the parameter determining the income elasticity of demand on GDP per capita, such that preferences adjust over time.

Our modelling framework is similar to other dynamic CGE models, such as the model employed by the World Bank to explore the expected trade and macroeconomic effects of trade tensions. Two other types of models have also been used in the literature to examine the impact of trade tensions. First, institutions such as the IMF and ECB employ macro-econometric models to explore the impact of possible future trade policy scenarios (See IMF (2018) and Dizioli and Van Roye (2018) respectively). These models differ considerably from our dynamic CGE model. On the one hand they include additional features such as monetary policy and short-run rigidities in different markets. On the other hand, they contain less sectoral detail and are less suitable to evaluate detailed trade policy scenarios and to project the sectoral effects of trade policy changes.

Second, new quantitative trade models in the spirit of Costinot and Rodriguez-Clare (2013) are employed for example by Felbermayer and Steininger (2019) to examine the effects of trade tensions. These models are similar to dynamic CGE models, albeit with some important differences. These models stress parsimony and structural estimation. Hence, these models containing less parameters and less modelling features, thus abstracting from features such as non-homothetic preferences and institutional details of the global economy such as export taxes.[2] In terms of the impact these models tend to generate smaller negative effects of tariff increases than our dynamic CGE model, since they abstract from endogenous capital accumulation and investment.[3]

4 MODELLING A GLOBAL TRADE CONFLICT

We follow the most recent economic literature to determine the tariff increases in case of a global trade conflict and employ the study by Nicita et al. (2018a). In this study the authors estimated the difference between non-cooperative and cooperative tariffs for a large set of countries at the HS 6-digit level. Based on estimates of export supply elasticities they have calculated the ability of countries to reduce the price they pay for their imports by raising their level of import tariffs. We take their estimates of the difference between cooperative (assumed to be the current situation) and non-cooperative tariffs (the tariffs in a "trade conflict") and aggregate them to the set of countries and regions used in our model to build the scenario of a global trade conflict.[4]

Before turning to the average projected increases in tariffs, we discuss the methodology employed in Nicita et al. (2018a) in more detail. These authors have shown that the impact on tariffs of the export supply elasticity faced by importers is different for cooperative and non-cooperative regimes, empirically measured by trade policy regimes with and without tariff water, respectively.[5] This reasoning is based on two relations. First, the premise is that countries do not have flexibility without tariff water and thus set tariffs cooperatively, whereas with tariff water countries can vary their tariffs, and can thus exploit this flexibility to set the tariffs non-cooperatively.

Second, Nicita et al. (2018a) argue that if tariffs are set non-cooperatively (with water) higher tariffs should be observed when importers have more market power as measured by a lower export supply elasticity.[6] In a non-cooperative setting, importers vary their tariffs according to their opportunities to

[2] See for further discussion of these differences Bekkers (2019).

[3] Bekkers and Rojas-Romagosa (2018) show that endogenous capital accumulation has a strong impact on the simulated effects of TTIP.

[4] The differences between cooperative and non-cooperative tariffs at the HS6 level from Nicita et al. are aggregated by calculating trade weighted averages.

[5] Water in the tariffs is typically measured by the difference between bound tariffs and applied tariffs.

[6] A smaller export supply elasticity of a trading partner implies that tariffs will lead to a stronger reduction in the price charged by the exporter and thus stronger terms of trade gains.

benefit from higher tariffs through terms of trade improvements. In contrast, when tariffs are set cooperatively (without water) the impact of the export supply elasticity facing importers should be positive. In a cooperative setting, importing countries will have an incentive in tariff negotiations to benefit the exporting firms of their trading partners. This requires reducing tariffs most on goods where the importers have most market power and exporters thus have smaller supply elasticities. In such markets exporters benefit most from elimination of tariffs which results in an increase in their export prices.

Nicita et al. (2018a) confirm their hypothesis empirically, showing with HS6 trade data that a lower export supply elasticity (more market power) leads to higher tariffs in a non-cooperative setting (with tariff water) and leads to lower tariffs in a non-cooperative setting (with tariff water). Hence, these empirical findings provide evidence for the fact that tariffs are set differently in a cooperative and a non-cooperative setting. These differences between cooperative and non-cooperative tariffs then provide the basis for our global trade conflict scenario.

Table 1 displays the average (trade weighted) tariff increase imposed by each country as importer and faced by each country as exporter.[7] The table shows that the large countries and regions are predicted to raise tariffs most in case of a trade conflict. However, it is not only size which determines the difference between cooperative and non-cooperative tariffs, but also market power vis-à-vis exporters although the two are probably correlated. We assume that the customs unions of the EU and the ASEAN FTA will not break down in case of a tariff conflict and thus that the members of these arrangements will not raise tariffs against other members of the trade area in a tariff conflict.[8] Obviously there are other large FTAs such as USMCA or Mercosur where we could have made the same assumption but do not. We have exempted the EU from intra-regional tariff increases given the long historical and political rationale underlying the European project. It does not seem likely that the EU would break down in the case of a trade war. We have also assumed the same thing about ASEAN for pretty much the same reasons. However, we have also conducted simulations where we assume ASEAN countries raise tariffs against one another and the results we obtain are very similar most likely because much of ASEAN countries' trade is still with non-ASEAN members.[9] So, for the EU and ASEAN the table displays both the trade weighted average tariff increase taking into account all trade (without asterisk) and only trade with other regions (with asterisk). Obviously, the trade weighted average increase for ASEAN and the EU is larger for extra-regional trade.

The table also shows the initial (current) trade weighted average tariff rates facing the different regions (per exporter) and imposed by the different regions (per importer). The table shows that in general richer countries and regions impose lower tariffs than they face, whereas it is the other way around for poorer countries and regions. China is in the middle and faces about the same trade weighted average tariff as it imposes. The imbalance between tariffs faced and tariffs imposed is similar for the European Union and the United States.

Comparing the level of initial tariffs with the tariff changes suggests that the tariff increases in case of a tariff conflict are huge. However, these tariff rates, based on the empirically estimated tariff increases in Nicita et al. (2018a and 2018b), are substantially smaller than in other studies such as Ossa (2014) in which the median non-cooperative tariff increase across all countries is 58.1%.[10]

[7] For some countries and regions Nicita et al. (2018a and 2018b) do not provide estimates. We employ an average of countries part of the Rest of the World for these countries (for Russia and Taiwan) and an average of other ASEAN countries (for Laos and Vietnam).

[8] We do not speculate about the outcome of Brexit and work with the status quo and the moment of writing. Therefore, Great Britain is assumed to still be part of the EU and would thus not face tariff increases vis-à-vis the EU.

[9] The reduction in the global value of trade and global GDP would respectively be 17.61% instead of 16.96% and 1.97% instead of 1.96%.

[10] The average tariff increase displayed in Table 1, 26%, is somewhat smaller than the average tariff increase reported by Nicita et al. (2018b), which is due to differences in trade values to calculate average tariff increases.

Table 1: Average initial tariffs and tariff increases in a trade conflict

Country/Region	Average initial tariffs		Tariff shocks in trade conflict	
	Faced as exporter	Applied to importer	Faced as exporter	Applied as importer
ASEAN	2.40	2.28	23.93	11.62
ASEAN*	2.85	2.66	30.75	14.61
Argentina	3.53	7.16	24.99	11.30
Australia	2.12	3.12	19.70	11.87
Brazil	4.99	8.16	30.30	13.11
Canada	1.18	0.92	44.17	21.13
China	4.43	3.67	31.01	28.07
EFTA	1.57	0.68	29.64	9.63
EU27	1.62	0.69	9.21	14.72
EU27*	4.23	1.68	24.17	36.32
East Asia	3.01	0.93	23.13	5.38
Great Britain	2.13	1.07	13.15	17.73
Great Britain*	4.04	2.28	24.93	37.69
Hong Kong	1.96	0.00	21.36	27.58
India	4.89	6.42	23.82	7.28
Indonesia	3.92	2.33	20.48	4.66
Indonesia*	4.71	3.02	24.82	6.34
Japan	4.34	1.91	31.94	29.10
Korea	3.75	5.54	28.89	13.34
Latin America	1.55	4.12	22.01	6.09
MENA	1.15	5.68	9.02	6.03
Mexico	0.59	1.08	50.42	5.14
New Zealand & Oceania	4.60	2.71	21.71	9.92
Rest of World	1.87	3.26	15.40	4.89
Russia	1.19	7.58	11.58	5.43
SSA	0.87	9.91	11.11	10.25
South Africa	2.32	4.78	24.26	9.17
South Asia	4.96	9.70	37.98	8.79
Taiwan	2.46	1.85	31.28	4.33
Turkey	4.87	1.37	30.69	5.73
USA	2.94	1.22	22.32	58.76
Average	3.09	3.09	25.57	25.57

Source: Nicita et al. (2018a and 2018b) elaborated by the WTO Secretariat.
Notes: Country level averages of initial tariffs and tariff shocks are calculated as trade-weighted averages. Entries with an asterisk (*) display the trade-weighted average tariff (shock) excluding intra-regional trade for the EU and ASEAN.

5 IMPACT OF A POTENTIAL TRADE CONFLICT

In this section we present and discuss the projected effects of a potential trade conflict. The first section outlines the macroeconomic effects. Section 5.2 addresses the sectoral effects and Section 5.3 goes into the employment effects.

5.1 Macroeconomic effects

Table 2 as well as Figures 1 to 3 display the simulated effects of a potential trade conflict on real income, real GDP, and the value and volume of exports. The global average decline in real GDP and the value of exports is projected to be respectively 1.96% and 16.95% in 2022 relative to the baseline.

The impact on the value of trade in general reflects the size of the tariff increases (as displayed in Table 1). Trade is projected to fall more in large countries with big tariff increases such as China, the United States, and Japan. The impact on the value of trade for the EU is positive, reflecting the fact that intra-EU trade will pick up when tariffs on exports outside of the EU increase. The model projects a fall in the value of exports from the EU to other regions (thus excluding intra-regional trade) of 32% (not displayed in the table). Given the large weight of the EU in global trade, the reduction in global trade would rise from about 17% to 26% when excluding intra-EU trade. In the table, the figure of 17% includes intra-EU trade, since trade within the EU is effectively part of global trade.

The trade and welfare effects of a global tariff conflict are in general smaller than the effects obtained in Ossa (2014). Ossa reports a global average welfare loss of 2.9% and a 58% average reduction in trade. In comparison to Ossa's work both our scenario and our model are different. The median increase in tariffs is 58% in Ossa (2014), whereas it is only 32% in our study. Therefore, we get smaller trade effects. Our model contains both intermediate linkages and endogenous capital accumulation, whereas these features are omitted in Ossa (2014). Both features tend to lead to larger welfare effects (Costinot and Rodriguez-Clare, 2013; Bekkers and Rojas-Romagosa, 2018). Hence, our model would probably generate much larger welfare losses than reported in Ossa (2014) if the same tariff increase scenario were used.

The change in real income, defined as nominal income divided by the price level and a measure for the change in welfare, vary between -0.18% for the EU and -0.26% for the United States on the one hand and -6% for Canada and -6.62% for ASEAN on the other hand. In general, a large country like the United States seems to be better able to benefit from favourable changes in its terms of trade facing only small expected real income losses. However, there are exceptions to this pattern, since China for example would also incur considerable losses. In general, countries with large losses such as Canada, China, Korea and Mexico tend to export a relatively large share of their goods to the United States, which is projected to raise tariffs the most according to the estimates of Nicita et al. (2018a, 2018b). China's large losses seem to arise because it exports a lot to the countries who raise their import tariffs the most — the United States and the EU.

On average, real income in the ASEAN region would be 6.62% lower in case of a global trade conflict, even though intra-ASEAN trade is exempted from rising tariffs in the trade conflict scenario. The reason is that ASEAN countries are rather dependent on extra-regional trade (outside of ASEAN), that they are relatively small open economies and are thus more vulnerable to rising tariffs in a global trade conflict. Furthermore, they export a relatively large share to big markets such as the United States. Although Indonesia is a member of ASEAN, it much less affected instead since it is a more closed economy.

Table 2: Macroeconomic and aggregate trade effects of trade conflict on and other regions in 2022 (in percent)

All changes are relative to the baseline projection

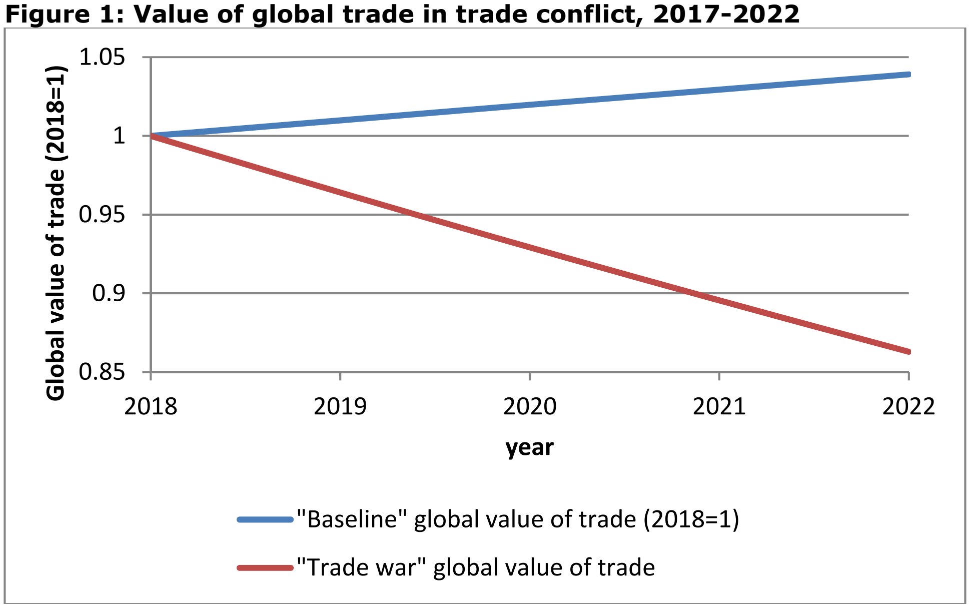
	Real income	Real GDP	Value of exports	Real exports
ASEAN	-6.62	-4.12	-13.80	-11.33
Australia	-1.27	-0.45	-15.62	-13.91
Brazil	-0.90	-0.37	-22.86	-22.24
Canada	-6.00	-3.32	-25.02	-22.38
China	-3.99	-3.14	-35.70	-34.82
EFTA	-5.66	-1.96	-21.77	-18.56
EU 27	-0.18	-1.03	2.82	-4.76
Great Britain	-0.62	-0.99	-6.56	-12.33
India	-1.29	-0.51	-17.84	-16.19
Indonesia	-0.62	0.36	-14.07	-11.42
Japan	-2.92	-1.97	-29.19	-26.41
Korea	-5.58	-3.34	-23.38	-19.65
Latin America	-0.77	0.02	-16.65	-15.25
Mexico	-5.38	-1.18	-17.90	-11.82
Middle East and Northern Africa	-2.09	-0.16	-10.65	-8.38

Russia	-1.92	-0.37	-10.73	-8.12
Sub-Saharan Africa	-1.66	-0.86	-13.79	-12.20
South Africa	-2.35	-1.03	-17.59	-15.61
Turkey	-2.87	-0.88	-19.98	-15.87
United States	-0.26	-2.18	-55.80	-61.51
Global average	**-2.25**	**-1.96**	**-16.96**	**-18.41**

Note: The table displays cumulative percentage changes in 2022.

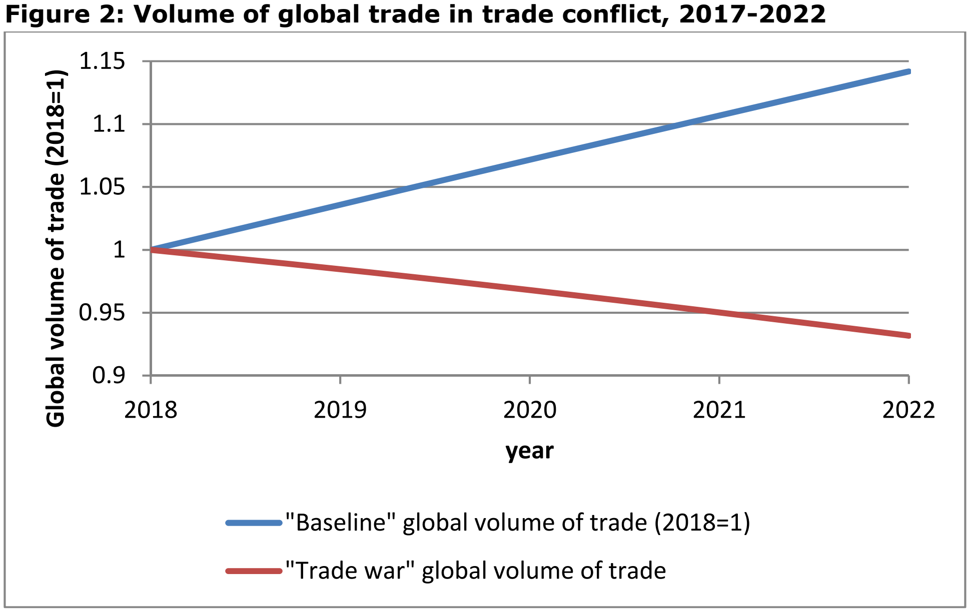
Source: WTO trade model simulation results.

Figure 1: Value of global trade in trade conflict, 2017-2022



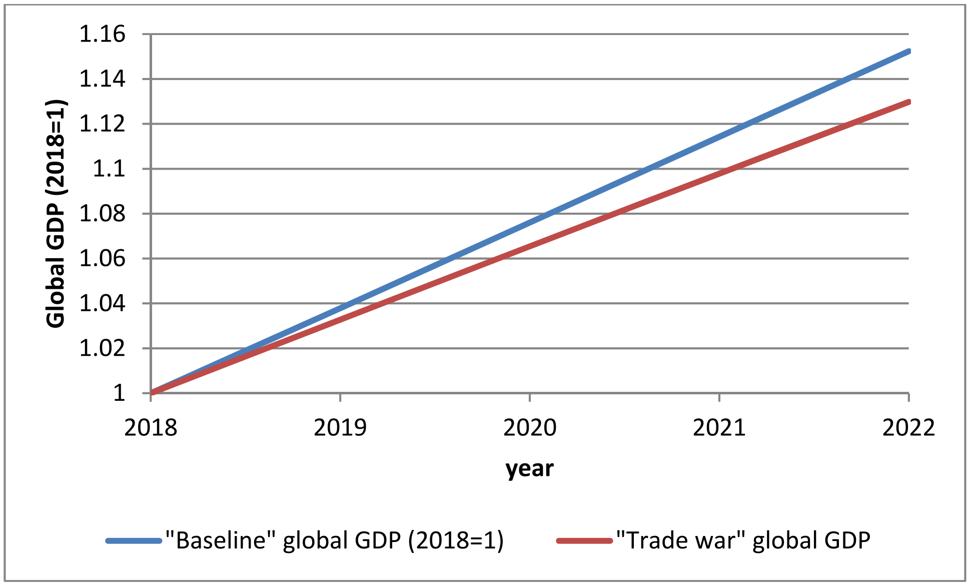
Source: WTO Global Trade Model simulation results.

Figure 2: Volume of global trade in trade conflict, 2017-2022



Source: WTO Global Trade Model simulation results.

Figure 3: Global GDP in trade conflict, 2017-2022



Source: WTO Global Trade Model simulation results.

5.2 Impact on sectoral production and exports

Behind the relatively modest aggregate macroeconomic effects, there are much larger sectoral shifts with production rising in some sectors and falling in other sectors. To shed light on these sectoral effects, Table 3 displays the change in real net output or value added in different selected sectors for the four main economic regions in the world, the United States, the EU, China and Japan. We can draw four main conclusions from the table. First, the United States tends to lose in the agricultural sectors such as grains and oil seeds, whereas it is projected to expand production in most of the manufacturing sectors. Second, the changes in China are a mirror image of the changes in the United States: production expands in the agricultural sectors and contracts in most manufacturing sectors. Third, production in relatively low value-added sectors such as textiles and wearing apparel would expand in the United States, the EU and Japan, whereas it would fall in China. This seems to indicate that a global trade conflict would lead to less specialization of countries according to their comparative advantage. This point will be further discussed below. Fourth, as expected, production in the transport sector falls, because of a reduction in trade and thus a reduced demand for transportation services. Changes in the other services sectors are not displayed, because they are limited, since they are obviously not directly affected by the tariff increases.[11]

[11] As analysed below the share of services in the economy also falls in the trade war scenario, because of more demand for production factors in the manufacturing sectors.

Table 3 Changes in sectoral real output in 2022, selected sectors (in percent)

Sector	United States	EU 27	China	Japan
Grains	-13	-4	0	39
Oil seeds	-34	64	38	169
Fossil fuels	-25	-5	13	20
Electronic equipment	25	30	-9	-2
Ferrous metals	11	3	-1	-9
Leather products	35	40	-14	83
Machinery & equipment	7	-2	0	-7
Other manufacturing	8	4	-6	11
Metal products	7	2	-4	-1
Other Metals	8	27	6	-5
Motor vehicles and parts	7	-11	15	-13
Textiles	27	32	-11	10
Transport equipment	-16	-4	14	0
Wearing apparel	61	44	-16	36
Transport	-4	-7	-1	-1

Source: WTO trade model simulation results.

Table 4 shows percentage changes in sectoral exports for the same set of sectors and countries. This table appears to display the same pattern of sectoral changes in production as Table 3. However, there are important differences. First, exports tend to fall in many more sectors for the regions displayed. This is expected, because the large increase in import tariffs would lead to a reorientation away from exports to domestic sales. The negative impact on exports is particularly large in the United States, since this country is projected to raise import tariffs most and is relatively closed thus leading to a large reduction in export sales in percentage terms when sales are reoriented to the domestic market. In the EU exports in some mainly low value-added sectors rise due to the assumed exemption of intra-EU sales from the trade conflict.

Table 4 Changes in sectoral exports in 2022, selected sectors

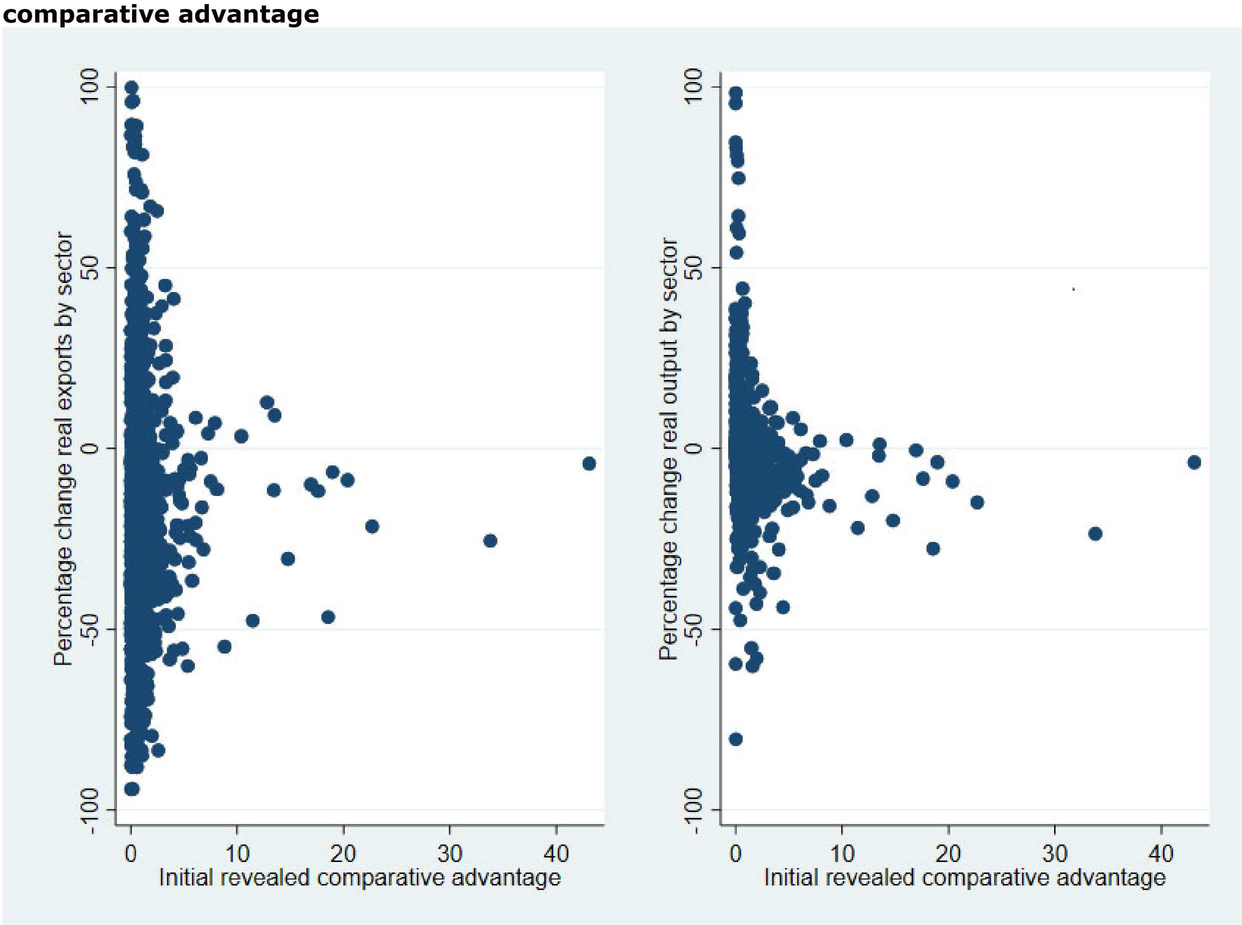
Sector	United States	EU 27	China	Japan
Grains	-56	-17	4	-9
Oil seeds	-49	96	-13	-37
Fossil fuels	-60	-10	-28	-16
Electronic equipment	-88	29	-47	-39
Ferrous metals	-70	0	-24	-27
Leather products	-88	40	-28	-76
Machinery & equipment	-79	-14	-37	-34
Other manufacturing	-83	-3	-32	-23
Metal products	-78	-7	-42	-33

Other metals	-83	28	-17	-74
Motor vehicles	-73	-16	-32	-26
Textiles	-79	35	-39	-64
Transport equipment	-83	-14	-17	-20
Wearing apparel	-85	52	-41	-55
Transport	-31	-20	-4	-5

Source: WTO trade model simulation results.

We remarked on the large sectoral shifts in production that results from a global trade conflict. Given that they result from increased tariff protection, they are likely to lead to a more inefficient allocation of resources. Is there any way that one could substantiate such a conjecture? To answer this question of whether countries reorient their production and exports away from their initial revealed comparative advantage (RCA) we plot in Figure 4 the relation between initial revealed comparative advantage in 2018 and the percentage change in respectively real exports (left panel) and real output (right panel). The figure makes clear that there seems to be a negative relation between initial RCA and sales, although the relation is stronger for production than for exports. For exports we see many observations in the Southwest corner, so with large negative percentage changes in exports combined with low RCA. This reflects that exports in general tend to fall with countries reorienting towards domestic sales. For real output we see a stronger negative (non-linear) relation with initial RCA.

Figure 4: Change in real exports and real value added as a function of initial revealed comparative advantage



Source: WTO trade model simulation results.

In Table 5 we examine the relation between initial RCA and changes in respectively real exports and real output more formally, regressing the latter two variables on initial RCA and initial RCA squared, using unweighted and weighted regression. The latter gives observations with a larger initial value of exports or output more weight. The table shows that for the unweighted regression the relation is non-significant for changes in exports and highly significant for changes in output. In the weighted regressions the relation is significant for both variables. The marginal effect at the mean value of initial RCA is displayed as well, showing a negative and significant impact. However, since the relation is highly non-linear the negative effect obviously varies with initial RCA.

Table 5: Regression of percentage change in real exports and in real output on initial revealed comparative advantage

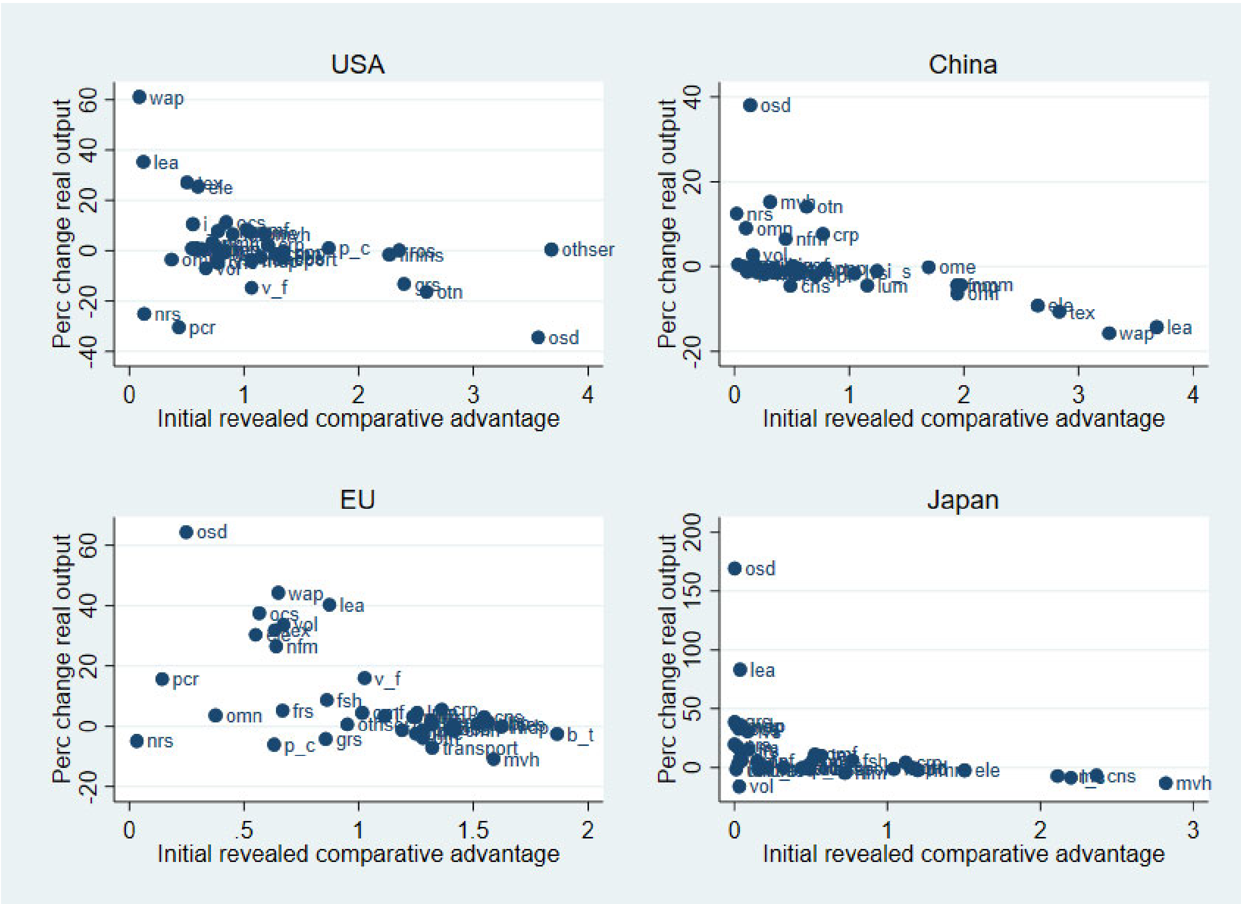
Variables	Exports unweighted	Exports weighted	Output unweighted	Output Weighted
RCA	-0.744	-3.936***	-2.875***	-5.153***
	(0.781)	(1.216)	(0.340)	(0.536)
RCA squared	0.0203	0.131**	0.0706***	0.160***
	(0.0274)	(0.0634)	(0.0120)	(0.0280)
Constant	-12.49***	-7.642***	4.340***	8.252***
	(1.288)	(1.519)	(0.561)	(0.670)
Average marg. Effects	-0.704	-3.674**	-2.733***	-4.832***
	-0.734	-1.123	-0.32	-0.495
Observations	1,053	1,053	1,053	1,053

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001
Source: WTO trade model simulation results.

Figure 5 illustrates that we should interpret the regression results with caution. The strength of the negative relation between initial RCA and the change in real output tends to vary across countries. However, the figure makes clear that there is a consistent negative relation between initial comparative advantage and changes in real output in the four countries shown. Countries specialize less in sectors in which they have a comparative advantage in the case of a global trade conflict. This sectoral reorganization of production explains part of the negative welfare effects of a global trade conflict. Instead of benefiting to the maximum from international specialization countries will reorient their resources to sectors in which they are comparatively less efficient based on initial specialization patterns.[12] Going back to Table 3, one sees that the United States raises its production in sectors such as textiles and apparel and reduces production in grains and oilseeds.

[12] See Levchenko and Zhang (2016) for a treatment of the welfare costs of specializing less according to comparative advantage. We leave a decomposition exercise showing how much the reduced specialization contributes to the welfare costs of a global trade conflict for future work.

Figure 5: Change in real value added as a function of initial revealed comparative advantage in four countries



Source: WTO trade model simulation results.

We conclude the discussion of comparative advantage by examining the change in the mean and standard deviation of revealed comparative advantage comparing 2018 without a trade conflict scenario and 2022 with a trade conflict scenario. We see that the dispersion in comparative advantage (standard deviation in column 3) falls substantially, thus reflecting that countries would export less according to their comparative advantage. In a world without differences in sectoral productivity or factor abundance there would be no variation in comparative advantage.

Table 6: Summary statistics of revealed comparative advantage in 2018 and in 2022 after trade conflict

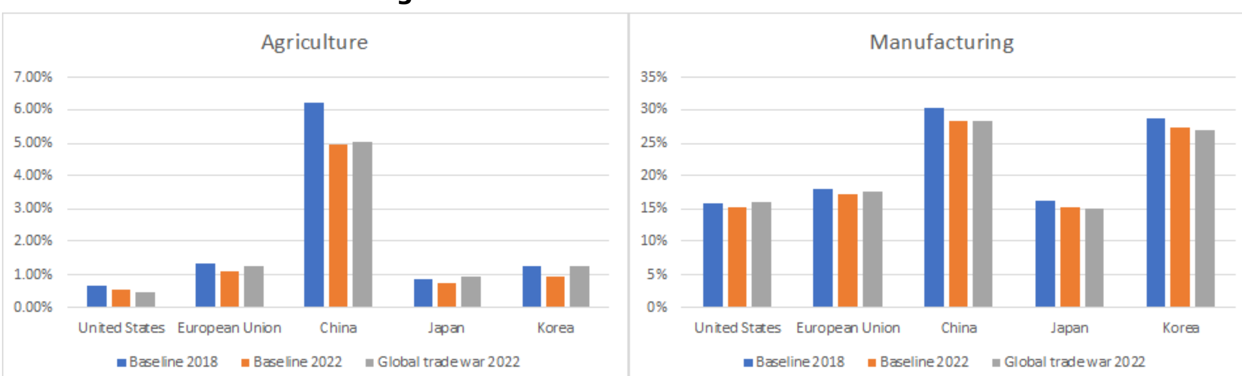
	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	Mean	Standard deviation	Min	Max
RCA 2018	1,053	1.228	2.601	6.95e-07	43.09
RCA 2022 with trade conflict	1,053	1.183	2.428	8.55e-07	40.46

Source: WTO trade model simulation results.

The increase in output in most of the manufacturing sectors in the United States raise the question to what extent manufacturing production and employment would increase under a global trade conflict scenario. Figure 6 displays the share of value added in agriculture and manufacturing in the baseline in 2018, in the baseline in 2022 and under a global trade conflict scenario in 2022 for China, the European Union, Japan, Korea and the United States.[13] The figure makes clear that despite the double-digit changes in Table 3 the increase in the share of the entire manufacturing sector in the global economy is somewhat limited, from about 15.1% to 15.9%.[14] Furthermore, the figure makes clear that the increase in the manufacturing share is about the same size as its decrease in the baseline from 2018 to 2022 which would suggest that the trade conflict would effectively offset the baseline trend. In the baseline the share of manufacturing in the total economy falls because of the different types of structural change, i.e. higher productivity growth in manufacturing reducing the value share of manufacturing; changing preferences away from food and manufacturing goods to services; and lower savings rates which in general tend to reduce investment. The European Union displays a similar pattern as the United States. In China the share of manufacturing would stay virtually constant in a global trade conflict. The figure shows that Korea is one of the countries where the manufacturing share would fall slightly under a trade conflict.

The left panel of Figure 6 shows the share of agriculture in the different economies. The initial share is obviously small. Furthermore, the share of agriculture in total production in the United States would fall with a global trade conflict, whereas it would increase somewhat in the other countries displayed. This trend is in line with the general trend described above. The United States has an initial comparative advantage in agriculture and so its share in agriculture would fall under a global trade conflict.

Figure 6: The share of value added in agriculture and manufacturing in the baseline in 2018 and 2022 and in 2022 with a global trade conflict



5.3 Employment effects

The WTO Global Trade Model is a medium-run model that does not model short-run fluctuations in employment or unemployment. Nevertheless, it is possible to explore the impact of a potential global trade conflict on the number of workers moving between sectors. The trade shocks lead to a reallocation of workers across sectors which will be costly. Table 7 displays three indicators of labour movement between sectors for both high-skilled and low-skilled workers, first a labour displacement indicator, second the percentage of workers leaving the initial sector of employment, and third the number of

[13] Since wages are uniform across sectors and the share of labour in total income are not changing much in a global trade conflict scenario, the share of income in the different sectors (payments to all production factors) are also a good proxy for the change in the share of employment in manufacturing.

[14] A rising share of manufacturing in the trade war scenario goes along with a falling share of services and fossil fuels, as production factors are reallocated from services and fossil fuels to manufacturing. The share of services and fossil fuels are projected to fall respectively from 1.4% to 1% and from 82.8% to 82.5%. As analysed above the fall in the services sector is not only driven by a stronger demand for production factors in manufacturing, but also by the output reduction in the services sector transport, for which demand falls with less trade. We have not analysed to what extent the reduction in the share of fossil fuels is driven by less demand for inputs from this sector in sectors like transport.

workers leaving the initial sector of employment.[15] The labour displacement indicator is calculated as the weighted standard deviation of percentage changes in sectoral employment.[16] To calculate the number of workers leaving the initial sector of employment, we need data on the initial number of high-skilled and low-skilled workers employed.[17]

The table shows that the share of workers leaving their initial sector in case of a global trade conflict would be substantial, from 0.65% and 0.76% in respectively Brazil and Canada to 4.46% and 4.92% in the EFTA countries and Canada respectively, with a weighted global average of 1.15% and 1.74% for high-skilled and low-skilled workers respectively. The high numbers for Canada and EFTA can be explained by the fact that these two regions will face significant increases in tariffs imposed on their exports since the United States and the European Union are their main trading partners, respectively. In Brazil and Australia, we observe less variation in sectoral production. The estimates for the number of workers leaving their initial sector of employment are obviously highest for the most populous regions like China, India and Sub-Saharan Africa. Globally the estimated number of workers leaving their initial sector of employment is projected to be about 69 million.[18]

The estimates of the number of workers leaving their initial sector of employment should be treated with caution. In the one hand they might underestimate the number of people having to change jobs, because they only measure net labour displacement between sectors and not the reallocation of workers between firms within sectors, which cannot be calculated with our model. Taking into account the intra-sectoral reallocation between firms within sectors would raise the number of workers having to change employment because of a global trade conflict. On the other hand, they overestimate the number of people changing jobs, since our model assumes that wages are identical across sectors and workers will thus immediately leave sectors with lower wages. In reality there are costs of labour movement and workers will only move if their current situation is significantly worse than their outside option.[19]

[15] In principle workers could also leave their initial sector of production, because of better opportunities in other sectors. However, the simulation results show that real wages fall in all regions in a global trade conflict scenario, hence labour mobility is not driven by increasing wages. The fall in real wages of low-skilled workers ranges between 14.09% in Canada and 0.54% in the European Union.

[16] See for further discussion for example Bekkers, Francois and Rojas-Romagosa (2018).

[17] We calculate the initial number of workers as the value paid to workers divided by the initial wage. Since all the baseline data are values, we need additional data to get a proxy for the number of workers and the wage rate. As discussed in the Appendix we employ the UN data on labour force participation and data from the literature on the skill premium. To reduce the likelihood that the estimate for the skill-premium has a strong impact on the results, we only report the estimated total number of workers leaving their initial sector of employment and show that this estimate is robust to changes in the assumed skill premium. Further discussion of the calculation method is provided in the appendix.

[18] In calculating this number, we have assumed a skill premium of 1.8. With a skill premium of 1.5 the number would fall 68.22 million and with a skill-premium of 2, it would rise to 69.59 million. Hence, the global estimates are not very sensitive to the assumed skill premium.

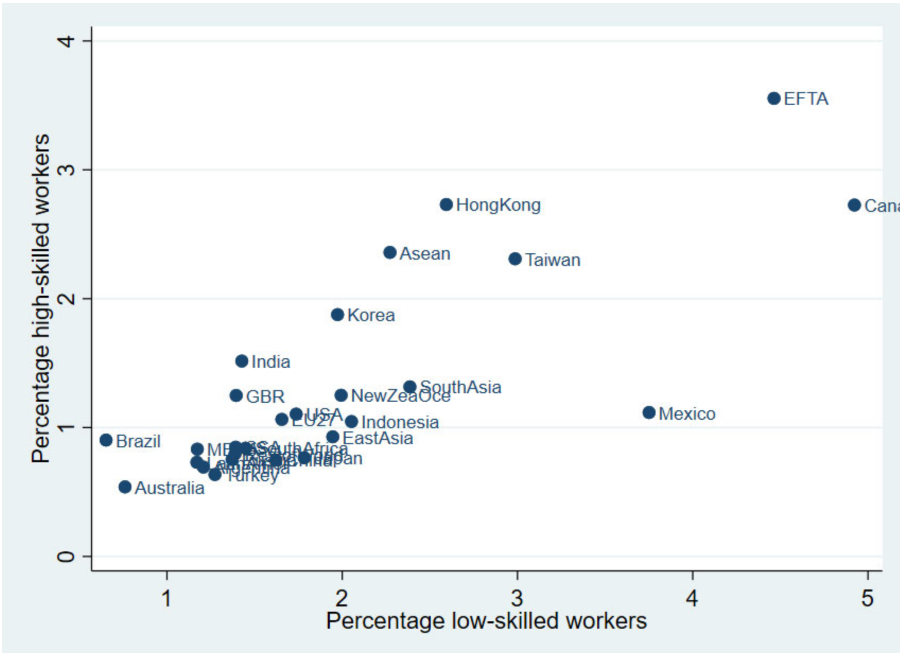
[19] See for example Artuç and McLaren (2015) who estimate relatively high costs of moving between sectors.

Table 7: Measures of labour displacement between sectors

Region	Labour displacement measure		Percentage of workers leaving initial sector		Number of workers leaving initial sector
	High-skilled	**Low-skilled**	**High-skilled**	**Low-skilled**	**Total**
ASEAN	6.30	6.57	2.36	2.27	5.61
Australia	3.82	4.52	0.54	0.76	0.10
Brazil	3.45	2.80	0.90	0.65	1.04
Canada	9.63	12.47	2.73	4.92	0.89
China	3.36	5.71	0.75	1.62	13.19
EFTA	12.22	14.48	3.55	4.46	0.35
EU27	5.40	7.27	1.06	1.66	3.73
Great Britain	6.71	6.70	1.25	1.39	0.52
India	4.70	4.86	1.52	1.43	12.42
Indonesia	4.70	6.75	1.05	2.05	3.18
Japan	3.68	6.79	0.77	1.78	0.97
Korea	5.39	6.68	1.88	1.97	0.66
Latin America	3.36	4.33	0.73	1.17	1.66
MENA	3.06	3.99	0.83	1.17	2.90
Mexico	5.50	11.62	1.12	3.75	2.44
Russia	2.54	3.94	0.75	1.37	1.00
Sub-Saharan Africa	3.76	4.97	0.85	1.39	6.36
Turkey	3.22	5.90	0.64	1.27	0.57
USA	4.56	6.42	1.10	1.74	2.92
Global average	**4.80**	**6.28**	**1.15**	**1.74**	**69.11**

Figure 7 displays the percentage of high-skilled and low-skilled workers leaving their initial sector of employment. The figure shows the same variation across countries as shown in Table 7. The figure also illustrates that on net a larger share of low-skilled workers leave their initial sector of production, because the sectors affected most, agriculture and manufacturing, are more low-skill intensive, whereas the least affected sector, services, is more high-skill intensive.

Figure 7: Percentage of high-skilled and low-skilled workers leaving initial sector of employment



6 CONCLUDING REMARKS

We have employed the WTO Global Trade Model to project the medium-run economic effects of a potential global trade conflict. The scenario for a global trade conflict is based on the estimates of the difference between cooperative and non-cooperative tariffs in the recent work of Nicita et al. (2018a, 2018b). Our analysis generated three main findings. First, the macroeconomic effects would be substantial. A global trade conflict starting in 2019 would reduce global GDP by about 1.96% in 2022 compared to a "baseline" situation without a trade conflict. For comparison, the financial crisis resulted in a decline of 12.4% in global trade and a contraction of 2.1% in global GDP. The value of global trade would be about 17% smaller (16.96%), whereas real income (nominal income divided by the price level) is projected to fall by 2.25%. There is substantial heterogeneity in the effects across countries with reductions in real income ranging between 0.18% and 0.26% for respectively the European Union and the United States and 6% and 6.62% for respectively Canada and the countries of ASEAN.

Second, behind the single-digit aggregate production effects there are much larger, double-digit sectoral production effects in many countries. Hence, there would be a painful adjustment process with many resources, labour and capital, having to be reallocated in the economy. In general, a global trade conflict would lead to a reallocation of resources away from their comparative advantage, thus constituting an important part of the welfare loss of a trade conflict. Nevertheless, the huge increase in tariffs in the United States would not lead to a substantial increase in the share of the manufacturing sector in the economy although it does reverse what would have been a decline otherwise (as shown in the baseline). Third, the large swings in sectoral production lead to substantial labour displacement. On average, 1.15% and 1.74% of high-skilled and low-skilled workers respectively would have to change sectors in response to a global trade conflict. Again, there is substantial heterogeneity across countries with the share of workers leaving their initial sector of employment projected to be almost 5% in Canada for example.

There are two important caveats to this study both related to the global trade conflict scenario employed. First, the question is whether political actors would follow rational rules in determining the size of tariff increases across sectors. Our analysis is based on empirically estimated differences between cooperative and non-cooperative tariffs, which are in turn based on political actors maximizing a social welfare function. However, the question is whether they do so in the real world. Second, assuming that political actors act rationally, what social welfare function do they employ and which groups in society (for example capital owners, workers, high incomes, low incomes, interests in particular sectors) receive the highest weight in their welfare function? In standard formulations, social welfare is the sum of consumer surplus, producer surplus and tariff revenues. This implies that political actors treat a dollar gained in one of these components (say consumer surplus) equally to a dollar lost in another component (producer surplus). Obviously, there could be less benign welfare functions. In Helpman and Grossman (1995) for example, political incumbers maximize a function that is a weighted average of social welfare and campaign contributions which implies organized producers are given more weight by political actors. As discussed at length in Nelson et al. (2019) the assumed social welfare function will have an impact on the optimal non-cooperative tariffs and the resulting Nash-equilibrium in case of a trade conflict.

Nevertheless, we have used the most recent estimates of the expected tariff increases in case of a global trade conflict available in the economic literature. Therefore, given our goal to project the medium-run effects of a potential trade conflict, a worst-case scenario for global trade policy, we think that we have employed the most reasonable scenario based on the current economic literature. Furthermore, given that the average tariff increases in our scenario are much smaller than for example in the work by Ossa (2014), we think that we have been on the cautious side.

Our work could be extended in three possible directions. First, the effects of uncertainty about a possible future trade conflict could be examined. At present, the global trade conflict is just a threat and not a reality. However, this does not mean that it cannot have real economic effects. In ongoing work, we combine insights from the literature on the effects of uncertainty about trade policy (Handley and Limão, 2017) with the global trade conflict scenario from Nicita et al. (2018a, 2018b) to come up with estimates of the trade effects of the increased probability of a global trade conflict. Second, the analysis on changes in specialization patterns away from comparative advantage could be extended. In particular, quantitative tools could be employed to determine how much the less-efficient pattern of specialization contributes to the welfare losses from a trade conflict. Third, in line with the discussion about the reasonability of the assumed scenario of a global trade conflict, other less-complicated scenarios could be explored, such as a 25% increase in tariffs across all sectors.

LITERATURE

Abrego, Lisandro, Raymond Riezman and John Whalley. 2006. "How Reasonable are Assumptions used in Theoretical Models? Computational Evidence on the Likelihood of Trade Pattern Changes." *Canadian Journal of Economics* 39(3): 781-789.

Daron Acemoglu and David Autor (2011). Skills, Tasks and Technologies: Implications for Employment and Earnings. Chapter 12 in Orley Ashenfelter David Card. Handbook of Labour Economics, Volume 4b.

Aguiar, Angel, Eddy Bekkers, Erwin Corong, and Dominique van der Mensbrugghe (2019). Manual WTO Global Trade Model.

Artuç, Erhan, John McLaren (2015). Trade policy and wage inequality: A structural analysis with occupational and sectoral mobility. Journal of International Economics 97: 278–294.

Bagwell, Kyle and Robert W. Staiger. 2002. *The Economics of the World Trading System.* Cambridge, MA: The MIT Press.

Baldwin, Robert E. and Richard Clarke. 1987. "Game-Modeling Multilateral Trade Negotiations". Journal of Policy Modeling 9(2): 257-284.

Balisteri, Ed J. and Russell H. Hillberry. 2017. "21st Century Trade Wars". Unpublished manuscript.

Bekkers, Eddy (2019). Comparing CGE and NQT Models: A Formal Overview of the Model Structures. WTO Working Paper No.

Bekkers, Eddy (2019). The Welfare Effects of Trade Policy Experiments in Quantitative Trade Models: the Role of Solution Methods and Baseline Calibration. WTO Working Paper No.

Bekkers, Eddy and Joseph F. Francois (2018). A Parsimonious Approach to Incorporate Firm Heterogeneity in CGE-Models. Journal of Global Economic Analysis 3(2): 1-68.

Bekkers, Eddy, Joseph F. Francois and Hugo Rojas-Romagosa (2018). Melting Ice Caps and the Economic Impact of Opening the Northern Sea Route. Economic Journal

Bekkers, E. and H. Rojas-Romagosa (2018). The welfare effects of free trade agreements in quantitative trade models: A comparison of studies about Transatlantic Trade and Investment Partnership. World Economy 42(1): 87-121

Bouët, Antoine and David Laborde. 2018. "US Trade Wars in the Twenty-first Century with Emerging Countries: Make America and its Partners Lose Again". *The World Economy* 41(9): 2276-2319.

Costinot, A. and A. Rodríguez-Clare (2013). "Trade Theory with Numbers: Quantifying the Consequences of Globalization," in Handbook of International Economics, ed. by G. Gopinath, E. Helpman, and K. Rogoff, North Holland, vol. 4.

Cronshaw, Mark B. 1997. "Algorithms for Finding Repeated Game Equilibria." *Computational Economics* 10:139-168.

Deardorff, Alan V. and Robert M. Stern. 1987. "Tariff and Defensive Responses: A Computational Analysis". *International Economic Journal* 1(2):1-23.

Dellink, Rob, Jean Chateau, Elisa Lanzi, Bertrand Magne (2017). Long-term economic growth projections in the Shared Socioeconomic Pathways. Global Environmental Change 42: 200-214.

Dixon, P.B., and M.T. Rimmer (2002). Dynamic general equilibrium modelling for forecasting and policy: a practical guide and documentation of MONASH, 1st ed., vol. 256. Amsterdam: Elsevier.

Dizioli, Allan Gloe and Björn van Roye (2018). Macroeconomic implications of increasing protectionism. ECB Economic Bulletin Issue 6/2018.

Foreman-Peck, James, Andrew Hallett and Yue Ma. 2007. "Trade Wars and the Slump". European Review of Economic History. 11: 73-98.

Foure, Jean, Agnes Benassy-Quere, and Lionel Fontagne (2013). Modelling the world economy at the 2050 horizon. Economics of Transition 21(4): 617-654.

Felbermayr, Gabriel and Marina Steininger (2019). Trump's trade attack on China – who laughs last? EconPol Policy Brief 2019-13.

Grossman, Gene M. and Elhanan Helpman. 1995. "Trade wars and Trade Talks." *Journal of Political Economy* 103(4): 675-708.

Hamilton, Bob and John Whalley. 1983. "Optimal Tariff Calculations in Alternative Trade Models and Some Possible Implications for Current World Trading Arrangements". *Journal of International Economics* 15(1983): 323-348.

Harrison, Glenn and E. E. Rutstrom. 1991. "Trade Wars, Trade Negotiations and Applied Game Theory". *The Economic Journal*, 101 (May 1991): 420-435.

He, Chuantian, Chunding Li, Jing Wang and John Whalley. 2017. "The Armington Assumption and the Size of Optimal Tariffs." *Economic Modelling*. 66(2017): 214-222.

International Monetary Fund (2018). World Economic Outlook. Challenges to Steady Growth. October 2018.

Johnson, Harry G. 1953. "Optimum Tariffs and Retaliation." *Review of Economic Studies* 21(2): 142-153.

Krugman, Paul. 1980. "Scale Economies, Product Differentiation, and the Pattern of Trade." *American Economic Review* 70 (5): 950–959.

Markusen, James R. and Randall M. Wigle. 1989. "Nash Equilibrium Tariffs for the United States and Canada: The Roles of Country Size, Scale Economies, and Capital Mobility". *Journal of Political Economy* 97(2):

Nelson, Doug, Eddy Bekkers, Joseph Francois and Hugo Rojas-Romagosa (2019). Rational Trade Wars & Stupid Trade Disputes.

Nicita, Alessandro, Marcelo Olarreaga and Peri Silva. (2018a). "Cooperation in WTO's Tariff Waters?", *Journal of Political Economy*, 126(3): 1302-1338.

Nicita, Alessandro, Marcelo Olarreaga and (2018b). " A Trade War Will Increase Average Tariffs by 32 Percentage Points", https://voxeu.org/article/trade-conflict-will-increase-average-tariffs-32-percentage-points

Ossa, Ralph. 2011. "A 'New Trade' Theory of GATT/WTO Negotiations." *Journal of Political Economy* 119(1):122-152.

Ossa, Ralph. 2014. "Trade Wars and Trade Talks with Data." *American Economic Review 1*04 (12): 4104–4146.

UN Department of Economic and Social Affairs Population Division (2015). World Population Prospects. The 2015 Revision.

APPENDIX

Table A1 Aggregation of regions, sectors and production factors

Regions	Sectors
Argentina	Grains
ASEAN	Vegetables, fruits, nuts
Australia	Oil seeds
Brazil	Other crops
Canada	Livestock
China	Forestry
EFTA	Fishing
European Union 27	Fossil fuels
Great-Britain	Minerals nec
Hong Kong	Meat and dairy products
India	Processed rice
Indonesia	Vegetable oils
Japan	Other processed food
Korea	Beverages and tobacco products
Mexico	Textiles
Middle East and North Africa	Wearing apparel
New Zealand, Oceania	Leather products
Rest of East Asia	Wood products
Rest of Latin America	Paper products, publishing
Rest of South Asia	Petroleum, coal products
Rest of World	Chemical, rubber, plastic products
Russia	Mineral products nec
South Africa	Ferrous metals
Sub-Saharan Africa	Metals nec
Taiwan	Metal products
Turkey	Motor vehicles and parts
United States	Transport equipment nec
	Electronic equipment
Production factors	Machinery and equipment nec
Capital	Manufactures nec
High-skilled labour	Utilities
Low-skilled labour	Construction
Land	Trade
Natural resources	Transport
	Communication
	Finance and insurance
	Business services nec
	Recreation and other services
	Public Administration/Defence/Health/Education

We need to obtain measures for the number of high-skilled and low-skilled workers or equivalent (given that value data are available) measures for high-skilled and low-skilled wages. The value of factor income spent on high skilled workers is equal to:

$$w(r,s)L(r,s) = EVFP(r,s)$$

We divide both sides by the number of high-skilled workers, $L(r,s)$, to obtain an expression for the high-skilled wage, $w(r,s)$:

$$w(r,s)=\frac{EVFP(r,s)}{POP(r)}\frac{POP(r)}{L(r,s)+L(r,u)}\frac{L(r,s)+L(r,u)}{L(r,s)}$$

$$=\frac{EVFP(r,s)}{POP(r)}\frac{POP(r)}{L(r,s)+L(r,u)}\left(1+\frac{w(r,u)L(r,u)}{w(r,s)L(r,s)}\frac{w(r,s)}{w(r,u)}\right)$$

$$=\frac{EVFP(r,s)}{POP(r)}\frac{1}{PR(r)}\left(1+\frac{SP(r)}{SPV(r)}\right)$$

Hence, we can write the high-skilled wage as a function of observables in the GTAP data, the wage sum, EVFP(r,s), the ratio of the wage sum to skilled and unskilled workers or the skill premium in value, SPV(r), and population, POP(r). The participation rate, PR(r), can be obtained from UN projections. The skill premium, SP(r), defined as the ratio of high-skilled to low-skilled wages, is set at 1.8, following the data reported for the US in the handbook chapter by Acemoglu and Autor (??). These authors report a log skill-premium (the log wage of people with college relative to people with high-school) in 2009 in the United States of about 0.68, corresponding with a 97% higher wage of college educated relative to high-school educated. Since we expect the skill premium in most other regions to be smaller than in the United States, we assume a skill premium (the ratio of high-skilled wage to low-skilled wage) of 1.8. However, as discussed in the text the reported total number of workers leaving their initial sector of employment is robust to changes in the assumed skill premium.

We get for low-skilled wages:

$$w(r,u)=\frac{EVFP(r,u)}{POP(r)}\frac{POP(r)}{L(r,s)+L(r,u)}\frac{L(r,s)+L(r,u)}{L(r,u)}$$

$$=\frac{EVFP(r,s)}{POP(r)}\frac{POP(r)}{L(r,s)+L(r,u)}\left(1+\frac{w(r,s)L(r,s)}{w(r,u)L(r,u)}\frac{w(r,u)}{w(r,s)}\right)$$

$$=\frac{EVFP(r,u)}{POP(r)}\frac{1}{PR(r)}\left(1+\frac{SPV(r)}{SP(r)}\right)$$

Since we do not have good estimates for the skill-premium per region in the simulations, we report only the total number of workers leaving their initial sector of employment, since this measure is relatively insensitive to the assumed skill-premium as is discussed in the main text.