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 WP/19/143

IMF Working Paper

Strategy, Policy, and Review Department and Western Hemisphere Department

Trade Wars and Trade Deals: Estimated Effects using a Multi-Sector Model[1]

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June 2019

Abstract

This paper studies the potential long-term effects of three illustrative scenarios using a multi-sector computable general equilibrium (CGE) trade model calibrated to 165 countries. The first scenario estimates effects from potential U.S. auto tariffs. The second analyzes a 'transactional deal' between the U.S. and China to close their bilateral deficit. The third, in the absence of such a deal, considers a potential escalation in bilateral tariffs between the two countries. Some common features emerge across all three scenarios: the overall effects on GDP tend to be relatively small albeit negative in most cases, including for the U.S. However, sectoral disruptions and positive and negative spillovers to highly exposed 'by-stander' economies can be large. There is also heterogeneity at the subnational level in the U.S. -- richer states tend to benefit from certain scenarios. We discuss how estimated impacts depend on the extent to which the U.S. is able to re-shore production in protected sectors. These results can usefully complement estimates obtained through macroeconomic models that are better suited to capture dynamic effects, such as those stemming from trade policy uncertainty. More generally, our results both underscore the value of adhering to the existing levels of liberalization, and highlight the risks associated with a fragmentation or even a complete breakdown of the trading system.

JEL Classification Numbers: D57, D58, F10, F12.

Keywords: general equilibrium; trade; tariffs; trade tensions; global value chains.

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[1] We are extremely grateful to Lorenzo Caliendo for sharing some of his codes and for many insightful conversations, and to Nigel Chalk, Rupa Duttagupta, Martin Kaufman, Daniel Leigh and Brad McDonald for extensive discussions. We would also like to thank Helge Berger, James Daniel, Ben Hunt, Florence Jaumotte, Koshy Mathai, Susanna Mursula, Jay Peiris, Roberto Piazza, Rafael Portillo, Marika Santoro and various IMF seminar participants for constructive comments. All errors are ours.

Table of Contents

I. INTRODUCTION

After five decades of negotiations that culminated with the creation of the WTO in 1995, low tariffs in advanced economies became one of the pillars of the international trading system, facilitating trade, prompting subsequent liberalization in emerging markets, and underpinning the development of global supply chains. While there was, and still is, room for further tariff reductions in certain sectors of advanced economies, average tariffs had reached such low levels that the negotiating agendas of advanced economies eventually evolved to address non-tariff barriers ranging from regulatory cooperation to digital trade. This landscape changed abruptly in 2018 when the U.S. administration imposed, or announced they might impose, higher tariffs targeting specific sectors or specific trading partners. From the U.S. perspective, the tariffs respond to concerns about various longstanding market-distorting government interventions and policies by trading partners, including on technology transfer and subsidies to state-owned enterprises, and in some cases concern regarding U.S. national security interests. With the prospect of higher tariffs taking center stage again, their possible adverse effects on different economies is a key concern among policy makers around the world. In this paper, we use a multi-sector trade model to systematically estimate the effects of three potential trade policy actions by the U.S. that might have systemic importance.

While trade policy agendas slowly expanded to other issues, the theory of international trade continued to make progress in developing models to understand how tariff barriers might affect global production and consumption patterns. We take advantage of this progress by simulating the effect of tariff changes using one such state-of-the-art computable general equilibrium model, developed by Caliendo, Feenstra, Romalis and Taylor (2017; CFRT henceforth), we simulate the effect of potential tariff changes using input-output data covering 165 countries and 17 sectors. We use detailed tariff data, including tariff data predating the current period of heightened trade tensions.

Two fronts of ongoing U.S.-related trade disputes give rise to the three scenarios we study. The first one relates to the potential introduction of tariffs on imported autos and auto-parts, in the context of the U.S. Commerce Department’s Section 232 (national security) investigation of the sector. The second set of scenarios corresponds to U.S.-China trade relations, which for the U.S. at least partly falls under the umbrella of a Section 301 (technology transfer) investigation. In particular, we model two possible outcomes of this dispute. The first one involves what we call a ‘transactional deal’ between the two countries, which resembles a managed-trade outcome. In our framework, such a deal could potentially involve an increase in Chinese purchases of U.S. goods and/or voluntary export restraints by China that limit its sales of certain goods to the U.S. The scenarios are calibrated such that each side closes half of the bilateral trade deficit between the two countries. In the absence of such a deal, an escalation of bilateral tariffs becomes more likely. Such an escalation is the focus of our third and final scenario.

It is important to note upfront that, as discussed in more detail subsequently, the implementation of these scenarios involves certain modeling choices. This is undoubtedly a reflection of the uncertainty surrounding the possible outcomes of ongoing trade negotiations. For instance, retaliation by trading partners following the introduction of tariffs by the U.S. could take different forms; a transactional deal between the U.S. and China could involve other sectors or include reforms that are pursued on a most-favored-nation basis; and an escalation of tensions between these two countries may go hand-in-hand with liberalization efforts vis-à-vis other partners. Given this intrinsic uncertainty, this paper aims to contribute more broadly to the understanding of the main drivers and channels through which some potential increases in trade barriers can affect production chains, trade, and consumption patterns around the world.

The uncertainty around ongoing negotiations is compounded in some cases with the fact that no perfect model exists to fully assess the effects of certain policy changes. For example, existing models may not be well suited to analyze changes in areas such as investment regimes and intellectual property, or—more fundamentally—the risks posed by a rejection of the rules-based global trading system (see e.g. Mattoo and Staiger, 2019). While the focus of this study is modeling the effect of changes in certain trade barriers, it is important to bear in mind that some policy changes not modeled explicitly within this framework can have first-order effects on economic activity.

Despite their varied nature, some common features emerge across all three scenarios we model. First, that while aggregate GDP effects are relatively small, they are negative for most countries. This includes the U.S., which is estimated to lose in most scenarios as 'protected' sectors do not expand sufficiently to make up for the loss of competitiveness in the rest of the economy. This is largely a result of increased protection applying to sectors for which foreign production is difficult to substitute domestically. Second, spillovers to third countries are generally a function of direct exposures to (i.e. gross trade flows with) the markets affected by the tariffs, although in some cases indirect exposures through supply chains are of first-order importance. Third, there is a wide variation at the sectoral level, with the results suggesting that there would likely be very high adjustment costs in the process of attaining a new equilibrium. This variation at the sectoral level also translates into heterogeneous impacts across U.S. geographic regions and across the income distribution. A transactional deal with China would, in particular, benefit U.S. states with a high share of primary sector (mining, hydrocarbons, and agriculture) activity in total value added, such as Arkansas, North Dakota, Oklahoma, and Wyoming, whereas these states would suffer most under the auto tariffs scenario. Importantly, richer states seem to benefit from certain trade scenarios, whereas poorer ones seldom benefit from any of these. Finally, we show how the estimated impacts are a function of various assumptions, including – crucially – the extent to which the U.S. is able to re-shore production in the affected sectors.

To see how the results of this paper contribute to our understanding of the potential effects of trade tensions, it is instructive to contrast the tool we use with other modeling approaches.[2] In particular, sectoral trade models (like the CFRT framework we use) can provide a useful complement to macroeconomic models, such as the IMF's Global Integrated Monetary and Fiscal (GIMF) model.[3] While the GIMF model can yield valuable information on shorter-term demand effects and the role for rigidities and longer-term macro distortions, trade models can shed light on potential long-term supply-chain disruptions. The trade model and

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[2] See Section II.A for further discussion of the modeling approach

[3] See e.g. Scenario Box 1 in IMF (2018a) for an application of GIMF to the auto-sector scenario, and Box 1.4 in IMF (2019) for a GIMF-based simulation of the U.S.-China escalation scenario.

the data that we use are particularly well-suited to study the longer-term allocative-inefficiency of tariffs that are targeted to specific productive sectors (17 in our calibration), and their spillovers to specific countries (165 in our calibration). Of course, no model can capture all aspects of reality, and this one is no exception. Most important to bear in mind is that the model we use does not have any dynamics, and as such it describes the steady state implications and ignores any effect trade tensions may have on uncertainty. As has been widely documented in recent research, the uncertainty related to trade policy can have detrimental effects on investment and economic activity.[4]

Our overarching finding that the trade scenarios we model tend to produce negative outcomes for the parties involved does not imply that the status quo is optimal. Rather, the U.S. and its trading partners could work constructively, not only to better address distortions in the trading system and in individual countries' trade regimes, but also to tap trade policy areas that have high growth potential (IMF-WB-WTO, 2018). Our results both underscore the value of adhering to the existing levels of liberalization, and highlight the risks associated with a fragmentation or even a complete breakdown of the trading system where new and longstanding issues remain unresolved.

The rest of the paper is organized as follows. Section II presents the model as well as the main databases used to estimate the impact of tariff changes. This section also discusses the estimation of elasticities of substitution, which are key for the model results. Section III describes the analyzed scenarios and presents the corresponding results. Section IV discusses the sensitivity of the results to the calibration of key parameters, including the assumed elasticities of substitution. Section V concludes.

II. Model, Data and Calibration

A. A Multi-sector Trade Model

Our simulations rely on the multi-sector computable general equilibrium model developed by Caliendo *et al* (2017; CFRT). The model puts together several recent advances in the theory of international trade. Most notable among them are the assumption that firms within each sector are heterogeneous in their productivity, and that international trade arises in the context of cross-border input-output relationships. Firm heterogeneity, as in Melitz (2003), has been found to explain various features of micro-data on trade, such as within-industry reallocation of resources in the wake of trade liberalization (for a survey, see Melitz and Redding, 2014). This means than in the policy simulations below, firms may enter or exit export markets in response to tariff changes. Likewise, trade in intermediate inputs should arguably be part of any model that aims to assess the potential effects of changes in trade barriers in a world with long and complex global supply chains. The approach to intermediate-input trade used in CFRT was originally developed by Caliendo and Parro (2015; CP).

[4] See e.g. Handley and Limão (2017). Scenario Box 1 in IMF (2018a) uses GIMF to gauge the effects of trade policy uncertainty on economic activity.

Admittedly, CFRT is not the only trade model with firm heterogeneity and supply-chain trade. However, their framework has two key advantages over other related contributions to the literature. To give a better sense of this, it can be instructive to highlight these two aspects by comparing the framework in CFRT with that of Costinot and Rodriguez-Clare (2014; CRC hereafter).[5]

First, in CRC, tariffs are modeled as a variable production *cost* that firms pay, rather than as a wedge in *revenues* firms receive. When modeled as a *cost* shifter, changes in bilateral tariffs act in exactly the same way as changes in the corresponding bilateral iceberg (i.e. non-tariff-barrier trade) cost (with the exception that tariffs generate revenue that can then be redistributed, thus affecting income and demand). As shown by CFRT, when modeled as a *revenue* shifter, a reduction in a bilateral tariff is analogous to a joint reduction of the bilateral iceberg cost as well as the fixed exporting cost.[6] The benefits of tariff reductions can therefore be potentially much larger when tariffs are (correctly) modeled as revenue shifters.

Second, the imperfect-competition models presented in CRC can produce corner solutions. For example, upon the imposition of tariffs on goods from industry *j* by country A, country B may shut down industry *j* altogether and specialize in other industries. This result, however, is non-generic, in the sense that it depends on a highly-specific calibration of elasticities of substitution. In particular, if instead of assuming an elasticity of substitution of one between home and foreign goods (i.e. a Cobb-Douglas aggregation), an elasticity higher than one is used, then corner solutions no longer arise (Kucheryavyy *et al*, 2016).[7] While all these aspects may seem largely technical, they matter a great deal in practice when modeling the effect of changes in trade barriers, particularly at the sectoral level.

Before proceeding, it is worth flagging some shortcomings of CFRT that, to the best of our knowledge, are common to most existing trade models (exceptions to this include e.g. Eaton *et al*, 2016, Reyes-Heroles, 2016 and Ravikumar *et al*, 2019). First and foremost, that the model does not account for investment. This is important as changes in capital accumulation, which could be prompted by episodes of closing off to trade, can lead to *inter alia* changes in productivity, thus affecting output over the medium and long term. Over shorter horizons, the omission of investment also implies that the effects of trade-policy uncertainty on investment decisions cannot be analyzed within this framework either. Lower consumer and producer

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[5] CRC present a number of quantitative trade models, the most complex of them having the same features as CFRT: firm heterogeneity, imperfect competition, and intermediate-input trade.

[6] See footnote 11 and eq. (10) in CFRT; see also Section 5 of the online Appendix in CRC. CRC argue for the simpler approach of modeling tariffs as cost shifters given lack of evidence of whether tariffs affect revenues or costs (see footnote 30 in CRC). Clearly, ad-valorem tariffs apply to the final price of goods, so that having them as revenue shifters appears to be the only realistic modeling approach (except for the case of perfect-competition models, in which price equals marginal cost and this modeling choice is therefore irrelevant).

[7] The fact that economies of scale may generate specialization is well known. What is problematic is that this result (a) appears to be non-generic, as it vanishes once an elasticity of substitution between home and foreign goods is just above unity, and (b) shows up under relatively mild changes in trade policy. For example, in a 28-sector and 15-country application of the monopolistic competition models by CRC using standard elasticity estimates, a 25 percent increase in U.S. auto tariffs leads to a 100-percent drop in total Canadian auto exports. These results are available from the authors upon request.

confidence or higher cost of funding (i.e. spreads) and financial market volatility can all dent investment and have significant macroeconomic effects.[8]

Lastly, it is worth mentioning that—in order to close the model, and as is standard in the new quantitative trade literature—overall trade balances are assumed fixed. This is another byproduct of the model featuring no dynamics. In particular, since the model is static and only allows for comparisons between pairs of steady states, it is unable to explain non-zero trade balances (which are intertemporal in nature). This short-coming may not be as serious as it may appear at first. From a conceptual viewpoint, there is overwhelming evidence that macroeconomic fundamentals are far more important than sectoral and bilateral-trade policies (including tariff changes) in determining countries' overall saving-investment balances (see, for instance, IMF, 2018b and IMF, 2019). From a practical point of view, dynamic models that allow for endogenous changes in overall trade balances have found a relatively muted effect on these, even under large changes in tariffs (see IMF, 2019).[9]

B. Construction of Main Database

The use of input-output (I-O) data is key to quantify and account for the bilateral interaction matrix not only across countries, but also across sectors. In this paper we rely on the Eora global supply chain database, which consists of a multi-region input-output table (MRIO), containing data for many countries in the world.

The original Eora database represents a balanced global MRIO table linking 26 sectors across 190 countries, with a complete annual time-series over the period 1990-2015. See Lenzen *et al* (2013) for a detailed description of the Eora database. Our trade-flow data correspond to the latest (2015) Eora table.

For the analysis presented in this paper, the Eora database is combined with 2015 applied-tariff data from UNCTAD's Trade Analysis Information System accessed through WITS. The intersection of both databases results in a combined I-O database, with 17 sectors and 165 countries. Table 1 lists the 17 sectors included in our analysis.

This database thus enables the analysis of all bilateral exposures—among the 165 countries—at the sectoral level. As an illustration of the data, Figure 1 presents the details of the sectoral gross exports (imports) of the U.S. to (from) some of its main trading partners, including Canada, China, Germany and Mexico, among others.

[8] Indeed, simulations based on macro models suggest that trade-policy-uncertainty and confidence effects can be significant relative to the direct effects of increase tariffs. See IMF (2018a).

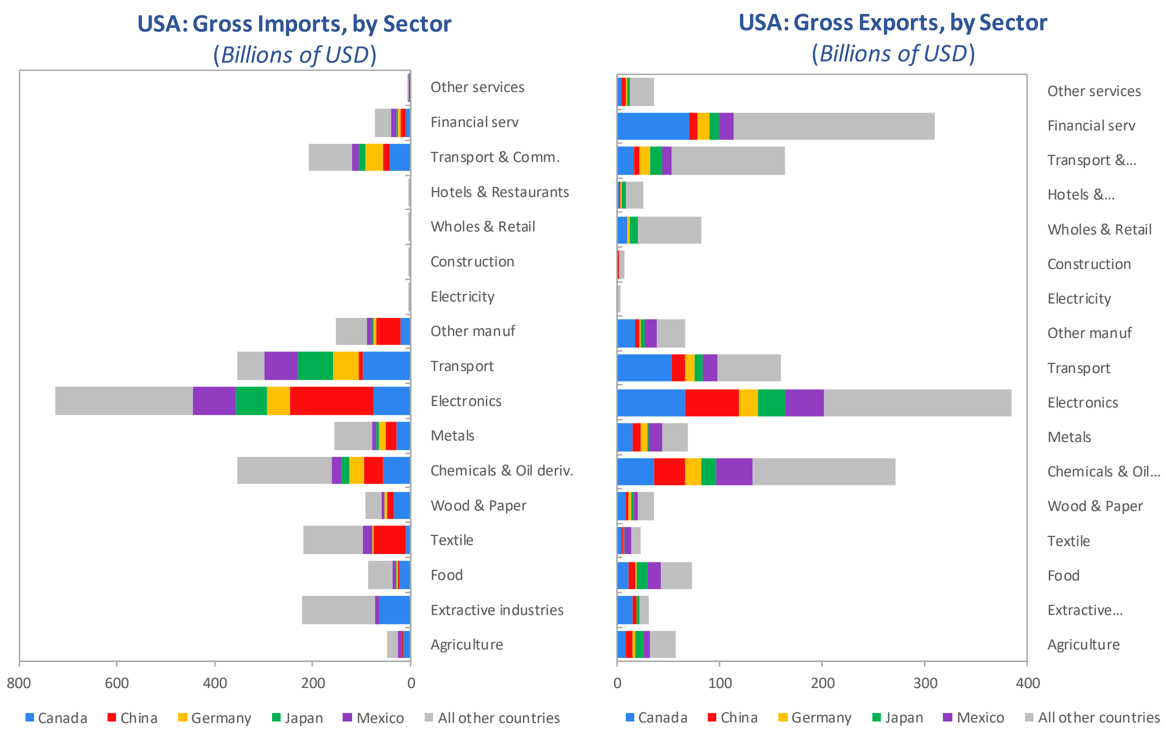
[9] Within the model we use, we are also reassured by the fact that countries' terms of trade do not exhibit large swings in any of the scenarios considered below. As argued by Ossa (2016), the customary assumption of fixed trade balances can produce "[…] extreme general equilibrium adjustments for high tariffs as the model then tries to reconcile falling trade volumes with constant aggregate trade deficits and cannot hold at all in the limit as tariffs approach infinity." Given our estimated price changes, the assumption of fixed overall deficits appears to be adequate for the changes in tariffs considered.

Table 1: Economic sectors included in the analysis

Goods	*Services*
Agriculture	Construction
Extractive industries	Wholesale & retail
Food	Hotels & restaurants
Textile	Transport & communication
Wood & paper	Financial services
Chemicals & oil derivatives	Other services
Metals	
Electronics	
Transport goods	
Other manufacturing	
Electricity	

Source: IMF staff calculations.

Figure 1: U.S. Sectoral Gross Trade Flows with Selected Countries, 2015



Source: Eora database; and IMF staff calculations.

C. Calibration of Elasticities of Substitution

In CFRT, there are two sets of sector-level elasticities that play a key role in determining the effect of new tariffs: (i) elasticities of substitution across foreign or domestic intermediate inputs (σ_s, where s indexes sectors); and (ii) elasticities of substitution across composite foreign and domestic inputs (ω_s). Elasticities in (i) are assumed larger than those in (ii). Such a determination is motivated by technical considerations, as explained in sub-section 2.A, as well as empirical considerations, since in practice switching inputs between two foreign suppliers is easier than switching from a foreign to a domestic supplier.

Estimating elasticities across intermediate inputs (σ_s)

The first set of elasticities – those across foreign or domestic intermediate inputs – are newly estimated in this paper. We follow the steps described just after Table 1 in CFRT. We start with estimating Γ^s in equation (1) following the triangular trade procedure described in Section 4 of Caliendo and Parro (CP 2015) for the goods-producing sectors in Eora. Data on tariffs for each sector, s, between any two countries, j and k, (τ_{kj}^{s}) and corresponding trade flows (X_{kj}^{s}) for the year 2016 are from UNCTAD Trade Analysis Information System and sourced through WITS.

$$\ln\left(\frac{X_{ni}^{s}X_{ih}^{s}X_{hn}^{s}}{X_{in}^{s}X_{hi}^{s}X_{nh}^{s}}\right) = -\Gamma^{s}\ln\left(\frac{\tau_{ni}^{s}\tau_{ih}^{s}\tau_{hn}^{s}}{\tau_{in}^{s}\tau_{hi}^{s}\tau_{nh}^{s}}\right) + \tilde{\varepsilon}^{s} \qquad (1)$$

Equation (1) is estimated over three samples, one with all bilateral trade data, another excluding 5 percent of the smallest flows and another excluding 10 percent of the smallest flows, the latter being our preferred sample as it excludes small outliers that unduly tilt the estimation.

Table 2. Sector-level trade elasticities

Sector #	Simplified sector name	CP (2015)	Preferred
1	Agriculture, Hunting, Forestry and Fishing	9.1	9.1 2/
2	Extractive Industries	13.5	19.0
3	Food, Beverages and Tobacco	2.6	2.5
4	Textiles, Textile Products, leather and footwear	8.1	3.0
5	Wood, Paper, Printing and Publishing	14.0 1/	5.4
6	Petroleum, Chemical, Non-Metallic Mineral Products	18.1 1/	12.1
7	Metal Products	7.0	13.9
8	Electrical equipment and Machinery	4.8 1/	2.6
9	Transport equipment	8.2	8.0 3/
10	Manufacturing, Nec; Recycling	4.0	4.0 2/

Sources: Caliendo and Parro (2015); and IMF staff calculations.
Notes: 1/ Simple-averaged elasticities of more disaggregated sectors. 2/ Using the same as CP. 3/ Simple-average of elasticities across goods producing sectors.

Table 2 shows our preferred calibration of Γ^s and compares it to the estimates in CP (2015).[10] Note that for sectors 1 and 10 we simply use the values from CP, as our estimates are not robust across samples. Estimates for sector 9 were also not robust as had been the case for CP, and – following CP – we take the mean elasticity across all other goods-producing sectors.

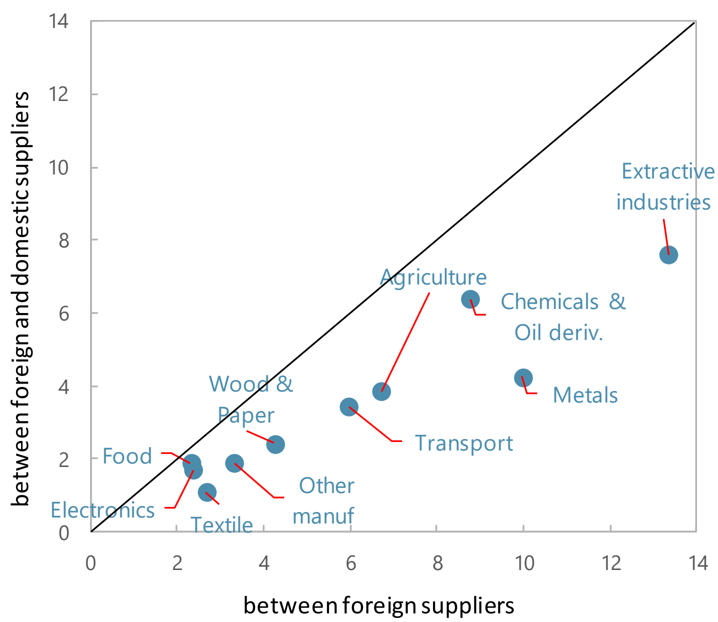
The estimates in Table 2 for Γ^s correspond to the first set of numbers in Table 1 of CFRT. We follow the procedure in CFRT and calibrate σ_s based on the relation between the sectoral elasticities of substitution and the Pareto shape parameter estimated by Eaton, Kortum and Kramarz (2011). In particular, if Γ^s denotes our estimated elasticities from Table 2, then $\sigma_s = (\Gamma^s + 1)/1.5$.

Calibrating elasticities across final domestic and foreign goods (ω_s)

To calibrate the foreign-domestic elasticities of substitution we rely on the estimates by Feenstra *et al* (2018; FLOR henceforth).

The codes provided in the published version of FLOR were used to estimate σ_s and ω_s, under their two-stage least squares procedure consistent with the estimates presented in their table 3. Then we computed the ratio σ_s/ω_s for each sector *s* and matched their sectors to the Eora-based sectors we use, to finally compute ω_s using our own estimates of σ_s. For sectors that could not be matched, we used the simple average of the ratio, which is 1.76. The resulting sectoral elasticities of substitution are presented in Figure 2.

Figure 2: Estimated Sectoral Elasticities of Substitution



Source: IMF staff calculations.

[10] Detailed estimates across all three samples are available upon request.

III. Scenarios and Results

This section is split in three sub-sections. The first defines and describes the scenarios analyzed. The second presents the main results for each of these scenarios using the multi-sector model on the U.S. and China. Finally, the third sub-section discusses spillovers to 'third countries'.

A. Scenario Definition

We quantify the impact of three scenarios: (i) the U.S. introduces tariffs on its imports of autos and auto-parts from all countries; (ii) the U.S. and China strike a "transactional deal" in which their bilateral trade deficit is cut in half in two ways; and (iii) the negotiations between the U.S. and China break down and they impose higher tariffs on imports from one another.

Each of these three scenarios is described in detail in what follows. In general, the baseline uses the configuration of tariffs in effect at end-2018, i.e. after some of the recent U.S. measures and its trading partners' responses, with the exception of scenario 3 where tariffs of 10 percentage points on $200 billion worth of U.S. imports from China and subsequent Chinese retaliation are excluded from the baseline. Finally, it is worth mentioning from the outset that, in setting our three scenarios, we make no judgment as to the consistency of the tariff changes or partner responses with any of the commitments countries may have made, either with the WTO or in other contexts.

Scenario 1: U.S. tariffs on imports of autos and auto-parts

In this scenario, the U.S. introduces a 25 percent tariff on all imports of vehicles and auto parts, independently of their origin or trading partner.[11] In retaliation, all trading partners directly affected by U.S. tariffs (i.e. those that export autos or auto-parts to the U.S.) also impose an equivalent 25 percent tariff on imports of vehicles and auto-parts from the U.S. In addition, given that several of these trading partners have a bilateral trade surplus of autos and auto-parts with the U.S. (see Figure 1), the imposition of the 25 percent tariff on imports from the U.S. of autos and auto-parts does not yield the same overall tariff revenue as it does for the U.S. Therefore, the scenario assumes that these countries would impose additional tariffs—uniformly across all other U.S. goods exports—such that their overall static tariff revenue equals that of the U.S.[12] In other words, for each country we have:

$$\begin{aligned} &25\%\ x\ value\ of\ U.S.\ auto\ \&\ auto\text{-}part\ imports\ from\ country\ i \\ &\qquad = 25\%\ x\ value\ of\ country\ i's\ auto\ \&\ auto\text{-}part\ imports\ from\ the\ U.S. \\ &\qquad +\ Z\%\ x\ value\ of\ country\ i's\ all\ other\ imported\ goods\ from\ the\ U.S. \end{aligned}$$

[11] USMCA side-letters would exempt Canada and Mexico from U.S. auto tariffs up to certain quotas. The potential effect of such exemptions is analyzed in more detail in the next section.

[12] Box 1 explores the effects on U.S. states of an alternative, 'selective' form of retaliation which targets specific U.S. sectors.

where the tariff rate $Z \geq 0$ is chosen such that the above equality holds.

Finally, all tariffs on autos and auto parts are mapped to the "transport equipment goods" sector in our calibration by using the share of autos and auto parts in total bilateral flows of auto-related, trains, airplanes and other transport equipment with the U.S. in 2017 from UN/Comtrade.

Scenario 2: A "transactional deal" between the U.S. and China

One of the main objectives of a trade deal between the U.S. and China appears likely to be the elimination, or at least a significant reduction, of the bilateral deficit between these two countries. We model two possible aspects that a deal aimed at reducing the bilateral deficit may involve. First, we introduce policy changes that induce an increase in Chinese purchases of U.S. goods such that the bilateral deficit is halved. We implement this change via a simultaneous reduction in Chinese non-tariff import barriers vis-à-vis the U.S. and an increase in non-tariff import barriers vis-à-vis non-U.S. trading partners. The simultaneous increase and reduction in these barriers is calibrated such that each achieves half of the goal (i.e. each reduces the bilateral deficit by one-quarter). We exploit the sectoral dimension of the model and data in two ways: the relative change in barriers is scaled by the inverse of the elasticity of substitution of each of these goods, with the exception of three sectors (agriculture, extractive industries and transport equipment) for which – in order to reflect reports of larger purchases possibly being targeted to specific sectors – we introduce especially large changes in barriers.[13]

The second possible aspect of a deal that we model is a reduction in exports of electronics and other manufactured goods from China to the U.S.[14] This is attained through the introduction of export tariffs on these sectors' goods bound for the U.S., with the sectoral changes inversely proportional to elasticities of substitution. This reduction in exports is calibrated such that it also reduces the bilateral deficit by one-half.[15]

Scenario 3: Escalation of trade tensions between the U.S. and China

Scenario 2 assumes that a deal is agreed between the U.S. and China. In the absence of such a deal, it is possible that, instead of a resolution of the ongoing dispute, tensions intensify leading to higher bilateral tariffs. Our third scenario therefore assumes that the U.S. imposes

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[13] The first consideration – that sectors with higher elasticities of substitution experience smaller tariff changes – has two key advantages, over and above offering a seemingly nondiscretionary way of handling the many degrees of freedom involved in modeling such a transactional deal. First, it helps avoid unreasonable changes in quantities that can emerge if large tariff changes are assumed for highly-elastic sectors. Second, by relating tariff changes to inverse elasticities as in Ramsey's optimal taxation framework, the calibration helps put a lower bound on how distortive such a deal can be in practice.

[14] Export restraints were used by Japan to limit its automobile exports to the U.S. before the creation of the WTO, and were part of the Multi Fibre Arrangement that limited developing countries' textile exports to developed countries. More recently, Korea agreed to voluntarily reduce its exports of steel and aluminum to the U.S. A WTO dispute settlement panel related to this issue has been recently established.

[15] See Appendix A for details on how we modified the model in CFRT to include export tariffs.

a 25 percent uniform tariff on all goods imported from China and that China retaliates by imposing the same 25 percent uniform tariff on all U.S. goods.[16]

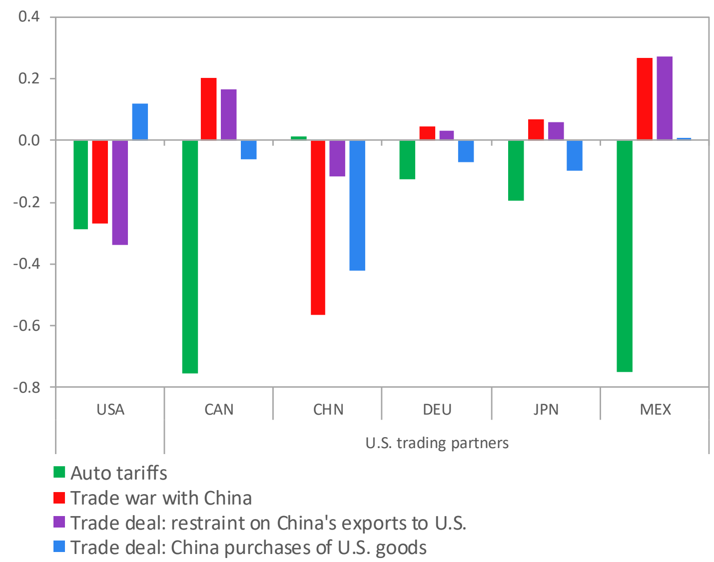
The remainder of this section presents the results obtained from model simulations of each of these scenarios, both for the U.S. as well as for its main trading partners and third countries.

B. Effects on the U.S.

An overarching result from our simulations is that U.S. GDP falls under all three scenarios — by around 0.2-0.3 percent of GDP—following the introduction of tariffs (Figure 3).[17] In other words, U.S. GDP falls under a wide range of trade 'tensions' and 'deal' scenarios.

Significant sectoral disruptions take place in the background (Figure 4). Moreover, and contrary to the effect on GDP, which was similar across scenarios, the changes in sectoral value added are fairly heterogenous and highly dependent on the scenario under consideration. For instance, the U.S. agricultural sector benefits noticeably from larger purchases of U.S. goods under a "transactional deal", as China treats such goods highly preferentially. However, the agricultural sector contracts under the auto tariffs scenario as several U.S. trading partners retaliate by increasing tariffs on that particular sector in order to match the intensity of the U.S. tariffs.

Figure 3: Real GDP impact on the U.S. and selected trading partners
(*percent change*)



Source: IMF staff calculations.

[16] As with scenario 2, the escalation scenario may in practice involve changes in policies that the model we use cannot quantify, such as e.g. restrictions on FDI or on technology-transfer policies.
[17] This general result is fairly robust to different specifications and varying assumptions, as will be shown in subsequent sections.

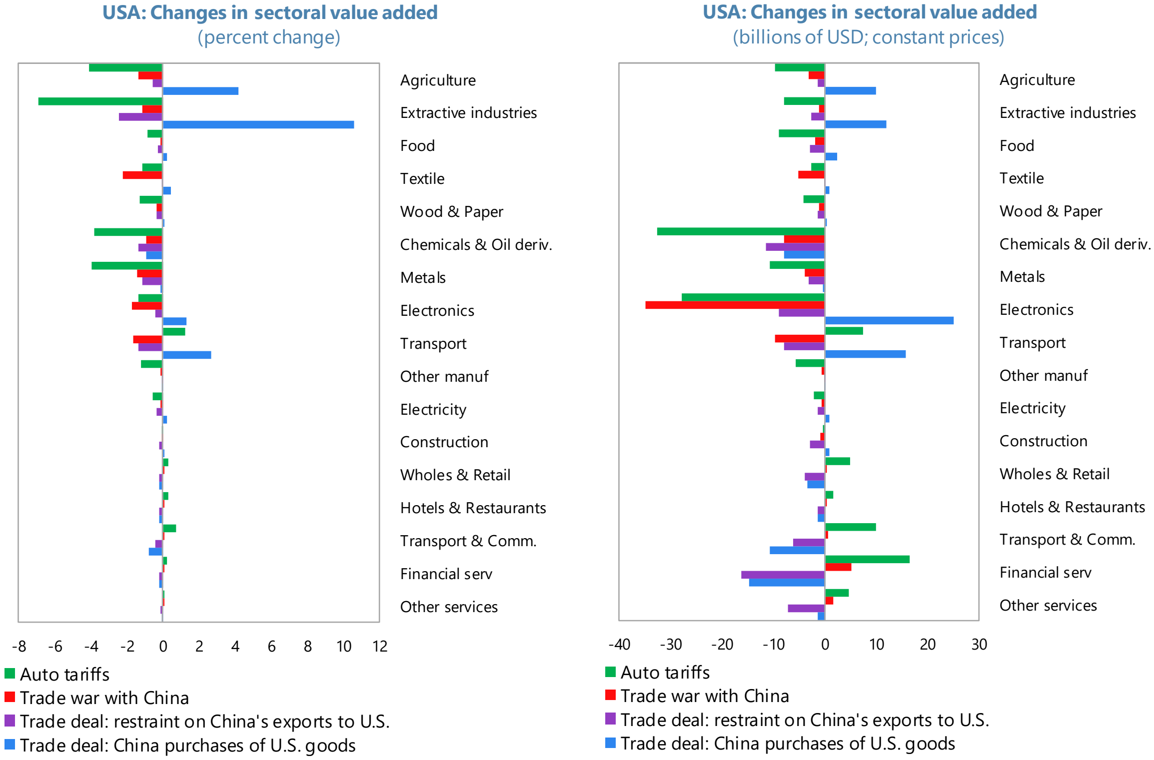
That the U.S. might lose out as a result of higher tariffs on a specific sector and across all partners (Scenario 1) or due to higher tariffs on a specific partner across all sectors (Scenario 3) is relatively unsurprising. Increased U.S. tariffs imply higher distortions for U.S. firms and consumers, with the new equilibrium associated with less-efficient and more-expensive suppliers. This effect is compounded by the income losses firms must grapple with as a result of U.S. partners' retaliation.[18]

Perhaps more surprising is that – on net – U.S. overall GDP appears to fall under the transactional-deal scenario with China (Scenario 2). This is due to the opposing effects of the two parts of the deal that were implemented: on one hand, additional purchases by China clearly benefit some sectors in the U.S. (see corresponding blue bars in Figure 3). However, the reduction in Chinese exports of selected manufacturing goods ("electronics" and "other manufacturing" sectors) to the U.S. does not lead to a meaningful expansion of the protected sectors in the U.S., which themselves partly rely on Chinese inputs to produce. This inability of U.S. protected sectors to expand also implies that all U.S. sectors now face higher input costs in those sectors, as foreign inputs are not easily substitutable with domestic production.[19]

[18] The estimated effects of scenarios 1 and 3 are similar to those obtained using GIMF in IMF (2018a) and IMF (2019), respectively.
[19] This parameter measuring the degree of substitutability is an important driver of the magnitude of the effects in all trade scenarios. This point is explored in more detail in Section IV.

Figure 4: Impact on U.S. Sectors

percent change



Sources: IMF staff calculations.

Another important issue, that is somewhat masked by the effect on overall GDP, is that the heterogeneity in the response at the sectoral level would lead to a diverse outcome at the regional level within the U.S. This is due to the relative geographical specialization of the different U.S. states across economic sectors (Box 1). In particular a "transactional deal" where China buys more from the U.S. would benefit states with a high share of the primary sector (mining, hydrocarbons, and agriculture) in total value added—for instance, Arkansas, North Dakota, Oklahoma, and Wyoming—whereas these states would suffer most under the "auto tariffs" scenario. The impact of an intensification of ongoing trade tensions between the U.S. and China or a "transaction deal" where China restraint some of its U.S.-bound exports would have a more homogeneous effect, with most states being negatively affected by these sector-wide tariff increases. Moreover, these results have important implications across the income distribution—as richer states (with higher median incomes and a higher proportion of the rich) would benefit relative to poorer ones in the auto tariff scenario as well an intensification of the ongoing trade war with China, while poorer states would only benefit when China purchases more primary products from the U.S.

Box 1: Trade Policy and its Potential Effects on U.S. States

Our simulations show that the introduction of higher tariffs to imports of certain goods or coming from certain countries would have, in the long run, negative effects on U.S. overall output. The impact at the sectoral level, however, is in some cases particularly large. In light of this heterogeneity, and given the diverse specialization patterns across U.S. states, this box explores the regional implications of these potential policy actions. More precisely, U.S. sectoral impacts obtained in our simulation results shown above are mapped (outside of the model) to changes in output at the state level based on the share of each productive sector in U.S. states' output.[20]

In a scenario where the U.S. introduces a 25 percent tariff on imports of autos and auto-parts across the board, and trading partners retaliate with the same tariff rate on U.S. auto goods and a uniform tariff rate across all other U.S. goods, primary good sectors (i.e. agriculture, mining, and hydrocarbon extraction) tend to suffer large falls in value-added (Figure 4). This in turn translates into larger falls in GDP in states where these sectors represent a relatively large share of output—such as Arkansas, North Dakota, Oklahoma, West Virginia, and Wyoming—which, in addition, do not reap the benefits from the increase in output in the U.S. auto industry under this scenario (see Box Figure 1 and Box Figure 3, Panel A). Certainly, the magnitude of these effects would directly depend on the specifics of the potential retaliation by trading partners. As a sensitivity analysis, we replace the uniform tariff retaliation by trading partners by a more *selective* retaliation, mainly targeting some 'emblematic' U.S. products (e.g. Harley Davidson motorcycles, blue jeans, bourbon whiskey, among other).[21] In this case, although these states are still among the ones with the higher GDP falls, their losses are largely reduced as their exposure to the "targeted sectors" is lower Box Figure 3, Panel B).

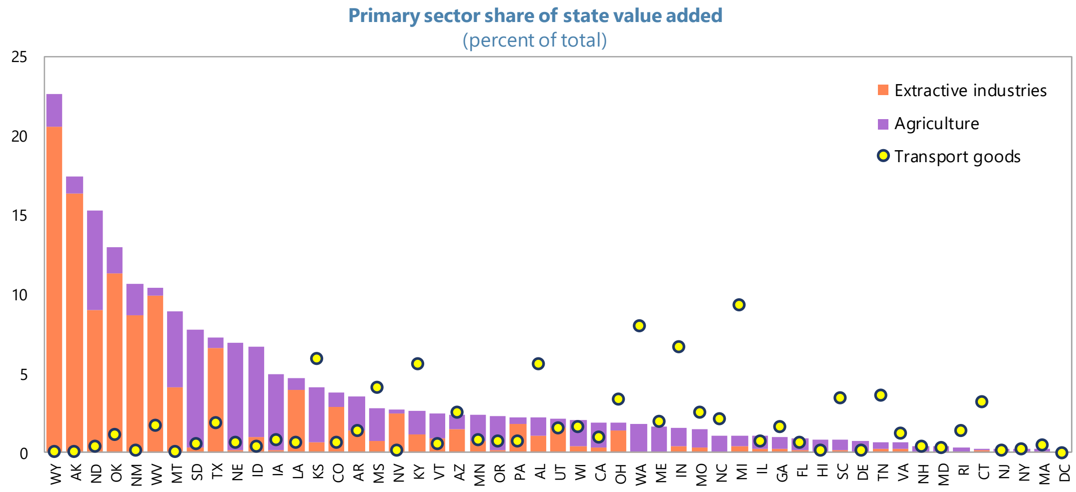
In a scenario where there is an intensification of trade tensions between the U.S. and China, with both countries introducing a uniform 25 percent tariff rate across all products, and thus with most sectors experiencing a fall in output, most U.S. states exhibit a negative change in GDP. Moreover, the effects appear to be relatively less heterogeneous across states than under most other trade scenarios (Box Figure 3, Panel C).

Finally, in a scenario where a "trade deal" is reached between the U.S. and China, and where China agrees to buy more selected U.S. goods—including in particular agriculture and hydrocarbon products—the states which are relatively exposed to these sectors and are overall less diversified, would tend to benefit from such a deal (Box Figure 3, Panel E). Nevertheless, a deal restraining some of China's exports to the U.S. would lead to losses in all states (Box Figure 3, Panel D).

[20] Our database breaks down economic activity into 17 sectors for each of the 50 states and the District of Columbia.

[21] This type of "selective retaliation" follows the spirit of the tariff retaliation that was envisaged by some of the U.S. main trading partners (e.g. Canada, the European Union, and Mexico) following the introduction of tariffs by the U.S. on imports of steel and aluminum products in March 2018.

Box Figure 1: U.S. States Exposure to Selected Sectors



Source: Eora Database (2015); and IMF staff calculations.

These differences regarding the impact across different geographic areas and under certain trade scenarios would likely lead to varying effects on other socio-economic indicators such as income, poverty and inequality. This is due to the fact that regions are themselves heterogeneous in terms of income and income distribution.

In fact, positive changes in GDP at the state level under the auto tariff scenario or a scenario with higher bilateral tariffs between the U.S. and China are positively associated with states having higher median income levels as well as a higher proportion of rich individuals (and lower proportion of the poor). In other words, based on simple correlations these specific trade scenarios tend to favor those richer states, and which have a higher proportion of wealthy people and lower poverty rates (see Box Figure 2 and Box Table 1).

By contrast, a "trade deal" scenario leading to additional purchases of certain U.S. goods by China, which tends to favor those states with a relatively higher share of primary good sectors (mining and agriculture), would seem to somewhat benefit states with lower average income, a higher proportion of lower earners, and a lower share of the wealthy.

Box Figure 2: Impacts Tend to Harm Poorer Regions and Lower-Income Households

	Poorer States	Richer States	Low-Income Households	High-Income Households
Auto Tariffs	✗	✓	✗	✓
Trade War with China	✗	✓	✗	✓
China's Export Restraints	✗	✓		✓
China's Purchase of U.S. Goods	✓	✗		✗

Notes: green check denotes “positive effect”; red cross denotes “negative effect”; empty cell denotes that the impact is not statistically significant at the 10 percent level. See Box Table 1 for details.

Source: IMF staff calculations.

Box Table 1: Link between Gains/Losses and Income Measures at the State-Level

Correlation of estimated state-level GDP changes with state-level income measures

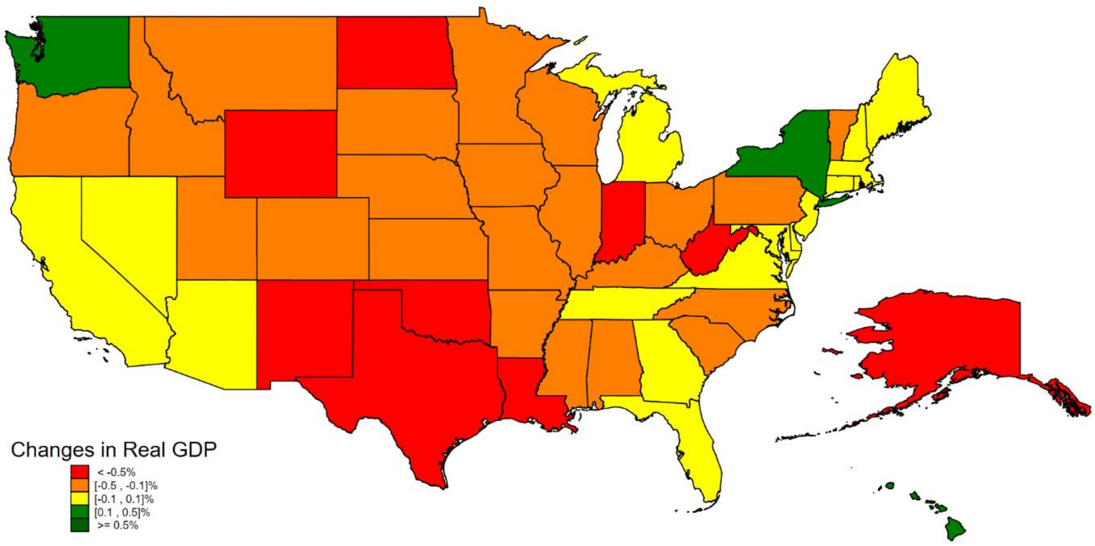
	States with higher median income	States with higher mean income	Higher proportion of low income household	Higher proportion of high-income households
Auto tariffs, uniform retaliation	0.3 **	0.4 ***	-0.1	0.4 ***
Auto tariffs, selected retaliation	0.5 ***	0.6 ***	-0.2	0.6 ***
Intensification of trade war with China	0.5 ***	0.6 ***	-0.3 *	0.6 ***
Trade deal: restraint on China's exports to U.S.	0.2	0.3 **	-0.1	0.3 **
Trade deal: China purchases of U.S. goods	-0.1	-0.2 *	0.0	-0.3 *

Notes: *, **, and *** denote statistical significance at the 10, 5, and 1 percent confidence level. “low income households” and “high-income households” denote those households with an annual income of less than $15,000 and more than $150,000, respectively.

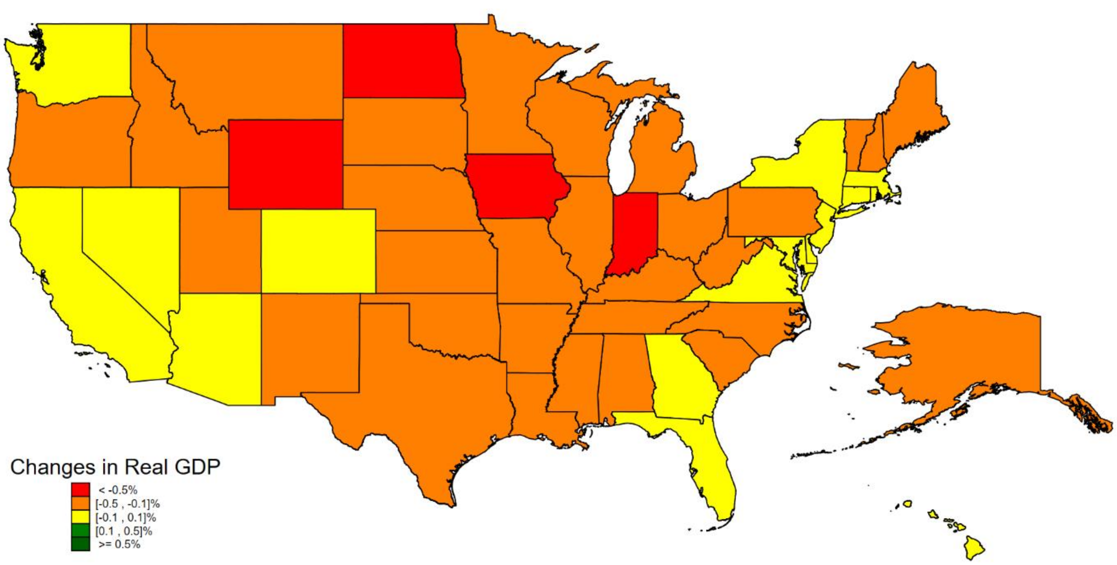
Source: IMF staff calculations.

Box Figure 2: Impact of Trade Scenarios on GDP at the State-Level

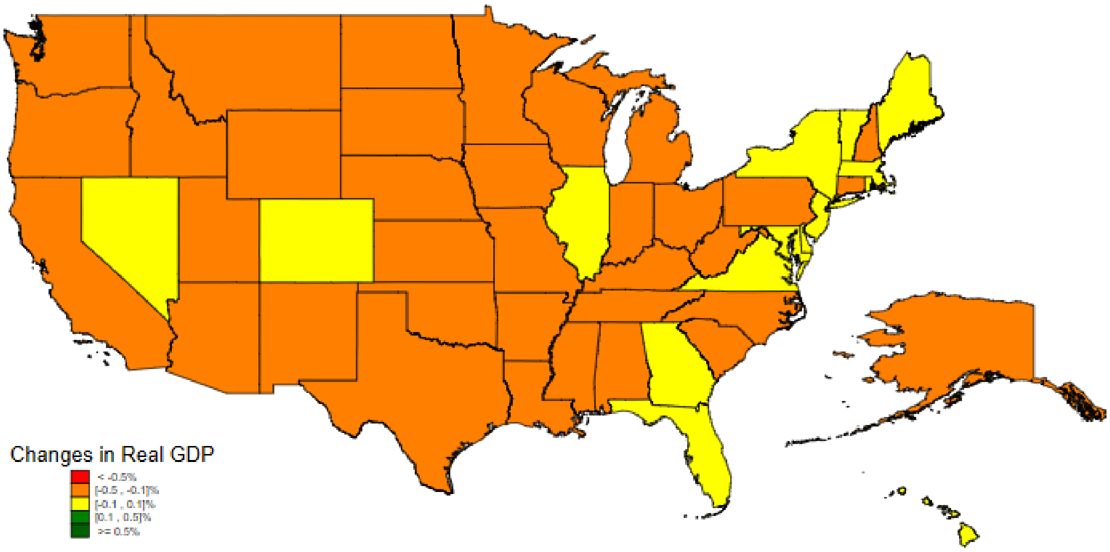
Panel A: Impact of "Auto-Tariffs"; Uniform Retaliation by Trading Partners



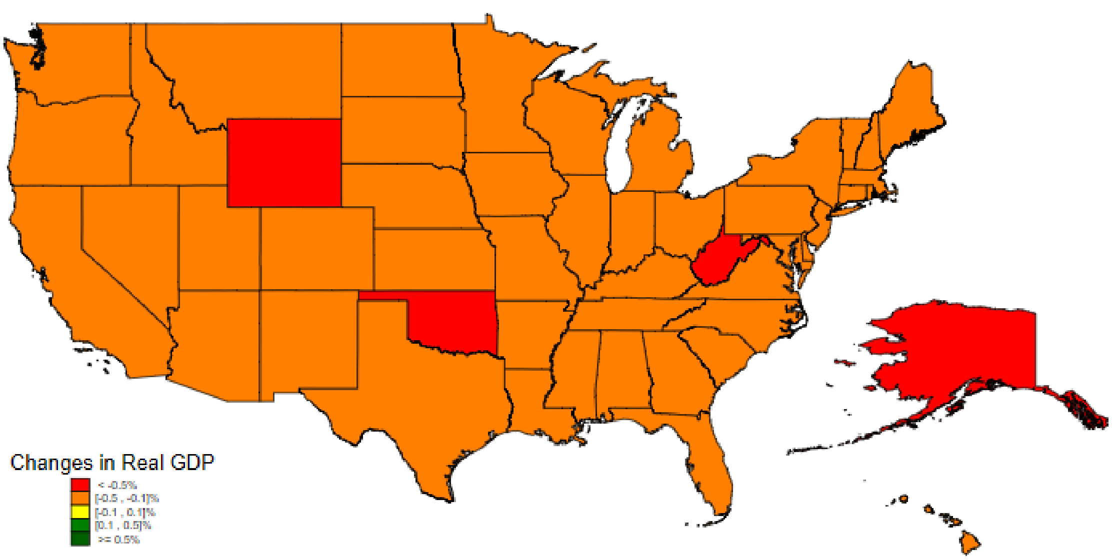
Panel B: Impact of "Auto-Tariffs"; Selective Retaliation by Trading Partners



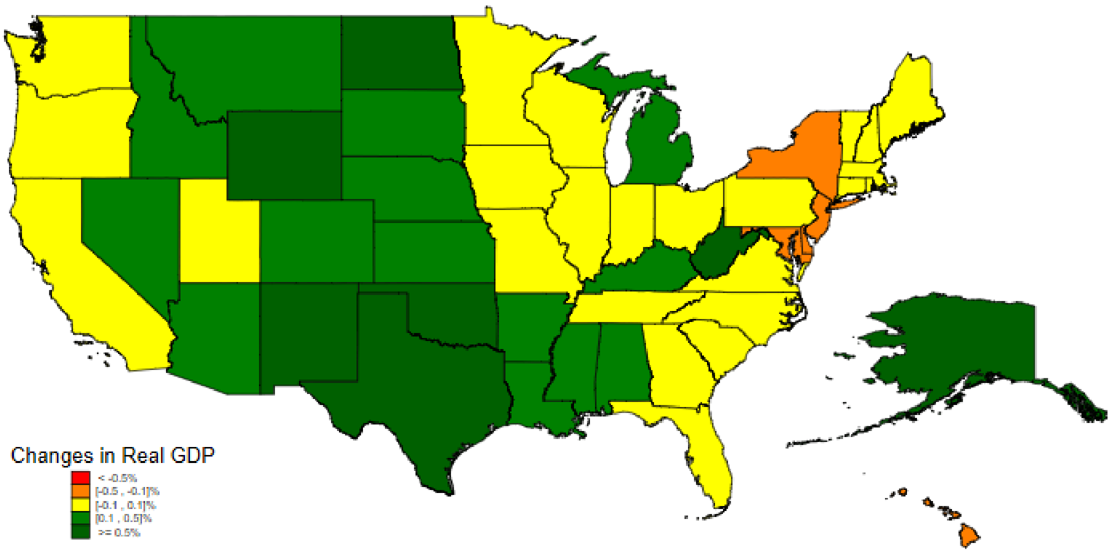
Panel C: Impact of "Trade War" Between the U.S. and China



Panel D: Impact of "Trade Deal: Restraint on China's Exports to the U.S."



Panel E: Impact of "Trade Deal: Additional Purchases of U.S. Goods by China"



Source: IMF staff calculations.

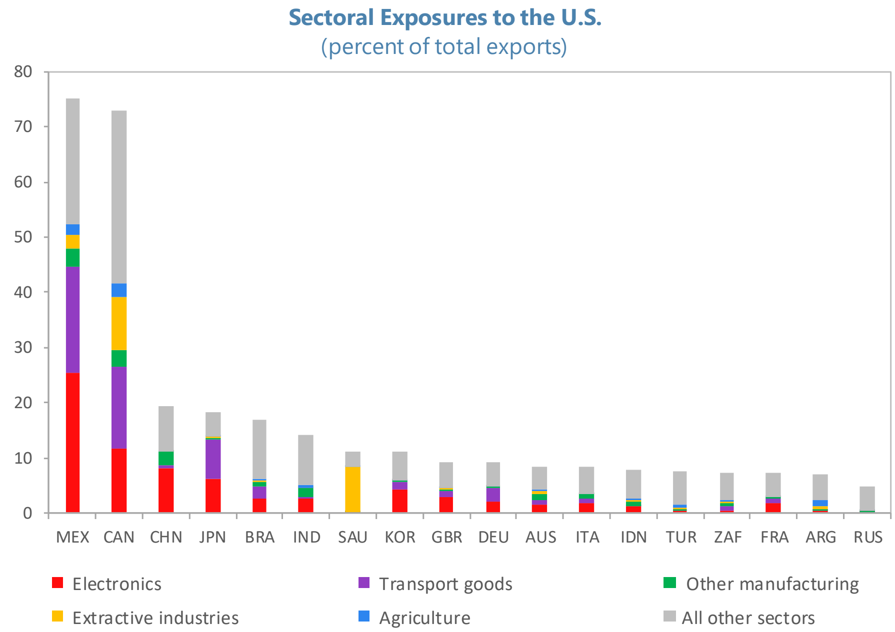
C. Impact and Spillovers to Other Countries

Impact on main trading partners

Figure 3 also shows the effect on overall GDP of some of the U.S. main trading partners—namely, Canada, China, Germany, Japan, and Mexico. Together, these five economies represent more than half of all U.S. imports. Contrary to the impact on the U.S., which is broadly similar across scenarios, the impact on these countries is rather heterogenous and highly dependent on the scenario under consideration.

In particular, when the U.S. and China impose bilateral tariffs on each other, both countries tend to suffer from this. Other countries—particularly Canada and Mexico, which are highly integrated with the U.S. —would tend to benefit in the long-run from less-intense competition with China in the U.S. market. Nevertheless, in Scenario 1 (tariffs on vehicles and auto-parts), these two countries would suffer the most given their significant exposure to the U.S. (Figure 5). This is also the case, to a lesser extent, for Germany and Japan.

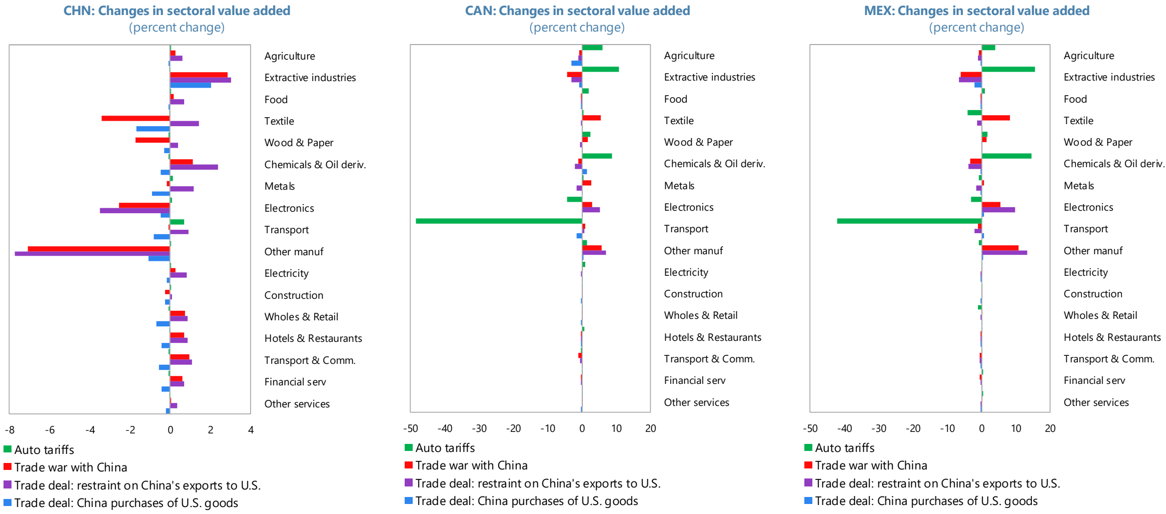
Figure 5: Trade Exposure to the U.S. in Selected Countries
direct exposures (i.e. gross trade flows)



Source: Eora Database (2015); and IMF staff calculations.

The heterogeneous response across countries under the different scenarios is even more striking across the different sectors. To illustrate this, Figure 6 shows the sectoral impacts for Canada, China, and Mexico. The transportation equipment sector—which includes autos and auto-parts —in both Canada and Mexico exhibit significant losses under a scenario where the U.S. imposes 25 percent tariffs on vehicles and auto-parts. In the case of China, some manufacturing sectors (such as electronics and other manufacturing) tend to experience significant losses, both when the U.S. increases tariffs on all Chinese goods (Scenario 3) and also when China agrees to reduce its exports of these goods to the U.S. under a bilateral "transactional deal" (Scenario 2).

Figure 6: Sectoral Impact in Selected Countries



Source: IMF staff calculations.

USMCA exemptions

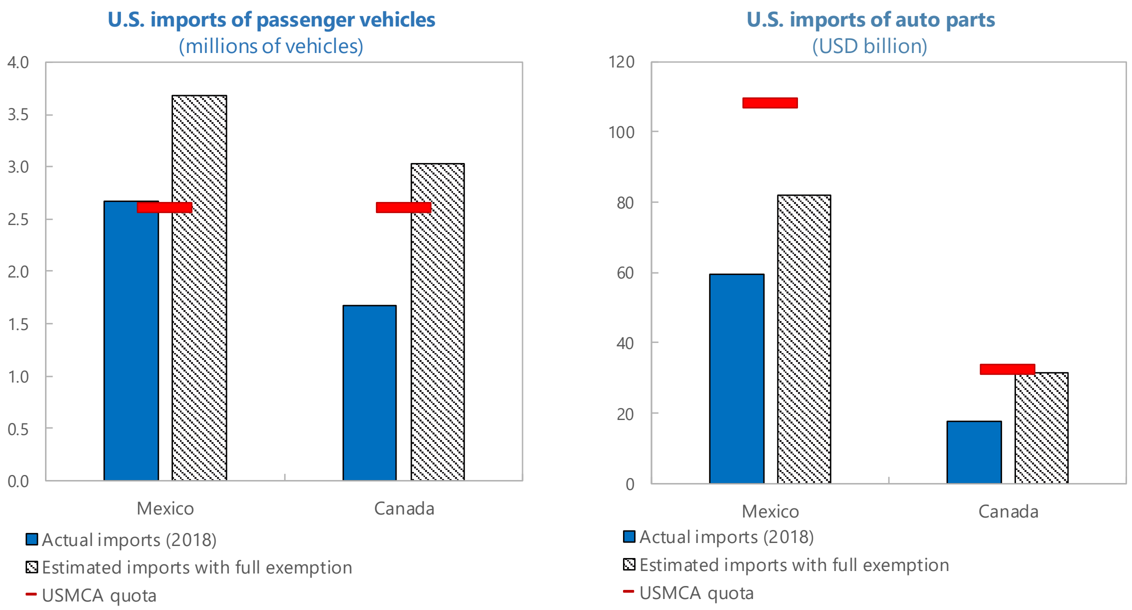
Side-letters to the United States-Mexico-Canada (USMCA) trade agreement stipulate certain exemptions for Canada and Mexico if the U.S. were to impose Section 232 tariffs on automobile imports.[22] If ratified, new Section 232 tariffs may be waived for Canada and Mexico, up to certain quantity and value quotas that vary by product and partner. Canada would be allowed to ship up to 2.6 million cars to the U.S. under USMCA preferences, well above the 1.8 million it sent in 2018, and $32.4 billion worth of auto parts without getting hit by tariffs. Mexico's side-letter is similar, except that the quota for auto parts is higher, at $108 billion.

To assess whether these quotas might become binding, we re-ran Scenario 1 but assuming that Canada and Mexico are fully exempt. We then applied the simulated increase in *real* transport equipment sales from USMCA partners to the U.S. to the corresponding observed 2018 exports of passenger vehicles, thus obtaining counterfactual exports of passenger vehicles for both countries. Since the quotas for auto-parts are set in terms of values rather than quantities, our counterfactual exports of auto-parts were obtained in the same way but using the simulated increase in *nominal* transport equipment sales. Our results, shown in Figure 7, indicate that exports of auto-parts would likely will remain within the USMCA quotas. In the case of passenger vehicles, however, the combination of more-stringent quotas with a significant simulated expansion in exports —as they gain market share relative to all other countries to which the auto and auto-parts tariffs still apply—implies that the quotas

[22] These side-letters are available from the website of the U.S. Trade Representative, for Canada and Mexico.

established by the USMCA would become binding.[23] In other words, tariffs would indeed kick-in on U.S. vehicle imports from Canada and Mexico.[24]

Figure 7: Potential Effect of the USMCA on Exports of Auto and Auto-parts



Source: IMF staff calculations.

Impact on other countries

In a world that is highly integrated, changes in trade barriers—either at the bilateral or multilateral level—can have a significant effect on other countries, even those not directly exposed to changing trade barriers. In this context, it is useful that our simulations include results for 165 countries. In order to summarize the information concisely, Figures 10 to 13 in the Appendix present color-coded maps representing the countries that would benefit or lose (in terms of overall GDP and real export changes) from these different trade scenarios.

What determines who wins and who loses? A key determinant of the outcome for each country is the ex-ante sectoral exposure of the different countries to the U.S., and to any other country directly involved in the imposition of tariffs (e.g. China under both Scenarios 2 and 3). To see this, it will be instructive to zoom in on one of the scenarios, bearing in mind that the observations made here regarding economic channels hold more generally across scenarios. For the purposes of illustration, let us then focus on the transactional deal between the U.S. and China (Scenario 2). On the one hand, any country selling e.g. agricultural goods to China would be negatively affected by the preferential treatment granted to U.S.

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[23] In fact, USMCA quotas are already binding for current levels of U.S. vehicle imports from Mexico.
[24] Alternatively, both countries could limit their exports of vehicles to the U.S. to remain within the USMCA quotas, and thus still not fully benefitting relative to a counterfactual where all their auto exports to the U.S. were the only ones exempted.

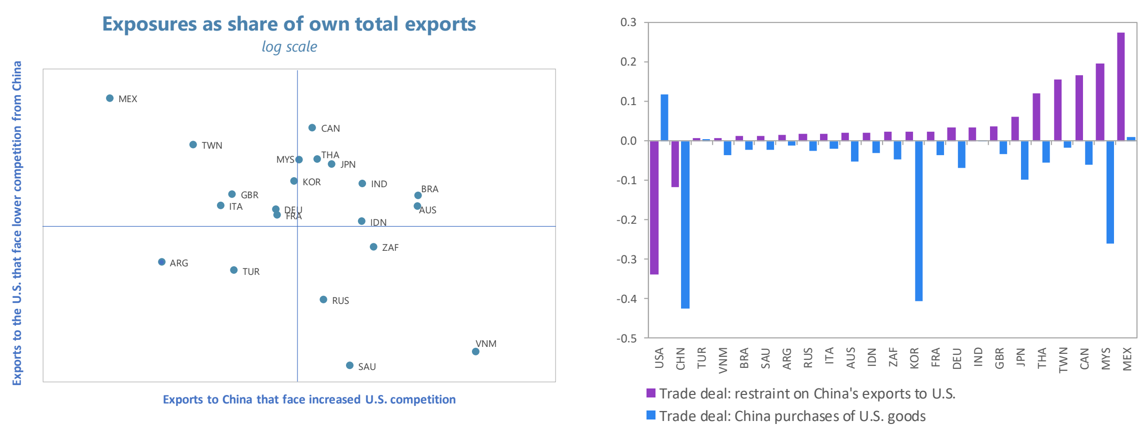
producers. This is measured on the horizontal axis of the left-hand-side chart of Figure 8. On the other hand, countries that sell e.g. electronics to the U.S. stand to benefit from the decreased competition with China; this is measured on the vertical axis of the chart. As can be clearly seen from the Figure, some countries, like Vietnam, would ex-ante be negatively exposed to this scenario, whereas others such as Mexico lie on the opposite end of the spectrum.

This prior is largely borne out by our simulations (Figure 8, right panel). As expected, Vietnam experiences a large negative effect due to the preferential tariff reduction on U.S. goods coming into China. Similarly, Mexico benefits exclusively because of the lower competition with Chinese producers in the U.S. market.

Not all effects follow as closely the pattern of direct exposures, underscoring the benefits of the model we are using to gauge the effects of tariffs. For example, consider the contrast between Korea and Malaysia. The panel on the left-hand-side of Figure 8 suggests that their ex-ante *direct* exposures to Chinese competition in the U.S. market is very similar. To this first-order approximation using direct exposures, therefore, one might expect both countries to experience similar benefits from decreased Chinese competition. However, while Malaysia sees large long-term gains, Korea barely benefits. The reason is that Chinese exports of electronics and other manufacturing going to the U.S. have a large Korean value-added component. Indirect exposures through global supply chains can be of first-order importance in cases such as this one.

Figure 8: Scenario 2 – A transactional U.S.-China deal

Ex-ante exposures (left) and simulated percent change in exports (right)



Source: Eora Database (2015); and IMF staff calculations.

Another crucial factor driving the quantitative gain/losses among different countries relates to the relative ease with which countries, particularly by the U.S, are able to replace foreign imported goods by domestically produced ones. This is analyzed in the following section.

IV. The Role of the Elasticity of Substitution Between Domestic and Foreign Goods

In addition to initial trade exposures, elasticities of substitution play a key role in driving the magnitudes and signs of the effects of these trade scenarios. Thus, this section analyzes the impact of varying the elasticities between final domestic and foreign-produced goods.

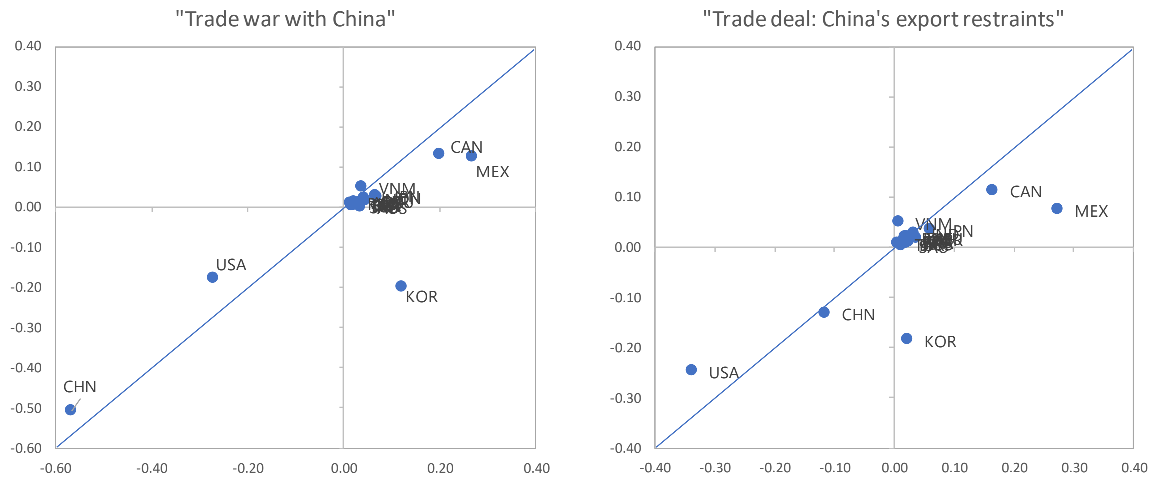
In particular, we consider the sensitivity of our baseline results to increasing the elasticity of substitution between foreign and domestic goods, which in the current context can be read as making it easier for any country to re-shore production. We implement this robustness check by raising sectoral foreign-domestic elasticities to be equal to foreign-foreign ones. In practice, it is as if every dot in Figure 2 above were to be raised upwards to the 45-degree line.[25]

We find that, in general, if re-shoring production were to be easier for the U.S., then potential losses would be larger for most other countries. This is shown by the fact that in Figure 9 most countries other than the U.S. lie below the 45-degree line.[26] Intuitively, in our baseline when the U.S. raises tariffs on its imports from any specific country (and/or in particular sectors), the goods imported from that country are likely to be substituted by imports of the same goods from other countries. This trade-diverting effect is driven by our baseline calibration based on the work by Feenstra et al. (2018): upon an increase in barriers with a specific partner, it is relatively easier to find another foreign supplier than it is to find a domestic one (see discussion in Section II.C). However, if it was equally easy for the U.S. to substitute those goods with domestic production, then trade diversion would be more muted and adverse spillovers would be much larger.

In the case of the scenarios primarily involving the U.S. and China, Figure 9 clearly shows that countries heavily involved in either the Asian or American value chain—such as Canada, Korea, and Mexico—would be hurt if re-shoring was easier. In the case of Korea, gains may even turn into losses.

[25] To avoid the non-generic case that leads to corner solutions (see discussion in Section II.A), we set foreign-domestic elasticities to be equal to foreign-domestic elasticities divided by 1.01.
[26] We only report results of this robustness check for the cases where China introduces export restraints and in the U.S.-China escalation scenario. We were unable to find a solution with higher foreign-domestic elasticities in the case of the auto tariff scenario.

Figure 9: Sensitivity of GDP Gain/Losses to Changes in Elasticities of Substitution
real GDP effects under baseline (horizontal axes) and alternative (vertical axes) calibrations



Source: IMF staff calculations.

V. Concluding Remarks

Following decades of growing trade flows and cooperation, the process of global trade integration faces an evident risk of stalling or going in reverse. In this paper, we use a multi-sector general equilibrium calibrated to 165 countries to quantify the potential effects of three specific scenarios that could, in principle, have systemic consequences for how global production and consumption are organized. We analyze three relevant and plausible scenarios in detail: (i) a scenario in which the U.S. imposes uniform tariffs on all imports of vehicles and auto-parts from all trading partners, who then retaliate by imposing equivalent tariffs on the U.S.; (ii) a scenario in which a transactional trade deal is reached between the U.S. and China to eliminate the bilateral deficit, with the latter purchasing more goods (especially primary products and other selected goods such as aircrafts) from the U.S., and limiting exports to the U.S. of selected manufacturing goods; and, in the absence of such deal, (iii) a possible escalation of the trade tensions between the U.S. and China, in which both economies introduce a 25 percent tariff on all their bilateral imports.

We find that GDP in the U.S. falls under most scenarios. While possibly expected in scenarios that include retaliation, we find that U.S. output losses also arise in the case where China voluntarily limits its exports of selected goods to the U.S. This is because those foreign goods (electronics and other manufacturing goods) are particularly difficult to substitute with domestic production, and thus tend to be replaced by additional imports from other countries.

Some production sectors and geographic regions in the U.S. exhibit substantial changes. A “transactional deal” with China would, in particular, benefit U.S. states with a high share of primary sector (mining, hydrocarbons, and agriculture) activity in total value added, whereas these states would suffer most under the “auto tariffs” scenario. While our model features no adjustment costs in the move toward the new long-run equilibrium, these results are indicative of the potentially disruptive nature of the tariff changes considered. Which sectors gain and which lose depends on the specific scenario under consideration. Moreover, these sectoral changes can have important socio-economic consequences across different U.S. regions, as some areas tend to be specialized in a small number of sectors that can greatly benefit—or suffer—from the introduction of tariffs.

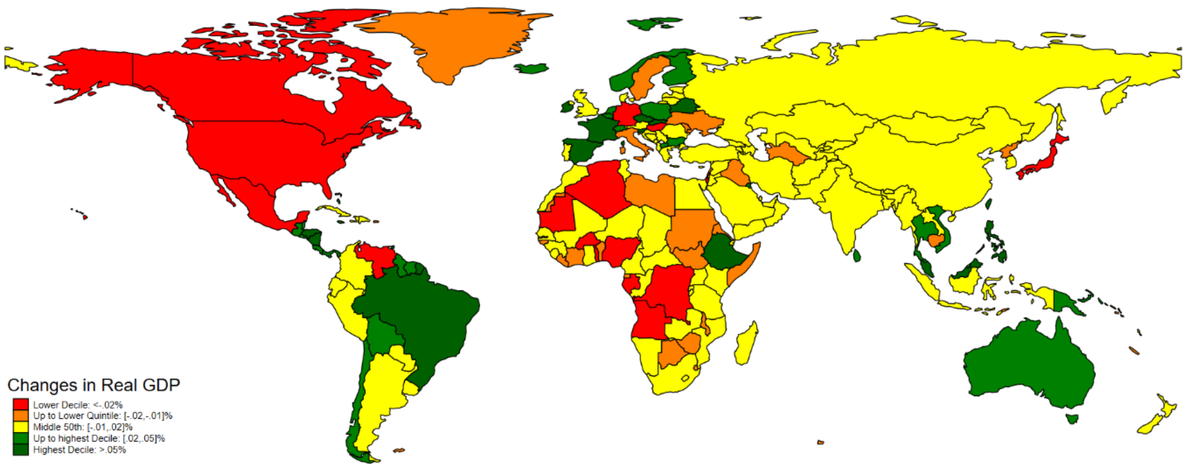
Regarding the effect on U.S. trading partners and other economies, the potential gains/losses as well as sector-level disruptions are also scenario-dependent. The initial sectoral exposures to the U.S. and other key players appear to be an important determinant of spillovers, although in some cases indirect exposures through global supply chains can be of first-order importance.

Besides input-output data, the other key inputs used to obtain these results are the sectoral elasticities of substitution. Following recent advances in the field of international trade, we calibrate separately the elasticity of substitution between foreign suppliers, and the elasticity of substitution between foreign and domestic suppliers. Key in this calibration is that, in every sector, it is easier to find another foreign supplier than it is to find a domestic one in response to a price change of a foreign good. In robustness checks we find that, if it were easier to re-shore production than it is in our baseline calibration, U.S. real GDP losses would be lower (though they generally remain negative) and most third countries would be worse off as they do not gain through trade diversion. In other words, spillovers would likely be harsher if re-shoring production to the U.S. ends up being easier than in our baseline calibration.

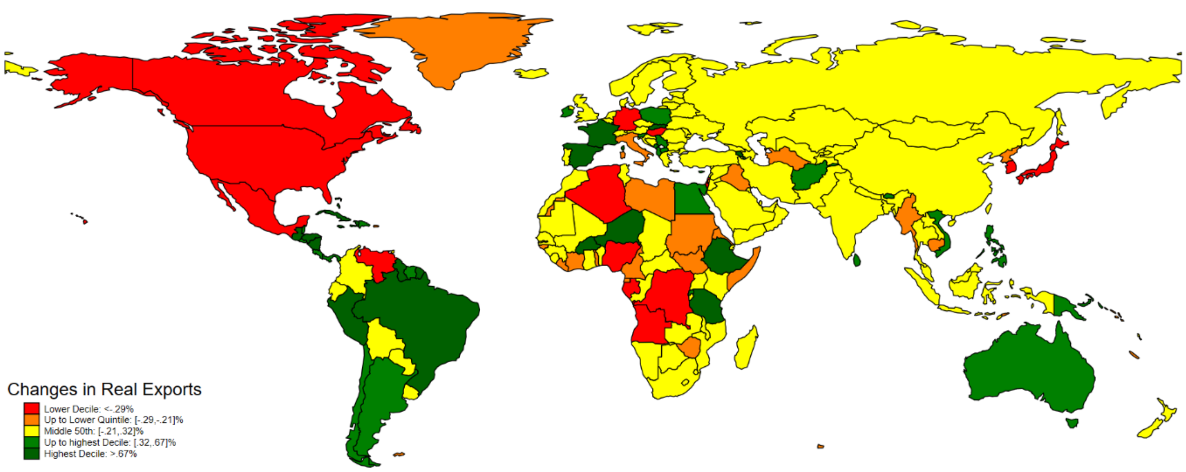
Our overarching finding that the trade scenarios we model tend to produce negative outcomes for the parties involved does not imply that the status quo is optimal. Rather, the U.S. and its trading partners could work constructively, not only to better address distortions in the trading system and in individual countries’ trade regimes, but also to tap trade policy areas that have high growth potential (IMF-WB-WTO, 2018). Our results both underscore the value of adhering to the existing levels of liberalization, and highlight the risks associated with a fragmentation or even a complete breakdown of the trading system where new and longstanding issues remain unresolved.

Figure 10: Impact of *"Auto-Tariffs"* on All Countries

Panel A: Impact on Real GDP



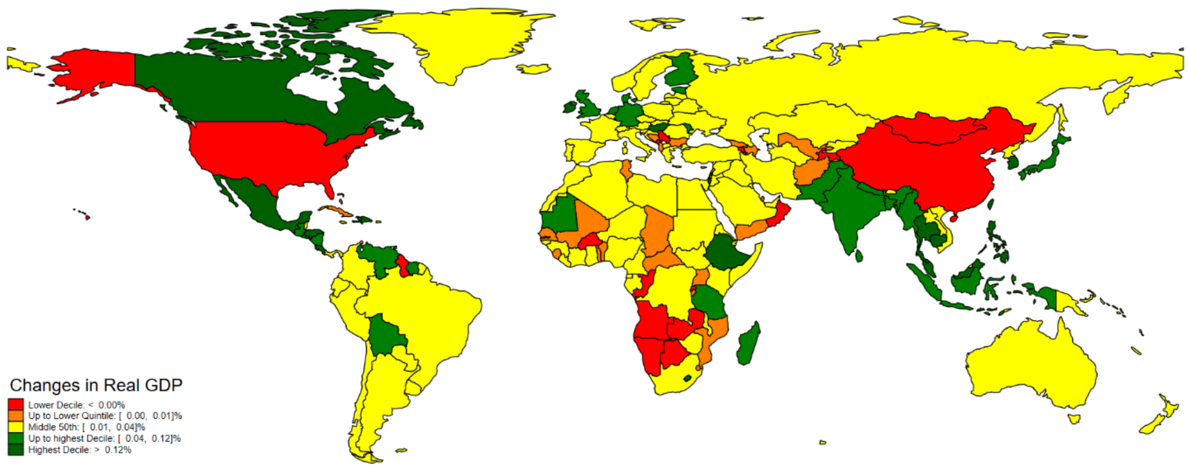
Panel B: Impact on Real Exports



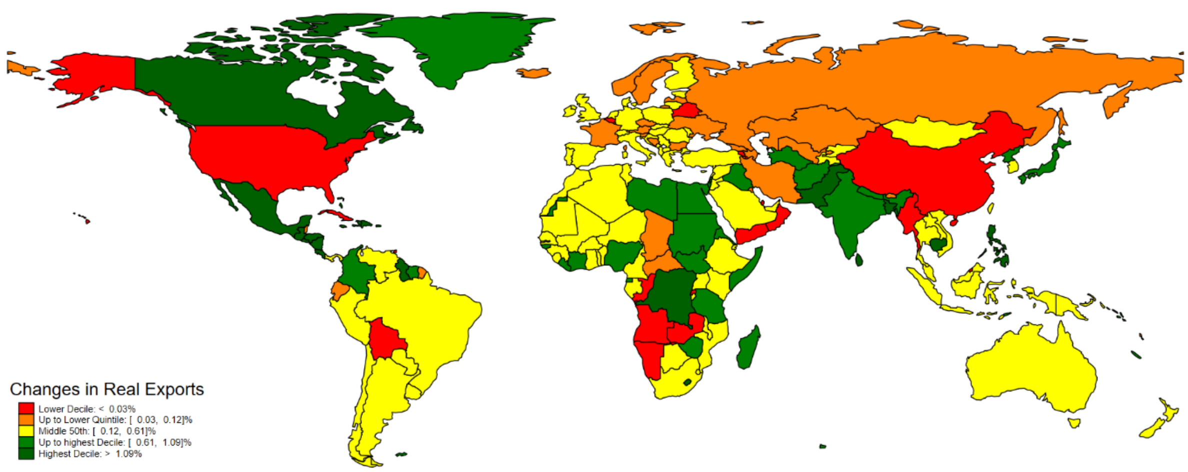
Sources: IMF staff calculations.

Figure 11: Impact of *"Trade War" Between the U.S. and China* on All Countries

Panel A: Impact on Real GDP



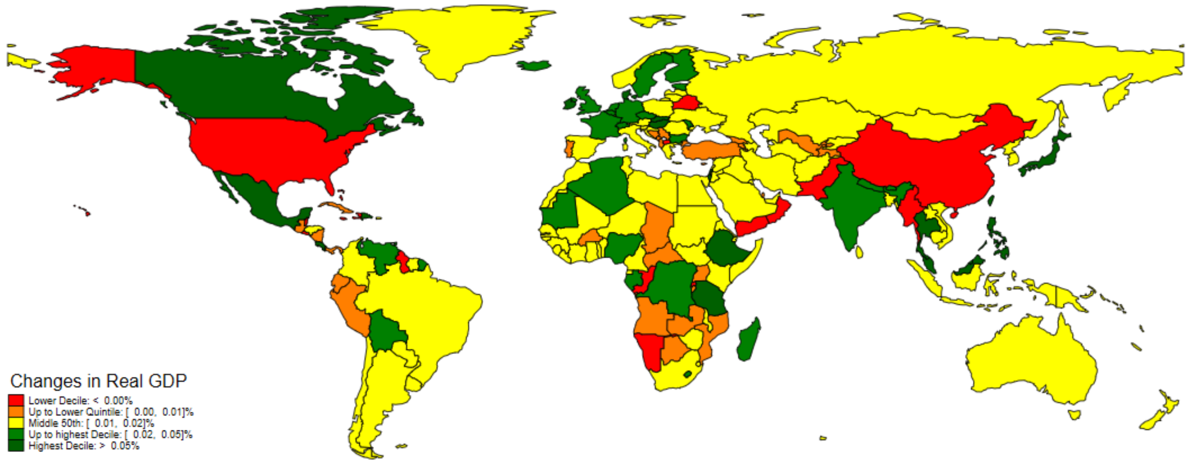
Panel B: Impact on Real Exports



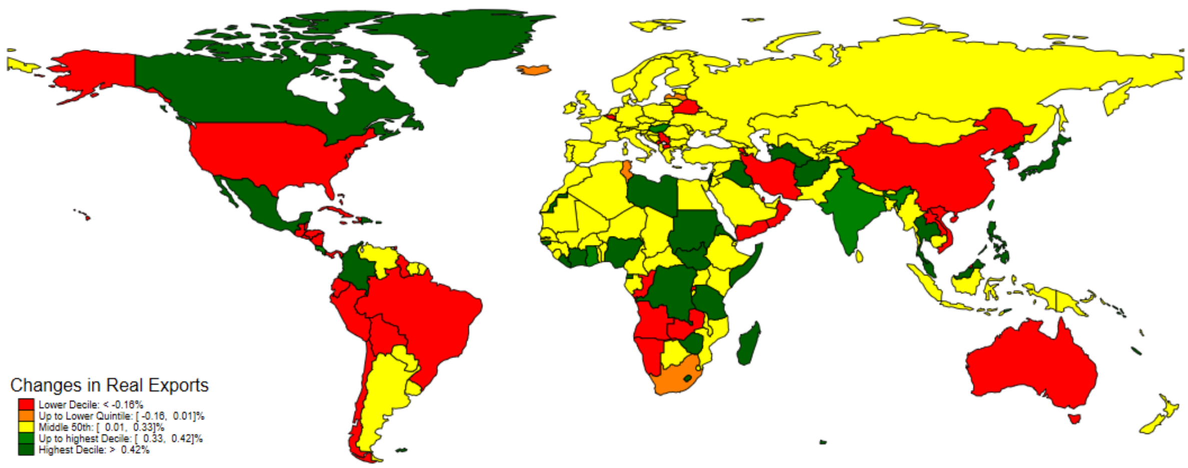
Source: IMF staff calculations.

Figure 12: Impact of *"Trade Deal: Restraint on China's Exports to the U.S."* on All Countries

Panel A: Impact on Real GDP



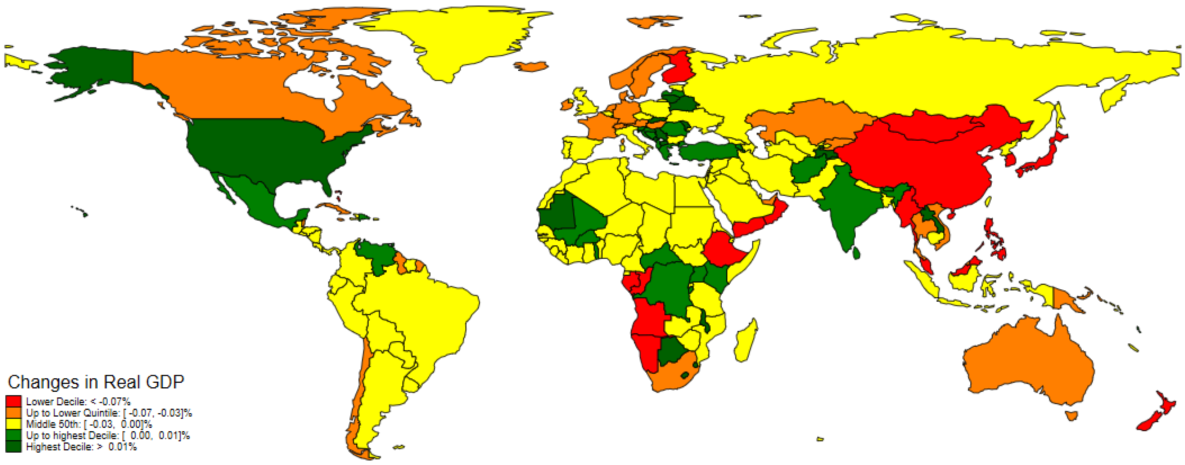
Panel B: Impact on Real Exports



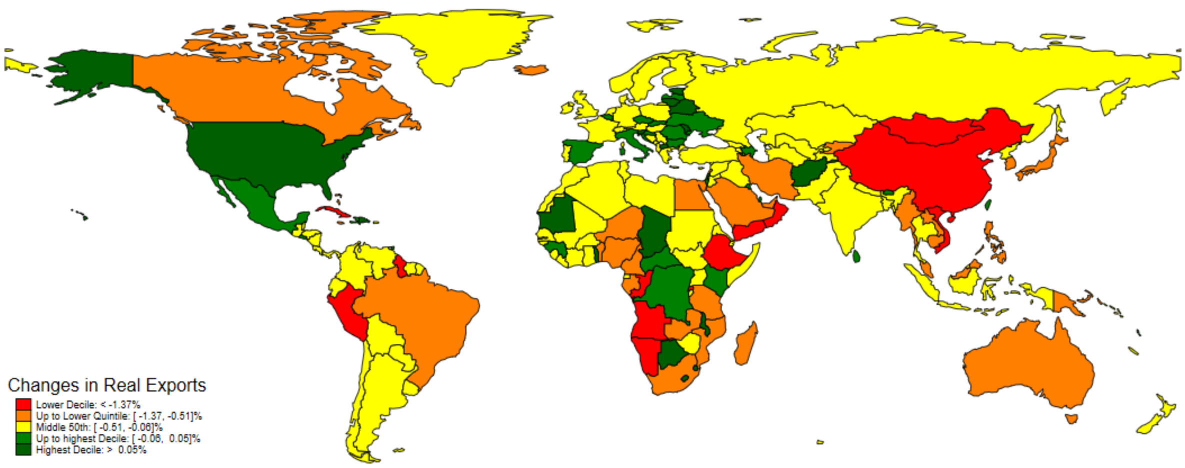
Source: IMF staff calculations.

Figure 13: Impact of *"Trade Deal: Additional Purchases of U.S. Goods by China"* on All Countries

Panel A: Impact on Real GDP



Panel B: Impact on Real Exports



Source: IMF staff calculations.

APPENDIX

A. Implementing export tariffs as part of the U.S.-China transactional deal

Equation (75) in CFRT defines tariff revenues for country i:

$$T_i^{'} = \sum_{s,\, j\neq i} \frac{t_{ji,s}^{'}}{1+t_{ji,s}^{'}} \lambda^{'}_{ji,s} Y_{i,s}^{'}$$

Note that this equation can be re-arranged to denote the multiplication of tariffs and imports:

$$T_i^{'} = \sum_{s,\, j\neq i} t_{ji,s}^{'} \frac{\lambda^{'}_{ji,s}}{1+t_{ji,s}^{'}} Y_{i,s}^{'} = \sum_{s,\, j\neq i} t_{ji,s}^{'} M^{'}_{ji,s}$$

We separate the equation above into two parts:

$$T_i^{'} = \sum_{s,\, j\neq i} t_{ji,s}^{'} M^{'}_{ji,s} = \sum_{s,\, j\neq i} \left(t_{ji,s}^{'} - t_{ji,s}\right) M^{'}_{ji,s} + \sum_{s,\, j\neq i} t_{ji,s} M^{'}_{ji,s} \tag{2}$$

Equation (2) for the USA and China is:

$$T_{USA}^{'} = \sum_{s,\, j\neq USA} t_{j,USA,s}^{'} M^{'}_{j,USA,s} - \sum_{s} \left(t_{CHN,USA,s}^{'} - t_{CHN,USA,s}\right) M^{'}_{CHN,USA,s}$$

$$T_{CHN}^{'} = \sum_{s} \left(t_{CHN,USA,s}^{'} - t_{CHN,USA,s}\right) M^{'}_{CHN,USA,s} + \sum_{s,\, j\neq i} t_{jCHN,s}^{'} M^{'}_{jCHN,s}$$

And equation (2) for other countries except the US and China, stays as before:

$$T_i^{'} = \sum_{s,\, j\neq i} t_{ji,s}^{'} M^{'}_{ji,s} \equiv r_i^{'} \tag{3}$$

This equates to adding an additional term to China's revenues:

$$T_{CHN}^{'} = \sum_{s} Y_{US,s}^{'} \left[\left(t_{CHN,US,s}^{'} - t_{CHN,US,s}\right) \frac{\lambda^{'}_{CHN,US,s}}{1+t_{CHN,US,s}^{'}} \right] + r_{CHN}^{'} \tag{4}$$

And subtracting the same term for the US:

$$T_{USA}^{'} = -\sum_{s} Y_{US,s}^{'} \left[\left(t_{CHN,US,s}^{'} - t_{CHN,US,s}\right) \frac{\lambda^{'}_{CHN,US,s}}{1+t_{CHN,US,s}^{'}} \right] + r_{USA}^{'} \tag{5}$$

These modifications are not to ex-post equilibrium values, but rather impact the equilibrium conditions, in particular the resource constraint equation, or CFRT's equation (74) reproduced below:

$$Y_{i,s}^{'} = \sum_{s'} \tilde{\gamma}_{i,ss'} \sum_{j} \frac{\lambda_{ij,s'}^{'}}{1+t_{ij,s'}^{'}} \lambda^{'}_{ij,s} Y_{j,s'}^{'} + \alpha_{i,s} \left(T_i^{'} + w_i^{'} L_i^{'} - S_i^{'}\right) \tag{6}$$

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