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Three essays on preferential trade agreement and trade policy

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Abstract

Three Essays on Preferential Trade Agreement and Trade Policy

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This dissertation consists of three chapters on Preferential Trade Agreements (PTAs) and trade policies. Increasing in numbers rapidly since 1990s, PTAs have extended their traditional focus on tariff reduction to deeper policy integration in areas such as competition policy, intellectual property rights, investment, and movement of capital. The first chapter of the dissertation uses a recently released dataset of PTA contents to quantify impacts of the horizontal depth of trade agreements on bilateral trade flows and national welfare for the period of 1980-2015. The results indicate that agreements that are deeper (covering a wider range of policy areas) contribute to larger trade growth and welfare gain. The second chapter of the dissertation expands the above analysis by using synthetic control matching (SCM) methods to obtain time-varying trade effects of PTAs, and isolates from the estimated total PTA effect the part contributed by different horizontal depths (coverages) of trade agreements. Built on the Anderson and van Wincoop (2003)'s set-up, we decompose and quantify the welfare effects of PTA deep integration for the different horizontal depths (coverages) of trade agreements for the period of 1988-2015, while controlling for the effect of tariff barriers. The third chapter of the dissertation analyses the short-run impact of 2018-2019 U.S.-China trade war on the Chinese economy, following the micro-to-macro approach of Fajgelbaum et al. (2020) and analyze the impacts of the 2018–2019 U.S.-China trade war on the Chinese economy. We use highly disaggregated trade and tariff data with monthly frequency to identify the demand/supply elasticities of Chinese imports/exports, combined with a general equilibrium model for the Chinese economy (that takes into account input-output linkages, and regional heterogeneity in employment and sector specialization) to quantify the partial and general equilibrium effects of the tariff war. This complements the studies focused on the ex post response of the U.S. economy by Amiti et al. (2019), Flaaen et al. (2020), Fajgelbaum et al. (2020), and Cavallo et al. (2021).

Contents

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To my grandparents, in loving memory.

Chapter 1

The Depth of Preferential Trade Agreements

1.1 Introduction

Preferential trade agreements (PTAs) were established by GATT Article XXIV in order to reduce tariffs and blocs between countries and their trading partners, and with this so-called "discriminatory" reduction of trade barriers, it serves as an exception to Most-Favored-Nations (MFN) principle in the GATT/WTO system. One of the major concerns about the effect of PTAs is that whether it is welfare-improving or harming. For the PTA member countries, it regulates to eliminate import tariffs over "substantial trade" to replace high-cost domestic production. However, because of import substitution it may also divert trade from a third-party country to PTA partners and therefore reduce the welfare of non-member countries. This issue is illustrated as whether PTAs are "trade creation" or "trade diversion" pointed out by Viner (1950). It raises the question that when the depth of PTAs increases, how does it affect the country's trade flows and welfare? With the trend that the current PTA negotiations are increasingly going beyond the "shallow" agreements and pushing toward deeper integration that addresses both non-tariff and behind-the-border policies, it is worthwhile to investigate into the effect of PTAs after taking the deep integration into consideration. For instance, in certain nondiscriminatory domestic provisions deep agreements are expected to bring more trade creations than shallow agreements do, as it could help achieve improved levels of "regulatory coherence" across PTA-partner countries (Bagwell et al., 2016). Such nondiscriminatory in nature provisions also apply to vis-à-vis outsiders, creating a positive spillover effect, or negative trade diversion (Baldwin and Low, 2009). Those behind-the-border provisions such as the competition policy and investment regulation, would be expected to help provide a better domestic trading environment and may reduce costs in facilitating the trade flows across the border. This kind of trade facilitation not only applies to the PTA partners but also benefits the outsiders.

In this paper we exploit a recently released dataset on the content of PTAs (Hofmann et al., 2017), to empirically point out the importance of the trade and welfare effects of PTA deep integration. This dataset explicitly tracks the content of PTA provisions changing over a long time period of 1958-2015. Newer agreements are "deeper" in the sense that they generally expand the coverage of policy areas compared with relatively older agreements. Using information from the content of PTA dataset, we further decompose the PTA indicator (define PTA_{ijt}=1 if there are any PTAs currently in force between two countries i and j at year t) into corresponding PTA subcategories based on policy areas covered and their legal enforceability. Then we assess the year-specific welfare effects of PTA and PTA subcategories on both PTA members and non-members within the time period of 1980-2015. In addition to the main analysis, we also attempt to evaluate the relationship between PTA deep integration and the multilateral trade liberalization (via GATT/WTO). In the past literature, abundant researches attempt to answer how the likelihood of PTA formation is affected by multilateral trade liberalization. Freund (2000) examines this question within a repeated-game model and finds that deeper multilateral trade liberalization leads to more PTAs. In this paper we take a further step to explore how the welfare effect of PTAs would be affected by the multilateral trade liberalization, taking into account the horizontal depth of trade agreements.

To reach the above goals, in the first step we build on the reduced-form empirical literature to assess the effect of PTAs on trade flows (Head and Mayer, 2015; Limão, 2016). In particular, as argued below, we adopt a parametric approach to obtain the partial direct effects of PTA and PTA subcategories, as well as the GATT/WTO effect on trade costs. We start with a baseline gravity regression which uses the PTA variable as one of the trade-cost proxies, and further replace it with its subcategory indicators to measure the heterogeneous effects across different horizontal lengths of agreements. By doing so, we are able to identify the trade effects of PTAs varying with the coverage of policy areas in the agreement. The approximated trade-cost effects due to PTA status are then used as shocks to quantitative trade models developed in the second step, to measure the welfare impacts of PTA deep integration. In addition, in order to examine whether the multilateral liberalization complements or circumvents the PTA deep integration, we also attempt to identify GATT/WTO membership indicators *bothwto*, *imwto* and *exwto* to potentially capture all changes in trade costs for each bilateral trade relationship due to GATT/WTO membership.[1] One potential identification problem is once argued in Cheong et al. (2014) that we cannot separately estimate the effects of GATT/WTO membership indicators in the parametric framework if using the exporter-year and importer-year FEs to control for countries' multilateral resistance (MR) terms. The indicator variables *bothwto* and *imwto* are multi-collinear. To overcome this difficulty and identify GATT/WTO membership indicators consistently within the current parametric framework, we instead propose an iterated regression methodology by utilizing the structural relationship between MR terms developed in a quantitative model.

Having augmented a standard gravity model to obtain the partial direct trade effects of PTA and PTA subcategories, we conduct the quantitative analysis in a consistent structural framework that incorporates potentially multiple margins of trade (intensive, extensive, and firm entry). It is built on the recent development in structural quantitative analysis of international trade, which features general equilibrium counterfactual analyses in high-dimensional models (Arkolakis et al., 2012; Costinot and Rodríguez-Clare, 2015). We take the matrices of estimated trade-cost effects due to PTA status for each country-pair at each year as inputs to quantitative trade models to assess the corresponding general-equilibrium

[1]We define *bothwto* = 1 when both countries are GATT/WTO members and zero otherwise; *imwto* = 1 when only the importing country is a GATT/WTO member and zero otherwise; and *exwto*=1 when only the exporting country is a GATT/WTO member and zero otherwise.

impacts. The quantitative framework used is consistent with the extended version of Arkolakis et al. (2012), where intermediate goods are used in production as well as in firm entry. The counterfactual changes in the key variables of interest had PTAs not existed are simulated, taking into account general equilibrium adjustments to the trade shocks across all countries. We find a general pattern from the counterfactual result that the country is inclined to reap increasing welfare gains when its PTA trading partners is growing in numbers over the years. And based on the classification of PTAs, the gains vary with the coverage of policy areas. To explore the welfare change after interacting with the GATT/WTO system, we further simulate the counterfactual changes by having the GATT/WTO membership not existed, and finds a potential complementary relationship between PTA deep integration and the multilateral liberalization. With the existence of the GATT/WTO membership, the welfare improvement from PTAs tends to become stronger if pushing toward a deeper form of integration.

Our empirical analysis is related with the discussion about trade creation or trade diversion of PTAs, taking into account the deep integration of PTA provisions. Previous research have provided abundant theoretical supports for the necessity of considering PTA deep integration in the analysis of trade creation or trade diversion effects of PTAs. Starting from the perspective of terms-of-trade (TOT) theory, Bagwell and Staiger (2001) show that it requires more conditions to hold, for a shallow integration approach to be sufficient to achieve globally efficient outcomes. Lee (2016) claims that in the hidden-information setting, a form of deep integration is needed to construct the optimal agreement as the first-best allocation implemented when the state were observable is not incentive compatible. Beyond the TOT theory, the presence of non-TOT externalities also calls for the need of deeper forms of integration. For example, if prices are determined by bilateral bargaining rather than market clearing conditions in the presence of offshoring, Antràs and Staiger (2012) indicate that the tariff is no longer the first-best policy for cost shifting, and governments find it unilaterally optimal to distort many of their policy choices across border and behind-the-border. Another explanation builds on the commitment theory, as Ethier (1998)'s model shows that the commitment motive best describes why governments might be interested in PTAs, and provides the potential theoretic support for deep integration in trade agreements as a solution to commitment problems.

This paper contributes to the empirical literature on the trade and welfare effects of PTAs by exploring the content of agreements. Due to lack of data used for indicating the deep integration, most of previous studies use simple PTA indicator variables to identify the presence of PTAs or distinguish between broad types of trade arrangements like Free Trade Agreement (FTA), Custom Union (CU), Economic Integration Agreement (EIA), etc. While Hofmann et al. (2017)'s dataset can effectively help to fill this gap. Two recent empirical research papers use this dataset to investigate into the effects of the horizontal depth of PTAs. Mattoo et al. (2017) use an augmented gravity model which includes a variable of the depth of agreements between PTA members (here the depth refers to the total number of provisions covered in one PTA) and a variable that captures a trading partner's PTA depth with other countries, to assess the impact of deep agreements on members' and nonmembers' trade flows. The results indicate that deep agreements lead to more trade creation and less trade diversion than shallow agreements. Osnago et al. (2019) construct a similar measure of the depth of PTAs, and find evidence that the depth of PTAs is correlated with vertical foreign direct investment (FDI). Unlike the measure of horizontal depth which is the sum of provisions indicated in the previous studies, in this paper we classify PTA provisions into different categories and focus on the number of categories (policy areas) covered in the agreement.[2] If any provision which belongs to a certain category is included, this category is then assumed to be covered by this agreement. This kind of variation in the PTA content is considered to bring important implications for the trade and welfare effects of PTAs, both on members and nonmembers. Another contribution of this paper is the empirical methodology developed to estimate the trade effects of PTA and GATT/WTO membership

[2]The number of categories is calculated according to the categorization of PTA provisions, and details will be introduced in Section 1.2.

within a consistent parametric framework. By adopting an iterated regression method, we are able to escape from the multi-collinearity problem noted in Cheong et al. (2014), and provide additional relevant insights for the longstanding debate on regionalism (via PTA) versus multilateralism (via GATT/WTO). Having identified the trade effects of PTA, PTA subcategories and GATT/WTO membership, it motivates us to conduct a counterfactual analysis about PTA's interaction with GATT/WTO, and partially analyze the impact of multilateralism on the welfare effects of regionalism, which is beyond the main focus of existing literature. The finding of our analysis proposes that there exits a complementarity between the horizontal depth of trade agreements and the multilateral trade system.

The paper is organized as follows, Section 1.2 describes the PTA dataset on the content of trade agreements. Section 1.3 develops the basic setup of the Melitz framework incorporating intermediates and trade imbalance. Section 1.4 presents the parametric estimation methodology and estimation results. The counterfactual analysis is discussed in Section 1.5, and Section 1.6 concludes.

1.2 PTA Data

The complete dataset used in this paper is comprised of three main components: PTA related indicators, trade flows and trade-cost proxy variables. The data sample is selected from 1980 to 2015.[3] The main concern about choosing this time period for our analysis is to well capture how the horizontal depth of PTAs changes over time, as well as its related impact on the international trade flows given the fact that the number of PTAs has increased dramatically in the last quarter century (Hofmann et al., 2017). In this section we mainly discuss how to construct PTA and PTA subcategories, and the rest part of data will be introduced in Data Appendix A.

In this paper we obtain PTA data from a recently released database of World Bank.[4]

[3]This time period covers the trade liberalization process after the Tokyo Round (1973-1979) and includes Uruguay Round (1986-1994).

[4]http://data.worldbank.org/data-catalog/deep-trade-agreements.

It contains 279 treaties which had been signed by 189 countries between 1958 and 2015.[5] They are all PTAs notified to the WTO and in force up to December 2015. Following the methodology proposed by Horn et al. (2010), its bilateral dataset maps a total of 52 disciplines across PTAs, and classifies them into two categories, based on the criteria that whether they currently exist under the mandate of the WTO (referred to as "WTO-plus" or WTO+), or outside the WTO mandate (referred to as "WTO-extra" or WTO-X). In the WTO+ area, there are 14 provisions such as customs regulations, export taxes, anti-dumping and countervailing measures, which reconfirm the existing commitments to the WTO, but take on commitments to go further. While the other 38 WTO-X provisions include areas such as competition policy, investment, environmental laws and nuclear safety, but have not been yet explicitly addressed by the WTO.

This dataset allows us to analyze the content of PTAs to get a better understanding of the horizontal depth of agreements. PTA provisions can be disaggregated depending on the specific questions under investigation. Besides the categorization of WTO+ and WTO-X provisions mentioned above, we could also classify provisions subject to their economic relevance. As described in Hofmann et al. (2017), the category of "Core" provisions consists of 14 WTO+ and 4 WTO-X provisions, forming a set of "core" rules not only advocating the goal of improving market access but also for the emergence of global production sharing practice (Damuri, 2012). Correspondingly, the other 34 provisions in the dataset could be classified as "Non-Core" provisions. For those 18 "Core" provisions, they can be further divided into two main categories, depending on whether they are implemented at the border (referred to as "Border") or behind the border (referred to as "Behind-the-border"). Alternatively, the "Core" provisions can also be classified by whether they are intrinsically discriminatory (referred to as "Preferential"), or applied on a non-discriminatory or Most Favored Nation basis (referred to as "MFN"). The complete categorization of PTA provisions is summarized

[5] This database includes 263 trade agreements and 16 Partial Scope Agreements (PSAs), while in its bilateral dataset, there is a total of 261 agreements mapping to 52 policy areas which excludes all PSAs and two Free Trade Agreements (FTAs).

in Table 1.1.

In addition, this dataset discusses legal issues. It distinguishes between coverage and legal enforceability of each provision in the PTA. According to Hofmann et al. (2017), a provision that is covered might still not be considered as legally enforceable due to unclear or loosely formulated legal language. It applies the assessment of legal enforceability to every provision in the agreement, and any provision can be viewed as covered, weakly legally enforceable or strongly legally enforceable. In general term, one provision is considered as weakly legally enforceable if the language used is sufficiently precise and committing, but the provision itself has been excluded from dispute settlement procedures under the PTA. If the dispute settlement procedures are further included, such a provision is considered as strongly legally enforceable. Figure 1.1 illustrates the assessment of legal enforceability in a schematic diagram.[6]

Finally, based on the categorization of PTA provisions described above, we can continue to build variables to represent the corresponding PTA subcategories. In this paper, the horizontal depth of a PTA is similar to the "provisional coverage" of an agreement (Damuri, 2012), but we make a little bit modification to facilitate our later empirical analysis. For example, an agreement that includes provisions in the categories of WTO+ and WTO-X can be seen as a "deeper" agreement than the one dealing with WTO+ provisions only. In our econometric estimation we adopt these constructed indicators of PTA subcategories to analyze the effect of depth on trade flows and welfare. To clearly illustrate the methodology of defining PTA subcategories, we draw four tree diagrams in Figure 1.2. In short, we first consider the WTO+ and WTO-X provisions, by decomposing the general indicator PTA_{ijt} into three PTA subcategories: define $(PTA\_P\_X)_{ijt} = 1$ if it includes at least one of WTO+ provisions and at least one of WTO-X provisions; define $(PTA\_P\_nX)_{ijt} = 1$ if it includes

[6]Explained by the scheme in Figure 1.1, the provision variable referring to "1st COVERAGE" takes the value of either zero or one to indicate whether the specific provision is covered or not, while the variable referring to "2nd LEGAL ENFORCEABLITY" is assigned the value of either zero, one or two, which means that this provision can be not legally enforceable, weakly legally enforceable or even strongly legally enforceable, respectively.

at least one of 14 WTO+ provisions, but none of 38 WTO-X provisions is covered in the agreement; and define $(PTA\_nP\_X)_{ijt} = 1$ if there are no WTO+ provisions, but include at least one of 38 WTO-X provisions. Here we only consider the stringent case of strongly legally enforceable provisions to highlight the importance of dispute settlement mechanism. To ensure the consistency of estimation, the sum of these three PTA subcategories is equal to the aggregate indicator PTA_{ijt} itself. Following a similar logic, we could continue to define two subcategories in respect to "Core" and "Non-Core" categories;[7] four subcategories in respect to "Border" and "Behind-the-border" categories;[8] and four subcategories in respect to "Preferential" and "MFN" categories.[9] Thus, in our analysis the horizontal depth of PTAs also depends on the policy areas covered in the agreement.

1.3 The Theoretical Model

Our estimation strategy and counterfactual analytical framework are based on the Melitz (2003) model with untruncated Pareto distribution. Each country is endowed with a fixed supply of labor L_i. Buyers have CES preferences with an elasticity of substitution $\sigma > 1$ defined over the differentiated varieties supplied by firms. The mass of entrants in country i is denoted as N_i, and the cost of each input bundle is c_i. Each entrant pays a fixed cost of entry $c_i F_i$ in order to take a productivity draw $1/a$ from a cumulative Pareto distribution $G_i(a)$ over the support $[0, \bar{a}_i]$ with dispersion parameter $\theta > (\sigma - 1)$. Firms of productivity level $1/a$ located in country i incur a constant marginal cost $c_i \tau_{ij} a_i$ and a fixed cost $c_i f_{ij}$ to serve country j, where τ_{ij} indicates the variable trade cost factor and f_{ij} the fixed trade cost in terms of input bundles. The trade costs in the model is assumed to be asymmetric.[10]

[7] Omitting the country and year subscript ijt, two PTA subcategories are denoted as "PTA_C_NC" and "PTA_C_nNC".

[8] Omitting the country and year subscript ijt, four PTA subcategories are denoted as "PTA_B_H_NC", "PTA_B_H_nNC", "PTA_B_nH_NC" and "PTA_B_nH_nNC".

[9] Omitting the country and year subscript ijt, four PTA subcategories are denoted as "PTA_Pref_MFN_NC", "PTA_Pref_MFN_nNC", "PTA_Pref_nMFN_nNC" and "PTA_nPref_MFN_NC".

[10] In robustness checks in Section 1.5.4, we allow the entry to use input bundles that have different labor intensity from the input bundles used in the production process. The modifications to the counterfactual equations are shown in the Math Appendix A.

Given CES preferences and monopolistic competition, firms in country i exit from serving market j if its cost draw is above the cutoff a_{ij} defined by the zero-profit condition:

$$\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{c_i\tau_{ij}a_{ij}}{P_j}\right)^{1-\sigma}E_j = c_i f_{ij}, \tag{1.1}$$

where P_j and E_j are the aggregate price index and the nominal expenditure of country j, respectively. It follows that the export value of country i to country j is $X_{ij} = \left(\frac{\sigma}{\sigma-1}\frac{c_i\tau_{ij}}{P_j}\right)^{1-\sigma}E_jN_iV_{ij}$ and $P_j^{1-\sigma} = \sum_i \left(\frac{\sigma}{\sigma-1}c_i\tau_{ij}\right)^{1-\sigma}N_iV_{ij}$, where

$$V_{ij} \equiv \int_0^{a_{ij}} a^{1-\sigma}dG(a) = \frac{\theta}{\theta-\sigma+1}\frac{a_{ij}^{\theta-\sigma+1}}{\bar{a}_i^{\theta}} \tag{1.2}$$

indicates the proportion of firms (weighted by their market shares) that export from i to j.[11]

Let Y_i denote the total sales of goods by country i to all destinations. Following the technique used in the literature on structural gravity equations (Anderson and van Wincoop, 2003; Anderson and Yotov, 2010; Head and Mayer, 2015; Anderson and Yotov, 2016), we can derive a modified gravity equation by imposing the market-clearing condition:

$$Y_i = \sum_j X_{ij} = \left(\frac{\sigma}{\sigma-1}c_i\right)^{1-\sigma}N_i\sum_j \left(\tau_{ij}/P_j\right)^{1-\sigma}E_jV_{ij} \tag{1.3}$$

to solve for $\left(\frac{\sigma}{\sigma-1}c_i\right)^{1-\sigma}N_i$ and substitute the result in the expression of X_{ij} and P_j to obtain:

$$X_{ij} = Y_iE_j\left(\frac{\tau_{ij}}{\Pi_iP_j}\right)^{1-\sigma}V_{ij}, \tag{1.4}$$

$$\Pi_i^{1-\sigma} \equiv \sum_j (\tau_{ij}/P_j)^{1-\sigma}V_{ij}E_j, \tag{1.5}$$

$$P_j^{1-\sigma} = \sum_i (\tau_{ij}/\Pi_i)^{1-\sigma}V_{ij}Y_i, \tag{1.6}$$

[11] As in Melitz (2003), suitable conditions are imposed such that not all firms export.

Equation (1.4) resembles the structural gravity equation, and Π_i and P_j in equation (1.5)–(1.6) the outward and inward multilateral resistance (MR) proposed by Anderson and van Wincoop (2003), but with the extra term V_{ij} indexing the extensive margin. To arrive at an implementable estimation equation, note that the definitions of a_{ij} and V_{ij} in (1.1) and (1.2) imply:

$$\tau_{ij}^{1-\sigma} V_{ij} = \left({\tau_{ij}}^{-\theta} {f_{ij}}^{-\frac{\theta}{\sigma-1}+1} \right) \left({P_j}^{\theta-\sigma+1} \right) \left({c_i}^{-\frac{\sigma\theta}{\sigma-1}+\sigma} \right) \left({E_j}^{\frac{\theta}{\sigma-1}-1} \right). \tag{1.7}$$

Using equation (1.7), we can rewrite the trade flow equation (1.4) and the MR equations (1.5)–(1.6) in terms of variable and fixed trade costs as:

$$X_{ij} = Y_i E_j \left(\frac{{\tau_{ij}}^{-\theta} {f_{ij}}^{-\frac{\theta}{\sigma-1}+1}}{\chi_i \, \zeta_j} \right), \tag{1.8}$$

where[12]

$$\chi_i \equiv \sum_j ({\tau_{ij}}^{-\theta} {f_{ij}}^{-\frac{\theta}{\sigma-1}+1} / \zeta_j) E_j, \tag{1.9}$$

$$\zeta_j = \sum_i ({\tau_{ij}}^{-\theta} {f_{ij}}^{-\frac{\theta}{\sigma-1}+1} / \chi_i) Y_i. \tag{1.10}$$

We may regard χ_i as the market access potential of exporter i, defined as the weighted average of its access to each market weighted by the destination market's expenditure E_j. Similarly, ζ_j can be regarded as the sourcing potential of importer j, with each bilateral sourcing relationship weighted by the source country's supply Y_i.

The aggregate budget constraint that allows for trade deficit requires that:

$$E_j = Y_j + D_j, \tag{1.11}$$

where D_j is the nominal trade deficit of country j. We assume that the input bundle combines

[12] Specifically, $\chi_i \equiv \Pi_i^{1-\sigma} / {c_i}^{-\frac{\sigma\theta}{\sigma-1}+\sigma}$ and $\zeta_j \equiv P_j^{-\theta} / {E_j}^{\frac{\theta}{\sigma-1}-1}$.

labor and intermediate inputs with a constant labor share β_i. Intermediates comprise the full set of goods as for final demand, aggregated using the same CES function. This implies that the cost of an input bundle in country i is

$$c_i = w_i^{\beta_i} P_i^{1-\beta_i}. \tag{1.12}$$

Under the Pareto distribution for firm productivity, the aggregate profit is a constant share $\frac{\sigma-1}{\sigma\theta}$ of sales revenue. Thus, the free-entry condition requires that:

$$\frac{\sigma-1}{\sigma\theta} Y_i = N_i F_i c_i, \tag{1.13}$$

where the aggregate profit equals the total entry cost. Finally, the labor-market clearing condition requires that:

$$w_i L_i = \beta_i \left(1 - \frac{\sigma-1}{\sigma\theta} + \frac{\sigma-1}{\sigma\theta}\right) Y_i, \tag{1.14}$$

where $\beta_i \left(1 - \frac{\sigma-1}{\sigma\theta}\right) Y_i$ is the part of labor cost incurred by firms in the production process and $\beta_i \left(\frac{\sigma-1}{\sigma\theta}\right) Y_i$ the part incurred in the entry process.

1.4 Econometric Estimation and Results

1.4.1 Effects of PTA and PTA subcategories

Our empirical estimation adopts the gravity model to identify the impacts of PTA on international trade flows. Two main issues are to be considered during the estimation. The first one is related to the outward and inward MR terms Π_i and P_j derived in equation (1.5) and (1.6). Anderson and van Wincoop (2003) illustrate the omitted variables bias which is introduced by ignoring prices in the cross-sectional gravity equation. They suggest using country-specific FEs to account for the MR terms in order to generate unbiased estimates. Subramanian and Wei (2007) emphasize this issue when examining the GATT/WTO effect on trade, and find a positive relationship. While controlling for the country-specific FEs helps to account for the endogeneity bias created by prices and the influence of PTA among other countries on the trade from country i to j, another issue that may arise is the "unobserved bilateral heterogeneity". Baier and Bergstrand (2007) believe that there are unobserved time-invariant bilateral variables influencing simultaneously the presence of a FTA and the volume of trade. Because these variables are likely correlated with FTAs, they are best controlled by using bilateral FEs.[13]

Taking above concerns into consideration, we rewrite the gravity equation (1.8) in its logarithm transformation and introduce the year subscript t as follows:

$$\ln X_{ijt} = \ln Y_{it} + \ln E_{jt} + \ln\left({\tau_{ijt}}^{-\theta} {f_{ijt}}^{-\frac{\theta}{\sigma-1}+1}\right) - \ln\left(\chi_{it}\,\zeta_{jt}\right). \tag{1.15}$$

Typically, the literature assumes that the unobserved variable/fixed trade cost is log-linear in a vector of trade-cost proxies $\mathbf{Z}_{ijt}$, and uses exporter-year and importer-year FEs to control for the MR terms χ_{it} and ζ_{jt}, respectively. Our benchmark regression for estimating the PTA effect is to rewrite the equation (1.15) as:

$$\begin{aligned} \ln X_{ijt} =& \beta_1\ gsp_{ijt} + \beta_2\ comcur_{ijt} + \beta_3\ curheg\_o_{ijt} + \beta_4\ curheg\_d_{ijt} + \beta_5\ PTA_{ijt} \\ &+ \eta_{it} + \psi_{jt} + \gamma_{ij} + \epsilon_{ijt} \end{aligned} \tag{1.16}$$

where X_{ijt} are imports of country j from country i at time t; η_{it} and ψ_{jt} are the exporter and importer time-varying FEs, respectively. γ_{ij} is the asymmetric time-invariant country-pair FEs. These time-varying directional country-specific dummies are used to control for the MR terms along with the sales and expenditure variables in equation (1.8). The common currency indicator $comcur_{ijt}$, which equals one if two countries use a common currency at time t. $curheg\_o_{ijt}$ equals one if exporter i is the current hegemon of importer j at time t,

[13]However, the existing literature has relied on the time invariant country-pair FEs to deal with the "unobserved bilateral heterogeneity", but it cannot take into account biases stemming from a time-varying dimension.

and $curheg\_d_{ijt}$ equals one if importer j is the current hegemon of exporter i at time t. The GSP indicator gsp_{ijt} equals one if importer j offers GSP preferential treatment to exporter i, and PTA_{ijt} equals one if there is at lease one PTA currently in force between exporter i and importer j at time t.

After identifying the PTA effect on trade flows (β_5), we further continue to investigate the heterogeneous effects varying with the content of provisions. We replace PTA_{ijt} in equation (1.16) with variables corresponding to different PTA subcategories constructed according to the classification of PTAs introduced in Section 1.2. For instance, to examine the effects related to the WTO+ and WTO-X provisions, we will replace PTA_{ijt} with $(PTA\_P\_X)_{ijt}$, $(PTA\_nP\_X)_{ijt}$, and $(PTA\_P\_nX)_{ijt}$. The sum of these three variables should be equal to the aggregate indicator itself for a non-redundant estimation of the GATT/WTO effect in the next stage. So far we have only considered positive trade flows, which are consistent with the settings in the following counterfactual analysis.[14]

Table 1.2 reports the regression estimates based on the gravity equation (1.16) and the modified equations. It presents the impact of PTA and PTA subcategories on positive international trade flows, after controlling for the exporter-year FEs, importer-year FEs and country-pair FEs. Regarding the trade-cost proxy variables, the coefficient of $comcur_{ijt}$ is significantly positive, while the estimates of $curheg\_o_{ijt}$ and $curheg\_d_{ijt}$ are both insignificant, supporting the argument that there is no substantial impact of hegemony on the international trade flows. One remark here is with regard to the GSP indicator. The coefficients of gsp_{ijt} across different specifications are all insignificantly around zero, which shows that whether importer j offers GSP preferential treatment to exporter i or not does not necessarily contribute to the growth of bilateral trade flows. In the existing literature, the GSP's effects on aggregate trade flows depend on the empirical specification and dataset used (Subramanian and Wei, 2007; Rose, 2004).

Referring to the effects of PTA and PTA subcategories, Column (1) in Table 1.2 presents

[14]However, excluding zero trade from estimation is criticized to bias the estimates according to Silva and Tenreyro (2006).

the coefficient estimate of the aggregate indicator PTA_{ijt}. The result suggests that if there exists at least one PTA currently in force between one country pair, where the bilateral import trade can be around 32.4% higher holding other conditions constant.[15] The size and statistical significance of the PTA average effect during the selected time period are in line with the relevant literature, as summarized by Head and Mayer (2015) and Limão (2016). From Column (2) to (5), the aggregate indicator PTA_{ijt} is being decomposed into several subcategories, following the categorization of WTO+ and WTO-X, "Core" and "Non-Core", "Border" and "Behind-the-border", and "Preferential" and "MFN" provisions, respectively. Here we only consider the most stringent case, the strongly legally enforceable provisions where the dispute settlement procedures are available. In Column (2), we can see that covering both WTO+ and WTO-X categories in the agreement will increase the bilateral trade flow by around 33.8% and is larger than the one solely dealing with WTO+ provisions ($\hat{\beta}_{5,PTA\_P\_X} > \hat{\beta}_{5,PTA\_P\_nX}$). That means a deeper agreement that includes provisions on both tariff and non-tariff barriers induces larger trade flow than the one only focus on the tariff liberalization, while the estimated coefficient of covering WTO-X provisions ($\hat{\beta}_{5,PTA\_nP\_X}$) is insignificant. The ranking order in the magnitude of coefficient estimates of PTA subcategories in Column (3) are also well expected. As many of the provisions in the PTA are beyond trade issues, considering the categories of "Core" and "Non-Core" provisions in the agreement will tend to promote the import in a greater degree than the one including the category of "Core" provisions only ($\hat{\beta}_{5,PTA\_C\_NC} > \hat{\beta}_{5,PTA\_C\_nNC}$). Although those "Non-Core" provisions are not so relevant from an economic theory perspective as "Core" provisions, they still help to regulate a domestic environment with improved levels of "regulatory coherence"(Bagwell et al., 2016). A similar pattern could be observed when we continue to investigate into "Core" provisions from two lenses, "Border" and "Behind-the-border", and "Preferential" and "MFN" provisions. From Column (4), we can see that by including both "Border" and "Behind-the-border" provisions, the country-pair trade flows

[15] The percentage is calculated as ($\exp^{\hat{\beta}_5} - 1$)

increase by around 35.1%, which is a more substantial effect compared with that of including only one category ($\hat{\beta}_{5,PTA\_B\_H\_NC} > \hat{\beta}_{5,PTA\_B\_nH\_nNC}$; $\hat{\beta}_{5,PTA\_B\_H\_NC} > \hat{\beta}_{5,PTA\_B\_nH\_NC}$). The deepening of PTA negotiations is regarded as the greatest with the inclusion of "Border", "Behind-the-border" and 'Non-Core" measures simultaneously ($\hat{\beta}_{5,PTA\_B\_H\_NC}$). A similar result is obtained based on Column (5), the agreement also increases in the defined horizontal depth over time by covering more "MFN" and "Preferential" measures together. And the highest ranking of the coefficient ($\hat{\beta}_{5,PTA\_Pref\_MFN\_NC}$) among all PTA subcategories in this column reconfirms the pattern above. It supports the argument that in terms of the strongly legally enforceable provisions, the international trade promoting effect will be strengthened when a PTA involves policy areas that could achieve deeper forms of integration.

1.4.2 Effects of the GATT/WTO membership

Besides PTA and PTA subcategories, we also define GATT/WTO trade policy variables to exam their effects on international trade flows. In this section, we mainly focus on how to derive trade effects of *bothwto* and *imwto* of interest. According to WTO rules when a country becomes a GATT/WTO member, it is required to apply the tariff-bindings and non-tariff commitments negotiated in its accession package or in general trade negotiation sessions by the MFN principle to all other members. This is expected to lower the variable/fixed trade costs for exports from member i to member j. Unfortunately, it is not appropriate to run an Ordinary Least Squares (OLS) regression on the log transformation of gravity model with a similar specification of estimating PTA effect as we discussed above, because we can not estimate the standard set of exporter-year and importer-year FEs, the effect of *bothwto* and the effect of *imwto* all in the same regression. As suggested by Cheong et al. (2014), these indicator variables are multi-collinear. To avoid this problem, we do not attempt to estimate the effects of all variables of interest in one regression, instead we propose an iterated regression methodology to separately identify the GATT/WTO trade effect.

Before proceeding to estimation, we choose the world total output Y_w ($\equiv \sum_i Y_i$) to normalize χ_i in equation (1.9):[16]

$$\begin{aligned} \bar{\chi}_i &\equiv \frac{\chi_i}{Y_w} \\ &= \sum_j \left({\tau_{ij}}^{-\theta} {f_{ij}}^{-\frac{-\theta}{\sigma-1}+1} / \zeta_j \right) e_j \end{aligned} \tag{1.17}$$

And rewrite ζ_j in tirms of $\bar{\chi}_i$:

$$\zeta_j = \sum_i \left({\tau_{ij}}^{-\theta} {f_{ij}}^{-\frac{-\theta}{\sigma-1}+1} / \bar{\chi}_i \right) s_i \tag{1.18}$$

In equation (1.17) and (1.18), $e_j \equiv E_j/Y_w$ denotes the expenditure share of country j, and $s_i \equiv Y_i/Y_w$ denotes the output share of country i. The bilateral trade flow X_{ij} can be rewritten in terms of $\bar{\chi}_i$ and ζ_j as:

$$X_{ij} = \frac{Y_i E_j}{Y_w} \left(\frac{{\tau_{ij}}^{-\theta} {f_{ij}}^{-\frac{-\theta}{\sigma-1}+1}}{\bar{\chi}_i \, \zeta_j} \right) \tag{1.19}$$

With the interdependent relationship between equation equation (1.17) and (1.18), we are able to iterate over these two structural equations to obtain $\bar{\chi}_i$ and ζ_j. To model the unobserved trade cost, we follow the way in previous empirical models of bilateral trade flows (Anderson and Yotov, 2016; Egger et al., 2011). Equipped with the estimates from equation (1.16), in combination with data on the corresponding covariates, we can construct the matrix of baseline trade costs $\left({\tau_{ijt}}^{-\theta} {f_{ijt}}^{-\frac{\theta}{\sigma-1}+1} \right)$ as:

$$\begin{aligned} \ln \left({\tilde{\tau}_{ijt}}^{-\theta} {\tilde{f}_{ijt}}^{-\frac{-\theta}{\sigma-1}+1} \right) = &\hat{\beta}_1 \, gsp_{ijt} + \hat{\beta}_2 \, comcur_{ijt} + \hat{\beta}_3 \, curheg\_o_{ijt} + \hat{\beta}_4 \, curheg\_d_{ijt} \\ &+ \hat{\beta}_5 \, PTA_{ijt} + \tilde{\gamma}_{ij} \end{aligned} \tag{1.20}$$

where includes the same set of trade-cost proxies (gsp_{ijt}, $comcur_{ijt}$, $curheg\_o_{ijt}$, $curheg\_d_{ijt}$

[16]We can also normalize ζ_j by Y_w, and it does not affect the specification of equation (1.19).

and PTA_{ijt}), as well as the corresponding coefficients ($\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, $\hat{\beta}_4$ $\hat{\beta}_5$) and country-pair FEs ($\tilde{\gamma}_{ij}$) from the PTA regression of equation (1.16).[17] Taking the exponential transformation, we can approximate the trade-cost term as ($\tilde{\tau}_{ijt}{}^{-\theta} \tilde{f}_{ijt}{}^{-\frac{-\theta}{\sigma-1}+1}$).[18]Thus, with the expenditure share (e_j), the output share (s_i) and the starting values of approximated MR terms ($\tilde{\tilde{\chi}}_i$ and $\tilde{\zeta}_j$, where the initial values are set as one), we can solve the general equilibrium MR system by iterating over equation (1.17) and (1.18) after each round of adjustment, until $\tilde{\tilde{\chi}}_i$ and $\tilde{\zeta}_j$ converge. This iteration is conducted yearly from 1980 to 2015, and can be regarded as the inner loop of our whole iterated regression procedure.

At the same time, the trade-cost term is assumed to be related to the country-pair's GATT/WTO membership. With the approximated MR terms, we use the exporter-year and importer-year FEs for the estimation of GATT/WTO indicators to avoid the troublesome multi-collinearity problem.[19] Based on the correlations from equation (1.16) to (1.20), we can write the new regression equation as:

$$\begin{aligned} FE_{ijt} =& \alpha_1 \, bothwto_{ijt} + \alpha_2 \, imwto_{ijt} + \alpha_3 \, exwto_{ijt} + \alpha_4 \ln Y_{it} + \alpha_5 \ln E_{jt} \\ & - \alpha_6 \ln \tilde{\tilde{\chi}}_{it} - \alpha_7 \ln \tilde{\zeta}_{jt} - \alpha_8 \ln Y_{wt} + \epsilon_{ijt} \end{aligned} \tag{1.21}$$

where $FE_{ijt} \equiv \tilde{\eta}_{it} + \tilde{\psi}_{jt}$, the sum of the exporter-year and importer-year FEs estimated from equation (1.16). $\tilde{\tilde{\chi}}_i$ and $\tilde{\zeta}_j$ are the approximated MR terms iterated from the inner loop procedure discussed above. To begin with the iterated regression method, we first run the OLS regression on equation (1.21) to obtain the initial guess of the coefficients ($\hat{\alpha}_1^0$, $\hat{\alpha}_2^0$ and $\hat{\alpha}_3^0$).[20] Then incorporating the estimated effects of these three GATT/WTO indicators into

[17]As in this paper we allow the asymmetric trade costs, the country-pair FEs are also considered as directional.

[18]Besides the indicators which are usual controls in trade-cost proxies $\mathbf{Z}_{ijt}$, the reason to add the estimated country-pair FEs $\tilde{\lambda}_{ij}$ in equation (1.20) is to fully capture the impact of potential bilateral trade-cost proxies in $\mathbf{Z}_{ijt}$, such as bilateral distances, common colonizer indicator and common border indicator. They are all country-pair specific and their impact on international trade flows now has been absorbed into the country-pair FEs. In terms of internal trade costs, we use the common currency indicator ($comcur_{ij}$) to approximate them ($= \hat{\beta}_2 \, comcur_{ij}$).

[19]As in the regression equation (1.16), the trade effects of GATT/WTO indicators ($bothwto_{ijt}$, $imwto_{ijt}$ and $exwto_{ijt}$) have been absorbed into the exporter-year and importer-year FEs.

[20]Here the superscript of the coefficient is to count the outer loops of iteration.

the approximated trade-cost term:

$$\left(\ln \tilde{\tau}_{ijt}{}^{-\theta} \tilde{f}_{ijt}{}^{-\frac{-\theta}{\sigma-1}+1}\right)^{1} = \left(\ln \tilde{\tau}_{ijt}{}^{-\theta} \tilde{f}_{ijt}{}^{-\frac{-\theta}{\sigma-1}+1}\right)^{0} + \hat{\alpha}_1^0 \, bothwto_{ijt} + \hat{\alpha}_2^0 \, imwto_{ijt} + \hat{\alpha}_3^0 \, exwto_{ijt} \tag{1.22}$$

where $\left(\ln \tilde{\tau}_{ijt}{}^{-\theta} \tilde{f}_{ijt}{}^{-\frac{-\theta}{\sigma-1}+1}\right)^{0}$ is the approximated trade-cost term calculated from equation (1.20). Then in the second step, we update the approximated trade-cost term by equation (1.22), and the corresponding MR terms ($\tilde{\tilde{\chi}}_{it}$ and $\tilde{\zeta}_{jt}$) by using the inner loop iteration procedure as we discussed above. After updating the set of all related variables, we are able to run the OLS regression on equation (1.21) again to get new coefficients of GATT/WTO estimators ($\hat{\alpha}_1^1$, $\hat{\alpha}_2^1$ and $\hat{\alpha}_3^1$). Repeat this iterated regression procedure, after each round of adjustment until it converges in $\hat{\alpha}_1$, $\hat{\alpha}_2$ and $\hat{\alpha}_3$, we could obtain a set of GATT/WTO indicator estimates, which is consistent with our previous parametric estimation framework of PTA trade effects.

For the effects of *bothwto*, *imwto* and *exwto* on bilateral trade, we expect the *bothwto* effect to be stronger than *imwto* and *exwto* effect by taking the MFN treatment into consideration. Referring to the first column in Table 1.3, the coefficient estimate of $bothwto_{ijt}$ is significantly positive, which shows that the GATT/WTO membership has positive effects on trade among members. Also, the *bothwto* effect is bigger than the *imwto* and *exwto* effects ($\hat{\alpha}_1 > \hat{\alpha}_2$; $\hat{\alpha}_1 > \hat{\alpha}_3$) as we expected. The smaller effect of *imwto* relative to *bothwto* suggests that not all members extend their MFN treatment to nonmembers, or that such extensions are not granted at all times or to all nonmembers. Here we interpret the slightly negative coefficient of *exwto* as a potential result after removing the exporter country's preferential treatment such as export subsidies. Before joining the GATT/WTO, exporter countries tend to provide export subsidies to simulate the exports to other countries, however, after the accession to GATT/WTO, this preferential treatment has to be regulated within the regime of the multilateralism liberalization system, so that impose an negative effect on the bilateral trade flows. We take the estimates of GATT/WTO trade effects in Column (1) as our benchmark, later in the robustness checks we will extend our analysis to the heterogeneous patterns of trade liberalization shown in Column (2).

1.5 General Equilibrium Welfare Effects

In this section, we present the main results on the welfare effects of PTA and PTA subcategories, as well as its interaction with GATT/WTO. We also examine the sensitivity of results to the choice of parameter values for trade elasticity, and take the potential heterogeneity of GATT/WTO trade effects into consideration.

1.5.1 Counterfactual Analysis

To prepare for conducting the counterfactual analysis, we rewrite the system of structural equations in terms of changes à la the hat algebra of Dekle et al. (2007).[21] In particular, let x' denote the counterfactual value of a variable x and $\widehat{x} \equiv x'/x$ the ratio of the counterfactual to the factual value of the variable.

The market-clearing condition in equation (1.3) and the expression of $\Pi_i^{1-\sigma}$ imply the following:

$$\widehat{Y}_i = \widehat{N}_i \, \widehat{c}_i^{1-\sigma} \, \widehat{\Pi}_i^{1-\sigma}. \tag{1.23}$$

The MR structural relationship (1.5)–(1.6) and the trade flow equation (1.4) imply that:

$$\widehat{\Pi}_i^{1-\sigma} = \sum_j \alpha_{ij} \left(\widehat{\tau}_{ij}^{1-\sigma} \widehat{V}_{ij} / \widehat{P}_j^{1-\sigma} \right) \widehat{E}_j, \tag{1.24}$$

$$\widehat{P}_j^{1-\sigma} = \sum_i \lambda_{ij} \left(\widehat{\tau}_{ij}^{1-\sigma} \widehat{V}_{ij} / \widehat{\Pi}_i^{1-\sigma} \right) \widehat{Y}_i, \tag{1.25}$$

[21]Some scholars credit the hat algebra technique to Jones (1965), although the Jones hat algebra is in terms of small changes in the variables, while the algebra of Dekle et al. (2007) is in terms of ratios of counterfactual to factual values, so the latter in principle can accommodate large discrete changes. The Jones hat algebra is also heavily used in the computable general equilibrium (CGE) models, represented by the Global Trade Analysis Project (GTAP) of Hertel (1997).

where $\alpha_{ij} \equiv X_{ij}/Y_i$ is the share of country i's sales that goes to destination j, and $\lambda_{ij} \equiv X_{ij}/E_j$ is the share of country j's expenditure that is spent on source i.

Similar to the previous estimation, the counterfactual analysis is also conducted by the iteration method. Starting with any given initial values of the wage ratio $\widehat{w}_i$ and aggregate price index ratio $\widehat{P}_j$, by the labor market-clearing condition in equation (1.14), we have:

$$\widehat{Y}_i = \widehat{w}_i. \tag{1.26}$$

And by the aggregate budget constraint in equation (1.11), we could obtain:

$$\widehat{E}_i = \frac{Y_i}{E_i}\widehat{Y}_i + \frac{D_i}{E_i}\widehat{Y}_w, \tag{1.27}$$

where D_i is the nominal trade deficit of country i, and $\widehat{Y}_w = \sum_i s_i \widehat{Y}_i$.

Next, the Cobb-Douglas cost structure (1.12) for the input bundle requires that:

$$\widehat{c}_i = \widehat{w}_i^{\beta_i} \widehat{P}_i^{1-\beta_i}, \tag{1.28}$$

and the free-entry condition (1.13) implies that:

$$\widehat{N}_i = \widehat{Y}_i / \widehat{c}_i. \tag{1.29}$$

To close the model, note that given (1.7) we have:

$$\widehat{\tau}_{ij}^{1-\sigma}\widehat{V}_{ij} \quad = \quad \left(\widehat{\tau}_{ij}{}^{-\theta}\widehat{f}_{ij}{}^{-\frac{\theta}{\sigma-1}+1}\right)\left(\widehat{P}_j{}^{\theta-\sigma+1}\right)\left(\widehat{c}_i{}^{-\frac{\sigma\theta}{\sigma-1}+\sigma}\right)\left(\widehat{E}_j{}^{\frac{\theta}{\sigma-1}-1}\right), \tag{1.30}$$

where $(\widehat{\tau}_{ij}{}^{-\theta}\widehat{f}_{ij}{}^{-\frac{-\theta}{\sigma-1}+1})$ is the exogenous shocks given by the previous estimation of either PTA or GATT/WTO trade effects. Given the corresponding estimates we can calculate how the change in trade costs due to PTA status or GATT/WTO membership affects the endogenous variables in the economy, taking into account general equilibrium adjustment.

Thus, using the ratios of variables ($\widehat{Y}_i$, $\widehat{E}_i$, $\widehat{c}_i$, $\widehat{N}_i$, $\widehat{\tau}_{ij}^{1-\sigma}\widehat{V}_{ij}$) obtained from equation (1.26)–(1.30), we can update $\widehat{\Pi}_i^{1-\sigma}$ by equation (1.24), update $\widehat{w}_i$ ($=\widehat{Y}_i$) by equation (1.23) and update $\widehat{P}_j^{1-\sigma}$ by equation (1.25), with all the observable variables $\{\alpha_{ij}, \lambda_{ij}, Y_i\}$ and parameters $\{1-\sigma, \theta, \beta_i\}$. We repeat this procedure until it converges in $\widehat{w}_i$ and $\widehat{P}_j$. The welfare effects of given exogenous changes in trade cost can then be measured by the real wage:

$$\widehat{W}_i = \widehat{w}_i / \widehat{P}_i. \tag{1.31}$$

This formula evaluates the welfare effect based on changes in the real output, which in general can differ from the real expenditure given the presence of a trade deficit.

To illustrate the algorithm, suppose the estimated trade effect of PTA is γ_1. This implies an ex-post effect of $\left\{\widehat{\tau}_{ij}{}^{-\theta}\widehat{f}_{ij}{}^{-\frac{\theta}{\sigma-1}+1}\right\} = \exp(\gamma_1)$ for country pairs where exits at least one PTA currently in force at a given year. The shock $\left\{\widehat{\tau}_{ij}{}^{-\theta}\widehat{f}_{ij}{}^{-\frac{\theta}{\sigma-1}+1}\right\}$ can then be fed into the system (1.23)–(1.30) to derive the ex-post effects of PTA on the welfare (1.31) for this year. A similar algorithm applies to derive the ex-post effect of GATT/WTO policy variables ($bothwto_{ijt}$, $imwto_{ijt}$ and $exwto_{ijt}$).

For the parameter values, we choose $\sigma = 5$ as the benchmark, which lies within the range of trade elasticity often reported in the gravity literature; see Head and Mayer (2015) for a meta-analysis. For $\{\beta_i t\}$, we use the share of value added in gross output in country i, calculated as the median of the value-added shares across sectors obtained and combined from multiple sources as introduced in Data Appendix. The value varies in the range of $[0.26, 0.62]$ across countries in our dataset. For the parameter θ, we choose the value based on the estimate of $\theta - (\sigma - 1)$ from Helpman et al. (2004). Most of their estimates fall in the range of $[0.5, 1.5]$. We adopt $\theta - (\sigma - 1) = 1$ as the benchmark; i.e., $\theta = 5$ when $\sigma = 5$. We will provide robustness checks for alternative parameter values of θ and σ.[22]

[22] Alternative values of $\tilde{\theta} \equiv \theta/(\sigma-1)$ are suggested by Eaton et al. (2011), where they study the export behavior of French firms in a modified Melitz framework. Based on Figure 3B therein, the regression slope of -0.66 (between mean sales in France and entry into multiple countries) implies $\tilde{\theta} \approx 1.51$. If based on Figure 3C instead, the regression coefficient of -0.57 (between mean sales in France and entry into more difficult markets) implies $\tilde{\theta} \approx 1.75$. Their SMM estimate based on all the data suggests $\tilde{\theta} = 2.46$. Based on US firm

In the data, a country does not trade with every potential trading partner. Such trading relationships will be reflected by $\alpha_{ijt} = 0$ and $\lambda_{ijt} = 0$. All counterfactual changes in the trade costs calculated for these country pairs are multiplied by zero shares and hence do not affect the counterfactual results. In a sense, this is comforting, since the current framework cannot explain zero trade and counterfactual changes in the occurrence of zero trade. It is best to leave out zero-trade relationships from the analysis. Thus, whatever counterfactual effects we obtain using these frameworks are conditional on the positive trading relationships. This also suggests that previous OLS estimates we obtained based on positive trade flows are consistent with the design of the counterfactual analysis.

1.5.2 Counterfactual Results of PTA

We first conduct counterfactual analysis based on the Melitz framework (with $\sigma = 5$ and $\theta = 5$), where the shocks to the trade cost across years ($\widehat{\tau}_{ijt}^{1-\sigma}$ for all ijt) are calculated based on the estimated effects of PTA from Table 1.2.

Figure 1.3 provides a breakdown of the welfare effects by PTA status. In order to better present the results, we classify the countries into three subsets based on the total number of PTAs signed with their trading partners at a given year: zero, below the median, equal to or bigger than the median. Due to space constraints, we report the results for selected years. From Figure 1.3 we can see that the distribution of PTA welfare effects become increasingly more dispersed with a long right tail. The countries with more PTA partners gain more relative to other countries. In early years, there is only a small number of countries which have signed PTAs with their trading partners, and the distributions of all three country subsets are presented to be centrally concentrated around zero. And the welfare effects are relatively small, between 0 to +5%. The distribution of PTA welfare effects starts to become

data, Chaney (2008) uses a similar method as Helpman et al. (2004) of regressing the log of firm rank on the log of firm sales, and estimates $\tilde{\theta} \approx 2$. In Eaton et al. (2013), however, they find that simulations with $\sigma = 5.64$ and $\tilde{\theta} = 1.05$ match most closely the data and can explain the fact that a small number of French firms account for a large share of total exports. This set of parameter values implies $\theta = 4.87$ and is close to the benchmark values we adopt for the counterfactual simulations ($\sigma = 5$ and $\theta = 5$).

more dispersed since year 2000, especially for those countries in the third subset where the total number of PTAs is greater than the medium value of the whole country group. One remark here is that there is an increasing welfare gain for the countries with PTAs currently in force, but for those which were outside the PTA alliance they experienced a minor welfare loss around year 2000. For the impacts across geographical regions, we provide a summary in Table 1.4. We see that all OECD countries have gained, and in 2015 the mean and median gains are the greatest compared with other regions, at 2% by the Melitz framework. East and South Asia, and Eastern Europe and Central Asia have some very big winners and some small losers, leaving an overall positive welfare impact of more than 1.2%. Latin American and Caribbean countries have experienced relatively homogeneous and positive welfare effects, with a mean or median of 0.7%. Sub-Saharan Africa is the region which have seen generally smaller positive effects from signing PTAs. Besides the main geographical regions we mentioned above, other regions have experienced relatively big welfare effect from signing PTAs.

From Figure 1.4 to 1.7, we try to illustrate the welfare changes by decomposing the aggregate PTA indicator into different subcategories as we define in Section 1.2. To conduct the counterfactual analysis, we simultaneously shut down the effects of all the related PTA subcategories under the corresponding categorization of provisions. One remark relates to the classification of countries for better presenting the results. For example, concerning with "WTO+" and "WTO-X" provisions, in each single year we continue to allocate those countries without any PTAs in force to the subset named "no PTA" as we previously did. For the country which has signed at least one PTA, we count the total numbers of observations where PTA_nP_X=1, PTA_P_nX=1 or PTA_P_X=1 for all ijt, separately. If the number of observations where PTA_nP_X=1 dominates the other two counts, we choose to assign this country to the corresponding subset denoted as "PTA_nP_X". In this way we can allocate all countries to the corresponding subsets. To reduce the extra notations, we use the same names of PTA subcategories, as "PTA_nP_X", "PTA_P_nX" and "PTA_P_X", respectively.[23] By presenting the welfare results for different country subsets, we can find a general pattern sharing common characteristics. Similar to Figure 1.3, the distribution of PTA welfare effects still become increasingly more dispersed with a long right tail over the years as before, and for those countries with a dominant number of PTAs which are in deeper forms of integration (broader coverage of policy areas), they tend to gain more relative to countries in other shallow subsets. These heterogeneity in the PTA welfare effects across the different country subsets are mainly driven by the ranking order in the estimates of trade effects of PTA subcategories across different specifications in Table 1.2, and also by differences in country sizes and the adjustment of general equilibrium effects.

1.5.3 Interaction of PTA and GATT/WTO

The tension and interaction between multilateral trade liberalization (via GATT/WTO) and preferential trade liberalization (via PTA) have always been a hotly debated theoretical and policy question. In this section we conduct an welfare analysis of PTA deep integration in the counterfactual had all the GATT/WTO memberships not existed, and compare the effects with what we have obtained in Figure 1.3 under factual GATT/WTO memberships.

Based on the Melitz framework and benchmark parameter values ($\sigma = 5$ and $\theta = 5$), Figure 1.8 summarizes the welfare effects of PTA based on the categorization of provisions. There exists an universal pattern that without GATT/WTO membership, the ex-post welfare of PTAs are not affected much for countries without signing any PTAs with their trading partners, or dominantly signing relatively shallow agreements (for instance, in the subsets of "no PTA", "PTA_nP_X" and "PTA_nPref_MFN"). To contrast, for those countries which have been assigned to the subsets of signing a relatively larger number of PTAs with greatest depth (for instance, in the subsets of "no. of PTAs $\geq$ median", "PTA_P_X", "PTA_C_NC",

[23] In this way we classify countries based on the categorization of PTA provisions. In particular, for classifying countries in respect to "Border" and "Behind-the-border", and "Preferential" and "MFN" provisions, we combine those subsets of relatively small sizes compared with others, to clearly present the welfare change. Refer to Figure 1.2 for more details about how to build and combine the subsets.

"PTA_B_H" or "PTA_Pref_MFN"),[24] the ex-post gains become much smaller without the existence of GATT/WTO membership. This pattern becomes more prominent since year 2000, when the PTA surges in numbers, and more and more countries become the GATT/WTO members.

The above results suggest that by forming a dominant number of PTAs which is more deeply integrated, for instance, dominantly involving issues which are beyond the current WTO mandate or simple trade-related topics, countries are inclined to have stronger welfare improvement when they have already been included in a multilateral liberalization process. Currently, there are abundant literature providing broad theoretic supports for the view that the GATT/WTO is fundamentally well-designed to minimize the influence of terms-of-trade externalities on the policy choices of member governments and thereby solve the terms-of-trade problem, while providing a more mixed view of PTAs in this regard. For example, Bagwell et al. (2016) suggest many avenues where PTAs may worsen the terms-of-trade externality that the GATT/WTO multilateral approach is designed to eliminate. Nevertheless, when looking beyond the terms-of-trade argument, the same survey (pp. 1196–1206) suggests that PTAs could potentially address issues that GATT/WTO's shallow integration approach fails to do, for example, in response to the commitment problem (Ethier, 1998) or the complications introduced by production offshoring (Antràs and Staiger, 2012). Related to our discussion, Baldwin (2008) identifies three mutually compatible ways that PTA and GATT/WTO could interact with each other: PTA could affect GATT/WTO or verse versa, or both could be driven by the external factors. Research papers we mentioned above all look at the first channel and this channel is dominated in the literature to explore the relationship between PTA and multilateral liberalization. Compared with that, our analysis attempts to view from the reversed side, investigating into how nations' incentives to cut tariffs multilaterally could affect the welfare effects of PTA deep integration. Back to our result, it provides supporting evidence of the potential complementarity between deep

[24]The classification of countries is in line with the method described in Section 1.5.2

PTAs and GATT/WTO multilateral liberalization system. As shown in Figure 1.8, without the existence of GATT/WTO membership, a PTA of higher provisional depth experiences a more substantial welfare loss compared with relatively shallow agreements, especially in recent years. It indicates that when PTAs achieve deeper forms of integration, they may complement well with the shallow integration approach conducted by GATT/WTO.

1.5.4 Robustness Checks

In this section, we conduct several sensitivity analyses. We consider: allowing alternative levels of labor intensity in the entry process, raising the elasticity of substitution to an extremely high value ($\sigma = 10$), and varying firm dispersion parameter values ($\theta = \{4.5, 5.5, 6, 8, 10\}$). The results are reported in Tables 1.5 and 1.6, which give the median welfare effects of PTA. We also take the heterogeneous effects of GATT/WTO membership across different development combinations into consideration, and then redo the welfare analysis of the interaction of PTA and GATT/WTO to check the relative changes. This result is reported in Figure 1.9.

First, we allow the entry process in the Melitz model to use input bundles that have higher labor intensity than the input bundles used in the production process following Bollard et al. (2016) [BKL] and Arkolakis et al. (2012). The modifications to the counterfactual equations are shown in the Math Appendix. Let κ denote the value-added share in the entry process. The mean value-added share across the entry and the production process is then: $\bar{\beta}_i \equiv \beta_i \left(1 - \frac{\sigma-1}{\sigma\theta}\right) + \kappa \left(\frac{\sigma-1}{\sigma\theta}\right)$. The value $\bar{\beta}_i$ corresponds to the value-added share observed in the data. Since the maximum value-added share observed across countries in the data is 0.62, we set κ to take on values in $[0.8, 1]$ and calibrate β_i for given κ and observed $\bar{\beta}_i$. The effects on firm entry are summarized in Table 1.5, where we also include the Melitz benchmark results (when $\kappa = \beta_i = \bar{\beta}_i$). Consistent with theoretical implications, the relatively larger increase in the wage relative to the aggregate price (for countries with PTAs) implies a higher entry cost as κ increases, and hence weakens the incentive to entry. The reverse is true for countries without PTAs when they experience a smaller increase in the wage relative to the aggregate price; an increase in κ reduces the negative effect on entry. To the limit when $\kappa = 1$, the mass of firms remains constant, as suggested by the original Melitz model. These findings remain valid with respect to variations in the parameter values for σ, θ, and the caliper choice.

In spite of the impacts on firm entry as κ changes, Table 1.6 indicates that the impact of varying κ on welfare is negligible. To understand this result, note that we calibrate the parameter to imply the same mean value-added share as observed in the data. As κ increases in the entry, for given observed value-added shares $\bar{\beta}_i$, it implies smaller β_i in the production. A larger κ reduces the welfare effects (via smaller firm entry effects), but a smaller β_i amplifies them (since the multiplier effect via the use of intermediates in production is stronger). The simulation results suggest that these two countervailing effects exactly cancel out.

Next, based on these two tables we can also check the differences in welfare changes if allowing θ to vary within a range of values suggested by the literature (discussed in Footnote 22). A higher θ is expected to lower the welfare effect estimates in the Melitz model since the same observed changes in trade flows imply smaller changes in the underlying trade costs. Indeed, across Tables 1.5 and 1.6, the welfare effects of the Melitz model monotonically decrease as we increase θ from 4.5 to 10 with $\sigma = 5$. Then we expect the welfare effects to decrease when σ is bigger since goods are closer substitutes. In the Melitz model, we need to set the parameter $\theta > (\sigma - 1)$ such that the aggregate price is well defined. Thus, by setting $\sigma = 10$, we also modify θ up to $\theta = 10$. These parameter values are close to the upper-bound numbers used in the literature, so we could take the associated welfare effects under this setting as the lower-bound predictions.

Finally, we try to incorporate the heterogeneous patterns of trade liberalization into counterfactual analysis. Let H indicate developed and L developing countries. Let country pairs be classified according to their development combinations.[25] For example, LH indi-

[25] In order to investigate into the heterogeneous effects of GATT/WTO indicator variables on the bilateral international trade flows, we further classify countries as developed or developing based on their GDP per capita. Details about the classification are summarized in Data Appendix A.

cates developing exporter and developed importer country pairs, and HL developed exporter and developing importer country pairs; similarly, HH and LL represent developed and developing pairs. Referring to Column (2) in Table 1.3, the coefficient estimate of $bothwto_{ijt}$ shows that the GATT/WTO membership has a positive effect on the trade among members except the developing members, but the effect is heterogeneous. In particular, the effect is the largest among developed members and the weakest among the developing members ($\hat{\alpha}_{1,HH} > \hat{\alpha}_{1,LL}$). The effect tends to be larger when the importing country is a developed member ($\hat{\alpha}_{1,HH} > \hat{\alpha}_{1,HL}$, $\hat{\alpha}_{1,LH} > \hat{\alpha}_{1,LL}$). Furthermore, the trade effect tend to be more pronounced on exports by developed members than developing members ($\hat{\alpha}_{1,HH} > \hat{\alpha}_{1,LH}$). These findings are in line with our previous discussions that developed members tend to liberalize more than developing members, and such liberalization may be biased in composition in favor of developed countries' exports. In respect to the *imwto* effect, we note that the *bothwto* effects are at least equal or bigger than the *imwto* effects ($\hat{\alpha}_1 >= \hat{\alpha}_2$) for all development combinations. The statistically equal or smaller effect of *imwto* relative to *bothwto* suggests that not all members extend their MFN treatment to nonmembers, or that such extensions are not granted at all times or to all nonmembers. The effect of *imwto* is positive if the importing member is developed and zero to negative otherwise ($\hat{\alpha}_{2,HH} > 0$, $\hat{\alpha}_{2,LH} > 0$, $\hat{\alpha}_{2,HL} < 0$, and $\hat{\alpha}_{2,LL} < 0$). This suggests that developed members tend more likely to extend MFN treatment to imports from nonmembers. The negative effect of LL indicates that developing members actually tend to raise their trade restriction against nonmember developing countries (especially in recent years). For the welfare effects of PTA when interacting with GATT/WTO, the general pattern we find in Section 3.5 tends to become more prominent when shutting down the heterogeneous GATT/WTO trade effects across development combinations, especially in respect to "Preferential" and "MFN" provisions in Figure 1.9.

1.6 Conclusion

In this paper, we use a Melitz-type model to guide our analysis on the relationship between the horizontal depth of PTAs and the international bilateral trade flows. We have provided a comprehensive analysis of the effects of PTA and PTA subcategories on the trade flows and national welfare for the time period of 1980-2015. The results suggest a pattern that the countries with PTAs in force experience increasing welfare gains with the broader coverage of policy areas based on our classification of PTAs. This pattern becomes more distinct over the years when there is a surging number of countries forming PTAs with their trading members. For those countries which keep staying outside the PTA alliance, they do not experience welfare loss except within a short period around the beginning of 21th century. Welfare effects are heterogeneous across geographical regions with disproportionate larger gains accruing to Europe and Asia. Finally, in addition to the main analysis, we further measure the relative welfare changes of PTA and PTA subcategories when they interact with the GATT/WTO system, and finds a potential complementarity between PTA deep integration and the multilateral liberalization process.

In the current paper, we only measure the ex-post welfare effects of PTA depths, and many questions remain open. First, we didn't explicitly show the mechanism through which the different PTA provisions are determined in the negotiation stage, and also the specific channels through which the depth of PTAs could affect trade flows during the implementation stage. It requires detailed knowledge of exactly what sort of deep integration is going on in the PTAs to remove trade barriers. Second, in this paper we didn't find a substantial trade diversion effect of PTAs on those countries which are not being involved in any PTAs in a given year. It is partially linked to the so-called third-country externalities where PTAs may impose negative TOT externalities on PTA non-partner countries because of the discriminatory market access granted to PTA partners, and therefore diverts trade volumes that would otherwise have occurred between PTA-partner countries and third parties (Bagwell and Staiger, 2005). The literature suggest that this issue could become more prominent with the increasing focus of new PTAs on deep integration (Bagwell and Staiger, 2016). It would be interesting in the future work to find out how the depth of PTAs contributes to the substantial trade diversion and investigate into the TOT impacts of related provisions on third-party countries. Last, it may provide further insights to think about the mechanism design of PTA negotiations that would result in successful deep integration in a similar way as GATT's framework fosters successful tariff actting, given the assumption that they are complementarily interacted with each other.

Table 1.1: Categorization of PTA provisions

<table>
<tr><td rowspan="4">WTO+
(P)</td><td rowspan="6">Core (C)</td><td rowspan="2">Border (B)</td><td>Preferential
(Pref)</td><td>Tariffs Industrial goods
Tariffs agricultural goods
Anti-dumping
Countervailing measures
Export taxes</td></tr>
<tr><td>MFN</td><td>TRIMS
TRIPS
SPS
TBT
Customs</td></tr>
<tr><td rowspan="3">Behind-the-border
(H)</td><td>Preferential
(Pref)</td><td>Public procurement</td></tr>
<tr><td rowspan="2">MFN</td><td>State-owned enterprises
GATS
State aid</td></tr>
<tr><td rowspan="3">WTO X
(X)</td><td>Competition policy
IPR
Investment</td></tr>
<tr><td>Border (B)</td><td>MFN</td><td>Movement of capital</td></tr>
<tr><td>Non-Core
(NC)</td><td>Non-Core
(NC)</td><td>Non-Core
(NC)</td><td>Anti-corruption
Environmental laws
Labour market regulation
Consumer protection
Data protection
Agriculture
Approximation of legislation
Audiovisual
Civil protection
Innovation policies
Cultural cooperation
Economic policy dialogue
Education and training
Energy
Financial assistance
Health
Human Rights
Illegal immigration
Illicit drugs
Industrial cooperation
Information society
Mining
Money laundering
Nuclear safety
Political dialogue
Public administration
Regional cooperation
Research and technology
SMEs
Social Matters
Statistics
Taxation
Terrorism
Visa and asylum</td></tr>
</table>

Note: The classification is based on Hofmann, Osnago and Ruta (2017). "P", "X", "C", "NC", "B", "H" and "Pref" are abbreviates for "WTO+", "WTO-X", "Core", "Non-Core" ,"Border", "Behind-the-border" and "Preferential" provisions, respectively.

Table 1.2: Effects of PTA and PTA subcategories (1980-2015)

	(1)	(2)	(3)	(4)	(5)
	Trade (log of imports in million USD)				
gsp	0.002	0.003	0.005	0.005	0.002
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
comcur	0.527***	0.528***	0.517***	0.518***	0.516***
	(0.057)	(0.057)	(0.057)	(0.057)	(0.057)
curheg_o	0.489	0.488	0.487	0.486	0.487
	(0.333)	(0.333)	(0.332)	(0.332)	(0.333)
curheg_d	0.045	0.043	0.043	0.042	0.043
	(0.530)	(0.530)	(0.530)	(0.529)	(0.531)
PTA	0.281***				
	(0.023)				
PTA_nP_X		-0.105			
		(0.330)			
PTA_P_nX		0.264***			
		(0.045)			
PTA_P_X		0.291***			
		(0.024)			
PTA_C_nNC			0.210***		
			(0.033)		
PTA_C_NC			0.325***		
			(0.026)		
PTA_B_nH_nNC				0.182***	
				(0.052)	
PTA_B_nH_NC				0.362	
				(0.228)	
PTA_B_H_nNC				0.231***	
				(0.041)	
PTA_B_H_NC				0.325***	
				(0.026)	
PTA_nPref_MFN_nNC					-0.104
					(0.330)
PTA_Pref_nMFN_nNC					0.317***
					(0.074)
PTA_Pref_MFN_nNC					0.180***
					(0.035)
PTA_Pref_MFN_NC					0.322***
					(0.026)
N	670,360	670,360	670,360	670,360	670,360
R-sq	0.866	0.866	0.866	0.866	0.866
adj. R-sq	0.857	0.857	0.857	0.857	0.857
Exporter-Year	Yes	Yes	Yes	Yes	Yes
Importer-Year	Yes	Yes	Yes	Yes	Yes
Exporter-Importer	Yes	Yes	Yes	Yes	Yes

Note:
(a) The estimation is based on the equation (1.16). Refer to Figure 1.2 for more details on how we decompose the PTA indicator.
(b) Robust standard errors, clustered at the country-pair (asymmetric) level, are in parentheses. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 1.3: GATT/WTO heterogeneous effects (iterated estimation effects)

	(1)	(2) FEs
WTO_BOTH	0.146***	
	(0.007)	
WTO_BOTH_HH		0.694***
		(0.008)
WTO_BOTH_HL		0.279***
		(0.007)
WTO_BOTH_LH		0.347***
		(0.007)
WTO_BOTH_LL		-0.075***
		(0.007)
WTO_IM	-0.006	
	(0.007)	
WTO_IM_HH		0.406***
		(0.013)
WTO_IM_HL		-0.156***
		(0.012)
WTO_IM_LH		0.323***
		(0.009)
WTO_IM_LL		-0.206***
		(0.008)
WTO_EX	-0.021***	
	(0.007)	
WTO_EX_HH		-0.049***
		(0.013)
WTO_EX_HL		0.251***
		(0.008)
WTO_EX_LH		-0.447***
		(0.012)
WTO_EX_LL		-0.091***
		(0.008)
$\ln \zeta_{jt}$	-0.213***	-0.197***
	(0.004)	(0.004)
$\ln \bar{\chi}_{it}$	-0.198***	-0.182***
	(0.004)	(0.004)
$\ln Y_{it}$	0.931***	0.905***
	(0.001)	(0.001)
$\ln E_{jt}$	0.903***	0.871***
	(0.001)	(0.001)
$\ln Y_{wt}$	-1.080***	-1.049***
	(0.001)	(0.001)
N	670360	670360
R-sq	0.876	0.876
adj. R-sq	0.876	0.876

Note:
(a) The estimation is based on the equation (1.21). "WTO_BOTH", "WTO_IM" and "WTO_EX" in the table are referred to as *bothwto*, *imwto* and *exwto* in the equation, respectively.
(b) "FEs" stands for the sum of importer-year FEs and exporter-year FEs estimated from equation (1.16). Robust standard errors are in parentheses. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 1.4: Welfare effects of PTA by regions

	Mean	Median	Min	Max	Countries
Panel A. Ex-post Welfare effects of PTA (Melitz, 1980)					
OECD	0.70	0.59	-0.01	2.54	23
East and South Asia	-0.01	0.00	-0.03	0.00	21
East. Europe and Cent. Asia	-0.01	-0.01	-0.02	0.00	5
Latin America and Carribbean	0.18	0.00	-0.04	1.06	32
Midlle East and North Africa	0.02	-0.02	-0.03	0.67	19
Sub-Saharan Africa	-0.01	-0.01	-0.10	0.06	46
Other	0.05	0.00	-0.07	0.79	14
Panel B. Ex-post Welfare effects of PTA (Melitz, 2015)					
OECD	2.54	1.87	0.23	15.00	23
East and South Asia	1.41	0.79	-0.11	5.67	25
East. Europe and Cent. Asia	2.45	1.85	0.12	7.09	15
Latin America and Carribbean	0.79	0.57	-0.01	2.64	32
Midlle East and North Africa	0.84	0.56	0.06	3.18	23
Sub-Saharan Africa	0.52	0.18	-0.13	3.22	46
Other	1.55	0.71	-0.11	5.04	24

Note: Based on the estimates in Column (1) of Table 1.2, using the Melitz framework with parameters $\sigma = 5$ and $\sigma = 5$. The welfare effect of PTA (based on real output) is calculated given the observed PTA status relative to the counterfactual had PTA not existed ($PTA = 0$ for all ijt).

Table 1.5: Firm entry effects of PTA (Melitz vs BKL; median)

Parameters	PTA status	Year 1980 Melitz	Year 1980 BKL $\kappa = 0.8$	Year 1980 BKL $\kappa = 1$	Year 2015 Melitz	Year 2015 BKL $\kappa = 0.8$	Year 2015 BKL $\kappa = 1$
1. σ=5, θ=4.5	0	0.00	0.00	0	0.00	0.00	0
	1	0.16	0.06	0	0.12	0.05	0
	2	0.38	0.15	0	0.80	0.32	0
2. σ=5, θ=5	0	**0.00**	**0.00**	**0**	**-0.01**	**0.00**	**0**
(benchmark)	1	**0.15**	**0.06**	**0**	**0.11**	**0.04**	**0**
	2	**0.34**	**0.13**	**0**	**0.72**	**0.29**	**0**
3. σ=5, θ=5.5	0	0.00	0.00	0	-0.01	0.00	0
	1	0.13	0.05	0	0.09	0.04	0
	2	0.31	0.12	0	0.65	0.26	0
4. σ=5, θ=6	0	0.00	0.00	0	-0.01	0.00	0
	1	0.12	0.05	0	0.09	0.03	0
	2	0.29	0.11	0	0.60	0.24	0
5. σ=5, θ=8	0	0.00	0.00	0	0.00	0.00	0
	1	0.07	0.03	0	0.04	0.02	0
	2	0.15	0.06	0	0.32	0.13	0
6. σ=5, θ=10	0	0.00	0.00	0	0.00	0.00	0
	1	0.06	0.02	0	0.04	0.02	0
	2	0.15	0.06	0	0.30	0.12	0
8. σ=10, θ=10	0	0.00	0.00	0	0.00	0.00	0
	1	0.05	0.02	0	0.03	0.01	0
	2	0.11	0.04	0	0.22	0.09	0

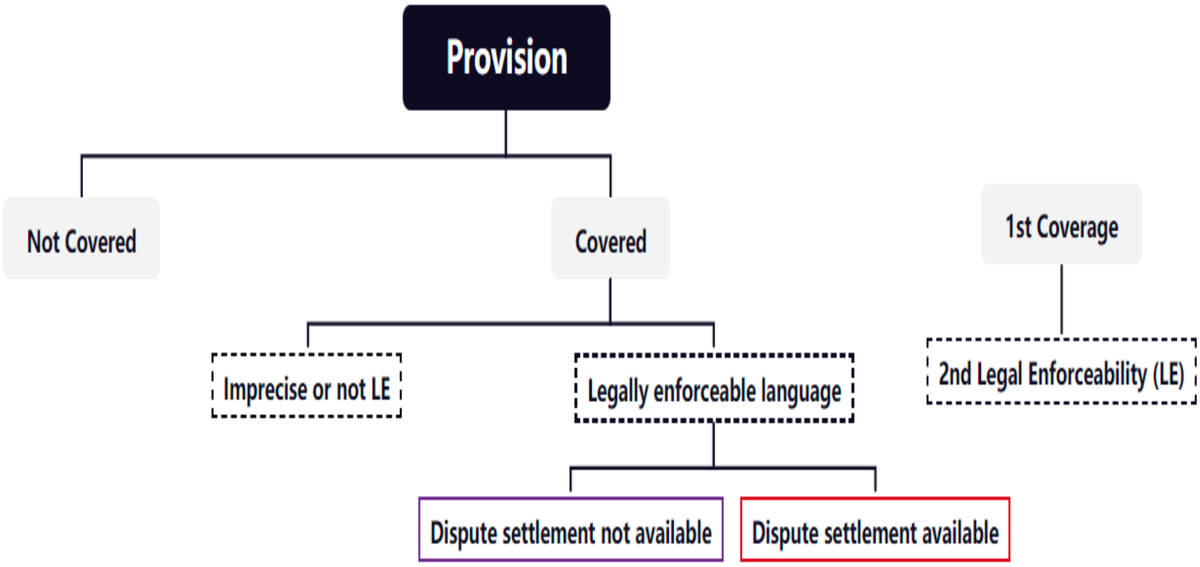
Note:
(a)Based on the Melitz or BKL framework. This set of analysis evaluates the effects of PTA given the observed PTA status relative to the counterfactual had PTA not existed (PTA=0 for all ijt).
(b)The value of PTA status depends on each country's total number of PTAs signed with its trading partners. The status equals zero for the countries without any PTAs in force; equals one if the number of PTAs is smaller than the medium value of the whole country group; and equals two if it is equal or greater than the medium.

Table 1.6: Welfare effects of PTA (Melitz vs BKL; median)

Parameters	PTA status	Year 1980 Melitz	Year 1980 BKL $\kappa = 0.8$	Year 1980 BKL $\kappa = 1$	Year 2015 Melitz	Year 2015 BKL $\kappa = 0.8$	Year 2015 BKL $\kappa = 1$
1. σ=5, θ=4.5	0	-0.0069	-0.0069	-0.0069	-0.0092	-0.0092	-0.0092
	1	0.3193	0.3193	0.3193	0.2362	0.2362	0.2362
	2	0.7488	0.7488	0.7488	1.6071	1.6071	1.6071
2. σ=5, θ=5	**0**	**-0.0068**	**-0.0068**	**-0.0068**	**-0.0102**	**-0.0102**	**-0.0102**
(benchmark)	**1**	**0.2891**	**0.2891**	**0.2891**	**0.2087**	**0.2087**	**0.2087**
	2	**0.6740**	**0.6740**	**0.6740**	**1.4410**	**1.4410**	**1.4410**
3. σ=5, θ=5.5	0	-0.0065	-0.0065	-0.0065	-0.0107	-0.0107	-0.0107
	1	0.2641	0.2641	0.2641	0.1860	0.1860	0.1860
	2	0.6127	0.6127	0.6127	1.3060	1.3060	1.3060
4. σ=5, θ=6	0	-0.0062	-0.0062	-0.0062	-0.0107	-0.0107	-0.0107
	1	0.2430	0.2430	0.2430	0.1679	0.1679	0.1679
	2	0.5617	0.5617	0.5617	1.1954	1.1954	1.1954
5. σ=5, θ=8	0	-0.0041	-0.0041	-0.0041	-0.0097	-0.0097	-0.0097
	1	0.1285	0.1285	0.1285	0.0812	0.0812	0.0812
	2	0.2995	0.2995	0.2995	0.6337	0.6337	0.6337
6. σ=5, θ=10	0	-0.0039	-0.0039	-0.0039	-0.0094	-0.0094	-0.0094
	1	0.1223	0.1223	0.1223	0.0769	0.0769	0.0769
	2	0.2846	0.2846	0.2846	0.6015	0.6015	0.6015
8. σ=10, θ=10	0	-0.0031	-0.0031	-0.0031	-0.0076	-0.0076	-0.0076
	1	0.0912	0.0912	0.0912	0.0561	0.0561	0.0561
	2	0.2108	0.2108	0.2108	0.4438	0.4438	0.4438

Note: Based on the Melitz or BKL framework. This set of analysis evaluates the effect of PTA given the observed PTA status relative to the counterfactual had PTA not existed ($PTA = 0$ for all ijt). Welfare is measured based on W_1 (real output). The PTA status is defined in a same way as Footnote (b) of Table 1.5.

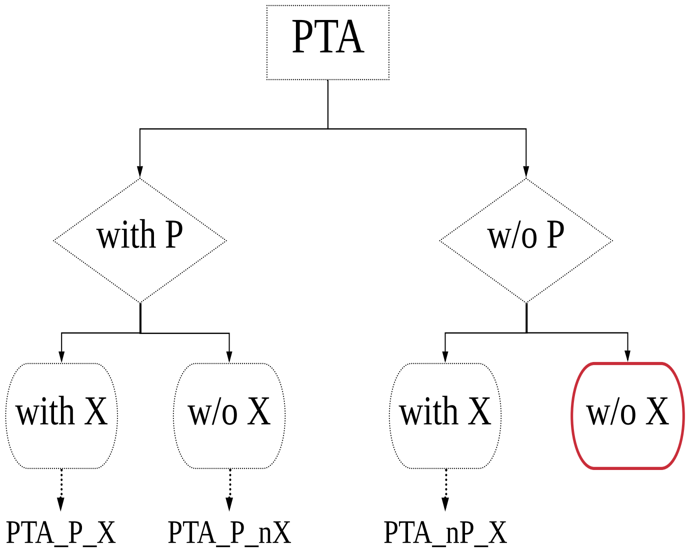
Figure 1.1: Assessment of legal enforceability



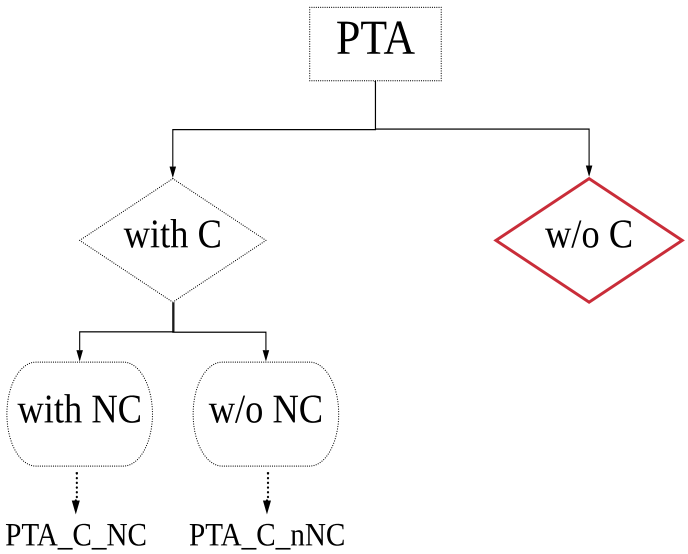
Note: Source from Hofmann, Osnago and Ruta (2017)

Figure 1.2: Classification of PTAs

(a) “WTO+” and “WTO-X”



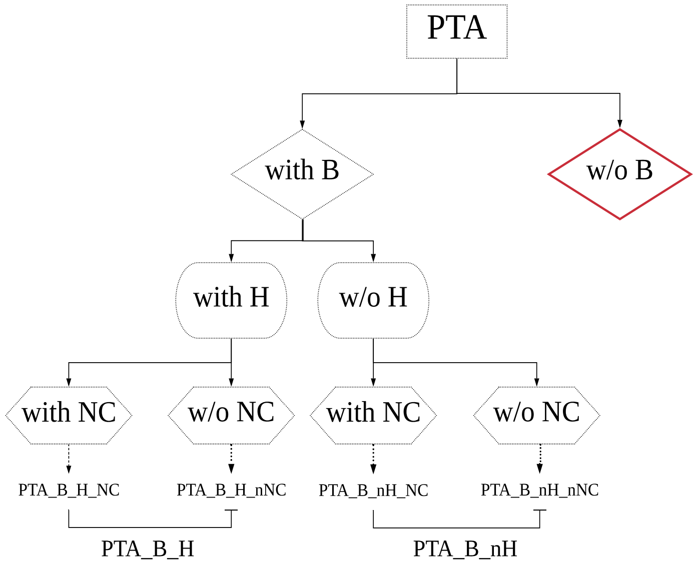
(b) “Core” and “Non-Core”



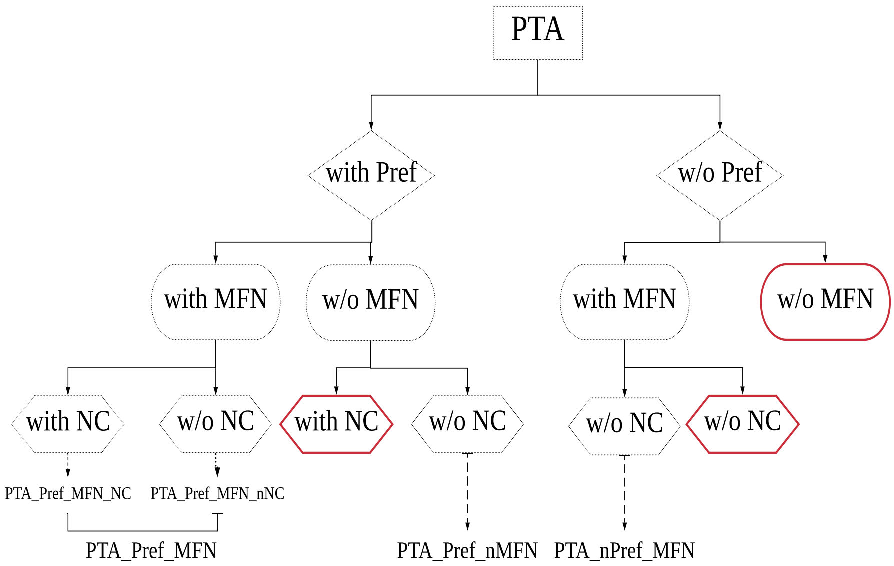
(continued on next page)

Figure 1.2: Classification of PTAs (continued)

(c) “Border” and “Behind-the-border”

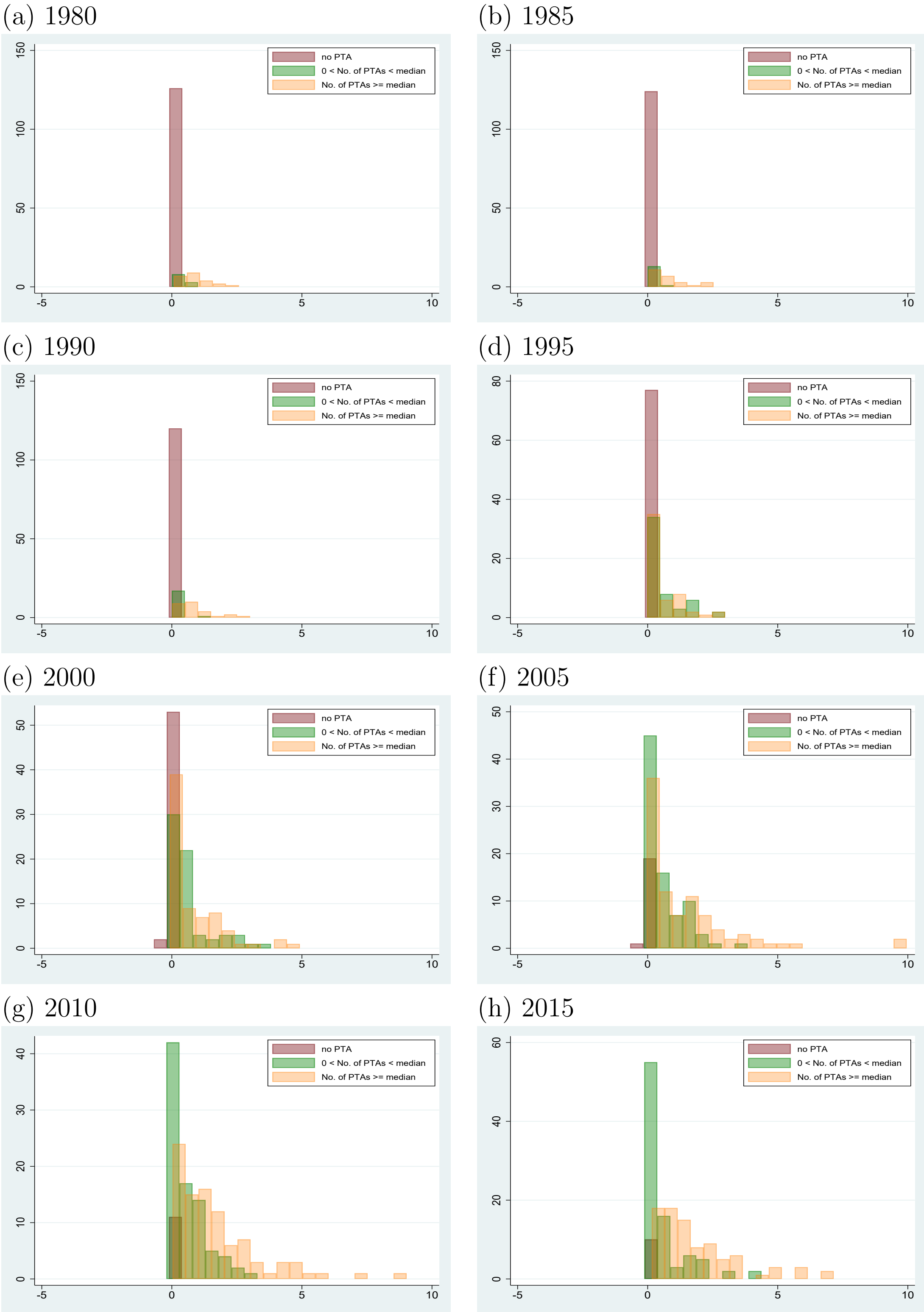


(d) “Preferential” and “MFN”



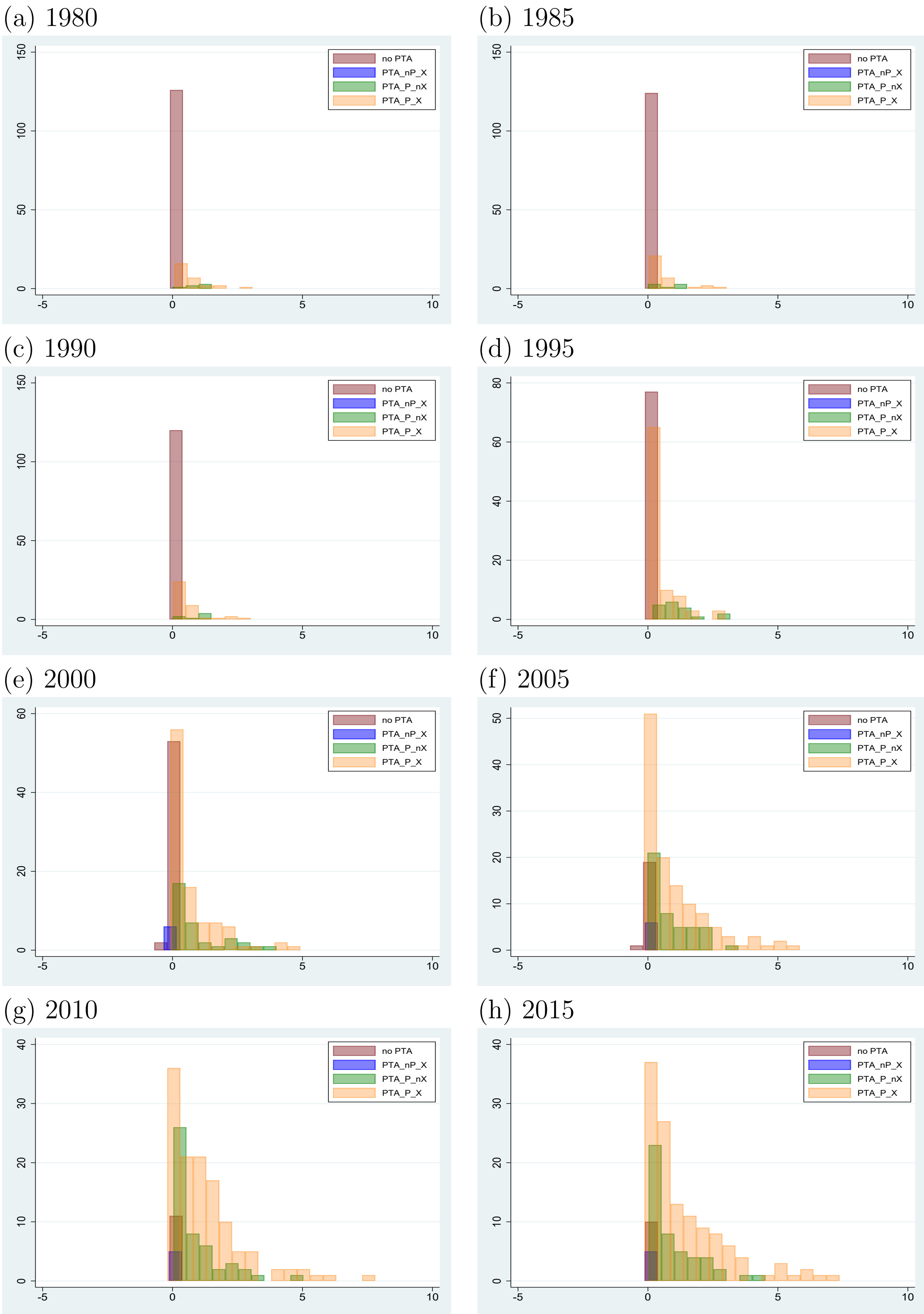
Note:
(a) “P” and “X” are abbreviates for “WTO+” and “WTO-X” provisions, respectively; “C” and “NC” are abbreviates for “Core” and “Non-Core” provisions, respectively; “B” and “H” are abbreviates for “Border” and “Behind-the-border” provisions, respectively; and “Pref” is the abbreviate for “Preferential” provisions.
(b) The subcategories highlighted in red indicates that there are no PTAs under this subcategory.

Figure 1.3: Welfare effects of PTA



Note: Based on the PTA estimates in Column (1) of Table 1.2, using the Melitz framework with parameters $\sigma = 5$, $\theta = 5$. This set of analysis evaluates the effects of PTA given the observed PTA status relative to the counterfactual had PTA not existed ($PTA = 0$ for all ijt). The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Figure 1.4: Welfare effects of PTA ("WTO+" and "WTO-X")

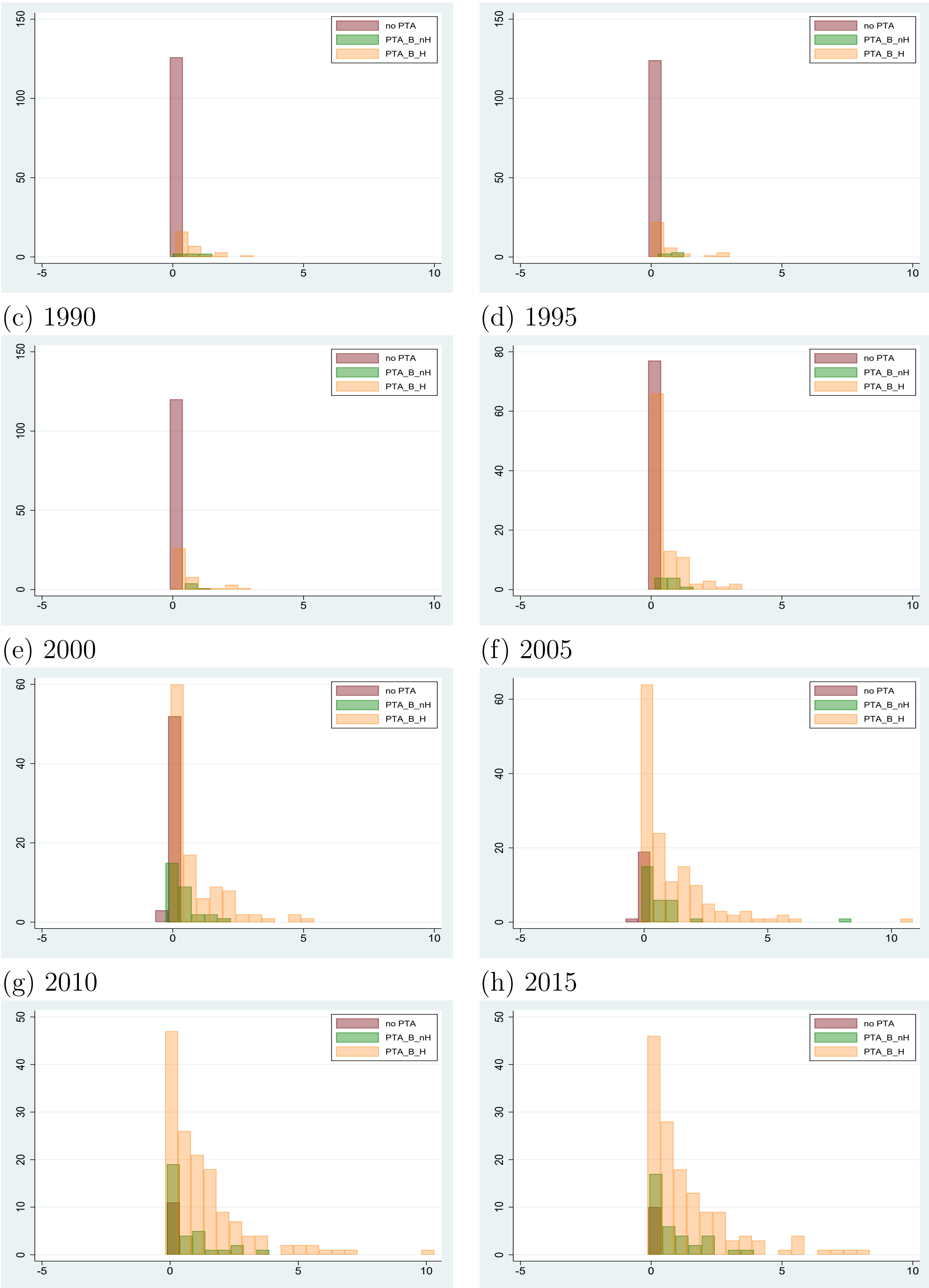


Note: Based on the PTA estimates in Column (2) of Table 1.2, using the Melitz framework with parameters $\sigma = 5$, $\theta = 5$. This set of analysis evaluates the effects of PTA given the observed PTA status relative to the counterfactual had PTA not existed ($PTA\_nP\_X = 0$; $PTA\_P\_nX = 0$ and $PTA\_P\_X = 0$; for all ijt). The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Figure 1.5: Welfare effects of PTA ("Core" and "Non-Core")

Note: Based on the PTA estimates in Column (3) of Table 1.2, using the Melitz framework with parameters $\sigma = 5$, $\theta = 5$. This set of analysis evaluates the effects of PTA given the observed PTA status relative to the counterfactual had PTA not existed ($PTA\_C\_NC = 0$; $PTA\_C\_nNC = 0$; for all ijt). The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

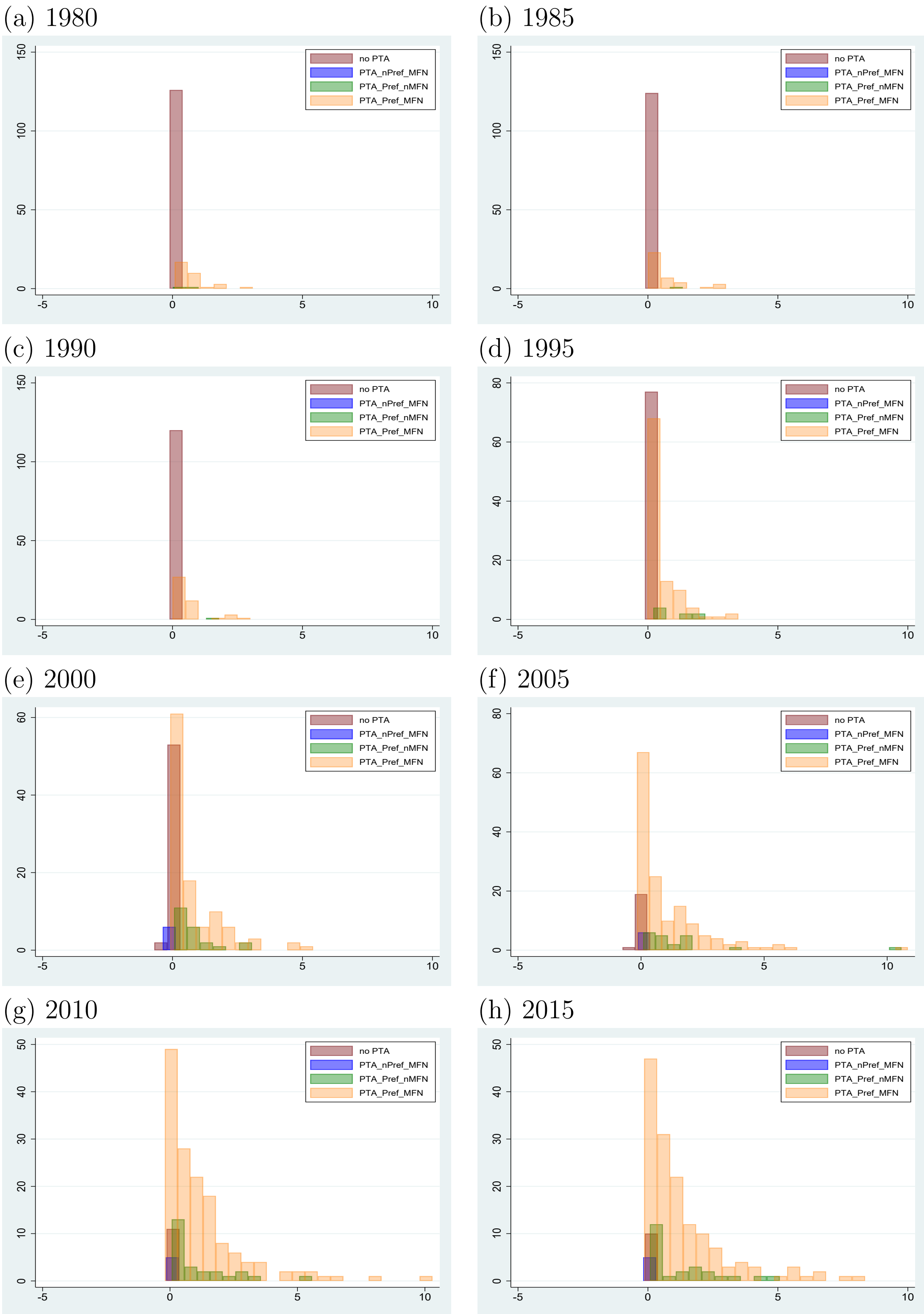
Figure 1.6: Welfare effects of PTA (“Border” and “Behind-the-border”)



(a) 1980 (b) 1985 (c) 1990 (d) 1995 (e) 2000 (f) 2005 (g) 2010 (h) 2015

Note: Based on the PTA estimates in Column (4) of Table 1.2, using the Melitz framework with parameters $\sigma = 5$, $\theta = 5$. This set of analysis evaluates the effects of PTA given the observed PTA status relative to the counterfactual had PTA not existed ($PTA\_B\_nH\_nNC = 0$; $PTA\_B\_nH\_NC = 0$; $PTA\_B\_H\_nNC = 0$ $PTA\_B\_H\_NC = 0$; for all ijt). The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

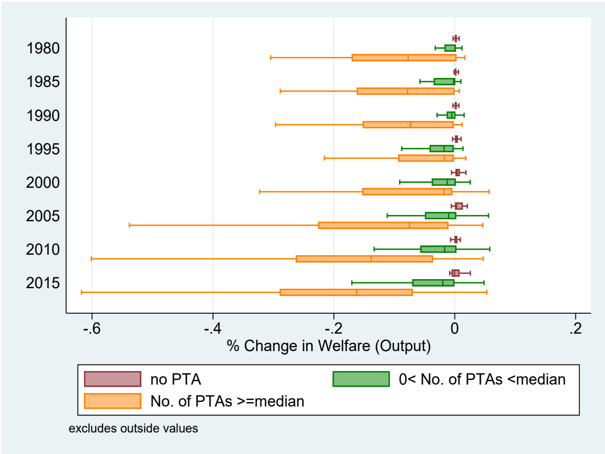
Figure 1.7: Welfare effects of PTA (“Preferential” and “MFN”)



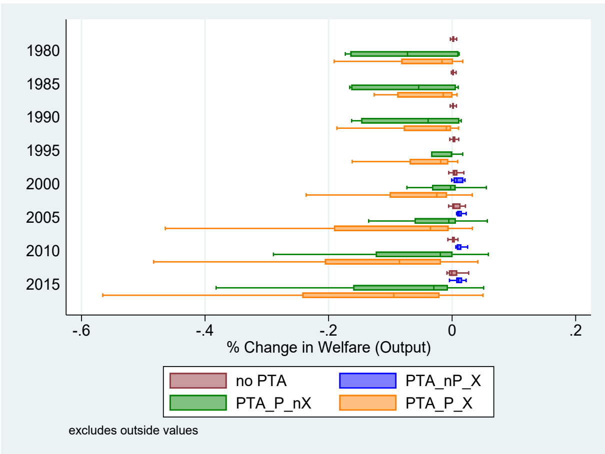
Note: Based on the PTA estimates in Column (5) of Table 1.2, using the Melitz framework with parameters $\sigma = 5$, $\theta = 5$. This set of analysis evaluates the effects of PTA given the observed PTA status relative to the counterfactual had PTA not existed ($PTA\_nPref\_MFN\_nNC = 0$; $PTA\_Pref\_nMFN\_nNC = 0$; $PTA\_Pref\_MFN\_nNC = 0$; $PTA\_Pref\_MFN\_NC = 0$; for all ijt). The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Figure 1.8: Welfare effects of PTA (without GATT/WTO versus with GATT/WTO)

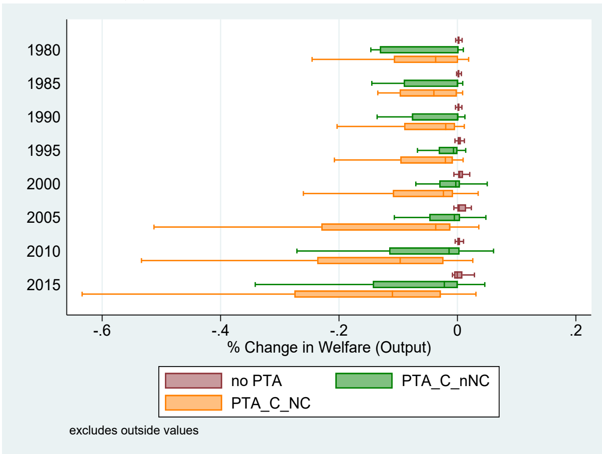
(a) PTA



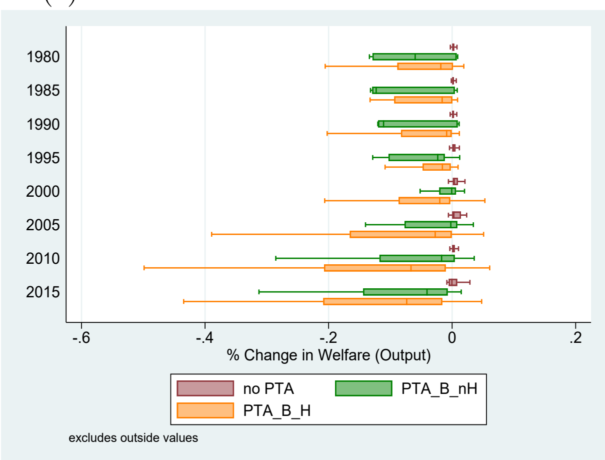
(b) “WTO+” and “WTO-X”



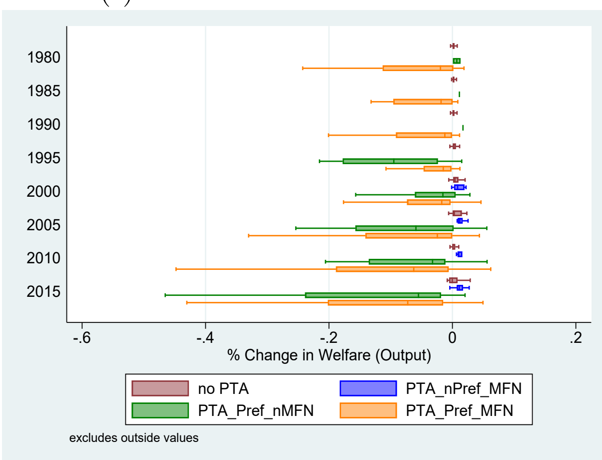
(c) “Core” and “Non-Core”



(e) “Border” and “Behind-the-border”



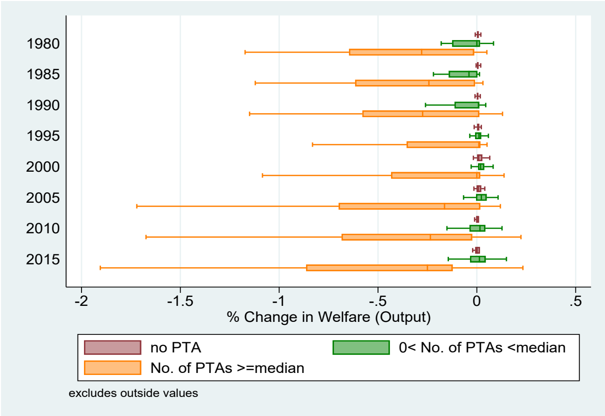
(f) “Preferential” and “MFN”



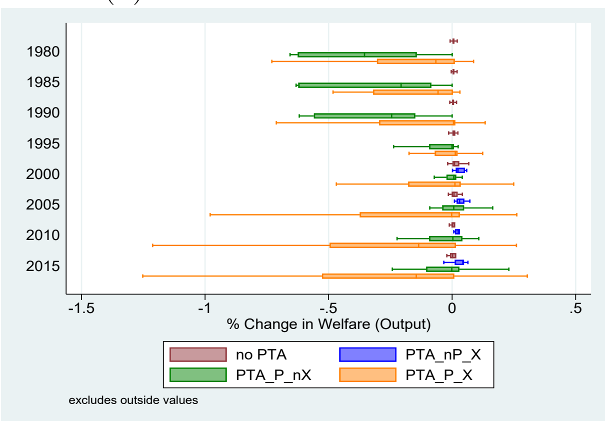
Note: Based on the PTA estimates from Table 1.2 and WTO estimates in Column (1) of Table 1.3, using the Melitz framework with parameters $\sigma = 5$, $\theta = 5$. This set of analysis evaluates the effects of PTA under each scenario had GATT/WTO membership not existed ($bothwto = 0$; $imwto = 0$; $exwto = 0$; for all ijt) relative to the scenario with the factual GATT/WTO membership. Outliers are omitted.

Figure 1.9: Welfare effects of PTA (without GATT/WTO versus with GATT/WTO: heterogeneous)

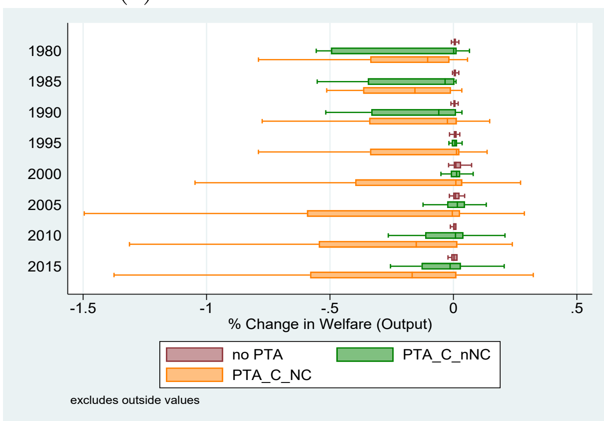
(a) PTA



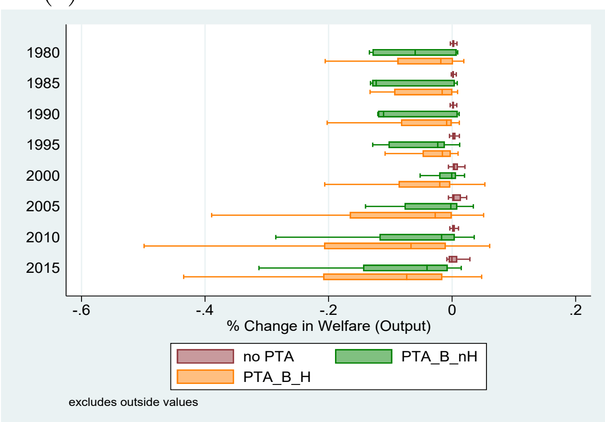
(b) “WTO+” and “WTO-X”



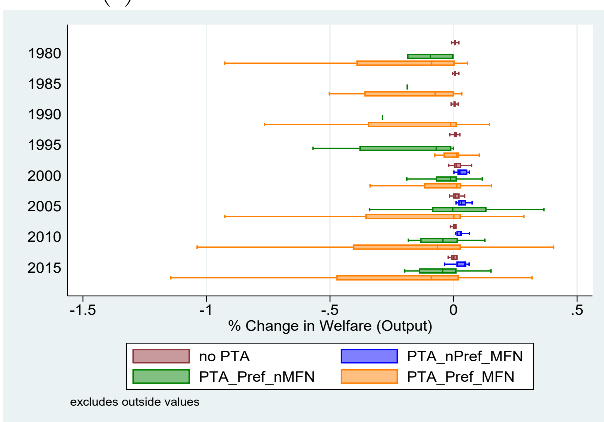
(c) “Core” and “Non-Core”



(e) “Border” and “Behind-the-border”



(f) “Preferential” and “MFN”



Note: Based on the PTA estimates from Table 1.2 and heterogeneous WTO estimates in Column (2) of Table 1.3, using the Melitz framework with parameters $\sigma = 5$, $\theta = 5$. This set of analysis evaluates the effect of PTAs under each scenario had GATT/WTO membership not existed ($bothwto = 0$; $imwto = 0$; $exwto = 0$; for all ijt) relative to the scenario with the factual GATT/WTO membership. Outliers are omitted.

Chapter 2

Decomposing the Welfare Effects of Deep Trade Agreements: A Synthetic Control Method

2.1 Introduction

While the focus of current PTA negotiations are increasingly going beyond the "shallow" agreements that mainly address the issues about trade liberalization, more attentions are being diverted to the PTA deep integration which involves both non-tariff and behind-the-border policies. Compared with shallow agreements, those agreements which are presented in a deeper form of integration are expected to induce a relatively larger degree of trade creation effects. It is seen in particular on domestic provisions which is nondiscriminatory in nature and could help achieve improved levels of "regulatory coherence" across PTA-partner countries (Bagwell et al., 2016). Such nondiscriminatory in nature provisions also apply to vis-à-vis outsiders, creating a positive spillover effect or negative trade diversion (Baldwin and Low, 2009). For instance, provisions related to the competition policy and investment regulation would help to achieve a more transparent and efficient domestic trading environment, and may reduce trade facilitation costs across the border. It is not only beneficial to partners staying inside the PTA alliance but also benefits those outsiders. To empirically address the importance of the trade and welfare effects of PTA deep integration, we exploit a recently released dataset which classifies the policy areas covered by PTAs (Hofmann et al., 2017). Newer agreements are viewed as "deeper" in the sense that they generally expand the coverage of policy areas compared with old agreements. Utilizing the information from the content of this PTA dataset, we follow certain categorization rules to further decompose the PTA indicator into subcategories based on policy areas covered and their legal enforceability.[1] The details about this PTA dataset have been discussed in the Section 1.2.

To assess the effects of PTAs on promoting trade flows, there are abundant empirical studies employing the parametric methods, such as the standard log-linear gravity equation (Head and Mayer, 2015; Limão, 2016; Baier and Bergstrand, 2007, 2009a; Anderson and Yotov, 2016). While its sound theoretical foundation and strong empirical explanatory power have led to a rapid adoption, its ability to identify the effects of PTAs on trade flows has been rather more problematic, especially in the attempt to address the endogeneity problem. Persson (2001) provides an excellent discussion of the self-selection problem when the country chooses to enter into currency union. Given that the decision to sign the PTA between any two countries is not random, as each country has to compare the cost and benefit of signing PTAs with its trading partners, non-parametric techniques may offer a valid alternative to the standard log-linear gravity equation. Several recent papers have successfully adopted non-parametric techniques to investigate the causal effect of currency union (Persson, 2001), free trade agreements (Egger et al., 2008; Baier and Bergstrand, 2009b) and other policies aimed at promoting trade (Chang and Lee, 2011).

In this paper we employ one of non-parametric approaches, the synthetic control method to estimate the trade effect on the country pairs which have received the treatment of PTA. In recent applications, this method has proven to be a valid means with which to assess the impact of policy interventions or any given events in conducting the comparative case studies (Abadie and Gardeazabal, 2003; Abadie et al., 2010, 2015; Saia, 2017). For each country pair which receives the treatment of PTA, this method could first construct its synthetic control unit as the convex combination of similar non-PTA pairings based on the pre-intervention

[1] Define pta_{ijt}=1 if there are any PTAs currently in force between two countries i and j at year t.

characteristics. We then compare the difference in the trade flows between the treated pair and its synthetic control unit during the post-intervention period. With the time-varying estimates of trade effects, we further obtain the part which is contributed by the horizontal depth of agreements while controlling for the factor of import tariffs. The counterfactual analysis is correspondingly conducted to further quantify the welfare effects of the deep trade agreements. It is built on the recent development in structural quantitative analysis of international trade, which features general equilibrium counterfactual analyses in high-dimensional models (Arkolakis et al., 2012; Costinot and Rodríguez-Clare, 2015). We take the matrices of estimated trade-cost effects due to PTA status for each country-pair at each year as inputs to quantitative trade models to assess the corresponding general-equilibrium impacts. The counterfactual changes in the key variables of interest had PTA-related indicators not existed are simulated, taking into account general equilibrium adjustments to the trade shocks across all countries. Based on the estimation and counterfactual results we find that a country is inclined to reap greater welfare gains with a dominant number of relatively deep agreements signed (covering a wider range of policy areas) relative to other countries.

This paper contributes to the empirical literature on measuring the impacts of PTA deep integration on the trade flows and national welfare with Hofmann et al. (2017)'s dataset, which maps 52 provisions covered in the current PTAs. Recently there have been a few empirical papers using this dataset to investigate into the effects of PTA horizontal depth on the trade flows, vertical FDI and other trade-related issues (Mattoo et al., 2017; Osnago et al., 2019; Mulabdic et al., 2017).[2] Another contribution of this paper is in the application of synthetic control method to estimate the trade effects of PTAs after taking into account the factor of tariff barrier. This data-driven procedure can offer a relatively transparent non-parametric method of choosing counterfactual units in comparative case studies and

[2]Unlike adopting the measure of horizontal depth which is the sum of provisions as previous studies did, in this paper we first classify policy areas into different subcategories, and define the depth as the total number of subcategories covered by one agreement (Section 1.2 introduces the categorization of PTA provisions in detail). As long as any policy area which has been allocated into a certain subcategory is included in the agreement, this subcategory is assumed to be covered as well.

ease the problem of self-selection in the estimation of PTA effects.

The remainder of this paper is organized as follows. In Section 2.2 we develop the basic setup of the Anderson and van Wincoop (2003) [AvW] framework incorporating the tariff barrier as a part of trade cost. Section 2.3 describes the synthetic control method and presents the estimation results. The counterfactual analysis of welfare changes is discussed in Section 2.4, and Section 2.5 concludes. The description about the horizontal depth of PTAs is provided in Section 1.2, and the rest of data sources and descriptions are supplemented in the Data Appendix A and B.

2.2 The Theoretical Model

Our estimation strategy and counterfactual analytical framework are based on the Anderson and van Wincoop (2003) model, where goods are differentiated by the country of origin, and buyers in each country j choose imports q_{ij} from country i for all i to maximize

$$Q_j = \left(\sum_i b_i^{(1-\sigma)/\sigma} q_{ij}^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)} \quad \text{st.} \quad \sum_i p_{ij} q_{ij} = E_j, \tag{2.1}$$

where b_i is a (dis)taste parameter for goods produced in i, $\sigma > 1$ is the elasticity of substitution across sources of imports. Following Caliendo and Parro (2015), we assume that there are two types of trade costs: variable trade costs and an ad-valorem flat-rate tariff. And $p_{ij} \equiv p_i \tau_{ij}(1+t_{ij})$ is the destination price, equal to the exporter's supply price p_i scaled up by the variable trade cost factor τ_{ij} and import tariff t_{ij} applicable over unit prices of country i's exports charged by the importing country j.

The solution to (2.1) implies a nominal value of after-duty exports from i to j equal to $X_{ij} = \left(\frac{b_i p_i \tau_{ij}(1+t_{ij})}{P_j}\right)^{1-\sigma} E_j$, where $P_j = \left[\sum_i (b_i p_i \tau_{ij}(1+t_{ij}))^{1-\sigma}\right]^{1/(1-\sigma)}$ and E_j are the aggregate price index and the nominal expenditure of country j, respectively. The goods market-clearing condition requires that:

$$
\begin{aligned}
Y_i &= \sum_j \frac{X_{ij}}{(1+t_{ij})} \\
&= \sum_j M_{ij} \\
&= (b_i p_i)^{1-\sigma} \sum_j (\tau_{ij}/P_j)^{1-\sigma} (1+t_{ij})^{-\sigma} E_j. \qquad (2.2)
\end{aligned}
$$

Using (2.2) to solve for $(b_i p_i)^{1-\sigma}$ and substituting the result in the expression of exports M_{ij} and P_j, we have:

$$
M_{ij} = \frac{Y_i E_j}{Y_w} \left(\frac{\tau_{ij}}{\Pi_i P_j} \right)^{1-\sigma} (1+t_{ij})^{-\sigma} \qquad (2.3)
$$

where

$$
\Pi_i^{1-\sigma} \equiv \sum_j (\tau_{ij}/P_j)^{1-\sigma} (1+t_{ij})^{-\sigma} e_j, \qquad (2.4)
$$

$$
P_j^{1-\sigma} = \sum_i (\tau_{ij}/\Pi_i)^{1-\sigma} (1+t_{ij})^{1-\sigma} s_i. \qquad (2.5)
$$

$Y_w \equiv \sum_i Y_i$ indicates the world output, $e_j \equiv E_j/Y_w$ indicates the expenditure share of country j, and $s_i \equiv Y_i/Y_w$ the output share of country i. Equation (2.3) resembles the structural gravity equation, and equation (2.4)-(2.5) imply the multilateral outward and inward multilateral resistance (MR) proposed by Anderson and van Wincoop (2003).

The aggregate budget constraint that allows for trade deficit requires that:

$$
E_j = Y_j + D_j + TR_j, \qquad (2.6)
$$

where D_j is the nominal trade deficit of country j and $TR_j \equiv \sum_i M_{ij} t_{ij}$ is the tariff revenue of country j collected at the border. We assume that the input bundle combines labor and intermediate inputs with a constant labor share β_i. This implies that the cost of an input bundle in country i is

$$c_i = w_i^{\beta_i} P_i^{1-\beta_i}. \tag{2.7}$$

In the AvW framework, goods markets are perfectly competitive. We assume that goods are produced one-to-one from the input bundle. This implies that the supplier price in country i p_i is as indicated in (2.7). Lastly labor-market clearing requires that:

$$w_i L_i = \beta_i Y_i. \tag{2.8}$$

2.3 Estimation

In this section, we employ the synthetic control method to estimate the trade effects that there would have been between any country pair with PTA signed, and then with the time-varying trade estimates of PTAs, we further separate the part which is contributed by different horizontal depths (coverages) of trade agreements after taking into account the import tariff factor.

2.3.1 Synthetic Control Method

We perform the synthetic control matching for 5156 country pairs which mutually sign PTAs between 1958 and 2014. For each country pair receiving the treatment of PTA at T_0, we compare the difference between trade flows of the treated pair and similar non-PTA pairings during a given post-intervention period. Based on Abadie et al. (2015), constructing a donor pool of comparison units requires restricting the donor pool to units which is unaffected by the event or intervention of interest and with characteristics similar to the treated unit. In this paper we restrict the donor pool to be the country pair which is without receiving the treatment ($pta_{ij} = 0$), located in the same geographical region respectively for both exporter and importer as the treated pair,[3] and also has available trade flows across the

[3]Following the United Nations Statistics Division (UNSD) methodlogy, we divide the world into six regions by: OECD countries, East and South Asia, East. Europe and Cent. Asia, Latin America and Caribbean,

whole chosen time period. The applicability of this method also requires a sizeable number of pre-intervention periods to increase the credibility about how well a synthetic control unit replicates the treated unit's characteristics and outcomes over an extended period of time prior to the treatment. In our setting, to study the intervention of PTA we choose the pre-intervention period as it is within 15 years prior to signing PTAs ($t = T_0 - 15, .., T_0 - 1$), including all years available in the constructed pseudo world.[4] To determine a proper length of post-intervention period, we consider the phase-in effect of agreements and expect the treatment effect to manifest itself only years later. At the same time, other factors not controlled for (by the same time effect condition and the matching covariates) may affect the trade flows and contaminate the result. Taking it into consideration, we choose the post-intervention period as it is within 10 years after signing PTAs ($t = T_0 + 1, ..., T_0 + 10$), and includes all years with available trade flows.[5]

Next let N be the number of available control country pairs in the donor pool. To choose the weight that best resembles the actual trade flows before receiving the treatment, we consider the minimization problem as follows,

$$\min_{W \in \Omega} (X_1 - X_0 W)' V (X_1 - X_0 W) \tag{2.9}$$

where $W = (w_1, ..., w_N)'$ is a $(N \times 1)$ vector of non-negative weights which sum to one. X_1 is a $(K \times 1)$ vector of pre-intervention values of K predictor variables for the treated country pair and X_0 is a $(K \times N)$ vector of pre-intervention values of K predictor variables for the N possible control country pairs. For the K predictors, motivated by the linear-log transformation of trade flow equation (2.3), we consider the following pre-intervention characteristics: the logs of values of bilateral trade flows $\ln M_{ij}$, the logs of exporter's output $\ln Y_i$, the logs of importer's expenditure $\ln E_j$, a list of trade-cost ($\tau_{ij}^{1-\sigma}$)

Middle East and North Africa, Sub-Saharan Africa, and Other.

[4] The construction of the pseudo world dataset is described in Data Appendix B.

[5] For each country pair, the total number of available years in the pre-intervention or post-intervention period is flexible, and the whole time period can be either continuous or discrete.

proxies, and corresponding endogenous variables derived by Baier and Bergstrand (2009a) for a linear approximation of the MR terms identified in equation (2.3).[6] Each predictor is averaged over the pre-intervention period. The values of the diagonal elements of V reflect the relative importance of the different predictors, and chosen by minimizing the mean squared prediction error (MSPE) of pre-intervention trade flows,

$$V^{\star} = \arg min_{V \in} (Z_1 - Z_0 W^{\star}(V))'(Z_1 - Z_0 W^{\star}(V)) \tag{2.10}$$

where V is the set of all non-negative diagonal $(K \times K)$ matrices. Let Z_1 be a $(T' \times 1)$ vector of pre-intervention actual bilateral trade flows (in logs) for the treated country pair and Z_0 be a $(T' \times N)$ vector containing the same variables for the N potential control country pairs.[7] The weight in matrix V reflects the predictive power of each predictor variable in regard to the outcome of interest over the pre-intervention period. A greater weight is assigned to highly predictive variables, so that the country pair of interest and the synthetic unit strongly match on them.

For a post-intervention period t (with $t \geq T_0$), the synthetic control estimator of the effect of the treatment is given by the comparison between the outcome of the treated unit and that of the synthetic unit, omitting the country-pair notation ij:

$$TE_t = z_{1,t} - \sum_{n=1}^{N} w_n^{\star} z_{0,nt} \tag{2.11}$$

where $w_n^{\star}$ is the element in vector $W^{\star}$ for the control unit n; $z_{1,t}$ and $z_{0,nt}$ indicate the post-intervention value of actual bilateral trade flows (in logs) for the treated pair and control pair at time t, respectively.

For instance, by performing the synthetic control method, the synthetic version of Belgium-

[6]We use the following trade-cost proxies: *gsp*, *comcur*, *curheg_o*, *curheg_d*, *heg_o*, *heg_d*, *comcol*, *comlang_ethno*, *contig*, *smctry*, *comleg*, $island_{od}$, $landlocked_{od}$, *bothwto*, *imwto* and *exwto*, which are defined in Data Appendix A in detail.

[7]In the empirical practice to select V matrix, we follow the SYNTH routine in STATA, which uses a data-driven regression based method to obtain the weights contained in the matrix V.

UK is constructed as a weighted average of Canada-Germany, Canada-UK and Denmark-Canada units, with the corresponding weights ($w_n^{\star}$=0.437; 0.4; 0.163) decreasing in this order. The rest of country pairs in the donor pool is assigned with the zero weight. Table 2.1 compares the pre-PTA characteristics of Belgium-UK to those of the synthetic Belgium-UK without joining the European Commission (EC) treaty. Overall, the result suggests that the constructed synthetic Belgium-UK unit is very similar to the actual country pair in terms of pre-PTA in those predictor variables. Figure 2.1 displays the logs of trade flow trajectory of Belgium-UK and its synthetic counterpart for the 1958-1983 period. The synthetic country pair closely reproduces the logs of trade flows of the treated country pair during the entire pre-PTA period (1958-1972). And our estimate of the PTA effect on the UK's import trade flows from Belgium is calculated by taking the difference between the actual trade flows and its synthetic counterpart based on equation (2.11), and visualized in Figure 2.1.

2.3.2 Estimation Method and Results

With the trade effects TE_{ijt} obtained from performing the synthetic control method, we are able to identify that part of PTA effect which is contributed to deep integration of agreements. We assume that the total PTA trade effects come from two sources: lower preferential tariff rates after joining the PTA, and deep provisions covered in the agreements. Then based on the equation (2.3):

$$TE_{ijt} = h(pta_{ijt}, \Delta \ln(1 + t_{ijt})) \tag{2.12}$$

where $\Delta(\ln(1+t_{ijt})$ refers to the difference in tariff rates with and without PTA. As we don't directly observe it from the data, in the empirical specification we try to use two terms to control for it:

- the tariff difference before and after signing the PTA for the treated country pair: $\Delta_1 \ln(1 + t_{ijt}) \equiv \ln(1 + t_{ij,t}) - \ln(1 + t_{ij,-1})$

- the tariff difference between the treated country pair and its synthetic control unit at time t during the post-intervention period: $\Delta_2 \ln(1+t_{ijt}) \equiv \ln(1+t_{ij,t}) - \sum_N w_n^* \ln(1+\tilde{t}_{ij,t})$

By decomposing the PTA indicator pta_{ijt} into subcategories based on our classification of PTAs and controlling for tariff effects, equation (2.12) is rewritten as:

$$TE_{ijt} = \sum_i \beta_i PTAdeep_{ijt} - \sigma_1 \Delta_1 \ln(1+t_{ijt}) - \sigma_2 \Delta_{2,T_0} \ln(1+t_{ijt}) + \epsilon_{ijt} \tag{2.13}$$

where TE_{ijt} is the trade effects of any treated country pair ij since signing PTAs during the post-intervention period (at t=$T_0, T_0+1, ...$); $PTAdeep_{ijt}$ indicates the PTA subcategory defined under different categorizations of PTA provisions. Following the methodology proposed by Horn et al. (2010), it totally maps 52 provisions, and in this paper we construct four sets of PTA-related variables to indicate the horizontal depth of PTAs:

- whether it covers the provision which has been already regulated by WTO or not: "WTO+" and "WTO-X";
- whether it covers the provision which is relevant from an economic theory perspective or beyond the trade issue: "Core" and "Non-Core";
- whether it covers the provision which is applied at the border or not: "Border+" and "Behind-the-border";
- whether it covers the provision which applies only to the countries that signed the PTA or on a non-discriminatory (MFN) basis: "Preferential" and "MFN".

The methodology on how to construct each $PTAdeep_{ijt}$ indicator is described in the previous chapter (Section 1.2) in detail. The sum of the indicators classified in the same category is equal to the general indicator pta_{ijt}. To avoid the disturbance from other possible causes which may affect the tariff reduction during the post-intervention period, we choose to use the variable $\Delta_{2,T_0}\ln(1+t_{ijt})$, the tariff difference between the treated country pair and its synthetic control unit at intervention year T_0, to replace $\Delta_{2,T_0}\ln(1+t_{ijt})$ in the regression.

Table 2.2 reports the regression estimates based on the equation (2.13). It presents the impact of PTA and PTA subcategories on the trade effects obtained from employing the synthetic control method, after controlling for the tariff effect. The range of data sample is up to 10 years from receiving the intervention of PTA at T_0. Regarding the two variables of tariff differences, from Column (1) to (5), the coefficients of $\Delta_{1,T_0}\ln(1+t_{ijt})$ and $\Delta_{2,T_0}\ln(1+t_{ijt})$ are both significantly greater than one, which are in line with the value ranges of the elasticity of substitution indicated by the past literature. We will take the larger estimate as the $\hat{\sigma}$, and feed it into the system of quantitative analysis in the next section.

Column (1) in Table 2.2 presents the coefficient estimate of the aggregate indicator pta_{ijt}. The result suggests that if there exists at least one PTA currently in force for one country pair, where the bilateral import trade effect can be around 9% higher holding other conditions constant.[8] Referring to the effects of PTA subcategories from Column (2) to (5) where the aggregate indicator pta_{ijt} is being decomposed into several subcategories, following the categorization of WTO+ and WTO-X, "Core" and "Non-Core", "Border" and "Behind-the-border", and "Preferential" and "MFN" provisions, respectively. Here we only consider the most stringent case, the strongly legally enforceable provisions where the dispute settlements are available. In Column (2), we can see that covering both WTO+ and WTO-X subcategories in one agreement will increase the bilateral trade effect by 11.73%. For the rest of two subcategories which only deals with either WTO+ or WTO-X provisions, the estimates are statistically insignificant. That means a deeper agreement that includes provisions on both tariff and non-tariff barriers would induce larger trade flows than the one solely focus on either the tariff liberalization or provisions beyond the current WTO mandate. The ranking order in the magnitude of coefficient estimates of PTA subcategories in Column (3) are also well expected. As many of the provisions in the PTA are beyond trade issues, consider-

[8] The percentage is calculated as $(\exp^{\hat{\beta}_1} - 1)$

ing the categories of "Core" and "Non-Core" provisions in one agreement tends to promote the import in a greater degree than the one including the category of "Core" provisions only ($\hat{\beta}_{5,PTA\_C\_NC} > \hat{\beta}_{5,PTA\_C\_nNC}$). Although those "Non-Core" provisions are not so relevant from an economic theory perspective as "Core" provisions, they still help to regulate a domestic environment with improved levels of "regulatory coherence"(Bagwell et al., 2016).

A similar pattern could be observed when we continue to investigate into "Core" provisions from two lenses, "Border" and "Behind-the-border", and "Preferential" and "MFN" provisions. From Column (4), we can see that through including both "Border" and "Behind-the-border" provisions, the trade effect increase by around 11.85%, while solely including the border measures is playing an insignificant role. The deepening of PTA negotiations is regarded as the greatest with the inclusion of "Border" and "Behind-the-border" measures simultaneously, and it reconfirms the pattern above among all PTA subcategories in this column. It supports the argument that in terms of the strongly legally enforceable provisions, the international trade promoting effect will be strengthened when a PTA involves areas that could achieve deeper forms of integration. An exceptional result obtained based on Column (5), a relatively higher ranking of the coefficient ($\hat{\beta}_{5,PTA\_Pref\_nMFN} > \hat{\beta}_{5,PTA\_Pref\_MFN}$) in the magnitude occurs when the agreement only covers "Preferential" measures. One possible explanation is that the measures which are preferential to specific trading partners tend to promote a larger trade growth than providing non-discriminatory treatments to all related parties.

As a robustness check, we also run the regression of equation (2.13) on the data sample with a shorter length of time period after signing the PTA ($t = T_0 + b, b = 1; 3; 5; 7; 9$). In line with the phase-in effect, we find that the effects of PTA subcategories are rising over time and the overall pattern mentioned above still holds, as presented in Table 2.3 - 2.6 if it varies with the length of post-intervention period of consideration.

2.4 Welfare Analysis

2.4.1 General Equilibrium System

To prepare for conducting the counterfactual analysis, we rewrite the system of structural equations in terms of changes à la the hat algebra of Dekle et al. (2007).[9] In particular, let x' denote the counterfactual value of a variable x and $\widehat{x} \equiv x'/x$ the ratio of the counterfactual to the factual value of the variable.

The trade flow equation $X_{ij} = \left(\frac{b_i p_i \tau_{ij}(1+t_{ij})}{P_j}\right)^{1-\sigma} E_j$ and the expression of P_j imply the following:

$$\widehat{X}_{ij} = \sum_j \left(\widehat{c}_i \widehat{\tau}_{ij} (\widehat{1+t_{ij}})/\widehat{P}_j\right)^{1-\sigma} \widehat{E}_j \tag{2.14}$$

$$\widehat{P}_j^{1-\sigma} = \sum_j \left(\widehat{c}_i \widehat{\tau}_{ij} (\widehat{1+t_{ij}}\right)^{1-\sigma} \frac{X_{ij}}{E_j} \tag{2.15}$$

where $\widehat{\tau}_{ij}^{1-\sigma}$ is the exogenous shocks given by the previous estimation of PTA trade effects. Then with equation (2.14) and (2.15), market-clearing condition in equation (2.2) imply the following:

$$\widehat{Y}_i = \sum_j \left(\widehat{c}_i \widehat{\tau}_{ij} (\widehat{1+t_{ij}})/\widehat{P}_j\right)^{1-\sigma} \frac{\widehat{E}_j}{Y_i} \frac{M_{ij}}{\widehat{1+t_{ij}}}. \tag{2.16}$$

In static trade models, there are no clear ways to deal with trade deficits in the counterfactual. We follow Caliendo and Parro (2015) and assume that in the counterfactual, a country's trade deficit as a share of world production remains constant: $\frac{D_i'}{Y_w'} = \frac{D_i}{Y_w} = \delta_i$. And by the aggregate budget constraint in equation (2.6), we could obtain:

$$\widehat{E}_j E_j = \widehat{Y}_j Y_j + \widehat{Y}_w D_j + \widehat{TR}_j TR_j, \tag{2.17}$$

[9]Some scholars credit the hat algebra technique to Jones (1965), although the Jones hat algebra is in terms of small changes in the variables, while the algebra of Dekle et al. (2007) is in terms of ratios of counterfactual to factual values, so the latter in principle can accommodate large discrete changes. The Jones hat algebra is also heavily used in the computable general equilibrium (CGE) models, represented by the Global Trade Analysis Project (GTAP) of Hertel (1997).

$$\widehat{TR}_j = \sum_i \left(\frac{\widehat{X}_{ij}}{\widehat{(1+t_{ij})}} t'_{ij} \right) \frac{M_{ij}}{TR_j}. \tag{2.18}$$

where $\widehat{Y}_w = \sum_i s_i \widehat{Y}_i$.

The counterfactual analysis is conducted by the iteration method. Starting with any given initial values of the wage ratio $\widehat{w}_i$, aggregate price index ratio $\widehat{P}_j$ and nominal expenditure $\widehat{E}_j$, by the labor market-clearing condition in equation (2.8), we have:

$$\widehat{Y}_i = \widehat{w}_i. \tag{2.19}$$

Next, the Cobb-Douglas cost structure (2.7) for the input bundle requires that:

$$\widehat{c}_i = \widehat{w}_i^{\beta_i} \widehat{P}_i^{1-\beta_i}, \tag{2.20}$$

Given the corresponding estimates we can calculate how the change in trade costs due to PTA status affects the endogenous variables in the economy, taking into account general equilibrium adjustment. In the current counterfactual analysis, we assume that import tariff cost remains unchanged ($\widehat{1+t_{ij}} = 1, t'_{ij} = t_{ij}$). Thus, using the ratios of variables ($\widehat{Y}_i$, $\widehat{E}_j$, $\widehat{c}_i$, $\widehat{\tau}_{ij}^{1-\sigma}$ and $\widehat{X}_{ij}$), we can update $\widehat{w}_i$ ($=\widehat{Y}_i$) by equation (2.16), update $\widehat{P}_j^{1-\sigma}$ by equation (2.15) and $\widehat{E}_j$ by equation (2.17), with all the observable variables and parameters $\{1-\sigma, \beta_i\}$. We repeat this procedure until it converges in $\widehat{w}_i$, $\widehat{P}_j$ and $\widehat{E}_j$. The welfare effects of given exogenous changes in trade cost can then be measured by the real wage:

$$\widehat{W}_i = \widehat{w}_i / \widehat{P}_i. \tag{2.21}$$

This formula evaluates the welfare effect based on changes in the real output, which in general can differ from the real expenditure given the presence of a trade deficit.

To illustrate the algorithm, suppose the estimated trade effect of PTA is γ_1. This implies an ex-post effect of $\widehat{\tau}_{ij}^{1-\sigma} = \exp(\gamma_1)$ for country pairs where exits at least one PTA currently in force at a given year. The shock $\widehat{\tau}_{ij}^{1-\sigma}$ can then be fed into the system (2.16)–(2.20) to derive the effects of PTA on the welfare (2.21) for this year.

For the parameter values, we take the values of σ from previous PTA estimation in Section 2.3.2. For $\{\beta_{it}\}$, we use the share of value added in gross output in country i, calculated as the median of the value-added shares across sectors obtained and combined from multiple sources as introduced in Data Appendix A. The value varies in the range of $[0.26, 0.62]$ across countries in our dataset.

2.4.2 Welfare Effects of PTA Deep Integration

We first conduct counterfactual analysis based on the AvW framework (with σ taken from the previous regression of equation (2.13)) within the time period of 1988-2015, where the shocks to the trade cost across years ($\widehat{\tau}_{ijt}^{1-\sigma}$ for all ijt) are calculated based on the estimated effects of PTA subcategories from Table 2.2.[10]

Table 2.7 provides a breakdown of the welfare effects by the dominant type of deep agreements. Relating to the classification of countries for better presenting the results, for example, concerning with "WTO+" and "WTO-X" provisions, in each single year we continue to allocate those countries without signing any PTAs in force to the subset named as "no PTA" as we previously did. For the country which has signed at least one PTA, we count the total number of observations where PTA_nP_X=1, PTA_P_nX=1 or PTA_P_X=1 for all ijt, separately. If the total number of observations where PTA_nP_X=1 dominates the other two types, we choose to assign this country to the corresponding subset denoted as "PTA_nP_X". Following this approach we are able to allocate every country to its corresponding subset. To reduce the extra notations, when we name the subset we use the same name of its dominant PTA subcategory like "PTA_nP_X", "PTA_P_nX" or "PTA_P_X". We classify all countries based on the categorization of PTA provisions. In particular, when

[10]The starting year is selected due to the data availability of tariff data which is available from 1988. We also construct a Rest of World (ROW) which includes those countries lacking tariff data in most of years. For the new bilateral PTA indicator between the ROW and its trading partner, we take the minimum value of PTA indicators between all ROW countries and the same corresponding country.

we classify countries in respect to "Border" and "Behind-the-border", or "Preferential" and "MFN" provisions, we combine those subsets which are of relatively small sizes to clearly present the welfare change. Refer to Figure 1.2 for a graphic illustration about how to build and combine the subsets.

To conduct the counterfactual analysis, we simultaneously shut down the effects of all the related PTA subcategories under the corresponding categorization of provisions. By presenting the welfare results in 1990, 2005 and 2015, we can find a general pattern sharing common characteristics among different categorizations of deep agreements. The median value of PTA welfare effects is generally increasing over time, and those countries tend to gain more relative to other countries if they have been enrolled in a dominant number of PTAs where the provisions are in deeper forms of integration. Even in the categorization of "Preferential" and "MFN" provisions where the ranking order of trade effect estimates as shown in Table 2.6 is unexpected, the estimate of the deep agreement is smaller than that of the relatively shallower one ($\hat{\beta}_{PTA\_Pref\_nMFN} > \hat{\beta}_{PTA\_Pref\_MFN}$), but the huge gap of welfare effects between the two subcategories is becoming closer and closer over time. To better present this relative change across years, we further draw the corresponding set of figures to depict the time trends of deep and shallow agreements over the whole period of 1988-2015, as shown in Figure 2.2.

We also use another set of figures to show the distribution of countries' welfare in selected years. From Figure 2.3 we can see that the distribution of PTA welfare effects become increasingly more dispersed with a long right tail. The countries with more PTA partners gain more relative to other countries. In early years, there is only a small number of countries which have signed PTAs with their trading partners, and the distributions of all three country subsets are presented to be centrally concentrated around zero. And the welfare effects are relatively small, between -10% to 0. The distribution of PTA welfare effects starts to become more dispersed from year 2000. From Figure 2.4 to 2.7, similar to Figure 2.3, the distribution of PTA welfare effects still become increasingly more dispersed with a long right tail over years as before, and in general the country which has signed a dominant number of relatively deeper agreements tends to gain more in welfare. These heterogeneity in the PTA welfare effects across country subsets are mainly driven by the ranking order in the magnitude of trade effect estimates of PTA subcategories across different specifications in Table 2.2, and also by differences in country sizes and the adjustment of general equilibrium effects.

2.5 Conclusion

In this paper, we adopt a recent non-parametric technique to provide estimated effects of PTA deep integration on the trade flows. Using the synthetic control method, we construct a counterfactual unit as a convex combination of similar non-PTA pairings, and this unit allows us to obtain the estimated difference in the bilateral trade flows between the country-pair with PTA signed and its constructed counterfactual unit. Then we use the theoretic framework built on Anderson and van Wincoop (2003) to guide our analysis on the relationship between the horizontal depth of PTAs and the trade effects obtained from the synthetic control method, and further decompose the welfare effects of deep agreements. The result of welfare analysis suggests a general pattern that the countries with PTAs in force experience increasing welfare gains with the broader coverage of policy areas based on the categorization of PTA provisions. This pattern becomes more distinct over the years, especially when there is a surging number of countries forming PTAs with their trading partners.

In the current paper there are still many questions remaining open. First, the AvW model that we use doesn't consider the firm entry effect which actually plays an important role in the measurement of welfare change. Also due to the data constraint of missing values in early years before 1988, we omit the tariff factor in the MR terms and the expenditure E_j when implementing the synthetic control method. Another limitation of using the synthetic control method is the lack of statistical inference in comparative case studies. It is difficult because of the small-sample nature of the data, the absence of randomization, and the fact that probabilistic sampling is not employed to select sample units (Abadie et al., 2015).

Although in the related literature they have developed a few of statistical tests like placebo tests (Abadie et al., 2015) or bootstrap inferences (Saia, 2017) to fill this gap, considering the size of country pairs performed by the synthetic control method in this paper, at the present stage we haven't conducted the corresponding inference tests so far.

Table 2.1: Trade flows predictor means before signing PTAs (Belgium-UK)

Predictor	Treated	Synthetic
ltrade	6.343347	6.335474
log_Yi	12.25189	11.90938
log_Ej	12.12587	12.08536
log_distw	6.619607	8.744254
gsp	0	0.263
gsp_MR	0.0866439	0.053697
comcur	0	0
comcur_MR	-0.0340598	-0.0323795
heg_o	0	0.226
heg_o_MR	0.3105913	0.0720987
heg_d	0	0.313
heg_d_MR	0.3715059	0.1637865
comlang_ethno	0	0.489
comlang_ethno_MR	0.2738394	0.5088107
comleg	0	0.489
comleg_MR	0.3472914	0.4401091
island_od	0	0
island_od_MR	0.0060076	0.0060076
landlocked_od	0	0
landlocked_od_MR	0.0002034	0.0002034
bothwto	1	1
bothwto_MR	0.9050668	0.8978091
imwto	0	0
imwto_MR	0.0419715	0.0419715
exwto	0	0
exwto_MR	0.041952	0.041952

Note: The predictor variable denoted with "MR" is the linear approximation of the corresponding trade-cost proxy variable, following the methodology by Baier and Bergstrand (2009a). All the predictor variables are averaged over the pre-intervention period of 1958-1972.

Table 2.2: Trade effects of PTA and PTA subcategories (1988-2015)

	(1)	(2)	(3)	(4)	(5)
			TE_{ijt}		
$\Delta_1 \ln(1+t_{ijt})$	-1.243***	-1.252***	-1.224***	-1.258***	-1.199***
	(0.1478)	(0.1478)	(0.1479)	(0.1477)	(0.1482)
$\Delta_{2,T_0} \ln(1+t_{ijt})$	-1.383***	-1.374***	-1.354***	-1.354***	-1.393***
	(0.1236)	(0.1237)	(0.1238)	(0.1236)	(0.1236)
PTA	0.090***				
	(0.0101)				
PTA_nP_X		0.075			
		(0.1142)			
PTA_P_nX		0.012			
		(0.0204)			
PTA_P_X		0.111***			
		(0.0111)			
PTA_C_nNC			0.068***		
			(0.0156)		
PTA_C_NC			0.102***		
			(0.0120)		
PTA_B_nH				-0.034	
				(0.0235)	
PTA_B_H				0.112***	
				(0.0107)	
PTA_nPref_MFN					0.075
					(0.1142)
PTA_Pref_nMFN					0.211***
					(0.0294)
PTA_Pref_MFN					0.078***
					(0.0104)
N		34355	34355	34355	34355
R-sq		0.013	0.013	0.014	0.013
adj. R-sq		0.013	0.013	0.014	0.013

Note:
(a) The estimation is based on the equation (2.13). Refer to Figure 1.2 for more details on how we decompose the PTA indicator.
(b) TE_{ijt} is the trade effect of any treated country pair ij since signing PTAs in the post-intervention period, $t = T_0 + 1, +2, .., T_0 + 10$ in this table, and we drop 10% outliers outside the range [5%, 95%]
(c) $\Delta(\ln(1 + t_{ijt})$ refers to the difference in tariff rates with and without PTA. $\Delta_{2,T_0} \ln(1 + t_{ijt})$ represents the tariff difference between the treated country pair and its synthetic control unit at intervention year T_0.
(d) The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.3: Trade effects of "WTO+" and "WTO_X" during post-intervention period

	(1)	(2)	(3)	(4)	(5)
			TE_{ijt}		
$\Delta_1 \ln(1+t_{ijt})$	-0.307	-0.894***	-1.094***	-1.036***	-1.180***
	(0.4328)	(0.2857)	(0.2067)	(0.1741)	(0.1549)
$\Delta_{2,T_0} \ln(1+t_{ijt})$	-1.513***	-1.459***	-1.410***	-1.337***	-1.329***
	(0.2548)	(0.1835)	(0.1541)	(0.1378)	(0.1276)
PTA_nP_X	0.119	0.207	0.177	0.153	0.131
	(0.2510)	(0.1792)	(0.1499)	(0.1326)	(0.1194)
PTA_P_nX	-0.113***	-0.057**	-0.027	-0.010	0.014
	(0.0383)	(0.0276)	(0.0239)	(0.0220)	(0.0208)
PTA_P_X	0.052**	0.065***	0.066***	0.079***	0.100***
	(0.0209)	(0.0156)	(0.0133)	(0.0120)	(0.0114)
N	8292	15734	22063	27986	32373
R-sq	0.007	0.008	0.009	0.009	0.012
adj. R-sq	0.007	0.008	0.009	0.009	0.012

Note:
(a) Table 2.3 reports the estimation results for the categorization of "WTO+" and "WTO-X", Column (1)-(5) present the results under data sample covering up to $t = T_0 + b$ (b=1; 3; 5; 7; 9), correspondingly. Other settings are the same as described in Table 2.2.
(b) The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.4: Trade effects of "Core" and "Non-Core" during post-intervention period

	(1)	(2)	(3)	(4)	(5)
			TE_{ijt}		
$\Delta_1 \ln(1+t_{ijt})$	-0.464	-0.999***	-1.159***	-1.073***	-1.203***
	(0.4295)	(0.2827)	(0.2047)	(0.1729)	(0.1546)
$\Delta_{2,T_0} \ln(1+t_{ijt})$	-1.529***	-1.485***	-1.438***	-1.363***	-1.349***
	(0.2551)	(0.1837)	(0.1541)	(0.1378)	(0.1276)
PTA_C_nNC	0.008	0.049**	0.063***	0.066***	0.072***
	(0.0294)	(0.0214)	(0.0184)	(0.0169)	(0.0160)
PTA_C_NC	0.020	0.031*	0.036**	0.058***	0.088***
	(0.0228)	(0.0170)	(0.0144)	(0.0130)	(0.0123)
N	8292	15734	22063	27986	32373
R-sq	0.006	0.007	0.008	0.009	0.011
adj. R-sq	0.005	0.007	0.008	0.008	0.011

Note:
(a) Table 2.4 reports the estimation results for the categorization of "Core" and "Non-Core", Column (1)-(5) present the results under data sample covering up to $t = T_0 + b$ (b=1; 3; 5; 7; 9), correspondingly. Other settings are the same as described in Table 2.2.
(b) The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.5: Trade effects of "Border" and "Behind-the-border" during post-intervention period

	(1)	(2)	(3)	(4)	(5)
			TE_{ijt}		
$\Delta_1 \ln(1 + t_{ijt})$	-0.377	-0.924***	-1.111***	-1.048***	-1.201***
	(0.4302)	(0.2833)	(0.2053)	(0.1730)	(0.1546)
$\Delta_{2,T_0} \ln(1 + t_{ijt})$	-1.519***	-1.464***	-1.416***	-1.341***	-1.328***
	(0.2549)	(0.1835)	(0.1540)	(0.1377)	(0.1275)
PTA_B_nH	-0.091**	-0.046	-0.016	-0.017	-0.021
	(0.0440)	(0.0315)	(0.0277)	(0.0255)	(0.0241)
PTA_B_H	0.037*	0.055***	0.058***	0.075***	0.101***
	(0.0201)	(0.0150)	(0.0128)	(0.0116)	(0.0110)
N	8292	15734	22063	27986	32373
R-sq	0.006	0.008	0.008	0.009	0.012
adj. R-sq	0.006	0.007	0.008	0.009	0.012

Note:
(a) Table 2.5 reports the estimation results for the categorization of "Border" and "Behind-the-border", Column (1)-(5) present the results under data sample covering up to $t = T_0 + b$ (b=1; 3; 5; 7; 9), correspondingly. Other settings are the same as described in Table 2.2.
(b) The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.6: Trade effects of “Preferential” and “MFN” during post-intervention period

	(1)	(2)	(3)	(4)	(5)
			TE_{ijt}		
$\Delta_1 \ln(1+t_{ijt})$	-0.574	-1.122***	-1.248***	-1.082***	-1.162***
	(0.4307)	(0.2839)	(0.2056)	(0.1735)	(0.1550)
$\Delta_{2,T_0} \ln(1+t_{ijt})$	-1.544***	-1.503***	-1.458***	-1.381***	-1.367***
	(0.2548)	(0.1833)	(0.1538)	(0.1376)	(0.1274)
PTA_nPref_MFN	0.130	0.219	0.184	0.155	0.130
	(0.2510)	(0.1790)	(0.1497)	(0.1325)	(0.1193)
PTA_Pref_nMFN	0.259***	0.333***	0.304***	0.257***	0.232***
	(0.0624)	(0.0444)	(0.0368)	(0.0329)	(0.0303)
PTA_Pref_MFN	-0.007	0.007	0.018	0.040***	0.067***
	(0.0193)	(0.0143)	(0.0123)	(0.0112)	(0.0107)
N	8292	15734	22063	27986	32373
R-sq	0.008	0.010	0.011	0.010	0.012
adj. R-sq	0.007	0.010	0.010	0.010	0.012

Note:
(a) Table 2.6 reports the estimation results for the categorization of “Preferential” and “MFN”, Column (1)-(5) present the results under data sample covering up to $t = T_0 + b$ (b=1; 3; 5; 7; 9), correspondingly. Other settings are the same as described in Table 2.2.
(b) The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2.7: Welfare effects of PTA and PTA subcategories (Median)

PTA_status	1990	2000	2015
No PTA	-0.05	-0.24	-0.23
PTA	-1.15	-1.17	-2.62
no PTA	-0.05	-0.24	-0.23
PTA_nP_X	-	-0.09	-0.27
PTA_P_nX	-0.37	-0.11	-0.92
PTA_P_X	-1.23	-1.71	-3.77
no PTA	-0.05	-0.2	-0.22
PTA_C_nNC	-0.94	-1.32	-2.38
PTA_C_NC	-1.2	-1.64	-3.86
no PTA	-0.05	-0.25	-0.27
PTA_B_nH	-0.88	-0.09	-1.42
PTA_B_H	-1.24	-2.03	-4.05
no PTA	-0.04	-0.17	-0.21
PTA_nPref_MFN	-	-0.05	-0.21
PTA_Pref_nMFN	-8.48	-4.02	-3.67
PTA_Pref_MFN	-0.89	-1.35	-2.88

Note:
(a)Based on the AvW framework, this set of analysis evaluates the effects of PTA or PTA subcategories given the observed PTA status relative to the counterfactual had PTA or PTA subcategories under the same categorization not existed (PTA=0 or $deepPTA$=0 for all ijt).
(b)The allocation of PTA status for each country depends on which type of PTA is dominant in the number of agreements signed with its trading partners. Footnote 9 illustrates the allocation rule in detail.

Figure 2.1: Trade flows between the Belgium-UK vs synthetic counterfactuals (in logs)

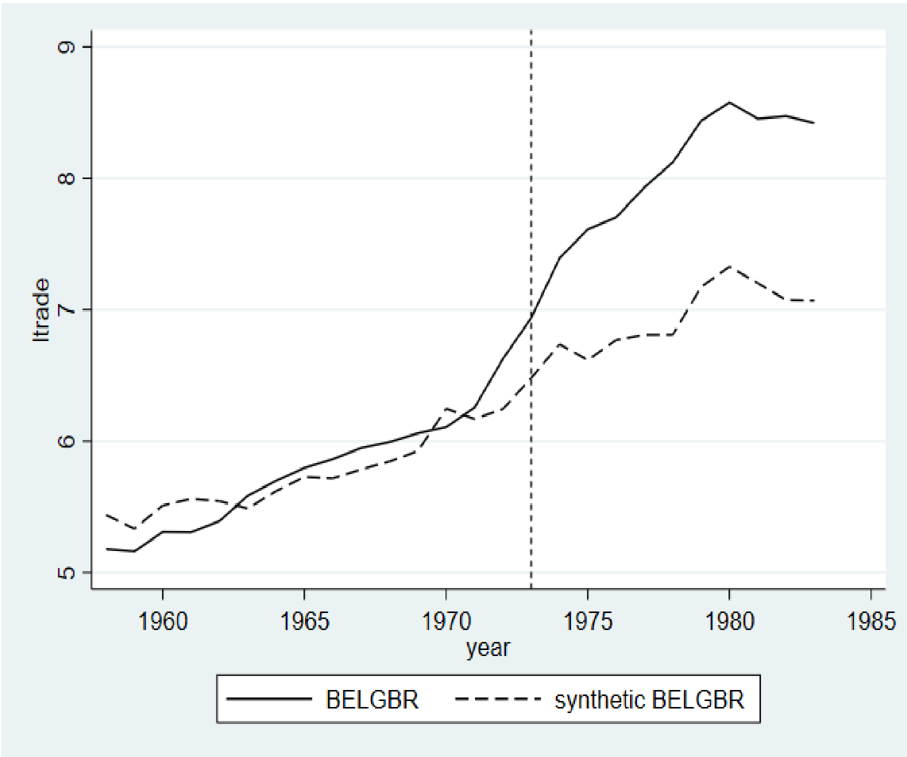
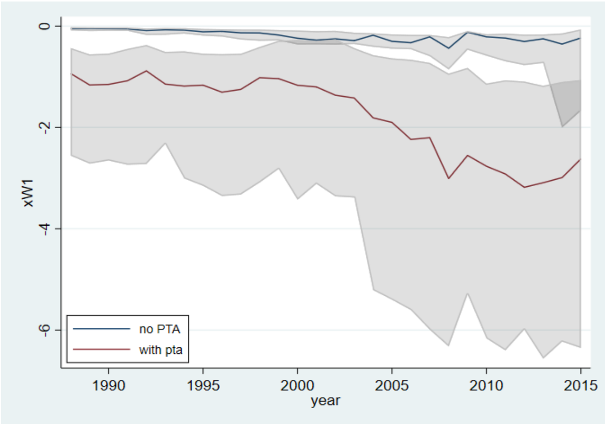
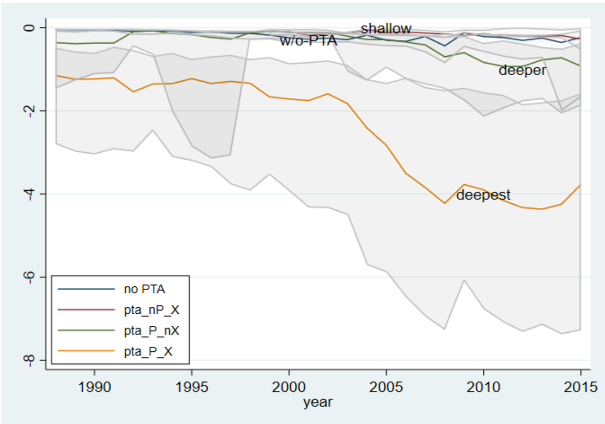


Figure 2.2: Welfare effects of PTA and PTA subcategories over time (Median; 1988-2015)

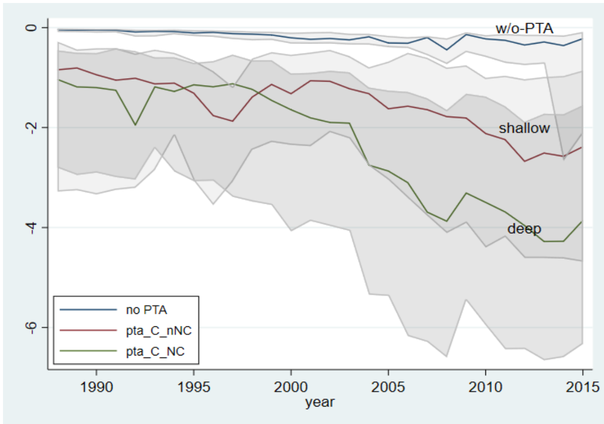
(a) PTA



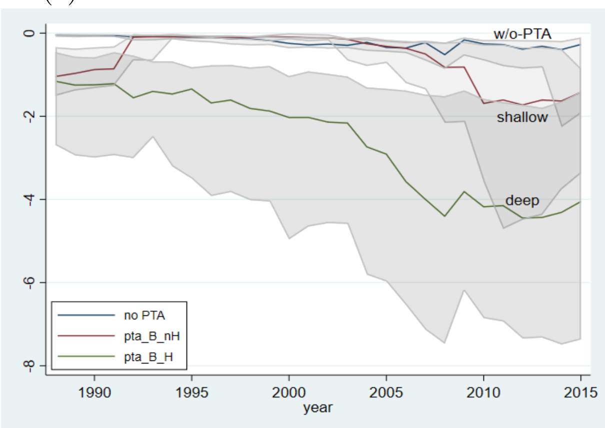
(b) “WTO+” and “WTO-X”



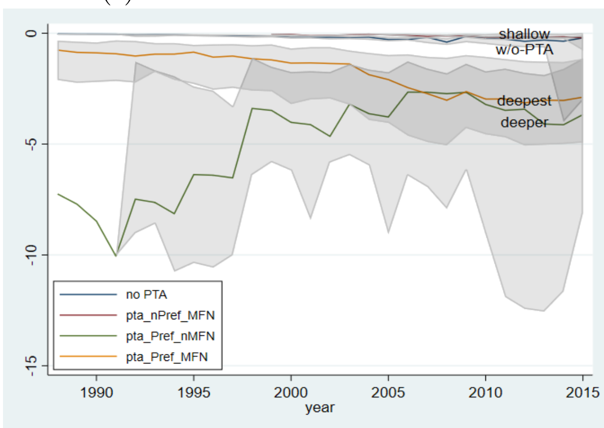
(c) “Core” and “Non-Core”



(e) “Border” and “Behind-the-border”



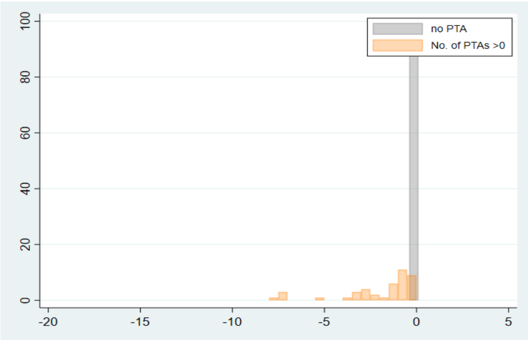
(f) “Preferential” and “MFN”



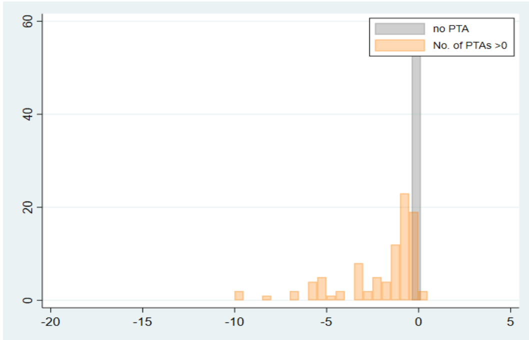
Note: Based on the PTA estimates and $\hat{\sigma}$ from Table 2.2. This set of analysis evaluates the effect of PTAs under each scenario had PTA subcategories not existed ($deepPTA = 0$ for all ijt) relative to the scenario with the factual PTA status. The y-axis indicates the % change in welfare (real output), and the x-axis refers to year. The gray shaded area characterizes the value range of welfare between 25% and 75% for each subcategory.

Figure 2.3: Welfare effects of PTA

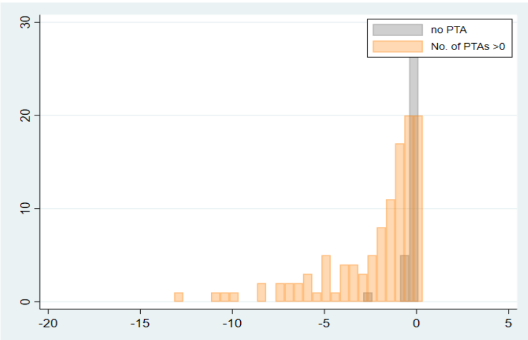
(c) 1990



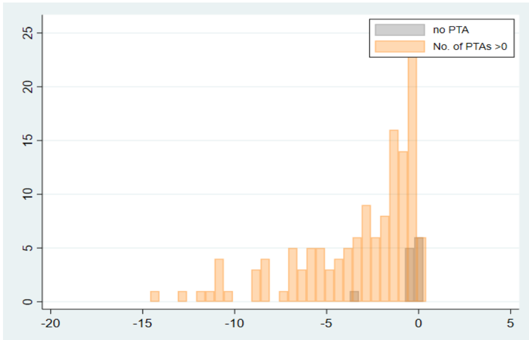
(d) 1995



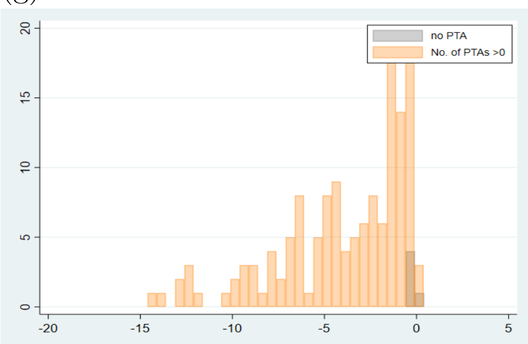
(e) 2000



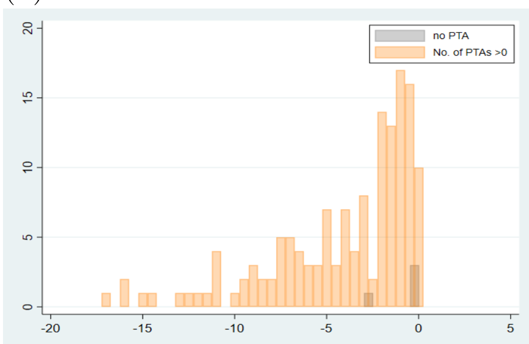
(f) 2005



(g) 2010



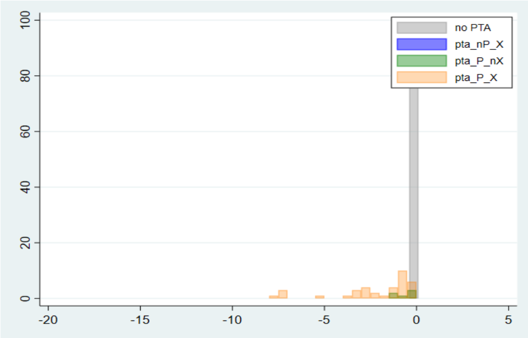
(h) 2015



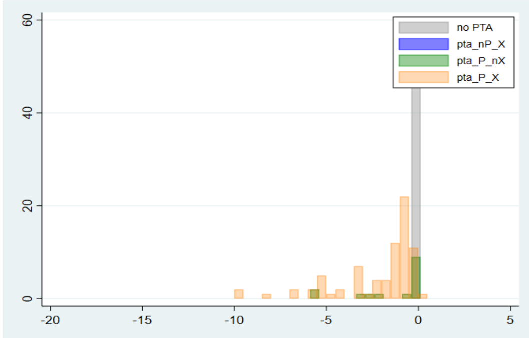
Note: Based on the PTA estimates and $\hat{\sigma}$ from Table 2.2. This set of analysis evaluates the effect of PTAs under each scenario had PTA subcategories not existed ($PTA = 0$ for all ijt) relative to the scenario with the factual PTA status. The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Figure 2.4: Welfare effects of PTA ("WTO+" and "WTO-X")

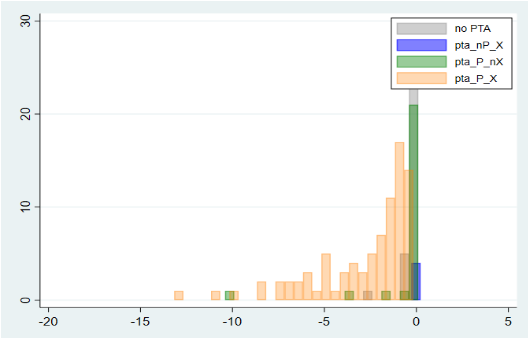
(c) 1990



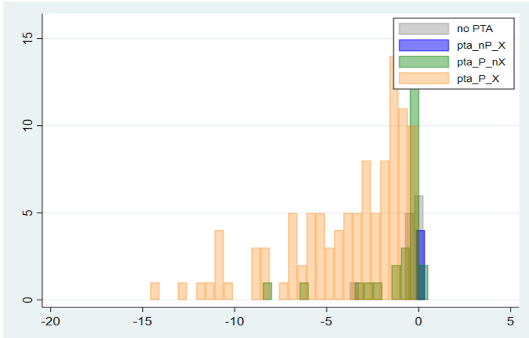
(d) 1995



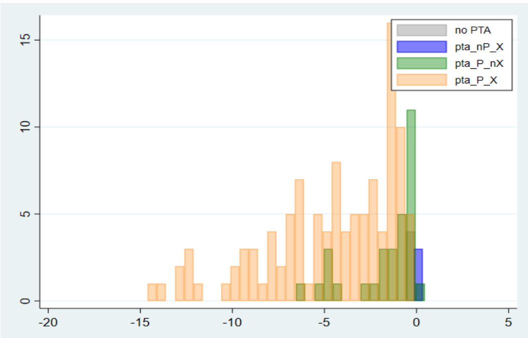
(e) 2000



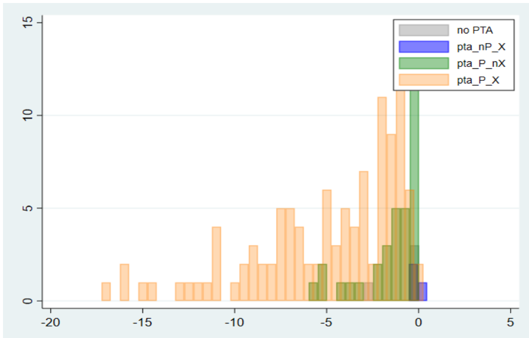
(f) 2005



(g) 2010



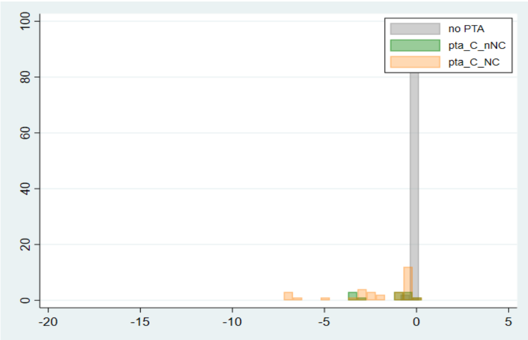
(h) 2015



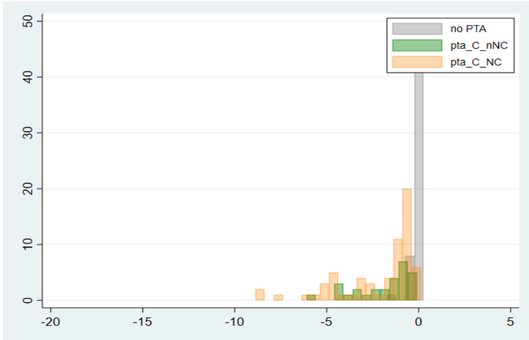
Note: Based on the PTA estimates and $\hat{\sigma}$ from Table 2.2. This set of analysis evaluates the effect of PTAs under each scenario had PTA subcategories not existed ($PTA\_nP\_X = 0$; $PTA\_P\_nX = 0$ and $PTA\_P\_X = 0$; for all ijt) relative to the scenario with the factual PTA status. The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Figure 2.5: Welfare effects of PTA ("Core" and "Non-Core")

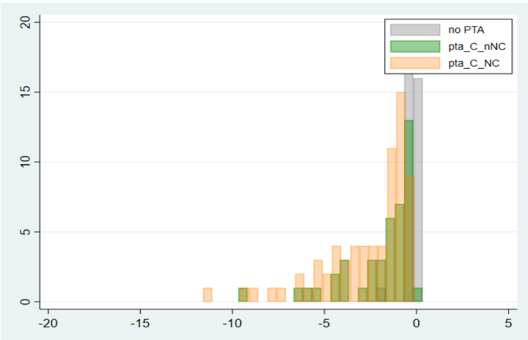
(c) 1990



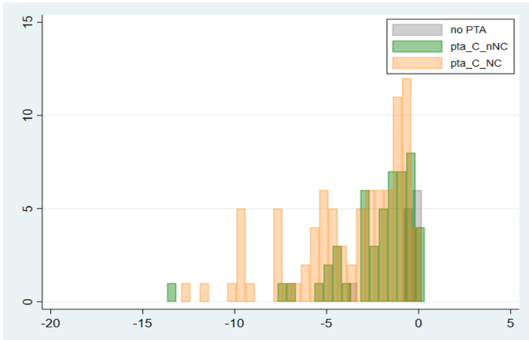
(d) 1995



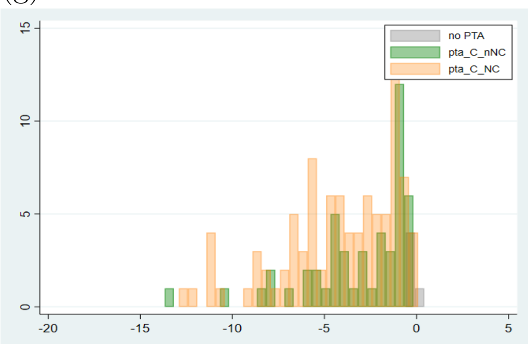
(e) 2000



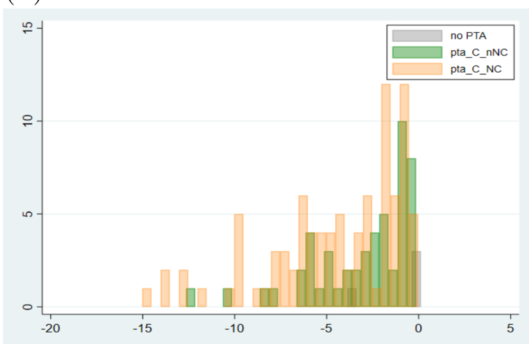
(f) 2005



(g) 2010



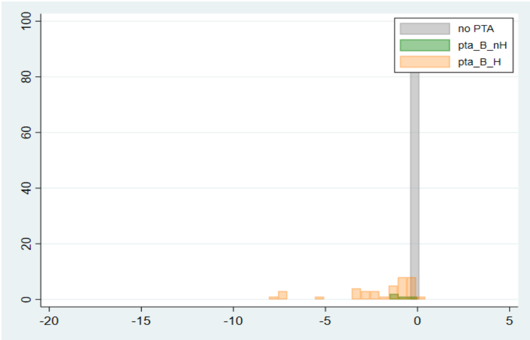
(h) 2015



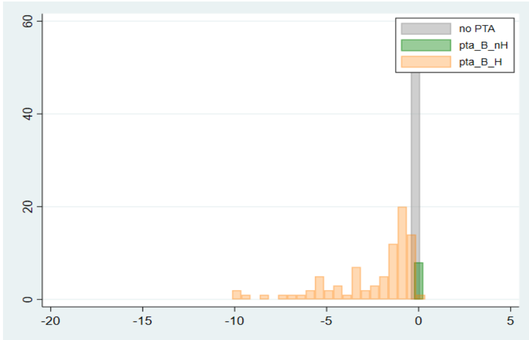
Note: Based on the PTA estimates and $\hat{\sigma}$ from Table 2.2. This set of analysis evaluates the effect of PTAs under each scenario had PTA subcategories not existed ($PTA\_C\_NC = 0$; $PTA\_C\_nNC = 0$; for all ijt) relative to the scenario with the factual PTA status. The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Figure 2.6: Welfare effects of PTA ("Border" and "Behind-the-border")

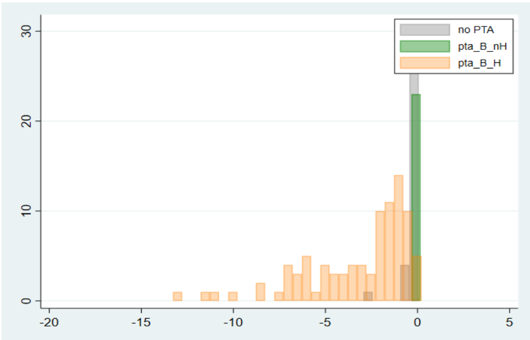
(c) 1990



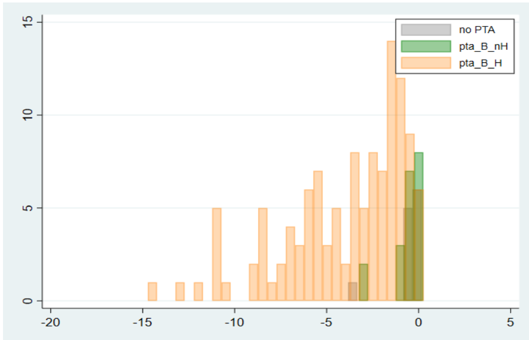
(d) 1995



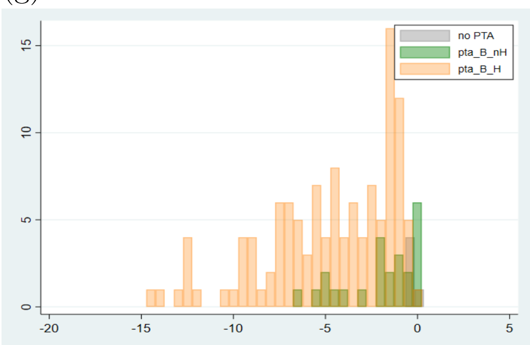
(e) 2000



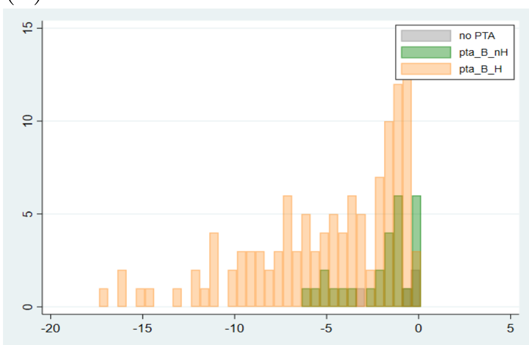
(f) 2005



(g) 2010



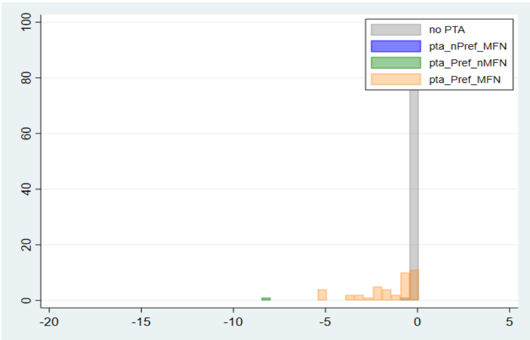
(h) 2015



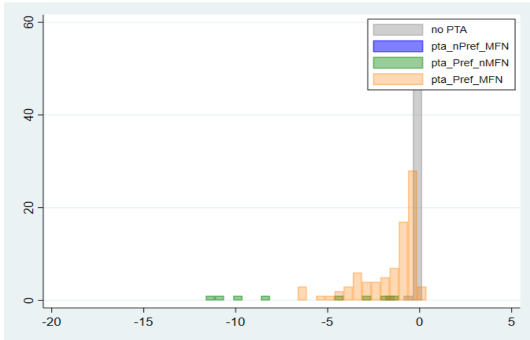
Note: Based on the PTA estimates and $\hat{\sigma}$ from Table 2.2. This set of analysis evaluates the effects of PTA given the counterfactual had PTA subcategories not existed ($PTA\_B\_nH = 0$; $PTA\_B\_H = 0$; for all ijt) relative to the scenario with the factual PTA status. The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Figure 2.7: Welfare effects of PTA (“Preferential” and “MFN”)

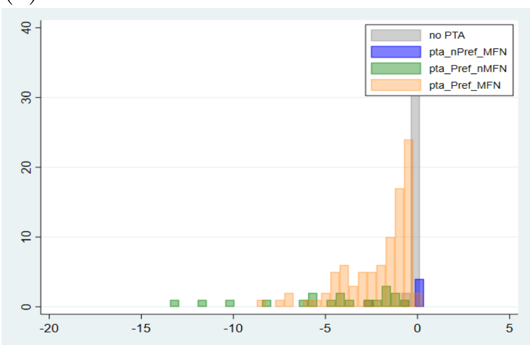
(c) 1990



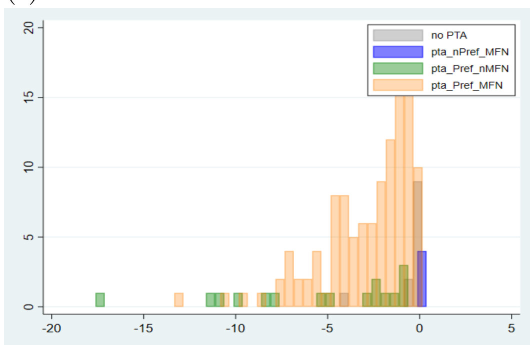
(d) 1995



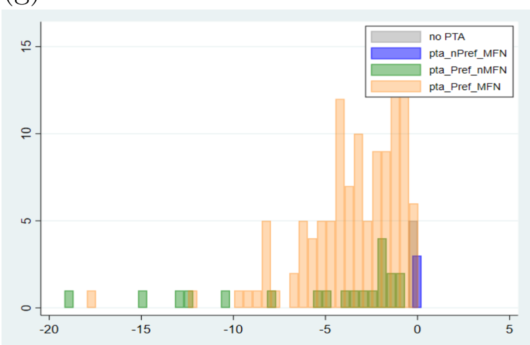
(e) 2000



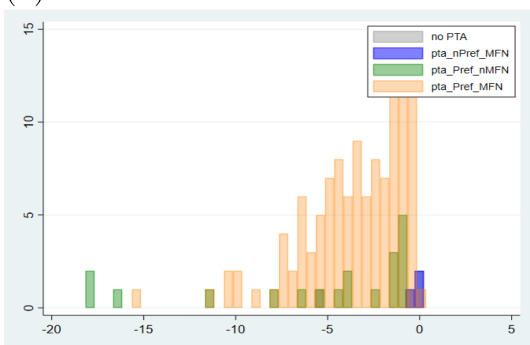
(f) 2005



(g) 2010



(h) 2015



Note: Based on the PTA estimates and $\hat{\sigma}$ from Table 2.2. This set of analysis evaluates the effects of PTA given the the counterfactual had PTA subcategories not existed ($PTA\_nPref\_MFN = 0$; $PTA\_Pref\_nMFN = 0$; $PTA\_Pref\_MFN = 0$; for all ijt) relative to the scenario with the factual PTA status. The y-axis indicates the number of countries, and the x-axis the % change in welfare (real output). Outliers are omitted.

Chapter 3

The Response of the Chinese Economy to the U.S.-China Trade War: 2018–2019

3.1 Introduction

During 2018–2019, in an unprecedented manner since the 1930s, the U.S. Trump administration imposed seven rounds of tariff increases that affected Chinese exports. This includes the first round in February 2018, on solar panel and washing machine imports, and the second, targeting iron, aluminum and steel products. They were followed by three rounds of tariff hikes in 2018 and two in 2019, targeting imports specifically from China. All told, these seven rounds of tariff increases affected \$325.1 billion (14.27%) of Chinese exports across 6428 HS-8 products (using 2017 pre-war trade values). The U.S. statutory tariff rate on these Chinese products increased from 3.55% to 28.53% (simple average).

In return, China raised tariffs on U.S. products (four rounds in 2018 and two in 2019). All told, 5833 distinct HS-8 products imported from the U.S. were targeted during the period 2018:1–2019:12. In 2017 trade values, these affected \$109.3 billion (or 5.93%) of Chinese imports. The retaliation tariff rate increased from 6.46% to 21.27% (simple average). As China raised its tariffs against U.S. products, it also unilaterally lowered its Most-Favored-Nation (MFN) tariff rates on imports from non-U.S. sources where the MFN rate applied. This took place in four rounds during 2018:5–11. All told, the lists covered 3054 products, with a pre-war trade value of \$145.7 billion (or 7.90% of Chinese imports in 2017). The tariff rate across these products decreased from 9.89% to 6.82% (simple average).

In the literature, Amiti et al. (2019), Flaaen et al. (2020), Fajgelbaum et al. (2020), and Cavallo et al. (2021) have evaluated the ex-post impacts on the U.S. economy of the 2018–2019 trade war (in terms of prices, import/export quantities, real wages, or welfare), given events up to 2018:12, 2019:1, 2019:4, and 2020:2, respectively. These studies generally employed highly disaggregated product and tariff line classifications, with a strong focus on identifying the U.S. demand and supply structure at the micro product/variety level and their corresponding elasticities. On the other hand, studies by Charbonneau and Landry (2018), Guo et al. (2018) and Itakura (2020) conducted ex ante predictions of the trade-war effects using, respectively, the quantitative models of Caliendo and Parro (2015) and the GTAP CGE model (based on tariff changes imposed in the early phase of the trade war and/or proposed tariff changes at the time of their studies). Given the nature of their modeling frameworks, the trade and tariff changes are typically organized at the sector level, with emphasis on general equilibrium adjustment across sectors and countries. Li et al. (2020) similarly examined the welfare impacts of the trade war based on the GTAP model, but with analysis incorporating the tariff revisions as of 2020:3 (after the Phase One Deal was reached between the U.S. and China on December 13, 2019). The trade elasticities used in these studies were often taken from the literature based on sector-level trade analysis, or built-in parameters assumed by the GTAP models.

In this paper, we follow the micro-to-macro approach of Fajgelbaum et al. (2020), but with China now modeled as the local economy (given a detailed general equilibrium structure), while each of its trading partners is modeled in reduced form. Corresponding to the setup of Fajgelbaum et al. (2020) for the U.S. economy, the demand system we estimate for the Chinese economy includes reallocations between the domestic bundle and the imported bundle within each sector (defined as a 2-digit GB/T code, a standard Chinese industry classification system), across products (defined as 8-digit HS product codes) within each sector's imported bundle, and across varieties (defined as country-product pairs) within each imported product. This demand system is interacted with foreign export supply at the variety level, and their joint effects on prices and quantities are aggregated up the hierarchy of demand to the product and sector levels. In contrast, the import demand and export supply structures for each of China's trading partners are specified/identified only at the variety level.

To estimate this system, we compile data on China's imports (exports) from (to) each of its trading partners, in terms of both quantities and values at the 8-digit HS level, with monthly frequency for the period 2017:1–2019:12. We similarly compile the Chinese tariff rates on imports with respect to each trading partner (at the HS-8 level), and the foreign tariff rates on China's exports (at the HS-6 digit level), with monthly frequency for the same period. These are constructed using the baseline statutory tariff rates that were in place at the start of 2017, amended with tariff changes announced by the Ministry of Finance, China, or the U.S. Trade Representative during the period studied.

As suggested by Fajgelbaum et al. (2020) and Zoutman et al. (2018), the import demand and foreign export supply elasticities can be identified simultaneously using changes in tariffs as an instrument, provided that these changes are uncorrelated with demand and supply shocks. We conduct tests to verify the validity of this condition from the Chinese economy's perspective, based on tariff shocks associated with the trade war during the period 2018:1–2019:12. Tables 3.3 and 3.6 report the variety-level estimation results, and Tables 3.4–3.5 the product-level and sector-level estimation results. Overall, the elasticities we estimate for the Chinese economy are smaller in magnitude than the U.S. counterparts obtained by Fajgelbaum et al. (2020). Table 3.7 summarizes the partial (direct) impacts on Chinese imports and exports, given the elasticity estimates and the tariff changes due to the trade war. Chinese imports of U.S. products targeted by the Chinese import tariff fell by 13.14% (weighted average). The MFN tariff cuts extended by China cushioned the negative impacts substantially. Chinese imports from these non-U.S. MFN sources of imports are estimated to have increased by 3.48% for targeted varieties. With the opposing effects combined, the overall change in Chinese imports of targeted varieties was muted at -3.64%. On the other hand, exports of Chinese products targeted by the U.S. tariffs fell by -24.48%. Thus, the major brunt of the tariff war on the Chinese economy was borne by its exports in partial equilibrium.

We then simulate for the Chinese economy the general equilibrium effects of the tariff shocks, given the elasticity parameters estimated above (at variety/product/sector level), and a supply-side structure calibrated to the observed labor allocation across Chinese sector-provinces, input-output structures across sectors, consumption allocation across non-tradable and tradable sectors, capital/labor/intermediate cost shares in sector-level production, and imports and exports across varieties. The system is large in dimension, including endogenous prices for each variety, product, and sector, wages for each sector-province, and final and intermediate expenditures across sectors. Thus, as in Fajgelbaum et al. (2020), the system is solved as a first-order linear approximation in log changes around the pre-war equilibrium in 2017, given the China-U.S. tariff shocks during 2018:1–2019:12.

Table 3.9 summarizes the effects on producers/exporters (EV^X), consumers/buyers of imports (EV^M), and tariff revenue (ΔR) in Columns (1)–(3) and the aggregate impacts in Column (4). Our analysis suggests large negative consequences of the trade war on both Chinese producers (-0.272% of China's GDP) and consumers (-0.057% of GDP), with the producers (exporters) suffering more than four times the loss of the buyers of imports. Both components further dominate the positive tariff revenue increase. As a result of the trade war, China sustained an aggregate loss of $37.898 billion, or 0.312% of its GDP. Without counter-retaliation, its loss would have been much larger, at $38.921 billion (0.321% of GDP), and would have been largely borne by producers (exporters). The retaliation against the U.S. imports shifted the burden to the Chinese buyers of imports. Further adjustment in the MFN tariff rates on non-U.S. imports lessened the loss of Chinese buyers of imports and shifted part of the burden back to the producers. Overall, the aggregate loss is significant statistically. In comparison, Fajgelbaum et al. (2020) reported much larger consumer loss (-0.27% of U.S. GDP), a positive effect on producers (0.05% of U.S. GDP), and only slightly negative aggregate effect (-0.04% of U.S. GDP) for the U.S. economy.

We then analyze the variation in exposure to the trade war across provinces in China. For this purpose, we construct the province-level exposure of tradable sectors by first computing the trade-weighted tariff changes for each GB/T-2 sector and then mapping them to provinces based on provincial employment structure. Figure 3.3 suggests that China tended to: (A) retaliate against the U.S. in sectors with a relatively high concentration in the outlying provinces such as Xinjiang, Hainan, and Heilongjiang; and (B) reduce MFN tariffs on sectors concentrated in provinces closer to the coast, such as Shanghai and Beijing. Overall, China's tariff increases tended to be biased toward inner provinces and turn negative in the Eastern provinces. Added to the burden, Panel (D) suggests that these provinces also faced higher tariff increase on their exports to the U.S.

Figure 3.4 summarizes the simulated effects of the trade war on real wage across provinces in general equilibrium. Every province experienced a reduction in the tradable real wage. Provinces with larger relative losses are concentrated in the Southeast, whose employment structures were hit more strongly by the U.S. tariff increase. The real wage losses would have been one level higher without the MFN tariff cuts by China. This contrasts with the finding in Table 3.9, where the MFN tariff cuts by China worsened the aggregate loss. This implies that the MFN tariff cuts helped cushion the impacts on workers/consumers via lower import prices, at the cost of producers (and the owners of capital and fixed structures), who faced greater competition in the product market. Overall, on average across provinces, the nominal wages for workers in tradable sectors decreased by 3.19%. These income losses were, however, cushioned by a lower cost of living, as the CPI of tradable goods decreased by 2.34% on average across sectors. As a result, real wages in the tradable sector fell by 0.32%.

The remainder of the paper is structured as follows. Section 3.2 documents the data used for the analysis and the timeline of the tariff events. Section 3.3 outlines the economic structure used for the analysis. Section 3.4 presents the estimation results of elasticities and partial equilibrium impacts on trade. Section 3.5 reports the simulated general equilibrium effects at the aggregate, across Chinese provinces, and across sources of imports and destination of exports. Section 3.6 concludes.

3.2 Data and Timeline

3.2.1 Data

We obtained the Chinese baseline tariff rates from the UN TRAINS database and its tariff rate changes from the Ministry of Finance, China. The former is available at the 10-digit Harmonized System (HS) level and the data were aggregated and matched to the latter, available at the HS-8 level. Starting with the baseline import tariff rate in January 2017, we update the rates at monthly frequency, given the official announcement by the Ministry of Finance, China, of any tariff changes. Note, however, that only tariff changes announced in association with the tariff war are used as sources of variations in the instrumental variable to identify the import demand and export supply elasticities.

We similarly obtained the baseline tariff faced by Chinese exports from the UN TRAINS database. These data are harmonized across countries up to the HS-6 digit level. The information on the U.S. tariff increase associated with the trade war is based on Fajgelbaum et al. (2019) (for tariff changes in 2018) and the Office of the United States Trade Representative (USTR) (for tariff changes in 2019). The tariff changes are aggregated from the HS-10 to the HS-6 level by simple averaging. The estimations of trade elasticities for Chinese exports are nonetheless conducted at the HS-8 level of trade (with the HS-6 tariffs assigned to all HS-8 products in the category). Because we work with monthly data and the tariff changes could be implemented anytime within a month, we scale the tariff changes by the number of days of the month they were in effect.

We obtained China's trade data with monthly frequency for the period 2017:1–2019:12

from the General Administration of Customs, China. The data on Chinese imports and exports are available at the HS-8 digit level (which we refer to as products) by the source of imports and the destination of exports. Country-product pairs are referred to as varieties. For each variety, the customs data report the quantities of imports and exports, the value of imports at the CIF price, and the value of exports at the FOB price. The import and export values are reported in current US$ values.

We classify sectors using the China Industry Classification system (GB/T 4754), which is widely used for reporting official statistics on companies and organizations throughout Mainland China. The sector-level data at the GB/T 2-digit level (denoted GB/T-2) were obtained from China's National Bureau of Statistics. These include the producer price index for industrial products (PPI); the sectoral output in monthly frequency; and the input-output (IO) tables for 2017. For the analysis in the paper, we classify a GB/T-2 sector as tradable if it is matched to at least one HS-6 code of the trade classification.

For the general equilibrium analysis, we collected the annual employment and wage data at the sector and province level from the China Labor Statistical Yearbook of 2017. It records the employment and total wages of urban units by sector and province. These are available for 31 provinces and 94 GB/T-2 sectors (covering services, agriculture, mining and manufacturing). All 39 sectors identified as tradable are covered individually in both the IO tables and the labor statistics dataset. We aggregate the remaining sectors as a single non-tradable sector, reconciling the IO tables and the labor statistics dataset. More details about the data are provided in Appendix C.1.

3.2.2 Timeline

Table 3.1 reports the list of tariff events enacted by the U.S. (Panel A) and China (Panel B1 and B2) during the period 2018:1–2019:12 of the trade war. For each tariff event, we identify the number of HS-8 products targeted and the quantum (and percentages) of Chinese exports and imports (in million US$) affected by the U.S. and Chinese tariff changes, respectively, based on 2017 pre-war trade flows. We summarize the extent of tariff changes in each event by the simple average of tariff rates (in percentage points) across targeted products before and after the implementation. Figure 3.1 illustrates the timing and the tariff changes.[1]

Panel A of Table 3.1 reports the seven waves of U.S. statutory tariff increases that affected Chinese exports during the period. This includes the first wave of tariff increases in February 2018 applied to solar panel and washing machine imports, and the second wave of tariffs, which targeted iron, aluminum, and steel products. They were followed by three tranches of tariff hikes in 2018 and two tranches in 2019, targeting imports specifically from China. In total, these seven rounds of tariff increase covered $325.1 billion (14.27%) of total Chinese exports across 6428 HS-8 products (using 2017 pre-war trade flows). The average U.S. statutory tariff rate on these Chinese products increased from 3.55% to 28.53%.

Panel B1 of Table 3.1 lists the seven rounds of China's retaliatory tariffs on U.S. products. All told, 5833 distinct HS-8 products imported from the U.S. were targeted. In 2017 trade values, these affected $109.3 billion (or 5.93%) of Chinese imports. The average retaliation tariff rate increased from 6.46% to 21.27%. The first wave of tariff increases by China against imports from the U.S. was enacted on April 2, 2018. China increased the tariff (by 15%–25%) on U.S. products (worth about $3 billion), including fruit, wine, seamless steel pipes, pork and recycled aluminum, in response to the U.S. steel and aluminum tariffs. In July and August 2018, China implemented two rounds of retaliatory tariff increases (by 25%) on U.S. products, including agricultural products, automobiles and aquatic products (List 1), and commodities such as coal, copper scrap, fuel, buses and medical equipment (List 2), respectively. In September 2018, China continued to respond to U.S. tariffs and enacted another round of tariff increases on about $60 billion worth of U.S. goods (List 3). In January 2019, China revised its lists and exempted U.S. autos (from an extra 25% tariff)

[1] In estimations and welfare analysis, the tariff changes applicable to a month are scaled by the number of days the changes were in effect in a month. Refer to the Data Appendix for additional details. For illustration purposes only, in Table 3.1 and Figure 3.1, the implementation month is taken to be the current month if the implementation date is before the 15th of the month and the next month otherwise. The 'before' and 'after' simple monthly average tariff rates correspond to those in the month before and the month after the implementation month.

and certain U.S. auto parts (from an extra 5% tariff). But as the tariff war escalated, in June and September 2019, China further increased tariffs on more than $68 billion worth of products imported from the U.S.

As China raised its tariffs against the U.S. products, it also unilaterally lowered its MFN tariff rates on imports from non-U.S. sources where MFN rates apply. Panel B2 of Table 3.1 summarizes four waves of China's MFN tariff cuts in May to November 2018. Products affected included pharmaceuticals (May), autos and ITA products (July), a subset of consumer goods (July) and industrial goods (November). In total, the lists covered 3054 products, with a pre-war trade value of $145.7 billion (or 7.90% of Chinese imports in 2017). The average tariff rate across these products decreased from 9.89% to 6.82%.

Table 3.2 reports the summary statistics for the extent of exposure to the tariff war by GB/T-2 codes. For Chinese imports, we report the number of targeted HS-8 products and varieties, and the means and standard deviations of tariff increases across targeted varieties within GB/T-2 codes. The Chinese sectors that received the most protection from tariff increases on U.S. products were agricultural products, chemicals, fuel, metals and waste resources. In contrast, the sectors of food, textiles, articles for cultural activities, and automobiles are shown to have been subject to MFN tariff cuts to a larger extent. On the export side, the table indicates that Chinese sectors that faced the largest tariff increases by the U.S. were metals, electrical equipment, machinery and computer products.

3.3 Economic Structure

In this section, we set up the economic structure à la Fajgelbaum et al. (2020). Sections 3.3.1–3.3.2 describe the demand/supply structure that guides the estimation in Section 3.4. Section 3.3.3 describes the full general equilibrium system that forms the basis of the welfare analysis in Section 3.5.

3.3.1 The Demand System and Preferences

Suppose there are S tradable sectors indexed by s. Within each of these sectors, aggregate demand (from producers and consumers) follows a three-tier CES structure: in the first tier, goods are differentiated by domestic and imported bundles (denoted as D_s and M_s respectively) in each sector; in the second tier, they are differentiated by products (indexed by g) within the domestic or imported bundle; and in the third tier, by varieties (indexed by ig), differentiated by country of origin i within each imported product category.

In particular, in the first tier, the demand from consumers for consumption (C_s) and the demand from producers for intermediate inputs (I_s) follow a CES structure:

$$C_s + I_s = \left(A_{Ds}^{\frac{1}{\kappa}} D_s^{\frac{\kappa-1}{\kappa}} + A_{Ms}^{\frac{1}{\kappa}} M_s^{\frac{\kappa-1}{\kappa}} \right)^{\frac{\kappa}{\kappa-1}}, \tag{3.1}$$

with an elasticity of substitution κ between the domestic and imported bundles, and sector-level demand shifters (A_{Ds} and A_{Ms}) for the domestic and imported bundles, respectively. This implies a sector-level price index: $P_s = \left(A_{Ds} P_{Ds}^{1-\kappa} + A_{Ms} P_{Ms}^{1-\kappa} \right)^{\frac{1}{1-\kappa}}$, given the price indices of domestic and imported bundles (P_{Ds} and P_{Ms}) in sector s.

In the second tier, the domestic or imported bundle (D_s or M_s) is each a CES aggregate of products within the sector (d_g, m_g), with an elasticity of substitution η and demand shifter (a_{Dg} and a_{Mg}, respectively) for $g \in \mathcal{G}_s$. This implies corresponding price indices (P_{Ds}, P_{Ms}), which are CES aggregates of, respectively, the prices of domestic and imported products (p_{D_g} and p_{M_g}) for $g \in \mathcal{G}_s$.

Finally, in the third tier, each imported product (m_g) is further a CES aggregate of varieties (m_{ig}) differentiated by country of origin i, with an elasticity of substitution σ and demand shifter a_{ig}:

$$m_g = \left(\sum_{i \in \mathcal{I}_g} a_{ig}^{\frac{1}{\sigma}} m_{ig}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{3.2}$$

and a corresponding price index: $p_{Mg} = \left(\sum_i a_{ig} p_{ig}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$, given the variety price p_{ig}. The above demand system implies that the values of demand for domestic goods and imported goods in sector s are:

$$P_{Ds} D_s = E_s A_{Ds} \left(\frac{P_{Ds}}{P_s} \right)^{1-\kappa}, \tag{3.3}$$

$$P_{Ms} M_s = E_s A_{Ms} \left(\frac{P_{Ms}}{P_s} \right)^{1-\kappa}, \tag{3.4}$$

where E_s is the aggregate expenditure on goods of sector s. In turn, the value of imports for product g in sector s is:

$$p_{Mg} m_g = P_{Ms} M_s a_{Mg} \left(\frac{p_{Mg}}{P_{Ms}} \right)^{1-\eta}, \tag{3.5}$$

and the quantity imported of product g's variety from country i is:

$$m_{ig} = m_g a_{ig} \left(\frac{p_{ig}}{p_{Mg}} \right)^{-\sigma}. \tag{3.6}$$

Given the ad valorem tariff rate τ_{ig} imposed on a variety and the variety's CIF price p^*_{ig} before tariff, the consumer price of the variety is:

$$p_{ig} = (1 + \tau_{ig})\, p^*_{ig}. \tag{3.7}$$

In the general equilibrium, to study the regional effects of tariffs, we divide China into R regions (effectively provinces). Each region is indexed by r and the set of regions is denoted by $\mathcal{R}$. There is one non-tradable sector in addition to the set of tradable sectors described above. Tradable sectors are freely traded within China but subject to trade costs internationally. The representative consumer in each region r is assumed to have a Cobb-Douglas preference for the non-tradable and tradable goods:

$$\beta_{NT} \ln C_{NT,r} + \sum_{s \in \mathcal{S}} \beta_s \ln C_{sr}, \tag{3.8}$$

where $C_{NT,r}$ is the consumption of the homogeneous non-tradable good, C_{sr} is the consumption of the tradable goods of sector s, and the β's sum to one. Consumers in a region r face the price of the non-tradable good $P_{NT,r}$ and the price index P_s for each sector s.

3.3.2 The Foreign Counterpart

For each trading partner, its export supply to China and its import demand for Chinese product at the variety level are specified as follows to fully characterize the international markets. For a product from country i, China faces an inverse foreign export-supply curve according to:

$$p^*_{ig} = z^*_{ig} m_{ig}^{\omega^*}, \tag{3.9}$$

where z^*_{ig} is a foreign export supply shifter, and ω^* is the inverse foreign export supply elasticity. The larger ω^* is, the more China can extract a decrease in the supply price from the exporter and hence a larger potential gain from imposing import tariffs.

The foreign import demand for the variety from China of product g is assumed to be similar to China's import variety demand:

$$x_{ig} = a^*_{ig} \left(\left(1 + \tau^*_{ig}\right) p^X_{ig} \right)^{-\sigma^*}, \tag{3.10}$$

where x_{ig} is country i's demand for product g from China, a^*_{ig} is a foreign import demand shifter, τ^*_{ig} is the ad valorem tariff set by country i on China's exports of product g, p^X_{ig} is China's export supply price of product g to market i, and σ^* is the corresponding foreign import demand elasticity.

3.3.3 The Supply-Side Structure

Production of tradable goods in each sector-region uses workers, intermediate inputs, and a fixed factor (capital and structures). In the short run, the primary factors of production (capital and labor) are assumed to be immobile across regions and sectors.[2] In particular, the production of tradable goods in a sector-region is assumed to be:

$$Q_{sr} = Z_{sr} \left(\frac{I_{sr}}{\alpha_{Is}}\right)^{\alpha_{Is}} \left(\frac{L_{sr}}{\alpha_{Ls}}\right)^{\alpha_{Ls}}, \tag{3.11}$$

where Z_{sr} is the productivity of sector s in region r, I_{sr} is the use of intermediate input bundle, L_{sr} is the labor input, and α_{Is} and α_{Ls} are the cost shares of intermediate goods and labor in total sales of sector s, respectively.

The intermediate input bundle used by sector s is assumed to be a Cobb-Douglas aggregate of inputs from other sectors, with $\alpha_s^{s'}$ representing the share of input s' in total sales of sector s. This implies that the cost of the intermediate input bundle used by sector s is:

$$\phi_s \propto \prod_{s' \in S} P_{s'}^{\frac{\alpha_s^{s'}}{\alpha_{Is}}}. \tag{3.12}$$

The owners of the fixed factor choose inputs I_{sr} and L_{sr} to minimize the cost of production, given the cost of the intermediate input bundle ϕ_s; the wage rate w_{sr} in sector s and region r; and the production target Q_{sr}. Given the producer price p_s in sector s, the fixed factor owners then choose the production level Q_{sr} that maximizes their profit:

$$\begin{aligned} \Pi_{sr} &\equiv \max_{Q_{sr}} p_s Q_{sr} - \phi_s I_{sr}(Q_{sr}) - w_{sr} L_{sr}(Q_{sr}) \\ &= \max_{Q_{sr}} p_s Q_{sr} - (1-\alpha_{Ks}) \left(\frac{\phi_s^{\alpha_{Is}} w_{sr}^{\alpha_{Ls}}}{Z_{sr}} Q_{sr}\right)^{\frac{1}{1-\alpha_{Ks}}}, \end{aligned} \tag{3.13}$$

where $\alpha_{Ks} \equiv 1 - \alpha_{Is} - \alpha_{Ls}$ is the share of capital cost in total sales of sector s. This implies an optimal output choice as a function of output and factor prices:

$$Q_{sr} = Z_{sr}^{\frac{1}{\alpha_{Ks}}} p_s^{\frac{1-\alpha_{Ks}}{\alpha_{Ks}}} \phi_s^{-\frac{\alpha_{Is}}{\alpha_{Ks}}} w_{sr}^{-\frac{\alpha_{Ls}}{\alpha_{Ks}}}, \tag{3.14}$$

[2]Nonetheless, in deriving the system (in log changes), Appendix C.2.1 also considers the scenario of labor mobility across sectors.

and the national production in sector s as:

$$Q_s = \sum_{r \in \mathcal{R}} Q_{sr}. \tag{3.15}$$

The non-tradable sector is assumed to use only labor for production: $Q_r^{NT} = Z_r^{NT} L_r^{NT}$, where Z_r^{NT} is the labor productivity of region r in the non-tradable sector, and L_r^{NT} is the employment in this sector in region r.

Output by sector Q_s is assumed to be allocated across products q_g at a constant marginal rate of transformation according to:

$$\sum_{g \in \mathcal{G}_s} \frac{q_g}{z_g} = Q_s, \tag{3.16}$$

where z_g is a product-level productivity shock. Assuming perfect competition, this pins down the local price of the domestic variety of product g at $p_{Dg} = \frac{p_s}{z_g}$. The price of the same variety when shipped to a foreign country i is $p_{ig}^X = \delta_{ig} p_{Dg}$, given the iceberg trade cost factor δ_{ig}. The market-clearing condition for the local variety of product g requires that:

$$q_g = \underbrace{\left(a_{Dg} D_s\right) \left(\frac{p_{Dg}}{P_{Ds}}\right)^{-\eta}}_{d_g} + \sum_{i \in \mathcal{I}_g^X} \delta_{ig} \underbrace{a_{ig}^* \left(\left(1 + \tau_{ig}^*\right) p_{ig}^X\right)^{-\sigma^*}}_{x_{ig}}. \tag{3.17}$$

Labor income and profits are assumed to be spent where they are generated. Total tariff revenue R and national trade deficit D are assumed to be distributed to each region in proportion to the population share b_r of the region. Thus, by accounting identity, final expenditures in region r are:

$$\begin{aligned} X_r &= w_{NT,r} L_{NT,r} + \sum_{s \in \mathcal{S}} w_{sr} L_{sr} + \sum_{s \in \mathcal{S}} \Pi_{sr} + b_r \left(D + R\right) \\ &= P_{NT,r} Q_{NT,r} + \sum_{s \in \mathcal{S}} \left(1 - \alpha_{Is}\right) p_s Q_{sr} + b_r \left(D + R\right). \end{aligned} \tag{3.18}$$

Finally, the optimal output choice Q_{sr} in (3.14) implies an (inverse) labor demand function in sector s of region r:

$$w_{sr} = \left(\frac{Z_{sr} p_s}{(L_{sr}/\alpha_{Ls})^{\alpha_{Ks}} \phi_s^{\alpha_{Is}}} \right)^{\frac{1}{1-\alpha_{Is}}}, \tag{3.19}$$

and an average wage for the tradable sectors in region r of:

$$w_r^T = \frac{\sum_{s \in S} w_{sr} L_{sr}}{\sum_{s \in S} L_{sr}}. \tag{3.20}$$

The wage in the non-tradable sector is then pinned down by the market-clearing condition:

$$w_r^{NT} = \frac{\beta_{NT} X_r}{L_r^{NT}}. \tag{3.21}$$

A general equilibrium given tariffs consists of producer prices $\{p_s\}$, import prices $\{p_{ig}^*\}$, price indices $\{p_{Mg}, P_{Ms}, P_{Ds}, P_s, \phi_s\}$, tradable sector wages $\{w_{sr}\}$ and non-tradable sector wages $\{w_r^{NT}\}$ such that (i) given these prices, consumers, producers and workers optimize their choices; (ii) domestic markets for final goods and intermediate inputs clear, international markets for imports and exports of every variety clear, and labor markets for every sector and region clear; and (iii) the government budget is balanced.

3.4 Identification and Estimation

In this section, we estimate the 3-tier demand system using the variation of import tariffs associated with the trade war as the instrument, and conduct pre-trend tests to support the validity of the instrument in Section 3.4.5.

3.4.1 Chinese import demand and foreign export supply elasticities at variety level (σ, ω^*)

We use variation in the Chinese import tariffs as the instrument to estimate the Chinese import demand and foreign export supply elasticities at the variety level, in the same spirit as the work of Fajgelbaum et al. (2020) for the U.S. economy using the U.S. import tariffs. The approach is based on the argument (cf. Zoutman, Gavrilova and Hopland, 2018) that if the tariff variations are uncorrelated with the unobserved import demand and export supply shocks, given the price received by foreign suppliers, an increase in tariff shifts the import demand curve downward and helps trace the foreign export supply curve. Similarly, given the price paid by buyers of imports, a tariff increase shifts the foreign export supply curve upward, which helps identify the import demand curve. Thus, one can identify the demand and supply elasticities simultaneously with the variation in tariffs as an instrument.

To increase the validity of the instrument, we exclude Chinese tariff changes that were due to free-trade agreements or due to regular adjustments (e.g., twice yearly MFN tariff revisions). Accordingly, we use only the changes in Chinese import tariffs against the U.S. products (and decreases in MFN tariffs against non-U.S. products) that were announced in association with the U.S.-China trade war during 2018:1–2019:12, as the variations in the instrument. Specifically, by adding a time subscript (t) and taking the log-difference in import demand equation (3.6) and foreign export supply equation (3.9), we may write their estimable equations as:

$$\Delta \ln m_{igt} = \psi_{ig}^{m} + \psi_{st}^{m} - \sigma \Delta \ln p_{igt} + \varepsilon_{igt}^{m}, \tag{3.22}$$

$$\Delta \ln p_{igt}^{*} = \psi_{ig}^{p^*} + \psi_{st}^{p^*} + \omega^* \Delta \ln m_{igt} + \varepsilon_{igt}^{p^*}, \tag{3.23}$$

where $\varpi = \{p^*, m\}$, and ψ_{ig}^{ϖ} and ψ_{st}^{ϖ} are variety and sector-time fixed effects, ε_{igt}^{m} and $\varepsilon_{igt}^{p^*}$ are the respective import demand and export supply residuals, collecting shocks to import demand $\Delta \ln a_{igt}$ and export supply $\Delta \ln z_{igt}^{*}$, respectively, and other unobservables not controlled for by the fixed effects. Note that in contrast to the U.S., which slapped tariffs against multiple trading partners in selected sectors and also against China in multiple products, China's tariff changes were mainly targeted at the U.S. or uniformly at non-U.S. MFN sources of imports of selected products. This implies limited variations in Chinese tariffs across sources of imports by product. Thus, we have modified the set of fixed effects (FE) controls used in Fajgelbaum et al. (2020). In particular, we drop the product-time (gt) FE—as there are limited variations left across i within gt in the case of Chinese import tariffs—and replace the remaining set of FEs (is, it) with (ig, st). Thus, we rely on within-variety time variations in tariffs as the source of identification, and use sector-time FEs to control for systematic bias in the sectoral pattern of Chinese trade policies or trade flows across time.

Following the identification strategy described above, we estimate the import demand elasticity σ and the foreign (inverse) export supply elasticity ω^* by instrumenting changes in the duty-inclusive price $\Delta \ln p_{igt}$ and in the import quantity $\Delta \ln m_{igt}$ with variations in the tariff $\Delta \ln(1 + \tau_{igt})$ in equations (3.22) and (3.23), respectively. The estimation results are reported in Table 3.3. Columns (1) to (4) report the reduced-form regressions of different trade outcomes (before-duty import value, import quantity, before-duty unit value and duty-inclusive unit value) on the tariff changes $\Delta \ln(1 + \tau_{igt})$ due to the trade war. Column (5) reports the IV regression estimation of foreign (inverse) export supply elasticity $\hat{\omega}^*$ based on equation (3.23), with its first-stage estimation in Column (2). Column (6) reports the IV regression estimation of import demand elasticity $\hat{\sigma}$ based on equation (3.22), with its first-stage estimation in Column (4).

Columns (1) and (2) show that the import value (before-duty) and quantity respond to tariff changes negatively in very similar magnitudes. The result in Column (3) further indicates that the before-duty unit values do not respond to tariff changes, suggesting a complete pass-through of tariffs to duty-inclusive prices. This is consistent with the result in Column (4), where the duty-inclusive unit value responds to tariffs with elasticity close to one.[3]

The IV estimate of ω^* in Column (5) is statistically insignificant and numerically negligible. This implies that we cannot reject a horizontal foreign export supply curve, consistent with the finding of a complete pass-through of tariffs in the reduced-form regressions. Column (6) reports the IV estimation of import demand elasticity σ. It is statistically significant at $\hat{\sigma} = 1.120$ (std. err. = 0.3158). Given these two elasticity estimates, we can calculate the partial (direct) impact on the import value of the targeted varieties. The results are summarized in Table 3.7. Specifically, if we consider China's retaliatory tariffs against the U.S. products, the weighted average change in import value of the targeted U.S. products would be:

$$\begin{aligned}
\overline{\Delta \ln \left(p_{ig}^* m_{ig}\right)}^{wa} &\equiv \sum_{ig} -\hat{\sigma} \frac{1+\hat{\omega}^*}{1+\hat{\omega}^*\hat{\sigma}} \Delta \ln \left(1+\tau_{ig}\right) \cdot \left(p_{ig}^* m_{ig}\right) / \sum_{ig} \left(p_{ig}^* m_{ig}\right) \\
&\equiv \underbrace{-\hat{\sigma} \frac{1+\hat{\omega}^*}{1+\hat{\omega}^*\hat{\sigma}}}_{-1.121} \underbrace{\overline{\Delta \ln \left(1+\tau_{ig}\right)}^{wa}}_{11.72\%} = -13.14\%,
\end{aligned}$$

where the response ratio $-\hat{\sigma}\frac{1+\hat{\omega}^*}{1+\hat{\omega}^*\hat{\sigma}}$ is implied by the variety-level import demand and export supply equations (3.22) and (3.23). The calculations use the elasticity estimates reported in Table 3.3, the pre-war duty-exclusive trade value of 2017 (as weights) and the latest revised tariff change for each variety observed during the period 2018:1–2019:12 (as the shock). Similar calculations suggest that the Chinese MFN tariff cuts (−3.10% on average across targeted varieties) associated with the tariff war imply a positive direct impact on import values of 3.48%. Together, these imply a combined impact of −3.64% on Chinese import value in partial equilibrium, based on the relative import values of China from the U.S. and from the non-U.S. MFN sources in 2017. The MFN tariff cuts thus helped cushion the drop in Chinese imports substantially.

[3]Since we measure the duty-inclusive price as the product of duty-exclusive price and the tariff factor: $p_{igt} \equiv p_{igt}^*(1+\tau_{igt})$, the estimate in Column (4), by construction, equals one plus the estimate in Column (3), subject to sample attrition across the two estimations.

3.4.2 Demand elasticity across products (η)

To estimate the demand elasticity η across products, we add the time subscript and take the log-difference over time of equation (3.5) such that:

$$\Delta \ln s_{Mgt} = \psi_{st} + (1-\eta)\Delta \ln p_{Mgt} + \varepsilon_{Mgt}, \tag{3.24}$$

where $s_{Mgt} \equiv \frac{p_{Mgt} m_{gt}}{P_{Mst} M_{st}}$ denotes the import share of product g in sector s; ψ_{st} is a sector-time fixed-effect term that helps control for the effect of sector-level import price index $-(1-\eta)\Delta \ln P_{Mst}$, among other time-variant sector-level unobservables; and the residual term ε_{Mgt} absorbs the product-level import demand shock $\Delta \ln a_{Mgt}$ and remaining unobservables.

Note that the import share of each product s_{Mgt} is observed in the data. The product-level import price index is constructed by aggregating the variety-level prices, and taking into account entry and exit of varieties, as in Feenstra (1994):

$$\Delta \ln p_{Mgt} = \frac{1}{1-\sigma} \ln \left(\sum_{i \in \mathcal{C}_{gt}} s_{igt}\, e^{(1-\sigma)\Delta \ln\left(p^*_{igt}(1+\tau_{igt})\right) + \Delta \ln a_{igt}} \right) - \frac{1}{1-\sigma} \ln \left(\frac{S_{g,t}\left(\mathcal{C}_{gt}\right)}{S_{g,t-1}\left(\mathcal{C}_{gt}\right)} \right), \tag{3.25}$$

where $\mathcal{C}_{gt}$ is the set of continuing imported varieties of product g between periods $t-1$ and t, $s_{igt} \equiv \frac{p_{igt} m_{igt}}{\sum_{i' \in \mathcal{C}_{gt}} p_{i'gt} m_{i'gt}}$ is the share of continuing imported varieties that originate from country i in period t, and $S_{g,t}(\mathcal{C}) \equiv \frac{\sum_{i' \in \mathcal{C}} p_{i'gt} m_{i'gt}}{\sum_{i' \in \mathcal{I}_{gt}} p_{i'gt} m_{i'gt}}$ is the share of all imported varieties $\mathcal{I}_{gt}$ of good g at time t accounted for by the varieties in set $\mathcal{C}$. The first term in equation (3.25) corresponds to the conventional price index for the set $\mathcal{C}_{gt}$ of continuing imported varieties. The second term adjusts the price index for the effect of entry and exit of varieties.[4] In the construction of the product-level price index, we use the estimated σ and the corresponding residuals (which reflect mean-zero demand shocks $\Delta \ln a_{igt}$) of equation (3.22) from Section 3.4.1.

Applying the same logic as in the estimation of variety-level elasticities σ and ω^*, we

[4]Equation (3.25) can be derived from the product-level import price index $p_{Mg} = \left(\sum_i a_{ig} p_{ig}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$ and the variety demand equation (3.6).

use product-level tariff changes as the instrument for $\Delta \ln p_{Mgt}$. We construct the IV by the simple average (instead of import-value weighted average) of the tariff changes across the continuing imported varieties:[5]

$$\Delta \ln Z_{Mgt} \equiv \ln \left(\frac{1}{N_{gt}^{c}} \sum_{i \in \mathcal{C}_{gt}} e^{\Delta \ln(1+\tau_{igt})} \right), \tag{3.26}$$

where N_{gt}^{c} is the number of continuing imported varieties of product g between $t-1$ and t.

Table 3.4 reports the estimation results of equation (3.24). Column (1) shows the impact of the instrument on the product-level trade share: higher product-level tariffs lower the import share of the targeted products. This implies that diversion to non-U.S. varieties is less than sufficient to offset the decrease in imports from the U.S. within the same product category. Column (2) provides the first-stage result of the IV regression of (3.24): the sign of the coefficient is positive as expected, since the product-level import price index is aggregated from duty-inclusive variety prices. Column (3) reports the IV estimate of the coefficient of the product-level import demand equation (3.24), which implies an elasticity estimate of $\hat{\eta} = 1.087$. The bootstrapped confidence interval for η, which accounts for the variance of $\hat{\sigma}$ and the demand shocks from the previous step in Section 3.4.1, is [1.041,1.131].

3.4.3 Demand elasticity across domestic and imported bundles (κ)

We further estimate the top-tier elasticity of substitution, κ, between the domestic and imported bundles within a sector. Taking the ratio of the expenditures on the imported bundle (3.4) and the domestic bundle (3.3), we have:

$$\Delta \ln \left(\frac{P_{Mst} M_{st}}{P_{Dst} D_{st}} \right) = \psi_s + \psi_t + (1-\kappa) \Delta \ln \left(\frac{P_{Mst}}{P_{Dst}} \right) + \varepsilon_{st}, \tag{3.27}$$

[5] As argued by Fajgelbaum et al. (2020), this avoids mechanical correlation of the instrument with the product-level trade share.

where ψ_s and ψ_t are sector and time fixed effects, used to help control for unobservables across sectors and time, respectively; while the residual ε_{st} absorbs the remaining relative demand shocks to imported and domestic bundles $\Delta \ln (A_{Mst}/A_{Dst})$. The monthly change in the expenditures on domestic goods of sector s, $\Delta \ln P_{Dst} D_{st}$, is not observable in the data. We use the difference between the changes in the sectoral production and exports as its proxy. The change in domestic sectoral price index, $\Delta \ln P_{Dst}$, is measured by the change in producer price index (PPI), $\Delta \ln p_{st}$, as implied by the theoretical setup. The change in the sectoral import price index, $\Delta \ln P_{Mst}$, is constructed from product-level import prices, $\Delta \ln p_{Mgt}$, in a similar manner as in equation (3.25):

$$\Delta \ln P_{Mst} = \frac{1}{1-\eta} \ln \left(\sum_{g \in \mathcal{C}_{st}} s_{gt} \; e^{(1-\eta)\Delta \ln p_{Mgt} + \Delta \ln \left(a_{Mgt}\right)} \right) - \frac{1}{1-\eta} \ln \left(\frac{S_{s,t}\left(\mathcal{C}_{st}\right)}{S_{s,t-1}\left(\mathcal{C}_{st}\right)} \right), \quad (3.28)$$

where $\mathcal{C}_{st}$ is the set of continuing imported products in sector s between periods $t-1$ and t, s_{gt} is product g's share in the set of continuing imported products of sector s, and $S_{s,t}(\mathcal{C})$ is the share of total import value of sector s at time t accounted for by products in set $\mathcal{C}$.[6] The required inputs, η and $\Delta \ln a_{Mgt}$, in (3.28) are based on their counterparts from the product-level estimation of equation (3.24) in Section 3.4.2. The change in relative price of imports $\Delta \ln \frac{P_{Mst}}{P_{Dst}}$ is similarly instrumented by the simple average of tariff changes across the continuing imported products in sector s:

$$\Delta \ln Z_{Mst} \equiv \ln \left(\frac{1}{N_{st}^c} \sum_{g \in \mathcal{C}_{st}} e^{\Delta \ln Z_{Mgt}} \right), \quad (3.29)$$

where N_{st}^c is the number of continuing imported products in sector s between $t-1$ and t, and $\Delta \ln Z_{Mgt}$ is the instrument defined in (3.26).

The estimation results are summarized in Table 3.5. Column (1) reports the estimated impact of the average sector-level import tariff changes on the sectoral relative import expen-

[6] That is, $s_{gt} \equiv \frac{p_{Mgt} m_{gt}}{\sum_{g' \in \mathcal{C}_{st}} p_{Mg't} m_{g't}}$, and $S_{s,t}(\mathcal{C}) \equiv \frac{\sum_{g' \in \mathcal{C}} p_{Mg't} m_{g't}}{\sum_{g' \in \mathcal{G}_{st}} p_{Mg't} m_{g't}}$, where $\mathcal{G}_{st}$ is the set of all products available in sector s at time t.

ditures. Columns (2) and (3) report the first and second stages of the IV estimation of (3.27), respectively. The estimated coefficients of the two reduced-form specifications in Columns (1) and (2) have the expected signs, but are imprecisely estimated. The IV estimate in Column (3) implies a statistically significant $\hat{\kappa} = 1.173$. The bootstrapped confidence interval for $\hat{\kappa}$, which takes into account the errors in the estimates $\{\hat{\sigma}, \hat{\eta}\}$ and the demand shocks from the previous stages, is [0.541,1.385].

3.4.4 Foreign import demand and Chinese export supply elasticities at variety level (σ^*, ω)

The foreign import demand and Chinese export supply structures at the variety level are estimated based on the same concept as in Section 3.4.1. Taking log changes of the foreign import demand equation (3.10) across time, we have:

$$\Delta \ln x_{igt} = \psi_{ig}^{x} + \psi_{st}^{x} - \sigma^* \Delta \ln \left(\left(1 + \tau_{igt}^*\right) p_{igt}^{X} \right) + \varepsilon_{igt}^{x}, \tag{3.30}$$

where we used ψ_{ig}^{x} and ψ_{st}^{x} to control for potentially unobserved product-destination and sector-time FEs; while the residual ε_{igt}^{x} absorbs remaining shifts in the foreign demand for Chinese products $\Delta \ln a_{igt}^*$. Assume that the export supply of China has a symmetric structure with the foreign export supply, that is, $p_{ig}^{X} = z_{ig} x_{ig}^{\omega}$, where ω is the inverse export supply elasticity of China and z_{ig} is the product-destination export supply shifter. This implies an estimable equation:

$$\Delta \ln p_{igt}^{X} = \psi_{ig}^{p^X} + \psi_{st}^{p^X} + \omega \Delta \ln x_{igt} + \varepsilon_{igt}^{p^X}, \tag{3.31}$$

where we have included the same set of FE controls as in (3.30); with the residual $\varepsilon_{igt}^{p^X}$ capturing remaining variations in the Chinese export supply shifters $\Delta \ln z_{igt}$, after controlling for the fixed effects. By analogous arguments as in Section 3.4.1, we use the variation in foreign tariffs due to the trade war as the instrument for the independent variables in equations (3.30)–(3.31) to identify σ^* and ω. For this set of estimations, we use only observations with

ig corresponding to the U.S. destination, because the U.S. is the only trading partner that raised tariffs against China in this trade war episode. This also limits the set of FEs we can include (product-destination FEs reduced to product FEs) in this case, compared with Fajgelbaum et al. (2020) for the U.S. economy.

Table 3.6 reports the estimation results. The pattern of these estimates is quite similar to those of σ and ω^* in Table 3.3: Columns (1) and (2) show that the export value and quantity fell with tariff increases implemented by the U.S., and Columns (3) and (4) imply that Chinese exporters did not change their supply price; the incidence of the U.S. tariff increases was largely borne by the U.S. buyers of imports. Column (5) reports the IV estimation of equation (3.31) with its first stage in Column (2). The estimate ($\hat{\omega} = -0.055$) is statistically insignificant, consistent with the reduced-form result that the U.S. faced a horizontal Chinese export supply curve. Column (6) reports the IV estimation of equation (3.30) with its first stage in Column (4). The result implies that $\hat{\sigma}^* = 1.012$ (std. err. = 0.1786), with a bootstrapped confidence interval of [0.161,1.302].

Given the elasticity estimates, we can calculate the partial (direct) impact on the Chinese export value of targeted products in similar ways as for Chinese imports. In particular, the weighted average change in Chinese export values across targeted products is:

$$\begin{aligned}\overline{\Delta \ln \left(p_{ig}^{X} x_{ig}\right)}^{wa} &\equiv \sum_{ig} -\hat{\sigma}^* \frac{1+\hat{\omega}}{1+\hat{\omega}\hat{\sigma}^*} \Delta \ln \left(1+\tau_{ig}^*\right) \cdot \left(p_{ig}^{X} x_{ig}\right) / \sum_{ig} \left(p_{ig}^{X} x_{ig}\right) \\ &\equiv \underbrace{-\hat{\sigma}^* \frac{1+\hat{\omega}}{1+\hat{\omega}\hat{\sigma}^*}}_{-1.0127} \underbrace{\overline{\Delta \ln \left(1+\tau_{ig}^*\right)}^{wa}}_{24.18\%} = -24.48\%,\end{aligned}$$

where the response ratio $-\hat{\sigma}^* \frac{1+\hat{\omega}}{1+\hat{\omega}\hat{\sigma}^*}$ is implied by the foreign import demand and Chinese export supply equations (3.30) and (3.31). The calculations use the elasticity estimates reported in Table 3.6, the pre-war duty-exclusive trade value of 2017 (as weights), and the latest revised tariff change for each variety observed during the period 2018:1–2019:12 (as the shock). The results are summarized in Table 3.7.

3.4.5 Pre-trend test

The identification of the import demand and export supply elasticities using tariff changes as the instrument requires the tariff variation to be uncorrelated with the demand and supply shocks. In this section, we conduct pre-trend tests to verify the potential validity of this approach. We show that the tariff changes associated with the trade war (the 18 events listed in Table 3.1) are not systematically correlated with the pre-war trends of the import and export outcomes in terms of values, quantities, before-duty prices and duty-inclusive prices.

Specifically, we compute the average monthly change of these outcome variables during 2017:1–2017:12, and regress them against the latest revised tariff change for each variety during the period of 2018:1–2019:12:

$$\overline{\Delta \ln y_{ig,2017}} = FE + \beta \Delta \ln (1 + \tau_{ig}) + \epsilon_{ig}. \tag{3.32}$$

The test is conducted for each of the three sets of events—China's retaliatory tariff changes against the U.S., China's tariff cuts on non-U.S. MFN sources of imports, and the U.S. tariff increases against Chinese products. We include suitable sets of fixed effects that are in line with the specifications used for the elasticity estimations in Sections 3.4.1 and 3.4.4, but obviously have to drop the time dimension (st to s), and also FEs with the country dimension (i) when the set of tariff events is targeted at the U.S. or China alone. The results are summarized in Table 3.8.

Panel A1 shows the pre-trend test where we consider China's retaliatory tariff increase against U.S. products. Since all targeted varieties are U.S. products, there are no variations across origins in this case (ig being equivalent to g); thus, only fixed effects along the sector (s) dimension are controlled for. The results indicate that all pre-war Chinese import outcome variables (with respect to the U.S. as the source of imports) are not systematically correlated with the subsequent tariff increase China imposed against the U.S. products.

Panel A2 reports the pre-trend test for China's tariff changes against non-U.S. sources of imports during the trade war. Note that MFN tariff cuts do not apply to all non-U.S. sources of imports (e.g., they are not applicable to FTA trading partners of China). With the extra variations in trade flows and tariffs across trading partners, we control for country-sector (is) and product (g) fixed effects in this case. We do not observe statistically significant correlations between pre-war Chinese imports from non-U.S. sources and China's subsequent MFN tariff cuts during the trade war. Finally, in Panel B, we conduct the pre-trend test for the U.S. tariff increase against Chinese products. For the same reason as in Panel A1, we include only sector (s) fixed effects. The estimated coefficients are insignificant statistically, suggesting that the pre-war export trends of Chinese products are not systematically correlated with subsequent increases in the U.S. tariff against China during the trade war.

3.4.6 Dynamic Specification Tests

In this section, we examine whether there exist anticipatory and delayed responses to changes in tariffs during the trade war. This would imply potential downward bias in the elasticity estimates using regressions based on contemporaneous variations in tariffs and trade. To this end, we allow for leads and lags in variety-level reduced-form regressions, controlling for the same set of FEs as in the main estimations:

$$\Delta \ln y_{igt} = \psi_{ig} + \psi_{st} + \sum_{m=-L}^{m=\ell} \beta_m^y [\ln(1+\tau_{ig,t-m}) - \ln(1+\tau_{ig,t-m-1})] + \epsilon_{igt}, \tag{3.33}$$

where L indicates the maximum leads and ℓ the maximum lags (in months) in the response of trade outcome $\Delta \ln y_{igt}$ to the tariff changes. In the following exercise, we set $\ell = L = 6$.

Figure 3.2(A) reports the cumulative estimated coefficients from regression of (3.33) for before-duty import values, quantities, before-duty unit values, and duty-inclusive unit values of Chinese imports at the variety level. There are no significant anticipatory effects in the duty-inclusive unit value and the import quantity, the two key variations used in estimations of σ in (3.22) and ω^* in (3.23), respectively. There also exist no significant delayed effects in the duty-inclusive unit value, as its cumulative effects after the tariff changes remain steady and quantitatively very similar to the contemporaneous effect. This supports the potential validity of the import demand elasticity estimate ($\hat{\sigma}$). Similarly, there exist no quantitatively large delayed effects in the import quantity. Third, the before-duty price does not decline before or after the tariff changes statistically, supporting the conclusion of a complete pass-through at the variety level.

Figure 3.2(B) reports the results for Chinese exports (with respect to the U.S. market, and the U.S. tariffs against Chinese products). The patterns are similar to those for imports overall. We find no evidence of tariff anticipatory/delayed effects on Chinese export quantities, the key variation used in the estimation of export supply elasticity ω in (3.31). The cumulative responses in the Chinese export quantity mostly reflect its contemporaneous response in the month of tariff changes. On the other hand, there appear to be some irregular anticipatory effects in the before-duty unit value five months before tariff changes; however, instead of declining as theory would suggest, it increases. Overall, there are no significant adjustments in the before-duty unit value over the 12-month horizon. The duty-inclusive unit value, by construct, is equivalent to the before-duty unit value before the month of tariff changes and hence is subject to the same caveat discussed above. Other than that, its cumulative responses upon tariff changes are similar to the contemporaneous impact (in the month of tariff changes) and hence exhibit no delayed effects. Overall, the pattern in the response of the duty-inclusive unit value does not invalidate the use of contemporaneous variations in tariffs and duty-inclusive unit values for the estimation of foreign demand elasticity σ^* in (3.30). In view of the caveat observed above, one may choose to adopt a more cautious approach and use the counterpart estimate (2.53) of the U.S. import demand elasticity from the U.S. perspective reported in Fajgelbaum et al. (2020), in place of our estimate (1.012) of the foreign import demand elasticity from the Chinese perspective. This would imply even larger negative welfare effects on Chinese producers of exports (given larger declines in export quantities, and as a result, larger downward adjustment in producer prices in general equilibrium). Thus, we can consider the welfare effects we report below in Section 3.5 (based on our estimate) as plausibly conservative figures.

3.5 Welfare Analysis

We now present the general-equilibrium impacts of the trade war on the Chinese economy. Given the tariff shocks, the changes in the endogenous variables are imputed based on first-order approximations of the economic structure set up in Section 3.3 around the pre-war equilibrium in 2017. This choice of first-order approximations (instead of exact hat algebras) is largely driven by the high dimensionality of the current setup (as detailed below).

Specifically, denote $\hat{x} \equiv d \ln x$. The system can be written in terms of the change in each endogenous variable $\{\hat{w}_{sr}, \hat{w}_r^T, \hat{w}_r^{NT}, \hat{L}_r^T, \hat{p}_s, \hat{\phi}_s, \hat{P}_s, \hat{P}_{Ms}, \hat{p}_{Mg}, \hat{p}_{ig}, \hat{R}, \hat{E}_s, \hat{X}, \hat{Y}, \widehat{P_s I_s}, \widehat{p_s Q_s}, \hat{X}_r\}$, given shocks to Chinese and foreign tariffs, $\{d\tau_{ig}, d\tau_{ig}^*\}$, as a result of first-order approximations. The characterization of the system of equations is provided in Appendix C.2.1. The numerical implementation is carried out by solving the linear system (C.1)–(C.4), (C.7)–(C.11), (C.14), (C.18)–(C.23), and (C.24) in the reduced form of $\hat{x} = A^{-1}y$, where $\hat{x}$ is a column vector consisting of changes in the endogenous variables, y is a column vector with functions of the given tariff shocks, and A collects the parameters of the economic structure. These include: *i*) demand-side Cobb-Douglas allocation shares (β_s, β_{NT}) for 39 tradable sectors and 1 non-tradable sector, and CES demand elasticities $(\sigma,\ \eta,\ \kappa)$ across varieties, products and domestic/imported bundles; *ii*) supply-side Cobb-Douglas input shares $(\alpha_{Ls}, \alpha_{Is}, \alpha_s^{s'})$ of labor and intermediates; *iii*) distributions of sales and employment across sectors and 31 provinces; *iv*) imports and exports across varieties from and to 119 trading partners; and *v*) variety-level foreign demand (σ^*) and supply (ω^*) elasticities.

We use the 2017 Chinese input-output (IO) tables, China Labor Statistical Yearbook of 2017, and the Chinese customs data for 2017, as documented in Appendix C.1, to parameterize the allocation shares. For the elasticities, we adopt their estimates from Section 3.4, and set them to zero for statistically insignificant estimates (i.e., $\omega^* = 0$). The shocks to the Chinese and U.S. tariffs, $\{d\tau_{ig}, d\tau^*_{ig}\}$, are measured by the latest revised tariff change for each variety observed during the period 2018:1–2019:12. As a result, we match the model to 2017 data on Chinese economic activities for 31 provinces, 39 tradable sectors (at the level of GB/T-2 digit codes), 1 non-tradable sector, 119 trading partners, 5,362 imported HS-8 products, 122,482 imported varieties (unique product-country-origins), 5,432 exported products, and 374,213 unique product-export-destinations.[7] In sum, the vector $\hat{x}$ includes 663,248 endogenous variables, where 656,166 of them correspond to the variety prices $\hat{p}_{ig}$.[8] Further details about the implementation are provided in Appendix C.2.2.

3.5.1 Aggregate Effects

Given the tariff shocks to the pre-war equilibrium in 2017, and the changes in the endogenous variables calculated from the system described above, the welfare impact for each primary factor (capital and labor) can be measured as the change in income at initial prices (before the tariff war) that would have left that factor indifferent to the changes in tariffs that took place. Adding up the equivalent variations across all primary factors (capital and labor in each province) gives the aggregate equivalent variation EV, or change in aggregate real income. This term can be rewritten as the change in income due to the cost difference in attaining the initial utility level given the price changes (following Dixit and Norman, 1980):

$$EV = \underbrace{\sum_s \sum_{g \in \mathcal{G}_s} \sum_{i \in \mathcal{I}_g} x_{ig} \Delta p^X_{ig}}_{EV^X} - \underbrace{\sum_s \sum_{g \in \mathcal{G}_s} \sum_{i \in \mathcal{I}_g} m_{ig} \Delta p_{ig}}_{EV^M} + \Delta R, \tag{3.34}$$

where EV^X is the increase in the value of the pre-war export basket, EV^M is the drop in income due to increase in the duty-inclusive cost of the pre-war import basket, and ΔR is

[7]The count is based on observations with positive trade value before the trade war.

[8]The count is based on a balanced panel of country-by-product, considering all the trading partners and products observed before and after the war in imports (and exports, respectively).

the change in tariff revenue.

Table 3.9 reports the decomposition by EV^X, EV^M, and tariff revenue (ΔR) in Columns (1)–(3) and the aggregate impacts in Column (4). The top panel reports the effects from the 2018–2019 trade war. The bottom two panels study two alternative hypothetical scenarios, where China retaliated against the U.S. but did not implement MFN tariff cuts, and where China did not retaliate against the U.S. or implement MFN tariff cuts. Each panel reports the monetary equivalent on an annual basis at 2017 prices in billions of US dollars, and the numbers relative to 2017 GDP of China.

The first column shows a decrease of EV^X of \$32.968 billion (0.272% of China's GDP) due to the trade war. This aggregate number equals a model-implied 2.510% decrease in the export price index times a 10.821% observed share of exports of agricultural and industrial sectors in GDP. This implies that the diversion of demand away from China's products (due to higher U.S. tariffs against China and due to China's lower MFN tariffs on non-U.S. sources of imports) dominates potential reallocation toward Chinese products (in response to China's higher tariffs against U.S. products). The drop in the export price indices and the decrease of EV^X would have been less, at \$29.899 billion (0.246% of GDP) if China had not lowered its MFN tariffs on non-U.S. sources of imports during the trade war. On the other hand, the decrease in the export price index would have been more severe if China had not retaliated against the U.S. (and had not changed its MFN tariffs accordingly). This scenario corresponds to a decrease of EV^X of \$37.254 billion (0.307% of GDP).

The next column shows that Chinese buyers of imports sustained an aggregate loss of \$6.906 billion (0.057% of GDP) because of the trade war. The loss would have been larger at \$11.002 billion (0.091% of GDP) if the Chinese government had not lowered MFN tariffs on non-U.S. sources of imports when it increased tariffs against U.S. products. The loss of buyers of imports, on the other hand, would have been negligible and statistically insignificant at \$0.000 billion (0.000% of GDP) if China had not counter-responded to the U.S. tariff hike. This is consistent with a horizontal foreign supply elasticity ω^*, so import price changes that consumers face reflect mainly import tariff changes, which in the last scenario are nil.

The final component of the decomposition implies an increase in tariff revenue of \$1.976 billion (0.016% of GDP). The tariff revenue increase would have approximately tripled at \$5.728 (0.047% of GDP)—with the increase in tariffs against the U.S.—if China had not also lowered MFN tariffs. In the third scenario, without counter-retaliation by China, the tariff revenue is shown to decrease, reflecting a decrease in import volume due to general equilibrium effects of U.S. tariffs on the Chinese economy.

In sum, these numbers imply large negative consequences of the trade war on both Chinese producers and consumers, dominating the positive tariff revenue increase. The loss of the producers (exporters) is more than four times the loss of the buyers of imports. Column (4) suggests an aggregate loss of \$37.898 billion, or 0.312% of China's GDP, as a result of the trade war. Without the counter-retaliation, the loss would have been much larger, at \$38.921 billion (0.321% of GDP), and mostly borne by producers (exporters). The retaliation against the U.S. imports shifted the burden to the Chinese buyers of imports (as seen in the transition from the third to the second scenario). With further adjustment in the MFN tariff rates on non-U.S. sources of imports, this lessened the loss of Chinese buyers of imports and shifted part of the burden back to the producers. Overall, the aggregate loss in EV is significant statistically, except in the second scenario.

3.5.2 Regional Effects

We now report the distributional impacts of the trade war across Chinese provinces, from workers' versus all primary factors' perspectives. Chinese import tariffs could negatively affect primary factor owners as consumers of imports. They could also lower the nominal return to primary factors, as the costs of intermediate inputs increase with the import tariffs. The costs of intermediate inputs could increase more in provinces whose production is more concentrated in sectors that use proportionally more inputs targeted by Chinese tariff increases. Simultaneously, the nominal return to primary factors could be negatively affected to larger extents in regions whose production is more concentrated in sectors targeted by the U.S. tariffs (through changes in the producer and export prices), less protected by China's retaliatory tariffs against the U.S., or subject to China's MFN tariff reductions.

Figure 3.3 illustrates the variation in exposure to the trade war across provinces in China: (A) due to China's tariff increases on U.S. products; (B) due to China's MFN tariff cuts; (C) due to the combination of the first two; and (D) due to the U.S. tariff increases on Chinese products. We construct the province-level exposure to tariff shocks by: *i*) computing the trade-weighted tariff changes of each GB/T-2 sector across varieties within the sector, using the 2017 trade shares; and *ii*) computing the wage-bill-weighted tariff changes for each province given the province's employment structure across sectors.[9]

Figure 3.3 suggests that China tended to: (A) retaliate against the U.S. in sectors with a relatively high concentration in the outlying provinces such as Xinjiang, Hainan, and Heilongjiang; and (B) reduce MFN tariffs on sectors concentrated in provinces closer to the coast such as Shanghai and Beijing. Overall, China's tariff increases tended to be biased toward inland provinces and turn negative in the Eastern provinces. Added to the burden, Panel (D) suggests that these provinces also faced higher tariff increases on their exports to the U.S.

Figure 3.4 shows the effects of the trade war on real wages across provinces. The first map (A) shows the province-level reduction in real wages in tradable sectors due to the trade war, and the second map (B) shows real wage losses in the hypothetical scenario where China had not reduced MFN tariffs. Every province experienced a reduction in the tradable real wage. Provinces with larger relative losses are concentrated in the Southeast, whose employment structures were hit more strongly by the U.S. tariff increase. Map (B) suggests that the real wage losses would have been one level higher without the MFN tariff cuts by China.

[9]The exposure of region r to the Chinese import tariff changes is $\Delta\tau_r = \sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_{Tr}L_r^T}\right)\frac{\sum_{g\in G_s}\sum_{i\in\mathcal{I}_g}p_{ig}^*m_{ig}\Delta\tau_{ig}}{\sum_{g'\in G_s}\sum_{i'\in\mathcal{I}_{g'}}p_{i'g'}^*m_{i'g'}}$, and the exposure to the U.S. tariff changes is $\Delta\tau_r^* = \sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_{Tr}L_r^T}\right)\frac{\sum_{g\in G_s}\sum_{i\in\mathcal{I}_g}p_{ig}^Xx_{ig}\Delta\tau_{ig}^*}{\sum_{g'\in G_s}\sum_{i'\in\mathcal{I}_{g'}}p_{i'g'}^Xx_{i'g'}}$, where $w_r^TL_r^T$ are total tradable wages in province r.

This contrasts with the finding in Table 3.9, where the MFN tariff cuts by China worsened the aggregate loss. This implies that the MFN tariff cuts helped cushion the impacts on workers/consumers via lower import prices, at the cost of producers (and the owners of capital and fixed structures), who faced steeper competition in the product market.

Overall, on average across provinces, the nominal wages for workers in tradable sectors decreased by 3.19% (std. dev. = 0.08%). These income losses were, however, cushioned by a reduced cost of living, as the CPI of tradable goods decreased by 2.34% on average across sectors, reflecting an average 0.53% increase in import prices and 2.69% decrease in prices of domestic goods. As a result, real wages in the tradable sector fell by 0.32% (std. dev. = 0.04%).

Figure 3.5 sums up the total real expenditures of both capital owners and workers (i.e., profits and wage incomes in addition to tariff revenue transfer) for each province, and reports their simulated responses to the tariff war, with and without the MFN tariff cuts. The impacts of the full trade war are similar in percentage terms of real wages or real expenditures, as seen in Panel (A) of Figures 3.4 and 3.5. However, the large contrast between Panel (B) of Figure 3.4 and that of Figure 3.5 echoes the re-distributional effects of MFN tariff cuts from the producers of exports (EV^X) to the buyers of imports (EV^M), as highlighted in Section 3.5.1. The losses in real expenditures across provinces are mitigated while the losses in real wages are aggravated, without the MFN tariff cuts. Thus, the MFN tariff cuts in a way are used by the Chinese government to redistribute real incomes from capital owners to workers, at a greater cost to the aggregate welfare.

3.5.3 Trade Diversion Effects

In this section, we report the model-implied trade diversion effects of the trade war. Formulas are provided in Appendix C.2.3. Table 3.10 summarizes the diversion of Chinese imports and exports due to the trade war. As China increased tariffs on U.S. products and decreased MFN tariffs against the other trading partners, Chinese imports were diverted from U.S.

toward non-U.S. sources. The share of imports from the U.S. dropped from 9.15% to 8.21%. Chinese imports were mainly diverted toward countries in Europe and Asia, and in particular, Germany and Japan. Although China reduced imports from all sources due to general-equilibrium effects, the drop was proportionally less with respect to countries in Europe.

On the other hand, facing the U.S. tariff increase, China diverted its exports toward other markets. The share of exports to the U.S. declined from 19.16% to 16.16%. Meanwhile, its exports to destinations other than the U.S. generally increased by around 0.03%. Thus, as a result of the trade war, China tilted its sources of inputs toward countries in Europe and Asia (19.19% to 19.54%; 52.48% to 52.93%), and also relied more on countries in Europe and Asia as its markets (18.89% to 19.59%; 48.68% to 50.48%).

3.6 Conclusion

The U.S.-China tariff war escalated in a short span of 24 months during 2018:1–2019:12 before the Phase One Deal was reached in 2019:12. This paper provides an ex post analysis of the micro and macro responses of the Chinese economy to the tariff shocks of that period. This complements the studies by Amiti et al. (2019), Flaaen et al. (2020), Fajgelbaum et al. (2020), and Cavallo et al. (2021) for the U.S. economy.

In the first step, we use monthly variations during 2018:1–2019:12 in Chinese imports and exports of HS-8 digit products by source and destination countries to identify the elasticities of the Chinese economy's import demand and export supply at the product-country (i.e., variety) level. The identification relies on monthly variations in tariff rates that are uncorrelated with the unobserved demand and supply shocks of the corresponding variety. The tariff shocks associated with the tariff war are taken as the ideal instrument given its unprecedented and uncertain nature. The validity of the instrument was verified with pre-trend and dynamic tests. The resulting elasticity estimates provide a first view of the direct effects of the tariff war on Chinese imports and exports at the variety level.

In the second step, the estimated demand structure is embedded in a general equilibrium model with a supply-side structure calibrated to the Chinese economy. In particular, goods markets (for final demand and intermediate use) are integrated across Chinese provinces but primary inputs (labor and fixed structures) are confined to their current sector-province of employment in the short run. The effects of the tariff shocks on the demand for Chinese and foreign varieties aggregate up via the 3-tier demand system in China, and influence the Chinese producer prices across sectors and the real wages across sector-provinces. The exposure of a sector-province to the tariff war depends on a sector's exposure to the tariff shocks and a province's production structure across sectors.

The tariff war imposed a large welfare loss on Chinese producers/exporters (US$ 32.968 billion) and on buyers of imports (US$ 6.906 billion), with a net loss of aggregate welfare (US$ 37.898 billion) after taking into account the higher tariff revenue. The Chinese initiative to lower MFN tariffs as it raised tariffs against the U.S. products led to larger aggregate welfare losses at the cost of producers, but appeared to be an effective redistributive policy to cushion the impacts on consumers/workers. The loss of consumers/buyers of imports would have been higher (US$ 11.002 billion) and the average real wage in tradable sectors would have dropped by more (0.38% vs. 0.32%) if not for the MFN tariff cuts. The analysis also indicates that the provinces that are closer to the coast were hit harder (in terms of real wages in tradable sectors or real expenditures) by the tariff war. This occurred not only because these provinces were proportionally more specialized in products targeted by the U.S. tariff hike, but also because the Chinese government tended to lower MFN tariffs on products produced by these provinces. Finally, due to the tariff war, the Chinese economy reduced its share of imports from the U.S. (from 9.15% to 8.21%). At the same time, the share of its exports to the U.S. market dropped from 19.16% to 16.16%. Trade tended to be diverted toward countries in Europe and Asia (as sources of imports and as markets for exports).

Some comments are in order. First, similarly to Fajgelbaum et al. (2020), our estimates suggest horizontal foreign export supply and Chinese export supply curves at the variety level. Hence, the incidence of import tariffs is borne entirely by the importing country at the variety level (although foreign tariffs on Chinese exports can still affect Chinese producer/export prices through general equilibrium adjustments in the Chinese economy). This implies less policy room for China to retaliate for terms-of-trade gains, and might help explain the moderate increase in Chinese tariff rates for a majority of products included in its targeted list, and its move to lower MFN tariffs. Second, a potential caveat to the above finding is the nature of estimation specification, where sector-time fixed effects are controlled for. This is likely to reduce the magnitude of elasticity estimates, if the sector-time fixed effects used to control for unobservables also absorb a significant source of variations in variety-level imports/exports. Third, the general equilibrium structure used has a high resolution with respect to modeling of product/labor markets for the local economy and their supply response. The setup, however, has a very simple structure for the rest of the world (with only supply and demand responses specified at the variety level), and cannot accommodate general equilibrium adjustments in foreign countries or across countries. For example, it cannot address the repercussion of the trade war on the regional or global value chain in which China plays a critical role. Fourth, the model used is static in nature, and thus cannot address potential impacts in the long run due to factor reallocations across regions within the country. We leave these generalizations to future research.

Table 3.1: Trade War Events during 2018–2019

Event	Effective Date	Products	Trade Value in 2017		Tariff (%)	
		(# HS-8)	(million US$)	(%)	before	after
Panel A. Tariff increase on Chinese products enacted by U.S.						
1	February 7, 2018	12	983	0.04	1.11	31.11
2	March 27, 2018	248	2,868	0.13	7.17	22.99
3	July 6, 2018	957	59,890	2.63	1.38	26.91
4	August 23, 2018	345	19,810	0.87	15.39	34.60
5	September 24, 2018	3829	189,400	8.32	7.56	14.96
6	May 10, 2019	—"—	—"—	–"–	14.96	29.99
7	September 1, 2019	1859	131,400	5.77	12.59	22.60
Panel B1. China's retaliatory tariffs on U.S. products						
1	April 2, 2018	93	2,970	0.17	11.15	27.75
2	July 6, 2018	267	33,830	1.98	12.81	35.56
3	August 23, 2018	201	14,110	0.83	14.16	32.82
4	September 24, 2018	5190	58,160	3.41	9.91	16.43
5	January 1, 2019	120	14,250	0.83	24.39	13.53
6	June 1, 2019	4545	40,220	2.35	10.3	17.13
7	September 1, 2019	1153	28,670	1.68	9.63	18.47
Panel B2. China's MFN tariff cuts						
8	May 1, 2018	26	13,710	0.8	2.12	0
9	July 1, 2018	151	59,590	3.49	11.03	7.01
10	July 1, 2018	1376	36,030	2.11	13.69	7.01
11	November 1, 2018	1532	59,610	3.49	9.57	7.95

Note: The table reports tariff events implemented by the U.S. (Panel A) and China (Panel B), which are used as sources of identification in the estimations of demand and supply elasticities in Section 3.4. In addition to the retaliation against U.S. products (Panel B1), China also implemented MFN tariff cuts in response (Panel B2). The columns display: the number of HS-8 products affected; the value of trade affected (in million US$); the corresponding shares (%) in 2017; and the simple monthly average tariff rates (in percentage points) across targeted products in the month before and the month after the implementation month (which is taken to be the current month if the implementation date is before the 15th of the month and the next month otherwise). The denominator of trade share is the 2017 annual US$ value of total Chinese exports (imports) in Panel A (Panel B), respectively. See the text for data sources. In Panel A, Event 6 applies to the same set of products as Event 5 but with an upward revision of the tariff rates.

Table 3.2: Sector-Level Tariff Variations

		Imports (Chinese tariffs)				Exports (U.S. tariffs)			
				Δ Tariffs				Δ Tariffs	
Sector (1)	GB/T-2 (2)	# Products (3)	# Varieties (4)	Mean (5)	Std. dev. (6)	# Products (7)	# Varieties (8)	Mean (9)	Std. dev. (10)
Agricultural Products	1-5	77	121	0.15	0.10	94	94	0.24	0.11
Mining	6-12	126	410	0.09	0.13	71	71	0.21	0.07
Processing of Food from Agricultural Products	13	448	1687	0.07	0.21	371	371	0.21	0.09
Manufacture of Foods	14	174	1564	-0.01	0.15	143	143	0.22	0.09
Manufacture of Liquor, Beverages	15	75	790	-0.03	0.19	74	74	0.13	0.08
Manufacture of Tobacco	16	8	43	0.10	0.14	6	6	0.19	0.13
Manufacture of Textiles	17	740	13225	-0.02	0.11	777	777	0.20	0.08
Manufacture of Wearing Apparel and Accessories	18	160	5334	-0.06	0.10	158	158	0.12	0.06
Manufacture of Leather Products and Footwear	19	138	3320	-0.04	0.10	139	139	0.16	0.09
Manufacture of Wood Products	20	126	788	0.04	0.12	128	128	0.21	0.09
Manufacture of Furniture	21	31	234	0.08	0.13	34	34	0.25	0.04
Manufacture of Paper and Paper Products	22	121	2412	0.03	0.09	120	120	0.24	0.05
Printing and Reproduction of Recording Media	23	35	796	0.03	0.09	36	36	0.13	0.06
Manufacture of Articles for Culture Activities	24	210	4146	-0.05	0.12	195	195	0.15	0.08
Processing of Petroleum, Coking	25	41	114	0.17	0.12	27	27	0.23	0.05
Manufacture of Raw Chemical Materials	26	903	4254	0.08	0.11	876	876	0.23	0.08
Manufacture of Medicines	27	151	458	0.07	0.11	55	55	0.24	0.07
Manufacture of Chemical Fibers	28	54	54	0.17	0.08	64	64	0.20	0.09
Manufacture of Rubber and Plastics Products	29	154	1329	0.06	0.11	156	156	0.24	0.06
Manufacture of Non-metallic Mineral Products	30	232	3212	0.02	0.11	240	240	0.23	0.06
Smelting and Pressing of Ferrous Metals	31	223	1053	0.13	0.13	239	239	0.31	0.07
Smelting and Pressing of Non-ferrous Metals	32	177	400	0.15	0.09	130	130	0.22	0.06
Manufacture of Metal Products	33	299	4844	0.02	0.12	293	293	0.23	0.07
Manufacture of General Purpose Machinery	34	470	4232	0.07	0.11	509	509	0.27	0.11
Manufacture of Special Purpose Machinery	35	406	2123	0.08	0.12	454	454	0.24	0.12
Manufacture of Automobiles	36	180	2624	-0.03	0.09	160	160	0.23	0.09
Manufacture of Transport Equipment	37	64	440	0.06	0.14	101	101	0.24	0.10
Manufacture of Electrical Machinery	38	302	4057	0.00	0.13	276	276	0.29	0.12
Manufacture of Computers / Electronic Equipment	39	228	656	0.06	0.15	227	227	0.26	0.16
Manufacture of Measuring Instruments/Machinery	40	176	1012	0.04	0.11	205	205	0.28	0.15
Other Manufactures	41	57	1229	-0.04	0.12	40	40	0.14	0.07
Utilization of Waste Resources	42	26	55	0.23	0.10	30	30	0.19	0.08

Note: The table shows the mean and standard deviation of tariff changes for Chinese imports and exports across 2-digit GB/T sectors. A tariff change of 0.10 indicates a 10 percentage point increase. For imports, China implemented both retaliatory tariff increases against the U.S., and MFN tariff cuts on sources of imports where MFN rates apply. Sectors with the same number of targeted varieties and products in Columns (3) and (4) reflect import tariff increase targeting U.S. products without accompanying decrease in MFN tariffs. For Chinese exports, which faced only U.S. tariff increases, the number of products targeted by trading partners is equal to that of varieties targeted. Due to space constraints, we aggregate sectors of Agricultural products and of Mining.

Table 3.3: Estimation of Variety-level Elasticities—Import Demand (σ) and Foreign Export Supply (ω^*)

	$\Delta \ln p^*_{igt} m_{igt}$ (1)	$\Delta \ln m_{igt}$ (2)	$\Delta \ln p^*_{igt}$ (3)	$\Delta \ln p_{igt}$ (4)	$\Delta \ln p^*_{igt}$ (5)	$\Delta \ln m_{igt}$ (6)
$\Delta \ln(1+\tau_{igt})$	-1.133***	-1.121***	0.009	1.004***		
	(0.2940)	(0.2214)	(0.1740)	(0.1770)		
$\Delta \ln m_{igt}$					-0.008	
					(0.1549)	
$\Delta \ln p_{igt}$						-1.120***
						(0.3158)
Country $\times$ Product FE	Y	Y	Y	Y	Y	Y
Sector $\times$ Time FE	Y	Y	Y	Y	Y	Y
1st-stage F					40.179	81.805
Bootstrap CI					[-0.146,0.204]	[0.853,1.432]
R^2	0.038	0.027	0.035	0.027	0.012	0.192
N	2,207,210	2,129,628	2,129,660	2,129,138	2,129,628	2,129,138

Note: The table reports the variety-level import responses to import tariffs. Columns (1) to (4) report the reduced-form regression of different trade outcomes (before-duty import value, import quantity, before-duty unit value and duty-inclusive unit value) on the tariff changes. Column (5) reports the IV regression estimation of foreign (inverse) export supply elasticity $\hat{\omega}^*$ based on equation (3.23), with its first-stage estimation in Column (2). Column (6) reports the IV regression estimation of import demand elasticity $\hat{\sigma}$ based on equation (3.22), with its first-stage estimation in Column (4). Robust standard errors (in parentheses) are clustered at the product and country level. 90% bootstrap confidence intervals of ($\hat{\omega}^*$ and $\hat{\sigma}$) were constructed from 1000 samples. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Sample: monthly variety-level import data from 2017:1 to 2019:12.

Table 3.4: Estimation of Product-level Elasticity

	$\Delta \ln s_{Mgt}$ (1)	$\Delta \ln p_{Mgt}$ (2)	$\Delta \ln s_{Mgt}$ (3)
$\Delta \ln Z_{Mgt}$	-1.537**	17.639***	
	(0.6271)	(6.2563)	
$\Delta \ln p_{Mgt}$			-0.087***
			(0.0230)
Sector $\times$ Time FE	Y	Y	Y
1st-stage F			19.187
$\hat{\eta}$ (se[$\hat{\eta}$])			1.087 (0.0230)
Bootstrap CI			[1.041,1.131]
R^2	0.015	0.010	0.351
N	226,372	226,372	226,372

Note: The table reports product-level import responses to import tariffs. Column (1) reports the reduced-form regression of each imported product's share within sectoral imports, s_{Mgt}, on the product-level instrument, Z_{Mgt}. Column (2) reports the regression of the product-level import price index p_{Mgt} on Z_{Mgt}. Column (3) reports the IV estimation of product-level elasticity based on equation (3.24), with its first-stage estimation in Column (2). The product-level import price index is constructed using $\hat{\sigma}$ from Column (6) of Table 3.3 according to equation (3.25), and the instrument is constructed using equation (3.26). Robust standard errors (in parentheses) are clustered at the product level. 90% bootstrap confidence intervals of $\hat{\eta}$ were constructed from 1000 samples. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Sample: monthly product-level import data from 2017:1 to 2019:12.

Table 3.5: Estimation of Sector-level Elasticity

	$\Delta \ln \frac{P_{Mst} M_{st}}{P_{Dst} D_{st}}$ (1)	$\Delta \ln \frac{P_{Mst}}{p_{st}}$ (2)	$\Delta \ln \frac{P_{Mst} M_{st}}{P_{Dst} D_{st}}$ (3)
$\Delta \ln Z_{Mst}$	-15.055	86.888	
	(9.7353)	(201.2985)	
$\Delta \frac{P_{Mst}}{p_{st}}$			-0.173
			(0.3208)
Sector FE	Y	Y	Y
Time FE	Y	Y	Y
1st-stage F			0.546
$\hat{\kappa}(se[\hat{\kappa}])$			1.173 (0.3208)
Bootstrap CI			[0.541,1.385]
R^2	0.194	0.232	-
N	850	850	850

Note: The table reports sector-level import responses to import tariffs. Column (1) reports the reduced-form regression of the ratio of the expenditure on foreign goods and domestic goods, $\frac{P_{Mst} M_{st}}{P_{Dst} D_{st}}$, on the sector-level instrument, Z_{Mst}. Column (2) reports the regression of the ratio of sector-level import price index and domestic price index $\frac{P_{Mst}}{p_{st}}$ on Z_{Mst}. Column (3) reports the IV estimation of sector-level elasticity based on equation (3.27), with its first-stage estimation in Column (2). The sector import price index is constructed using $\hat{\sigma}$ from Column (6) of Table 3.3, and $\hat{\eta}$ from Column (3) of Table 3.4, according to equation (3.28), and the instrument is constructed using equation (3.29). Robust standard errors (in parentheses) are clustered at the sector level. 90% bootstrap confidence intervals of $\hat{\kappa}$ were constructed from 1000 samples. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Sample: monthly sector-level data from 2017:1 to 2019:12.

Table 3.6: Estimation of Variety-level Elasticities—Foreign Import Demand (σ^*) and Chinese Export Supply (ω)

	$\Delta \ln p^X_{igt} x_{igt}$ (1)	$\Delta \ln x_{igt}$ (2)	$\Delta \ln p^X_{igt}$ (3)	$\Delta \ln p^X_{igt}(1+\tau^*_{igt})$ (4)	$\Delta \ln p^X_{igt}$ (5)	$\Delta \ln x_{igt}$ (6)
$\Delta \ln(1+\tau^*_{igt})$	-1.064***	-1.072***	0.059	1.059***		
	(0.1920)	(0.1901)	(0.1495)	(0.1495)		
$\Delta \ln x_{igt}$					-0.055	
					(0.1358)	
$\Delta \ln p^X_{igt}(1+\tau^*_{igt})$						-1.012***
						(0.1786)
Product FE	Y	Y	Y	Y	Y	Y
Sector $\times$ Time FE	Y	Y	Y	Y	Y	Y
1st-stage F					24.120	58.295
Bootstrap CI					[-0.270,0.260]	[0.161,1.302]
R^2	0.058	0.055	0.028	0.028	0.070	0.165
N	162,054	161,494	161,494	161,494	161,494	161,494

Note: The table reports the variety-level export responses to U.S. import tariffs. Columns (1)–(4) report reduced-form regressions of different export outcomes (export values, quantities, before-duty unit values, and duty-inclusive unit values) on the tariff changes. Column (5) reports the IV estimation of Chinese (inverse) export supply elasticity $\hat{\omega}$ based on equation (3.31), with its first-stage estimation in Column (2). Column (6) reports the IV estimation of foreign import demand elasticity $\hat{\sigma}^*$ based on equation (3.30), with its first-stage estimation in Column (4). Robust standard errors (in parentheses) are clustered at the HS-6 level. 90% bootstrap confidence intervals of ($\hat{\omega}$ and $\hat{\sigma}^*$) were constructed from 1000 samples. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Sample: monthly variety-level export data from 2017:1 to 2019:12.

Table 3.7: Effects of Tariff Wars on China's Imports and Exports (Partial Effects)

	China's tariff increase against U.S. products		MFN tariff cuts		Combined	
IMPORT	Δ tariff	Δ import values	Δ tariff	Δ import values	Δ tariff	Δ import values
Varieties	11.72%	−13.14%	−3.10%	3.48%	3.25%	−3.64%
	U.S. tariff increase against Chinese products					
EXPORT	Δ tariff	Δ export values				
Varieties	24.18%	−24.48%				

Note: The table reports the weighted average change in the tariff rates of targeted varieties, and the implied change in the trade values of the targeted varieties. The formulas used are: i) $\overline{\Delta \ln \left(p^*_{ig} m_{ig}\right)}^{wa} \equiv \sum_{ig} -\hat{\sigma}\frac{1+\hat{\omega}^*}{1+\hat{\omega}^*\hat{\sigma}} \Delta \ln (1+\tau_{ig}) \cdot \left(p^*_{ig} m_{ig}\right) / \sum_{ig} \left(p^*_{ig} m_{ig}\right) \equiv -\hat{\sigma}\frac{1+\hat{\omega}^*}{1+\hat{\omega}^*\hat{\sigma}} \overline{\Delta \ln (1+\tau_{ig})}^{wa}$ for imports, where the response ratio $-\hat{\sigma}\frac{1+\hat{\omega}^*}{1+\hat{\omega}^*\hat{\sigma}}$ is implied by the demand and supply equations (3.22) and (3.23); and ii) $\overline{\Delta \ln \left(p^X_{ig} x_{ig}\right)}^{wa} \equiv \sum_{ig} -\hat{\sigma}^*\frac{1+\hat{\omega}}{1+\hat{\omega}\hat{\sigma}^*} \Delta \ln \left(1+\tau^*_{ig}\right) \cdot \left(p^X_{ig} x_{ig}\right) / \sum_{ig} \left(p^X_{ig} x_{ig}\right) \equiv -\hat{\sigma}^*\frac{1+\hat{\omega}}{1+\hat{\omega}\hat{\sigma}^*} \overline{\Delta \ln \left(1+\tau^*_{ig}\right)}^{wa}$ for exports, where the response ratio $-\hat{\sigma}^*\frac{1+\hat{\omega}}{1+\hat{\omega}\hat{\sigma}^*}$ is implied by the demand and supply equations (3.30) and (3.31). The calculations use the elasticity estimates reported in Tables 3.3 and 3.6, the pre-war duty-exclusive trade value of 2017 (as weights), and the latest revised tariff change for each variety observed during the period 2018:1–2019:12 (as the shock).

Table 3.8: Pre-trend Tests for Chinese Imports and Exports

Panel A1: China's retaliatory tariffs on U.S. products				
	$\overline{\Delta \ln p^*_{ig} m_{ig}}$ (1)	$\overline{\Delta \ln m_{ig}}$ (2)	$\overline{\Delta \ln p^*_{ig}}$ (3)	$\overline{\Delta \ln p_{ig}}$ (4)
$\Delta \ln(1+\tau_{ig})$	0.052	0.070	-0.029	-0.028
	(0.1870)	(0.2249)	(0.1452)	(0.1452)
Sector FE	Y	Y	Y	Y
R^2	0.012	0.020	0.014	0.014
N	5,064	4,951	4,951	4,950

Panel A2: China's MFN tariff cuts				
	$\overline{\Delta \ln p^*_{ig} m_{ig}}$ (1)	$\overline{\Delta \ln m_{ig}}$ (2)	$\overline{\Delta \ln p^*_{ig}}$ (3)	$\overline{\Delta \ln p_{ig}}$ (4)
$\Delta \ln(1+\tau_{ig})$	0.720	0.803	0.115	0.115
	(0.6089)	(0.6978)	(0.4236)	(0.4237)
Country × Sector FE	Y	Y	Y	Y
Product FE	Y	Y	Y	Y
R^2	0.144	0.144	0.132	0.132
N	66,886	64,844	64,844	64,820

Panel B: U.S. tariff increases on Chinese exports				
	$\overline{\Delta \ln p^X_{ig} x_{ig}}$ (5)	$\overline{\Delta \ln x_{ig}}$ (6)	$\overline{\Delta \ln p^X_{ig}}$ (7)	$\overline{\Delta \ln p^X_{ig}(1+\tau^*_{ig})}$ (8)
$\Delta \ln(1+\tau^*_{ig})$	0.037	0.073	-0.002	0.003
	(0.1204)	(0.1118)	(0.0801)	(0.0771)
Sector FE	Y	Y	Y	Y
R^2	0.007	0.012	0.005	0.005
N	5,483	5,473	5,473	5,445

Note: The table reports pre-trend tests for Chinese imports (Panels A1 and A2) and exports (Panel B) at the variety level. The dependent variables are the average monthly change of trade outcome variables during 2017:1–2017:12 in terms of before-duty trade value, quantity, before-duty unit value and duty-inclusive unit value. Panels A1 and B regress the pre-war trade outcomes of Chinese imports from (exports to) the U.S. on the (latest revised) tariff changes during the trade war period 2018:1–2019:12. Panel A2 regresses the trade outcomes of Chinese imports from non-U.S. sources on China's tariff changes on non-U.S. sources of imports during the trade war. Robust standard errors (in parentheses) are clustered at the product level (Panels A1 and B), and product and country level (Panel A2), respectively. The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Sample: monthly variety-level import and export data from 2017:1–2017:12 for the pre-trend variables, and 2018:1–2019:12 for the tariff changes.

Table 3.9: Aggregate Impacts

	EV^X (1)	EV^M (2)	ΔR (3)	EV (4)
2018–2019 trade war				
change ($ b)	-32.968	-6.906	1.976	-37.898
	[-45.159, 0.786]	[-15.524, 0.874]	[1.360, 3.708]	[-52.282, -3.153]
change (% GDP)	-0.272	-0.057	0.016	-0.312
	[-0.372,0.006]	[-0.128, 0.007]	[0.011,0.031]	[-0.431, -0.026]
2018–2019 trade war (w/o China's MFN tariff cuts)				
change ($ b)	-29.899	-11.002	5.728	-35.173
	[-41.841, 8.955]	[-19.590, -3.472]	[5.149, 7.977]	[-49.934, 6.157]
change (% GDP)	-0.246	-0.091	0.047	-0.290
	[-0.345, 0.074]	[-0.161, -0.029]	[0.042, 0.066]	[-0.411, 0.051]
2018–2019 trade war (w/o retaliation by China)				
change ($ b)	-37.254	0.000	-1.667	-38.921
	[-49.834, -12.266]	[-8.296, 7.719]	[-1.756, -0.755]	[-53.614, -13.211]
change (% GDP)	-0.307	0.000	-0.014	-0.321
	[-0.410, -0.101]	[-0.068, 0.064]	[-0.014, -0.006]	[-0.442, -0.109]

Note: The table reports the aggregate impact in Column (4) and its decomposition into EV^X, EV^M, and tariff revenue (ΔR) in Columns (1)–(3). The top panel reports the effects from the 2018–2019 trade war. The bottom two panels simulate hypothetical scenarios, where China retaliated against the U.S. but did not implement MFN tariff cuts, and where China neither retaliated against the U.S. nor implemented MFN tariff cuts. The first row in each panel reports the overall impact of each term in billions of US$. The third row scales the value by 2017 GDP of China. These numbers are computed using the model described in Section 3.3 and Appendix C.2, with $\{\hat{\sigma} = 1.120, \hat{\eta} = 1.087, \hat{\kappa} = 1.173, \hat{\omega}^* = \mathbf{0}, \hat{\sigma}^* = 1.012\}$. Bootstrapped 90% confidence intervals based on 1,000 simulations of the estimated parameters are reported in brackets.

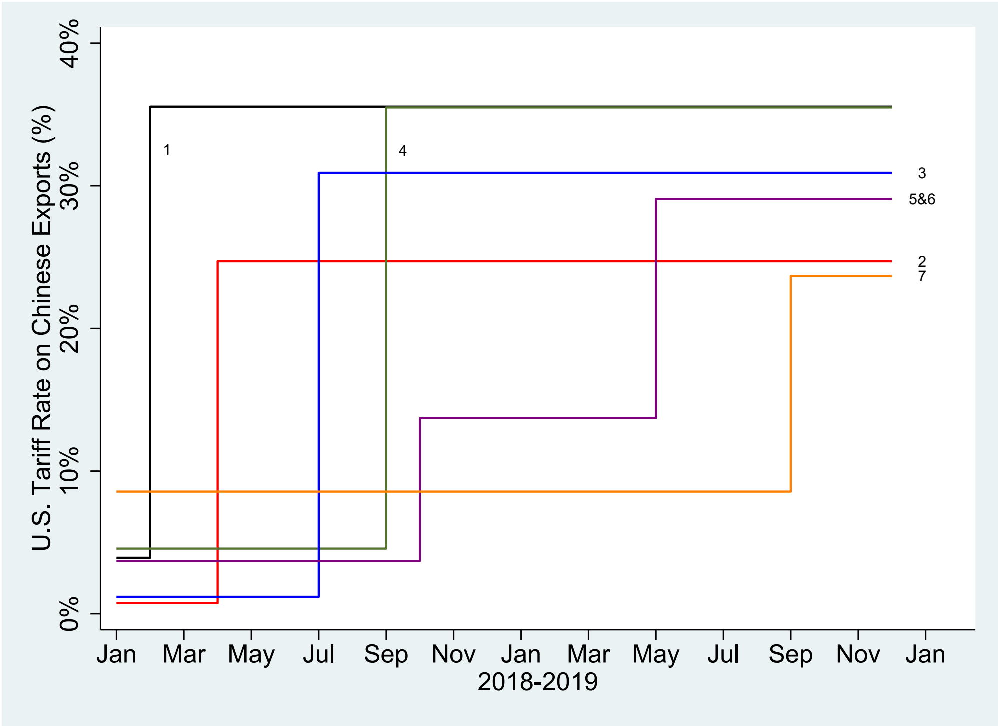
Table 3.10: Simulated Trade Diversion Impacts of the Trade War 2018–2019

	Δ trade volume (1)	Trade share w/o war (2)	Trade share with war (3)
Panel A. Imports			
U.S.	-13.97%	9.15%	8.21%
R.O.W.	-3.21%	90.85%	91.79%
North America	-12.11%	11.06%	10.14%
Canada	-3.36%	1.21%	1.22%
Mexico	-2.90%	0.70%	0.71%
Asia	-3.37%	52.48%	52.93%
Japan	-2.73%	9.80%	9.95%
Korea	-3.53%	10.58%	10.65%
Taiwan	-3.54%	9.26%	9.33%
ASEAN	-3.52%	12.61%	12.70%
Europe	-2.45%	19.19%	19.54%
France	-2.94%	1.61%	1.63%
Germany	-1.83%	5.74%	5.88%
The UK	-0.43%	1.30%	1.35%
Panel B. Exports			
U.S.	-18.64%	19.16%	16.16%
R.O.W.	0.03%	80.84%	83.84%
North America	-15.95%	22.15%	19.30%
Canada	0.03%	1.41%	1.46%
Mexico	0.03%	1.60%	1.66%
Asia	0.02%	48.68%	50.48%
Japan	0.03%	6.07%	6.30%
Korea	0.03%	4.56%	4.72%
Taiwan	0.00%	1.94 %	2.01%
ASEAN	0.02%	13.89%	14.40%
Europe	0.03%	18.89%	19.59%
France	0.03%	1.23%	1.27%
Germany	0.03%	3.15%	3.27%
The UK	0.03%	2.54%	2.63%

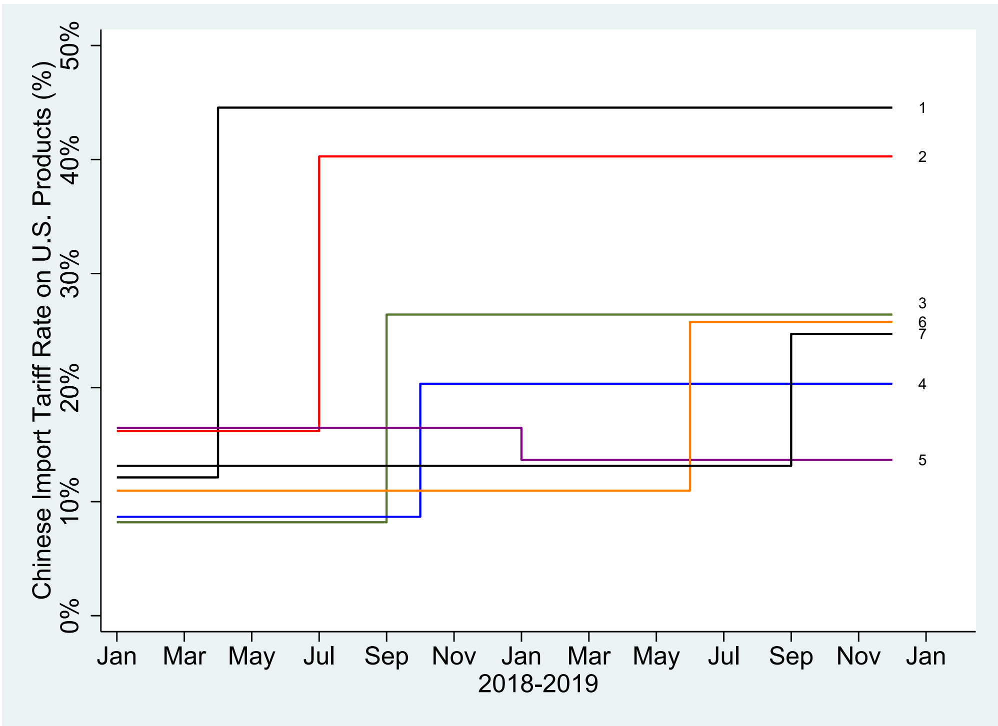
Note: The table reports the simulated changes in China's imports from and exports to its trading partners due to the trade war, using the 2017 Chinese economy given the tariff changes of 2018:1–2019:12. Section C.2.3 provides the formulas. Columns (2) and (3) report the trade shares by regions/countries without the trade war and as a result of the trade war.

Figure 3.1: Trade War Timeline

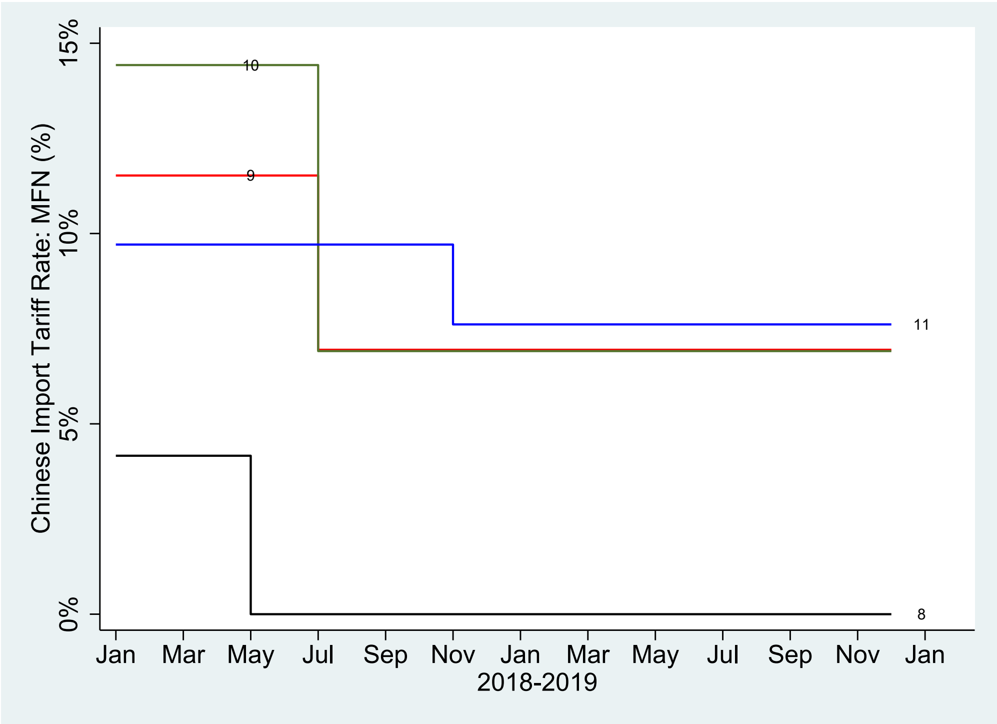
(A) U.S. tariffs on Chinese exports



(B1) Chinese retaliatory tariffs (on imports from U.S.)



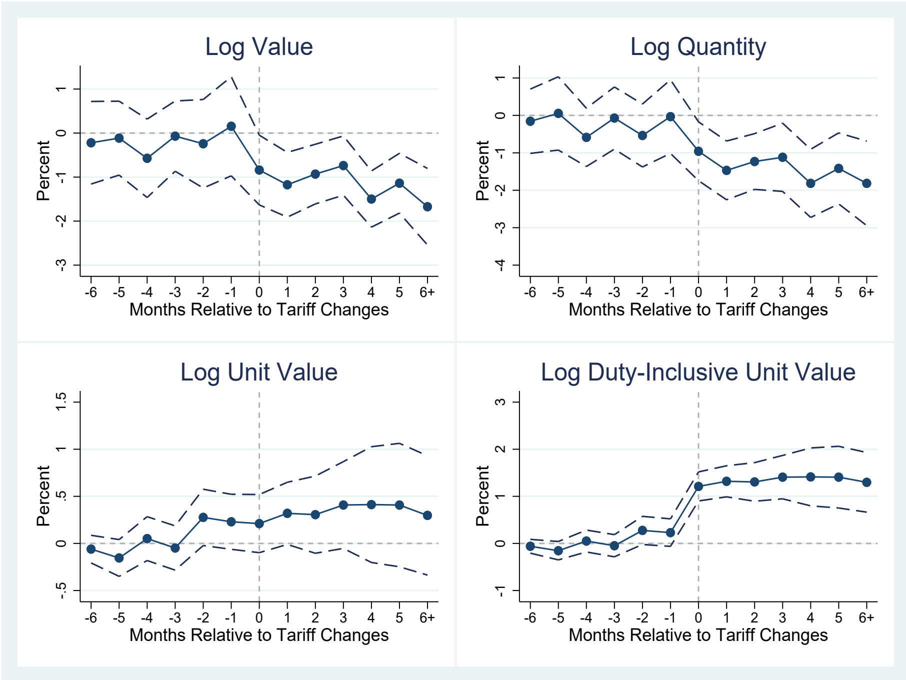
(B2) Chinese MFN tariff cut



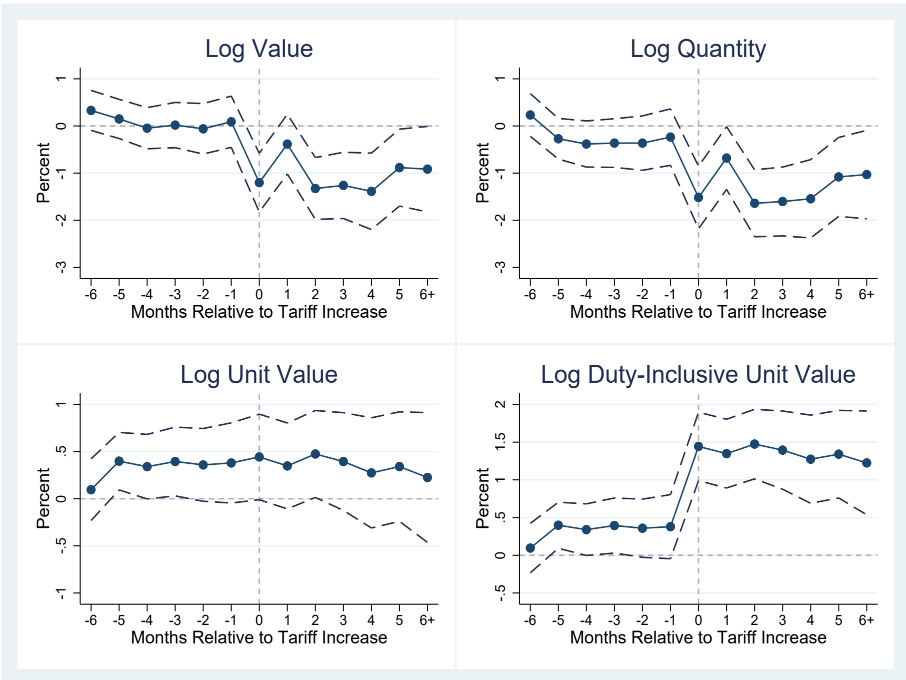
Note: The figure shows the unweighted average tariff rate of targeted import and export varieties for each tariff wave before and after they were targeted. The numbering of the events corresponds to those in Table 3.1. Refer to the Data Appendix for additional details on the construction of tariff rates and the scaling of tariff increases when the implementation date is not on the first day of the month. In drawing the above diagram, the implementation month is taken to be the current month if the implementation date is before the 15th of the month and the next month otherwise.

Figure 3.2: Dynamic Specification Tests

(A) Tariffs on Chinese Imports



(B) Tariffs on Chinese Exports

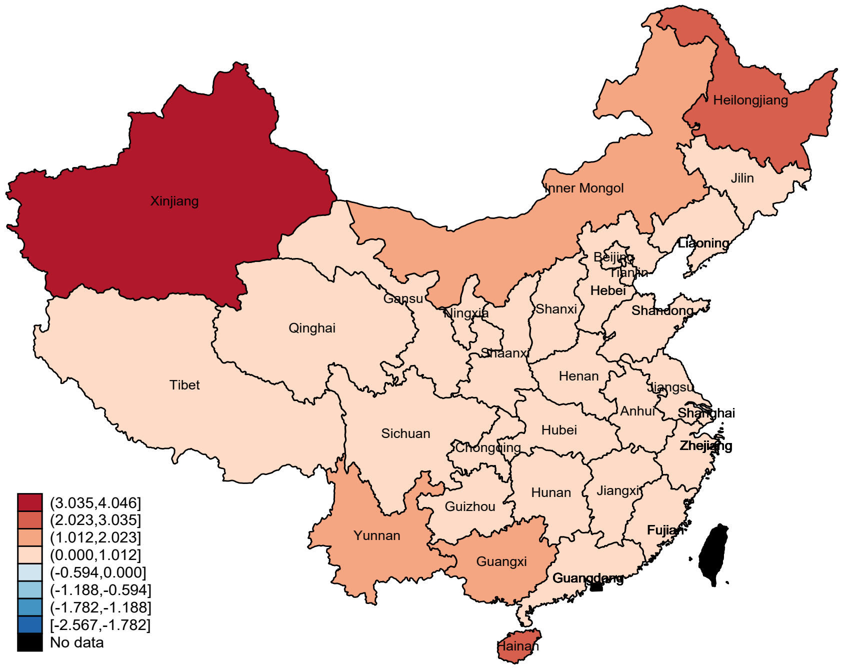


Note: Figures plot cumulative sum of β coefficients from the regression (3.33). Standard errors are clustered by country and HS-8 for imports; and by HS-6 for exports (with respect to the U.S. market). Error bands show 95% confidence intervals. Sample: variety-level import and export data for 2017:1–2019:12. As in Fajgelbaum et al. (2020), we replace missing leading and lagged tariff changes with zeros and include indicators for those missing values.

Figure 3.3: Regional Exposure to Tariff Increase of China and U.S.

(A) China's Tariff Increase on U.S. Imports, 2018–2019

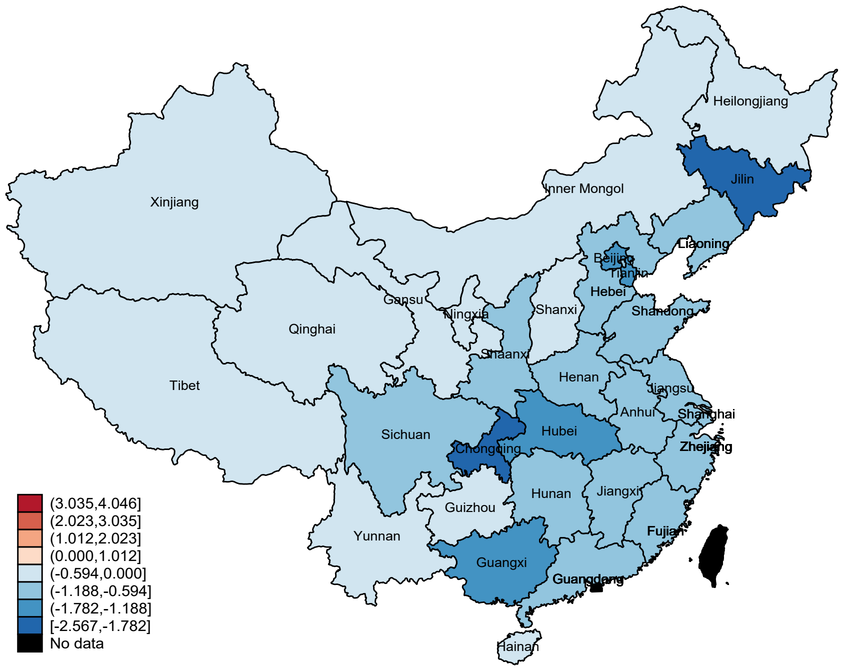
Weighted by Variety-Level China Import Share and Province-Level 2017 Tradable Sector Employee Wage Bill



Mean = 0.85, std = 0.52

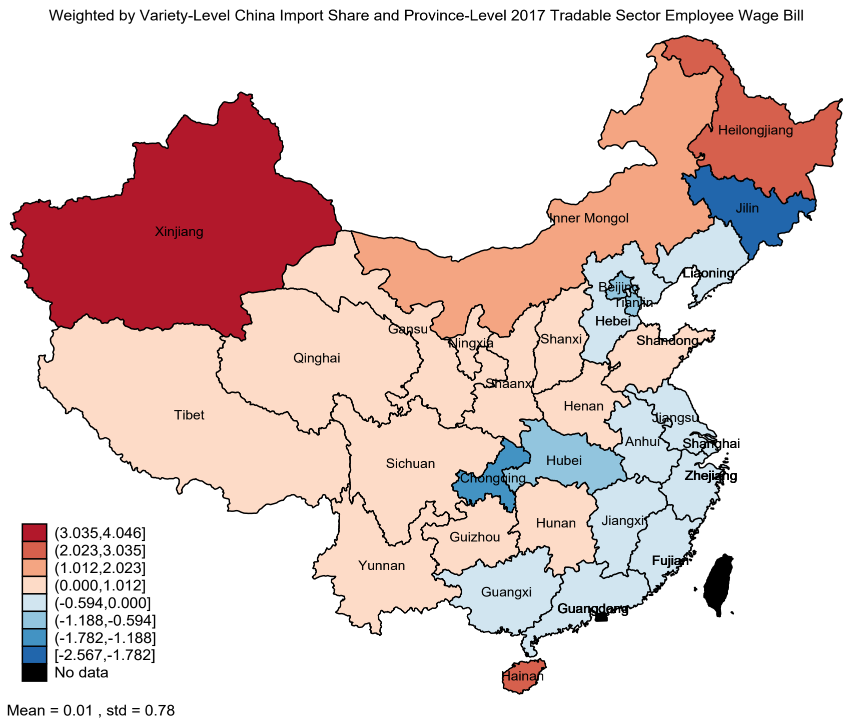
(B) China's MFN Tariff Decrease on Non-U.S. Imports, 2018–2019

Weighted by Variety-Level China Import Share and Province-Level 2017 Tradable Sector Employee Wage Bill

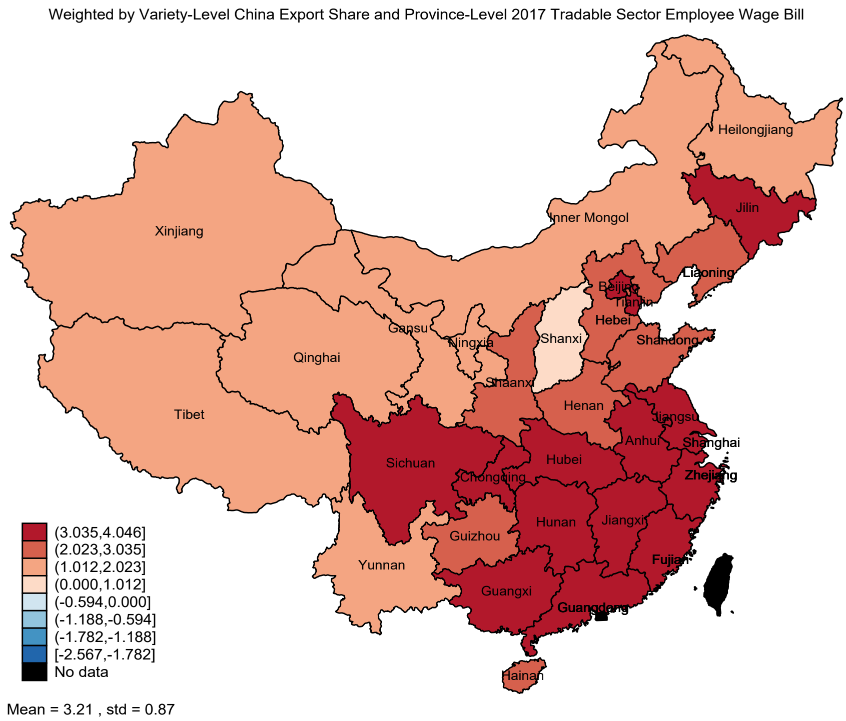


Mean = -0.89, std = 0.41

(C) China's Net Tariff Increase on Imports, 2018–2019



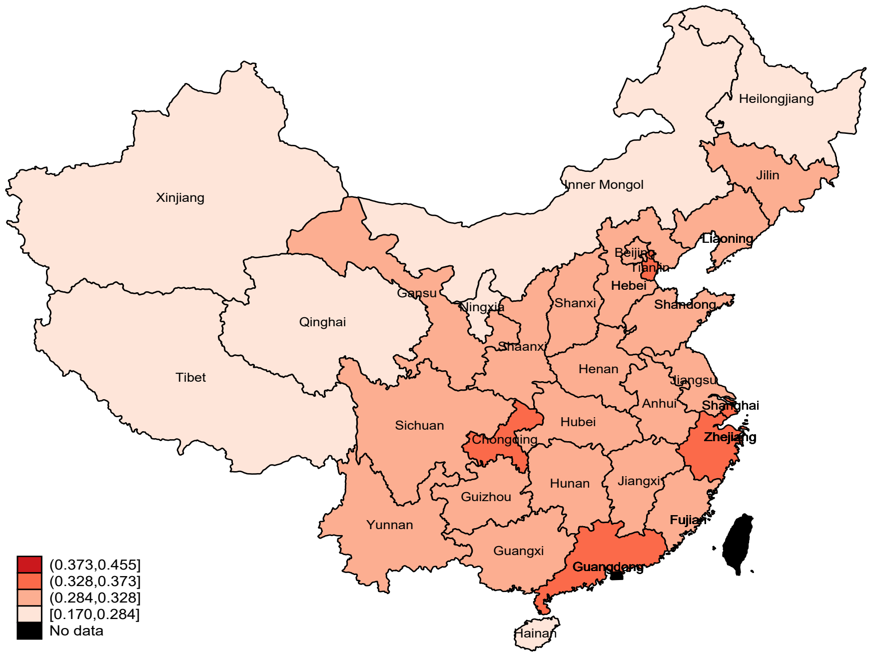
(D) U.S. Tariff Increase on China's Exports, 2018–2019



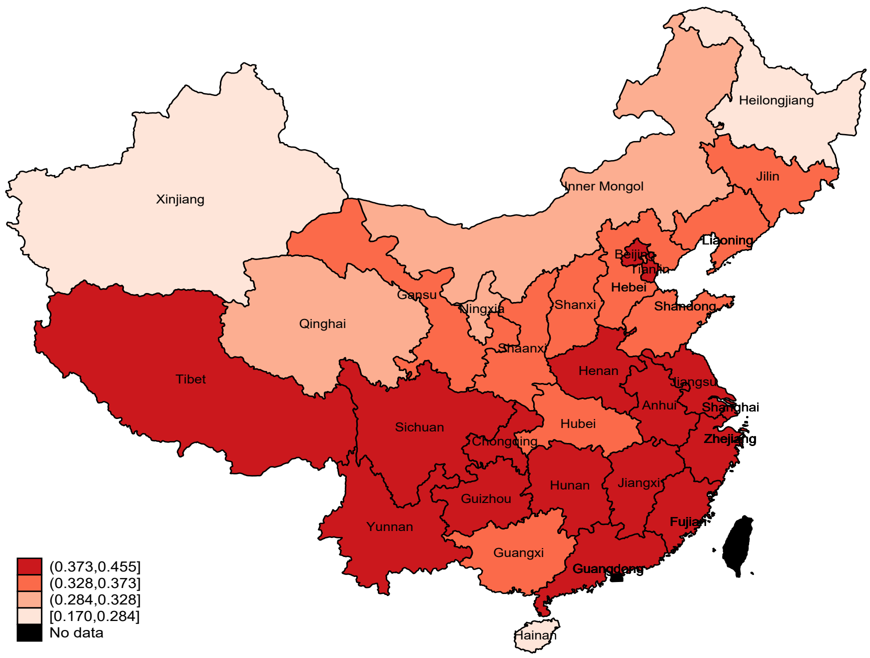
Note: The figure shows province-level exposure to China's tariff increases on U.S. imports (Panel A), China's MFN tariff decreases on non-U.S. imports (Panel B), China's net tariff increase (Panel C), and U.S. tariff increase on China's exports (Panel D), in relation to the trade war during 2018–2019, weighted by 2017 variety-level China trade shares (constructed from customs data) and by 2017 province-level tradable sector employee wage bill (constructed from China Labor Statistical Yearbook). Darker shades indicate exposure to larger tariff changes. Values indicate percentage point tariff changes.

Figure 3.4: Simulated Real Wage Impacts of the Trade War

(A) Tradable Real Wage Loss from Tariff Increases of China and U.S.



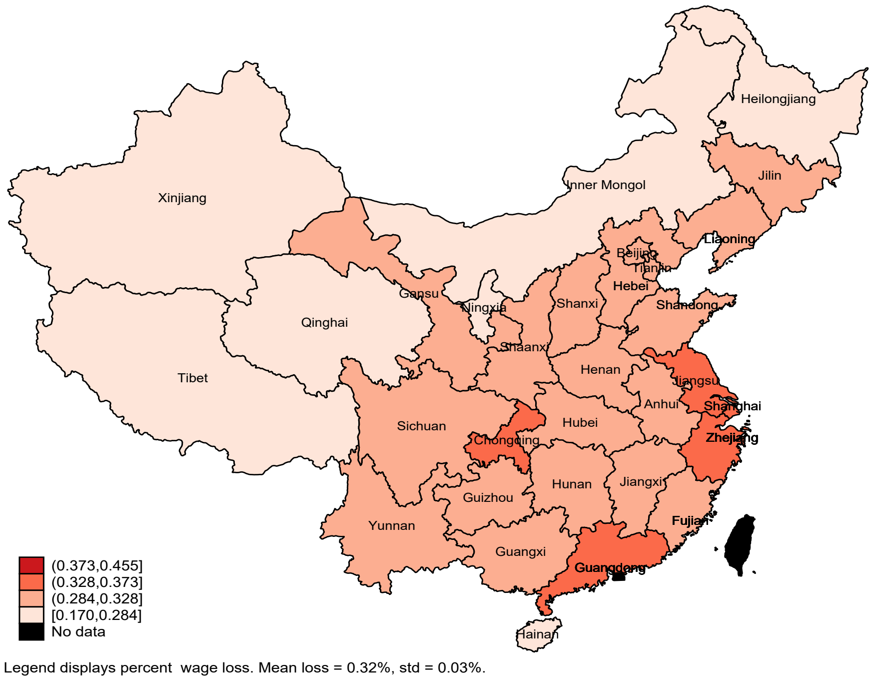
(B) Tradable Real Wage Loss from Tariff Increases of China and U.S. (w/o the MFN tariff adjustment by China)



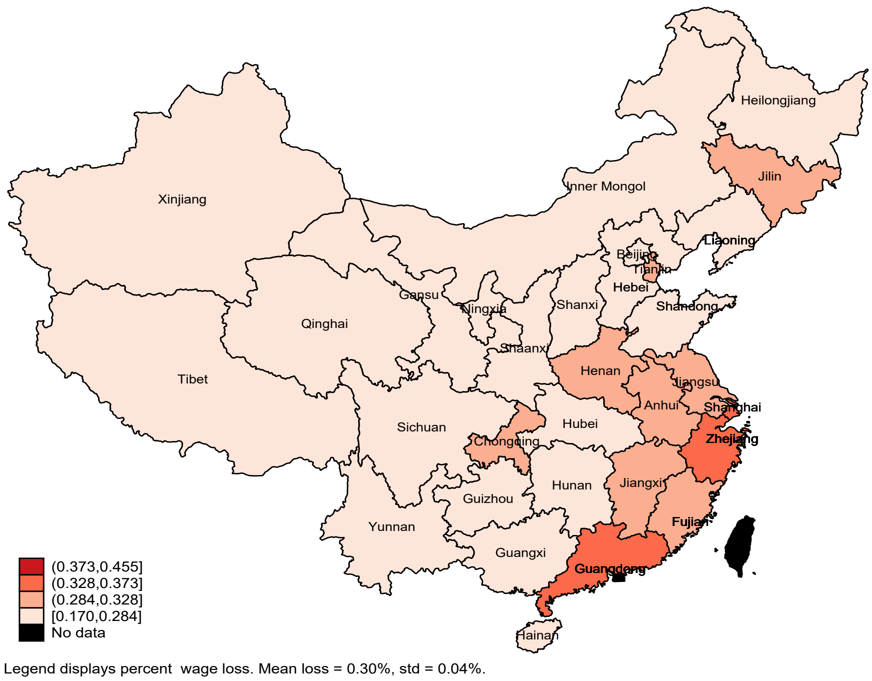
Note: The figure shows province-level mean tradable real wage losses as simulated from the model. Panel A shows losses in the full trade war scenario. Panel B shows losses in the full trade war scenario but without the MFN tariff cuts. Darker shades indicate greater losses. Values indicate percent real wage losses.

Figure 3.5: Simulated Real Expenditure Impacts of the Trade War

(A) Real Expenditure Loss from Tariff Increases of China and U.S.



(B) Real Expenditure Loss from Tariff Increases of China and U.S. (w/o the MFN tariff adjustment by China)



Note: The figure shows province-level mean real expenditure losses as simulated from the model. Panel A shows losses in the full trade war scenario. Panel B shows losses in the full trade war scenario but without the MFN tariff cuts. Darker shades indicate greater losses. Values indicate percent real expenditure losses.

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Appendix A

Appendix to Chapter 1

A.1 Data Appendix

A.1.1 Bilateral Trade Flow

Bilateral merchandise trade flows are firstly obtained from Correlates of War (COW) project[1]. Since this data is reported only up to year 2014, we construct the merchandise trade flows for year 2015 from the IMF Direction of Trade Statistics (DOTS)[2], based on the COW's method.

Bilateral commercial service trade is also incorporated whenever data is possible. Our first data source is the "WTO-UNCTAD-ITC annual trade in services dataset"[3]. It has two sub-databases: "Trade in commercial services, 2005-onwards (BPM6) " and "Trade in commercial services, 1980-2013 (BPM5)". Specifically, we compile the trade in service data from the product sector "*Memo item: Total services*" (with product code "*S200*") under BPM6 and complement it with data under BPM5. If the service trade is still not available, we further extract information from World Bank's "Trade in Services Database"[4]. Specifically, we use the "*Total EBOPS Services*" data with years spinning 1985-2011.

Then we can generate total bilateral trade flows by summing up the bilateral merchandise

[1] http://www.correlatesofwar.org/data-sets/bilateral-trade
[2] http://www.imf.org/en/Data
[3] https://www.wto.org/english/res_e/statis_e/trade_datasets_e.htm
[4] https://datacatalog.worldbank.org/dataset/trade-services-database

trade and commercial service trade together.

A.1.2 GDP, Value-added Share, and Gross Output

We use the GDP data from the World Bank's World Development Indicators (WDI).[5] and supplement the missing entries with the GDP data from the CEPII's gravity dataset,[6][7] We constructed the gross output Y_i data by taking the ratio of GDP and the value-added share β_i in gross output: $Y_{it} = GDP_{it}/\beta_{it}$.

The data on value-added share β_{it} are sequentially sourced from several databases as follows. The first source is "STAN STructural ANalysis Database"[8] which covers 37 countries for years 1970-2017. We take the ratio of "*Value added, current prices*" over "*Production (gross output), current prices*" for "*Industry: Total*".[9] The second source is the WIOD Socio-Economic Accounts [10] with three releases: November 2016 release (with data for years 2000-2014), July 2014 release (with data for years 1995-2011), and February 2012 release (with data for years 1995-2009) respectively. We use the latest release whenever possible. The third resource is the Input-Output Tables (IOTs) from the OECD Input-Output database[11]. There are four editions Input-Output Tables reported: 2018 edition (ISIC Rev.4), 2015 edition (ISIC Rev.3), 2002 edition (ISIC Rev.3), 1995 edition (ISIC Rev.2). We use the latest edition whenever possible. As an example, in the 2018 edition IOTs, we calculate the value-added share by aggregating the "*Value added at basic prices*" and "*Output at basic prices*" across all the sectors from "*Agriculture, forestry and fishing*" to "*Private households with employed persons*". Despite all the sources, some countries still do not have data in some years. Then we do the following data adjustment. If one country has available data for at least two years, we extrapolate the missing data in the middle by taking the mean value

[5] http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
[6] http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=8
[7] http://sites.google.com/site/hiegravity/data-sources
[8] https://www.oecd.org/industry/ind/stanstructuralanalysisdatabase.htm
[9] https://stats.oecd.org/Index.aspx?DataSetCode=STANI4_2016
[10] http://www.wiod.org/database/seas16
[11] https://www.oecd.org/sti/ind/input-outputtables.htm

of its nearest two entries. For countries with only one year data, we take this value for all the other years. For countries without any information, we borrow the value-added shares of the Rest of the World (ROW) from the OECD IOTs 2015 edition.

We use the population data from the WDI, and supplement the missing entries with the population data from the International Monetary Fund's International Financial Statistics (IFS) [12] and the CEPII's Gravity dataset. The data on GDP per capita are also sourced from the WDI. When it is missing in the WDI, we calculate the variable by the ratio of GDP and population as compiled above.

A.1.3 Expenditure

Based on bilateral trade flow, we construct the trade deficit of a country by: $\tilde{D}_{jt} = \sum_i X_{ijt} - \sum_i X_{jit}$. However, due to omission, the world trade deficit $\tilde{D}_{wt}$ does not always sum to zero. We allocate the discrepancy $\tilde{D}_{wt}$ to each country in proportion to its output share of the world, i.e., $D_{jt} = \tilde{D}_{jt} - s_j \tilde{D}_{wt}$. The gross expenditure of a country is then constructed as $E_{jt} = Y_{jt} + D_{jt}$

A.1.4 Classification of Developed and Developing countries

Rose (2004) and Subramanian and Wei (2007) classify the traditional industrialized countries as developed countries.[13] This is our benchmark. However, this classification is time invariant and thus does not reflect the rise of newly industrialized countries. Hence, we also consider classifying a country as developed based on the income threshold of US $6,000 per capita (in 1987 prices) used by the World Bank for high-income countries.[14] These thresholds have been updated annually by the World Bank since 1987, using the IMF's SDR (Special Drawing Rights) deflator to adjust for inflation. We extrapolate the thresholds for the period

[12] http://data.imf.org/?sk=4C514D48-B6BA-49ED-8AB9-52B0C1A0179B

[13] See Appendix Table 2 in Subramanian and Wei (2003).

[14] http://datahelpdesk.worldbank.org/knowledgebase/articles/378833-how-are-the-income-group-thresholds-determined

1978-1986 using the same SDR deflator.[15] The World Bank threshold is in terms of GNI per capita, but the GNI data in earlier years are not readily available for a large number of countries. Thus, we classify countries as developed or developing based on their GDP per capita instead.

Together, a county is classified as developed, if its GDP per capita exceeds the threshold constructed above or if it belongs to the set of traditional industrialized countries listed in Subramanian and Wei (2003). Otherwise, it is classified as a developing country.

A.1.5 Proxies for Asymmetric Bilateral Trade Cost

The main bulk of the trade cost variables is taken from CEPII's gravity dataset and GeoDist dataset.[16] The original dataset includes 225 countries. We drop French Southern and Antarctic Lands because it does not have a permanent population.

The WTO/GATT indicator variables $bothwto_{ijt}$ and $imwto_{ijt}$ are constructed from the CEPII variable *gatt_o* and *gatt_d* (which equal to one if the exporting country or importing country is a GATT/WTO member, respectively).[17] We also define $exwto_{ijt}$ as an indicator that equals one if only the exporter i is a GATT/WTO member in year t and zero otherwise. We add $exwto_{ijt}$ in the iterated regression to fully capture the impact of GATT/WTO indicators on international trade flows according to our specification.

The other variables used include common currency indicator, which equals one if two countries use a common currency ($comcur_{ijt}$); Because the identity of a colonizer versus a colony never switched in the period of our study, we constructed the indicator for whether exporter i is currently a colonizer of importer j based on the CEPII variable $curcol_{ijt}$ (whether i is currently a colony of j or vice versa) and *heg_o*: $curheg\_o = 1$ if $curcol_{ijt} = 1$ and $heg\_o = 1$. The indicator for whether importer j is currently a colonizer of exporter i is constructed in

[15] http://datahelpdesk.worldbank.org/knowledgebase/articles/378829-what-is-the-sdr-deflator

[16] http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=6

[17] We also make some corrections of WTO membership in CEPII's dataset with the information from WTO's website whenever we find strong evidence. For example, Madagascar has been a member of GATT since 1963 and a member of WTO since 1995 as indicated on WTO website, whereas it is always listed as a nonmember in CEPII's gravity dataset.

a similar way: $curheg\_d = 1$ if $curcol_{ijt} = 1$ and $heg\_d = 1$.

The data on whether importer j offers GSP preferential treatment to exporter i (gsp_{ijt}) are from the Database on Economic Integration Agreements (April 2017)[18] constructed by Scott Baier and Jeffrey Bergstrand by default. To supplement the missing gsp_{ijt} entries, we first use the information from WTO's Database on Preferential Trade Agreements.[19] If the gsp_{ijt} is still missing, we compile the data manually from the "Generalized System of Preferences: List of Beneficiary Countries" reported by the UNCTAD.[20] The UNCTAD updates the information on the GSP schemes from time to time, but not annually. The information on the GSP schemes is only available for years 2001, 2005, 2006, 2008, 2009, 2011, and 2015.

A.1.6 Pseudo World

For obvious reasons, we drop countries that do not have GDP data. We also drop countries that do not import or export to any other countries. Given the set of remaining countries, we constructed trade deficits and expenditures as discussed above, and drop countries if the constructed expenditure is negative. We also drop countries when its implied internal trade is negative: $X_{ii} \equiv Y_i - \sum_{j \neq i} X_{ij} < 0$. These are typical small territories whose data are prone to measurement errors. We iterate the process of constructing trade deficits and expenditures after each round of adjustment in the set of countries until the constructed expenditure and internal trade of all countries are positive. We call this set of countries the pseudo world and calculate the supply and expenditure shares of each country relative to the pseudo world. As shown in Table A.1, the number of countries included in the pseudo world increased from 161 in 1980 to 189 in 2015. The coverage of GDP share and import share in the pseudo world is close to that of all CEPII countries in the raw dataset. In Table A.2, we decompose the pseudo world import flows either by PTA status or GATT/WTO membership. We can find

[18] https://www3.nd.edu/ jbergstr/
[19] http://ptadb.wto.org/
[20] http://unctad.org/en/Pages/DITC/GSP/GSP-List-of-Beneficiary-Countries.aspx

a surge in the number of countries with PTAs currently in force since 1995 and an increase in intra-PTA trade flows over time. And GATT/WTO members are proportionally larger importers. The pseudo world covers a total of 244 PTAs and a detailed list of agreements is presented in Table A.3.

Table A.1: Characteristics of countries included in the pseudo world

	(a)	(b)	(c)	(d)	(e)
year	No. of countries in the raw data	No. of countries in pseudo world	GDP share of the pseudo world	Import share of the pseudo world	No. of obs. with positive bilateral imports
1980	161	160	0.996	0.979	11,363
1985	164	163	0.997	0.987	11,960
1990	166	165	0.988	0.986	13,776
1995	186	184	0.999	0.996	18,348
2000	192	192	0.998	0.996	22,132
2005	195	191	0.999	0.996	23,360
2010	193	191	0.998	0.992	24,271
2015	189	188	0.999	0.991	26,286

Note:
(a) refers to the number of countries: (i) with at least one non-missing bilateral import and one non-missing bilateral export number from the COW and DOTS, (ii) with trade cost proxy data, and (iii) with GDP data.
(b) refers to the number of countries in the pseudo world after the iterated adjustment described in the data appendix to ensure that every country has positive expenditure and internal trade.
(c) refers to the total GDP of the countries in the pseudo world relative to the world GDP aggregated by 224 CEPII countries.
(d) refers to the total imports of the countries in the pseudo world relative to the world imports aggregated by 224 CEPII countries.
(e) refers to the number of observations in the pseudo world with positive bilateral imports.

Table A.2: Characteristics of countries included in the pseudo world (PTA and GATT/WTO related)

	(a)	(b)	(c)	(d)	
year	No. of countries in the pseudo world	No. of countries which has signed PTA	Import share of countries which has signed PTA	Import share of observations with PTA=1	
1980	160	34	0.450	0.215	
1985	163	39	0.618	0.200	
1990	165	45	0.659	0.266	
1995	184	107	0.758	0.366	
2000	192	137	0.774	0.385	
2005	191	172	0.989	0.459	
2010	191	180	0.993	0.468	
2015	188	178	0.996	0.505	
	(e)	(f)	(g)	(h)	(i)
year	No. of countries in GATT/WTO	Import share of GATT/WTO members	Import share of nonmembers	Import share of *bothwto* observations	Import share of *imwto* observations
1980	83	0.860	0.140	0.672	0.188
1985	88	0.863	0.137	0.724	0.139
1990	98	0.920	0.080	0.819	0.101
1995	125	0.919	0.081	0.818	0.101
2000	138	0.908	0.092	0.794	0.115
2005	147	0.968	0.032	0.925	0.043
2010	151	0.965	0.035	0.921	0.044
2015	158	0.985	0.015	0.972	0.012

Note:
(a) refers to the number of countries in the pseudo world.
(b) refers to the number of countries with at least one PTA currently in force with trading partners in the pseudo world.
(c) refers to the total imports of countries with at least one PTA currently in force with trading partners relative to the total imports of the pseudo world.
(d) refers to the total imports of country pairs where the PTA indicator equals one relative to the total imports of the pseudo world.
(e) refers to the number of GATT/WTO member countries in the pseudo world.
(f) refers to the total imports of GATT/WTO member countries relative to the total imports of the pseudo world.
(g) refers to the total imports of nonmember countries relative to the total imports of the pseudo world.
(h) refers to the total imports of country pairs where both are GATT/WTO members relative to the total imports of the pseudo world.
(i) refers to the total imports of country pairs where only the importer is a GATT/WTO member relative to the total imports of the pseudo world.

Table A.3: List of Agreements

agreement	enter into force
Armenia - Kazakhstan	2001
Armenia - Moldova	1995
Armenia - Russian Federation	1993
Armenia - Turkmenistan	1996
Armenia - Ukraine	1996
ASEAN free trade area	1992
ASEAN-Australia-New Zealand	2010
ASEAN-India	2010
ASEAN-Korea	2010
Australia-New Zealand (ANZCERTA)	1983
Australia-Singapore	2003
Australia-Thailand	2005
Brunei Darussalam - Japan	2008
CAFTA-DR	2006
CAN	1988
Canada - Chile	1997
Canada - Colombia	2011
Canada - Costa Rica	2002
Canada - Honduras	2014
Canada - Israel	1997
Canada - Jordan	2012
Canada - Panama	2013
Canada - Rep. of Korea	2015
Canada-EFTA	2009
Canada-Peru	2009
Carribean Community and Community Market (CARICOM)	1973
CEFTA	2007
CEZ	2004
Chile - Colombia	2009
Chile - Costa Rica (Chile - Central America)	2002
Chile - El Salvador (Chile - Central America)	2002
Chile - Guatemala (Chile - Central America)	2010
Chile - Honduras (Chile - Central America)	2008
Chile - Malaysia	2012
Chile - Mexico	1999
Chile - Nicaragua (Chile - Central America)	2012
Chile - Viet nam	2014
Chile-Australia	2009
Chile-China	2006
Chile-Japan	2007
Chile-Korea	2004
China - Costa Rica	2011
China - Macao, China	2003
China-ASEAN	2005
China-Hong Kong	2004
China-New Zealand	2008
China-Pakistan	2007
China-Peru	2010
China-Singapore	2009
CIS	1994
Colombia - Mexico	1995
Colombia - Northern Triangle (El Salvador, Guatemala, Honduras)	2009
COMESA	1994
Costa Rica - Peru	2013
Costa Rica - Singapore	2013
Dominican Republic - Central America	2001
EAEC	1997
East African Community (EAC)	2000
East African Community (EAC) - Accession of Burundi	2007
East African Community (EAC) - Accession of Rwanda	2007
EC (10) Enlargement	1981
EC (9) Enlargement	1973
EC Enlargement (12)	1986
EC Enlargement (15)	1995
EC Enlargement (25)	2004
EC Enlargement (27)	2007
EC Treaty	1958
EC-Albania	2006
EC-Algeria	2005
EC-Bosnia Herzegovina	2008
EC-Cameroon	2009
EC-CARIFORUM	2008
EC-Chile	2003
EC-Cote d'Ivoire	2009
EC-Croatia	2002
EC-Egypt	2004
EC-Faroe Islands	1997
EU - Republic of Moldova	2014
EU (28) Enlargement	2013
Eurasian Economic Union (EAEU)	2015
Eurasian Economic Union (EAEU) - Accession of Armenia	2015
Eurasian Economic Union (EAEU) - Accession of Kyrgyz Republic	2015
EU-San Marino	2002
GCC	2003
Georgia - Armenia	1998
Georgia - Azerbaijan	1996
Georgia - Kazakhstan	1999
Georgia - Russian Federation	1994
Georgia - Turkmenistan	2000
Georgia - Ukraine	1996
Guatemala - Chinese Taipei	2006
Gulf Cooperation Council (GCC) - Singapore	2013
Hong Kong, China - Chile	2014
Hong Kong, China - New Zealand	2011
Iceland - China	2014
Iceland - Faroe Islands	2006
India - Bhutan	2006
India-Japan	2011
India-Malaysia	2011
India-Singapore	2005
India-Sri Lanka	2001
Israel - Mexico	2000
Japan - Australia	2015
Japan - Peru	2012
Japan-ASEAN	2008
Japan-Indonesia	2008
Japan-Malaysia	2006
Japan-Mexico	2005
Japan-Philippines	2008
Japan-Singapore	2002
Japan-Switzerland	2009
Japan-Thailand	2007
Japan-Viet Nam	2009
Jordan - Singapore	2005
Korea, Republic of - Australia	2014
Korea, Republic of - Turkey	2013
Korea, Republic of - US	2012
Korea, Republic of-India	2010
Korea, Republic of-Singapore	2006
Kyrgyz Republic - Armenia	1995
Kyrgyz Republic - Kazakhstan	1995
Kyrgyz Republic - Moldova	1996
Kyrgyz Republic - Russian Federation	1993
Kyrgyz Republic - Ukraine	1998
Kyrgyz Republic - Uzbekistan	1998
Malaysia - Australia	2013
MERCOSUR	1991
Mexico - Central America	2012
Mexico - Uruguay	2004
NAFTA	1994
New Zealand - Chinese Taipei	2013
New Zealand - Malaysia	2010
New Zealand - Singapore	2001
Nicaragua - Chinese Taipei	2008
Pacific Island Countries Trade Agreement (PICTA)	2003
PAFTA	1998
Pakistan - Malaysia	2008
Pakistan - Sri Lanka	2005
Panama - Chile	2008
Panama - Chinese Taipei	2004
Panama - Costa Rica (Panama - Central America)	2008
Panama - El Salvador (Panama - Central America)	2003
Panama - Guatemala (Panama - Central America	2009
Panama - Honduras (Panama - Central America)	2009
Panama - Nicaragua (Panama - Central America)	2009
Panama - Peru	2012
Panama - Singapore	2006
Peru - Chile	2009
Peru - Korea, Republic of	2011
Peru - Mexico	2012
Peru - Singapore	2009
Russian Federation - Azerbaijan	1993
Russian Federation - Belarus	1993
Russian Federation - Belarus - Kazakhstan	1997
Russian Federation - Kazakhstan	1993

EC-FYR Macedonia	2001
EC-Iceland	1973
EC-Israel	2000
EC-Jordan	2002
EC-Lebanon	2003
EC-Mexico	2000
EC-Morocco	2000
EC-Norway	1973
Economic and Monetary Community of Central Africa (CEMAC)	1999
ECOWAS	1993
EC-Palestinian Authority	1997
EC-South Africa	2000
EC-Switzerland Liechtenst0	1973
EC-Tunisia	1998
EC-Turkey	1996
EEA	1994
EFTA - Albania	2010
EFTA - Bosnia and Herzegovina	2015
EFTA - Central America (Costa Rica and Panama)	2014
EFTA - Chile	2004
EFTA - Colombia	2011
EFTA - Egypt	2007
EFTA - Former Yugoslav Republic of Macedonia	2002
EFTA - Hong Kong, China	2012
EFTA - Jordan	2002
EFTA - Lebanon	2007
EFTA - Mexico	2001
EFTA - Morocco	1999
EFTA - Palestinian Authority	1999
EFTA - Peru	2011
EFTA - SACU	2008
EFTA - Singapore	2003
EFTA - Tunisia	2005
EFTA - Ukraine	2012
EFTA-Israel	1993
EFTA-Korea	2006
Egypt - Turkey	2007
El Salvador - Honduras - Chinese Taipei	2008
EU - Central America	2013
EU - Colombia and Peru	2013
EU - Eastern and Southern Africa States Interim EPA	2012
EU - Georgia	2014
EU - Korea, Republic of	2011
EU - Papua New Guinea/Fiji	2009
Russian Federation - Republic of Moldova	1993
Russian Federation - Tajikistan	1993
Russian Federation - Turkmenistan	1993
Russian Federation - Uzkbekistan	1993
Russian Federation-Ukraina	1994
SACU	2004
SAFTA	2006
Singapore - Chinese Taipei	2014
Southern African Development Community	2000
Switzerland - China	2014
Thailand - New Zealand	2005
Trans-Pacific Strategic Economic Partnership	2006
Treaty on a Free Trade Area between members of the Commonwealth of Independent States (CIS)	2012
Turkey - Albania	2008
Turkey - Bosnia and Herzegovina	2003
Turkey - Chile	2011
Turkey - Former Yugoslav Republic of Macedonia	2000
Turkey - Georgia	2008
Turkey - Israel	1997
Turkey - Jordan	2011
Turkey - Mauritius	2013
Turkey - Morocco	2006
Turkey - Palestinian Authority	2005
Turkey - Tunisia	2005
Turkey-EFTA	1992
Ukraine - Azerbaijan	1996
Ukraine - Former Yugoslav Republic of Macedonia	2001
Ukraine - Moldova	2005
Ukraine - Uzbekistan	1996
Ukraine Tajikistan	2002
Ukraine-Belarus	2006
Ukraine-Kazakhstan	1998
Ukraine-Turkmenistan	1995
US - Colombia	2012
US - Panama	2012
US-Australia	2005
US-Bahrain	2006
US-Chile	2004
US-Israel	1985
US-Jordan	2001
US-Morocco	2006
US-Oman	2009
US-Peru	2009
US-Singapore	2004
West African Economic and Monetary Union (WAEMU)	2000

Note: There are a total of 244 PTAs covered in the pseudo world based on the dataset constructed by Hofmann, Osnago and Ruta (2017). That dataset covers all PTAs notified to the WTO and in force as of December 2015.

A.2 Math Appendix

A.2.1 Alternative Formulations of the Input Bundle in the Melitz Framework

Suppose that instead of (1.12), the entry uses an input bundle with a different labor intensity, characterized by:

$$c_i^e = w_i^\kappa P_i^{1-\kappa}. \tag{A.1}$$

The free-entry condition in (1.13) is modified to be:

$$\frac{\sigma-1}{\sigma\theta} Y_i = N_i F_i c_i^e, \tag{A.2}$$

and the labor-market clearing condition is instead:

$$w_i L_i = \beta_i \left(1 - \frac{\sigma-1}{\sigma\theta}\right) Y_i + \kappa \left(\frac{\sigma-1}{\sigma\theta}\right) Y_i. \tag{A.3}$$

In addition to (1.26) and (1.28), we have:

$$\widehat{c}_i^e = \widehat{w}_i^\kappa \widehat{P}_i^{1-\kappa}, \tag{A.4}$$

and the modified free-entry counterfactual equation:

$$\widehat{Y}_i = \widehat{N}_i \widehat{c}_i^e. \tag{A.5}$$

Thus, we have one extra set of variables $\{\widehat{c}_i^e\}$ to determine but also one extra set of conditions (A.4).

To set the parameter for κ, define $\bar{\beta}_i \equiv \beta_i \left(1 - \frac{\sigma-1}{\sigma\theta}\right) + \kappa \left(\frac{\sigma-1}{\sigma\theta}\right)$. The value $\bar{\beta}_i$ corresponds to the value-added share observed in the data. The assumption $\kappa = \beta_i$ corresponds to the case where $\bar{\beta}_i = \beta_i$. In general, following Bollard et al. (2016), we allow for the scenarios where the input bundle used for entry is more labor intensive than in production, i.e., $\kappa > \beta_i$. Thus, we set κ to take on values greater than $\max_i\{\bar{\beta}_i\}$, where $\max_i\{\bar{\beta}_i\}$ is the maximum value-added share observed across countries in the data (0.62). In particular, we allow κ to take on values in $[0.8, 1]$. Given $\bar{\beta}_i$ and κ, we then back out the values for β_i.

Appendix B

Appendix to Chapter 2

B.1 Supplementary Data Appendix to A.1

B.1.1 Import Tariffs

The import tariff data is collected from two sources, the United Nations Conference on Trade and Development (UNCTAD) Trade Analysis and Information System (TRAINS) and the World Trade Organization (WTO) Integrated Data Base (IDB).[1] It has been available since 1988. There are four types of tariff rates, Effectively Applied (AHS), Preferential (PRF), MFN applied and MFN bound tariff rates. We take the AHS rate as our benchmark, and supplement the missing entries with PRF, MFN applied and MFN bound rates in order. They are all simple averaged across products. After combining all types of tariff rates to one general rate t_{ijt}, to increase the number of non-missing observations, we interpolate the tariff data first and then extrapolate it by taking the values from the closest non-missing years to increase the number of non-missing tariffs. Finally, in the counterfactual analysis we construct the rest of the world (ROW) by aggregating 49 countries together where most of tariff data is missing in the data sample, and take the average of tariff rates from the same importer with the same PTA status. By following the above steps, we are able to obtain a complete set of tariff rates in our data sample.

[1] http://wits.worldbank.org/WITS/WITS/AdvanceQuery/TariffAndTradeAnalysis/AdvancedQueryDefinition.aspx?Page=TariffandTradeAnalysis

B.1.2 Pseudo World

For obvious reasons, we drop countries that do not have GDP data. We also drop countries that do not import or export to any other countries. Given the set of remaining countries, we constructed trade deficits and expenditures as discussed above, and drop countries if the constructed expenditure is negative. We also drop countries when its implied internal trade is negative: $M_{ii} \equiv Y_i - \sum_{j \neq i} M_{ij} < 0$. These are typical small territories whose data are prone to measurement errors. We iterate the process of constructing trade deficits and expenditures after each round of adjustment in the set of countries until the constructed expenditure and internal trade of all countries are positive. We call this set of countries the pseudo world and calculate the supply and expenditure shares of each country relative to the pseudo world. PTA-related characteristics of countries included in the pseudo world is presented in Table B.1. As same as in the previous chapter, this pseudo world also covers a total of 244 PTAs and a detailed list of agreements has been presented in Table A.3.

Table B.1: PTA-related characteristics of countries included in the pseudo world

	(a)	(b)	(c)	(d)
year	No. of countries in the pseudo world	No. of countries which has signed PTA	Import share of countries which has signed PTA	Import share of observations with PTA=1
1960	115	15	0.453	0.124
1965	129	20	0.476	0.153
1970	142	20	0.455	0.174
1975	149	25	0.430	0.209
1980	160	34	0.450	0.215
1985	163	39	0.618	0.200
1990	165	45	0.659	0.266
1995	184	107	0.758	0.366
2000	192	137	0.774	0.385
2005	191	172	0.989	0.459
2010	191	180	0.993	0.468
2015	188	178	0.996	0.505

Note:
(a) refers to the number of countries in the pseudo world.
(b) refers to the number of countries with at least one PTA currently in force with trading partners in the pseudo world.
(c) refers to the total imports of countries with at least one PTA currently in force with trading partners relative to the total imports of the pseudo world.
(d) refers to the total imports of country pairs where the PTA indicator equals one relative to the total imports of the pseudo world.

Appendix C

Appendix to Chapter 3

C.1 Data Appendix

C.1.1 Definitions

Products, varieties and sectors are defined as follows in the analysis:

- Products are defined at the Harmonized System 8-digit level (denoted as HS-8). For example, the HS 8-digit code 40131000 covers the product "inner tubes of rubber used on motor cars."

- Varieties are defined at the product-country level. For example, imports (exports) of "inner tubes of rubber used on motor cars" from (to) the U.S. are a distinct variety.

- Sectors are defined according to the China Industry Classification system (GB/T 4754) at the 2-digit level (denoted as GB/T-2). For example, the GB/T-2 code 29 covers "manufacture of rubber and plastics products."

C.1.2 Variety-level Data on Trade and Tariffs

Trade Data

We obtain China's trade data in monthly frequency for the period 2017:1–2019:12 from the General Administration of Customs, China.[1] We observe the Chinese imports and exports at the HS-8 digit level by the source of imports and the destination of exports (i.e., at the variety level). For each variety, the customs data report the quantities of imports and exports, the value of imports at the CIF price, and the value of exports at the FOB price. The import and export values are reported in current US$ values.

Tariff Data

Our tariff data comprise two main components, the baseline tariff rates applied to Chinese imports and exports, and tariff changes associated with the U.S.-China trade war. For the Chinese baseline tariff rates, we downloaded the annual tariff schedule of China from the UN TRAINS database via the World Integrated Trade Solution (WITS).[2] Given the tariff rates available at the HS-10 level, we assume that the most-favored-nation (MFN) rate is applied to imports from WTO members, the preferential rate is applied to trading partners with which China has any preferential trade agreement (PTA) in place, and the general duty rate (GDR) is applied to the rest of the world. We then take the simple average of the HS-10 level tariff rates as the HS-8 level tariff rate. This aggregation is due to the fact that the tariff rate changes (or tariff rates in general) published by the Chinese Ministry of Finance are only available at the HS-8 level.[3] We cross-check, correct and supplement the missing values of the data obtained from TRAINS with the annual tariff schedules released by the Ministry of Finance. After constructing the baseline import tariff rate for January 2017, we then update the rates in monthly frequency, given the official announcement by the Ministry

[1] http://www.customs.gov.cn/.

[2] http://wits.worldbank.org/WITS/WITS/QuickQuery/Tariff-ViewAndExportRawData/TariffViewAndExportRawData.aspx?Page=TariffViewAndExportRawData.

[3] http://gss.mof.gov.cn/zhengwuxinxi/zhengcefabu/index_3.html.

of Finance of any tariff changes (tariff increases against the U.S. or MFN tariff cuts against the other WTO members).[4] These tariff changes are specified at the HS-8 level.[5]

For tariffs faced by Chinese exports, we compile the annual tariff rates imposed by Chinese trading partners from the UN TRAINS database.[6] In particular, we use the simple average of Effectively Applied (AHS) tariff rates by Chinese trading partners against China. These are available at the HS-6 digit level. For tariff changes associated with the trade war, we obtain that part of information from Fajgelbaum et al. (2019) (for tariff changes in 2018) and the Office of the United States Trade Representative (USTR)[7] (for tariff changes in 2019). The tariff changes are aggregated from the HS-10 to the HS-6 level based on simple average. The use of the HS-6 digit for tariffs faced by Chinese exports is because the HS codes are only harmonized across countries up to the level of HS-6 codes. The estimations of trade elasticities for Chinese exports are nonetheless conducted at the HS-8 level of trade (with the HS-6 tariffs assigned to all HS-8 products in the category). Thus, the same caveat noted by Fajgelbaum et al. (2020) applies, that we may overestimate the value of Chinese exports subject to tariffs and underestimate the foreign import demand elasticity.

Following Fajgelbaum et al. (2020), we scale tariff increases by the number of days of the month they were in effect. For example, a 15 p.p. tariff increase enacted on the 20th day of a 30-day month is assigned a 5 p.p. tariff increase (15 * 10/30 = 5) in the initial month, and an additional 10 p.p. increase in the subsequent month.

[4] `http://gss.mof.gov.cn/zhengwuxinxi/zhengcefabu/index_3.html`.

[5] Beside the tariff changes associated with the trade war, in constructing the applied tariff rates we also record other tariff revisions. These include annual MFN rate adjustments (normally twice a year, in January and July), tariff reductions resulting from longstanding treaty commitments, new PTAs signed between China and its trading partners, or the removal of import tariff barriers for certain products due to its 13th Five-Year Plan for National Economic and Social Development. These other tariff revisions are used to construct a more precise measure of the applied tariff rate. Their variations, however, are not used in the construction of the instrumental variables, i.e., not used as the source of identification of the elasticities.

[6] `http://wits.worldbank.org/WITS/WITS/AdvanceQuery/TariffAndTradeAnalysis/AdvancedQueryDefinition.aspx?Page=TariffandTradeAnalysis`.

[7] `https://ustr.gov/`.

C.1.3 Sector-level Data

We classify sectors using the China Industry Classification system (GB/T 4754), which is widely used in the collection of official statistics on companies and organizations throughout Mainland China. The sector-level data at the GB/T 2-digit level (denoted GB/T-2) are obtained from China's National Bureau of Statistics.[8] The classification includes 97 sectors in total, and 43 sectors in agriculture, mining and manufacturing.

1. Measure of $\triangle \ln P_{Dst}$: The change in the price index of domestically produced goods is proxied by the change in the producer price index. The producer price index for industrial products (PPI) is available with monthly frequency for 40 industrial sectors.

2. Measure of $\triangle \ln(P_{Dst}D_{st})$: The monthly change in expenditures on domestically produced goods is measured as the difference between the changes in sectoral production and exports. The data on the sectoral output (quantity) are available with monthly frequency but only for major products in 27 manufacturing sectors. We normalize the output of each product relative to 2016:1, and use the simple average across products within each sector as the sectoral production index.[9] The export quantity is constructed as the ratio of export values and the producer price index. The estimations of the elasticity κ are thus based on a subset of industrial sectors where the above data are available.

3. The input-output (IO) tables are compiled for 2017. These tables quantify annual inputs and outputs of commodities by intermediate and final users in 2017, for 88 sectors.

For the analysis in the paper, we classify GB/T-2 sectors as tradable if they are matched to an HS-6 code in the trade data. For the cross-walk between GB/T sectors and HS

[8] `http://www.stats.gov.cn/`.

[9] The methodology of constructing the production index usually requires the industrial value-added of each product to be used as the weight in calculating the index, but such data are not available. Thus, in our calculation, we take the weight to be equal across the major products.

products, we use the conversion table of Sheng (2002) (available for 36 industrial sectors), and the concordance tables from WITS (ISIC-HS)[10] and from China's National Bureau of Statistics (ISIC-GB/T)[11] (available for all economic activities). Minor modifications are further made where a product is mapped to more than one sector, using our interpretations of the official descriptions of the products and sectors. There are a total of 39 tradable sectors.

C.1.4 Province-level Data

For the general equilibrium analysis, we collect the annual employment and wage data at the sector and province level from the China Labor Statistical Yearbook of 2017. It records the employment and total wages of urban units by sector and region. These are available for 31 provinces and 94 GB/T-2 sectors (covering services, agriculture, mining and manufacturing sectors). All of the 39 tradable sectors are covered individually in both the IO tables and the labor statistics dataset. We aggregate the remaining sectors as a single non-tradable sector, thus reconciling the IO tables and the labor statistics dataset.

C.2 Appendix to Section 3.5 (Welfare Analysis)

The general-equilibrium (GE) system follows that of Fajgelbaum et al. (2020). We provide its full derivations in Section C.2.1 for ease of reference (correcting some typos of the original paper along the way), and document its implementations in the context of China in Section C.2.2. Section C.2.3 describes how we evaluate the trade diversion impact given shocks to the system.

[10]https://192.86.102.134/product_concordance.html.
[11]http://www.stats.gov.cn/tjsj/tjbz/hyflbz/201710/t20171012_1541679.html.

C.2.1 General Equilibrium System of Changes

The model solution is derived as a system of first-order approximations around an initial equilibrium corresponding to the period before the trade war. Every market-clearing condition is expressed in log-changes. The outcome depends on endogenous variables, observed initial shares, elasticities and tariff shocks. Letting $\hat{x} \equiv d \ln x$, the system describes the log-change of each endogenous variable given shocks to Chinese and foreign tariffs, $\{d\tau_{ig}, d\tau^*_{ig}\}$. Using market-clearing conditions, the solution of the model can be expressed as a system for the changes in wages per efficiency unit $\{\hat{w}_{sr}\}$, average wages in the tradable sectors $\{\hat{w}^T_r\}$, wages in the non-tradable sector $\{\hat{w}^{NT}_r\}$, employment in the tradable sector $\{\hat{L}^T_r\}$, producer prices $\{\hat{p}_s\}$, intermediate input prices $\{\hat{\phi}_s\}$, sector price indices $\{\hat{P}_s\}$, sector-level import price indices $\{\hat{P}_{Ms}\}$, product-level import price indices $\{\hat{p}_{Mg}\}$, duty-inclusive prices of imported varieties $\{\hat{p}_{ig}\}$, tariff revenues $\hat{R}$, sector-level expenditures $\{\hat{E}_s\}$, national final consumer expenditures $\hat{X}$, national value added $\hat{Y}$, national intermediate expenditures by sector $\{\widehat{P_s I_s}\}$, national sales by sector $\{\widehat{p_s Q_s}\}$, and final consumer expenditures by region $\{\hat{X}_r\}$.

Wages, Producer Prices, Input Prices, and Tradable Employment

The first set of equations characterizes $\{\hat{w}_{sr}, \hat{w}^T_r, \hat{w}^{NT}_r, \hat{L}^T_r, \hat{p}_s, \hat{\phi}_s\}$, given $\{\hat{X}_r, \hat{E}_s, \hat{P}_s, \hat{\tau}^*_{ig}\}$. First, by (3.19), we have:

$$\hat{w}_{sr} = \frac{1}{1 - \alpha_{Is}} \left(\hat{p}_s - \alpha_{Is}\hat{\phi}_s - \alpha_{Ks}\hat{L}_{sr} \right).$$

Define χ^I as an indicator that equals one if labor is immobile across sectors and zero otherwise. In the case where $\chi^I = 1$, it follows that:

$$\begin{aligned}
\hat{L}_{sr} &= 0, \\
\hat{w}_{sr} &= \frac{1}{1-\alpha_{Is}}\left(\hat{p}_s - \alpha_{Is}\hat{\phi}_s\right), \\
\hat{w}_r^T &\equiv \frac{dw_r^T}{w_r^T} = \frac{\sum_{s\in S} dw_{sr}L_{sr}}{\sum_{s\in S} w_{sr}L_{sr}} = \sum_{s\in S}\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\frac{dw_{sr}}{w_{sr}} = \sum_{s\in\mathcal{S}}\left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right)\frac{\hat{p}_s - \alpha_{Is}\hat{\phi}_s}{1-\alpha_{Is}}.
\end{aligned}$$

In the alternative case where $\chi^I = 0$, we have instead:

$$\begin{aligned}
w_{sr} &= w_r^T, \\
\hat{w}_{sr} &= \hat{w}_r^T = \frac{1}{1-\alpha_{Is}}\left(\hat{p}_s - \alpha_{Is}\hat{\phi}_s - \alpha_{Ks}\hat{L}_{sr}\right), \\
\hat{w}_r^T &\equiv \frac{dw_r^T}{w_r^T} = \sum_{s\in S}\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\left(\frac{dw_{sr}}{w_{sr}} + \frac{dL_{sr}}{L_{sr}} - \frac{dL_r^T}{L_r^T}\right), \\
\hat{L}_r^T &\equiv \frac{dL_r^T}{L_r^T} = \frac{\sum_{s\in S} dL_{sr}}{L_r^T} = \sum_{s\in S}\frac{L_{sr}}{L_r^T}\frac{dL_{sr}}{L_{sr}}.
\end{aligned}$$

Thus, it follows that:

$$\begin{aligned}
\hat{w}_r^T &= \sum_{s\in S}\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\left(\hat{w}_{sr} + \hat{L}_{sr} - \hat{L}_r^T\right) \\
&= \sum_{s\in S}\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\hat{w}_{sr} + \sum_{s\in S}\frac{L_{sr}}{L_r^T}\hat{L}_{sr} - \hat{L}_r^T \\
&= \sum_{s\in S}\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\hat{w}_{sr} \\
\sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right)\frac{1-\alpha_{Is}}{\alpha_{Ks}}\hat{w}_r^T &= \sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right)\frac{1}{\alpha_{Ks}}\left(\hat{p}_s - \alpha_{Is}\hat{\phi}_s - \alpha_{Ks}\hat{L}_{sr}\right) \\
\sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right)\frac{1-\alpha_{Is}}{\alpha_{Ks}}\hat{w}_r^T &= \sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right)\frac{\hat{p}_s - \alpha_{Is}\hat{\phi}_s}{\alpha_{Ks}} - \hat{L}_r^T.
\end{aligned}$$

In sum, we have:

$$\begin{aligned}
\hat{w}_{sr} &= \chi^I \frac{\hat{p}_s - \alpha_{Is}\hat{\phi}_s}{1-\alpha_{Is}} + \left(1-\chi^I\right)\hat{w}_r^T, \qquad \text{(C.1)}\\
\hat{w}_r^T &= \chi^I \sum_{s\in\mathcal{S}} \left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right) \frac{\hat{p}_s - \alpha_{Is}\hat{\phi}_s}{1-\alpha_{Is}} + \left(1-\chi^I\right) \frac{\sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right)\frac{\hat{p}_s-\alpha_{Is}\hat{\phi}_s}{\alpha_{Ks}} - \hat{L}_r^T}{\sum_{s\in S}\left(\frac{w_{sr}L_{sr}}{w_r^T L_r^T}\right)\frac{1-\alpha_{Is}}{\alpha_{Ks}}}. \qquad \text{(C.2)}
\end{aligned}$$

Second, by the wage rate for non-tradable sectors (3.21), we have:

$$\hat{w}_r^{NT} = \hat{X}_r - \hat{L}_r^{NT}$$

and by full employment in each region, it follows that:

$$\hat{L}_r^T = -\frac{L_r^{NT}}{L_r^T}\hat{L}_r^{NT}.$$

Thus, in sum:

$$\begin{aligned}
\hat{w}_r^{NT} &= \chi^I \hat{X}_r + \left(1-\chi^I\right)\hat{w}_r^T, \qquad \text{(C.3)}\\
\hat{L}_r^T &= \left(1-\chi^I\right)\left(\hat{w}_r^T - \hat{X}_r\right)\frac{L_r^{NT}}{L_r^T}. \qquad \text{(C.4)}
\end{aligned}$$

Third, note that by the setup, $p_{Dg} = \frac{p_s}{z_g}$; $p_{ig}^X = \delta_{ig}\, p_{Dg}$; and $P_{Ds} = \left(\sum_{g\in\mathcal{G}_s} a_{Dg} p_{D_g}^{1-\eta}\right)^{\frac{1}{1-\eta}}$ holds. It follows that $\hat{p}_{Dg} = \hat{p}_{ig}^X = \hat{P}_{Ds} = \hat{p}_s$. By (3.16) and (3.17), we have:

$$\begin{aligned}
\hat{Q}_s &= \sum_{g\in\mathcal{G}_s} \frac{d_g/z_g}{Q_s}\hat{d}_g + \sum_{g\in\mathcal{G}_s}\sum_{i\in\mathcal{I}_g} \frac{\delta_{ig}x_{ig}/z_g}{Q_s}\hat{x}_{ig},\\
&= \sum_{g\in\mathcal{G}_s} \frac{p_{Dg}d_g}{p_s Q_s}\hat{d}_g + \sum_{g\in\mathcal{G}_s}\sum_{i\in\mathcal{I}_g} \frac{p_{ig}^X x_{ig}}{p_s Q_s}\hat{x}_{ig}.
\end{aligned}$$

Further, by equations (3.16)–(3.17), (3.3) and (3.10), we have:

$$\begin{aligned}\hat{d}_g &= \hat{D}_s = \hat{E}_s + (\kappa - 1)\hat{P}_s - \kappa \hat{p}_s, \;\; \forall\, g \in \mathcal{G}_s \\ \hat{x}_{ig} &= -\sigma^* \left(\frac{d\tau^*_{ig}}{1+\tau^*_{ig}} + \hat{p}_s \right).\end{aligned}$$

Given that $\sum_{g\in\mathcal{G}_s} p_{Dg} d_g = P_{Ds} D_s$, it follows that:

$$\hat{Q}_s = \frac{P_{Ds}D_s}{p_s Q_s}\left(\hat{E}_s + (\kappa-1)\hat{P}_s - \kappa\hat{p}_s\right) - \sum_{g\in\mathcal{G}_s}\sum_{i\in\mathcal{I}_g}\frac{p^X_{ig}x_{ig}}{p_sQ_s}\sigma^*\left(\frac{d\tau^*_{ig}}{1+\tau^*_{ig}} + \hat{p}_s\right). \tag{C.5}$$

Further, by (3.15) and (3.14), we have:

$$\begin{aligned}\hat{Q}_s &= \sum_{r\in\mathcal{R}} \frac{Q_{sr}}{Q_s}\hat{Q}_{sr} \\ &= \sum_{r\in\mathcal{R}} \frac{Q_{sr}}{Q_s}\left(\frac{1-\alpha_{Ks}}{\alpha_{Ks}}\hat{p}_s - \frac{\alpha_{Is}}{\alpha_{Ks}}\hat{\phi}_s - \frac{\alpha_{Ls}}{\alpha_{Ks}}\hat{w}_{sr}\right) \\ &= \frac{1-\alpha_{Ks}}{\alpha_{Ks}}\hat{p}_s - \frac{\alpha_{Is}}{\alpha_{Ks}}\hat{\phi}_s - \sum_{r\in\mathcal{R}}\frac{p_sQ_{sr}}{p_sQ_s}\frac{\alpha_{Ls}}{\alpha_{Ks}}\hat{w}_{sr}.\end{aligned} \tag{C.6}$$

Finally, combining (C.5) and (C.6) yields:

$$\hat{p}_s = \frac{\frac{P_{Ds}D_s}{p_sQ_s}\left(\hat{E}_s + (\kappa-1)\hat{P}_s\right) + \frac{\alpha_{Is}}{\alpha_{Ks}}\hat{\phi}_s + \sum_{r\in\mathcal{R}}\frac{p_sQ_{sr}}{p_sQ_s}\frac{\alpha_{Ls}}{\alpha_{Ks}}\hat{w}_{sr} - \sigma^*\sum_{g\in G_s}\sum_{i\in\mathcal{I}_g}\frac{p^X_{ig}x_{ig}}{p_sQ_s}\frac{d\tau^*_{ig}}{1+\tau^*_{ig}}}{\frac{1-\alpha_{Ks}}{\alpha_{Ks}} + \frac{P_{Ds}D_s}{p_sQ_s}\kappa + \left(1 - \frac{P_{Ds}D_s}{p_sQ_s}\right)\sigma^*}, \tag{C.7}$$

where by (3.12), the change in the price index of intermediates is:

$$\hat{\phi}_s = \sum_{s'\in\mathcal{S}}\frac{\alpha^{s'}_s}{\alpha_{Is}}\hat{P}_{s'}. \tag{C.8}$$

Consumer Prices, Import Prices, and Tariff Revenue

The second set of equations characterizes $\{\hat{P}_s, \hat{P}_{Ms}, \hat{p}_{Mg}, \hat{p}_{ig}, \hat{R}\}$ given $\{\hat{E}_s, d\tau_{ig}\}$. First, given that $P_s = \left(A_{Ds}P_{Ds}^{1-\kappa} + A_{Ms}P_{Ms}^{1-\kappa}\right)^{\frac{1}{1-\kappa}}$, the sector price index changes according to a weighted average of producer prices and the import price index:

$$\hat{P}_s = \frac{P_{Ds}D_s}{E_s}\hat{p}_s + \left(1 - \frac{P_{Ds}D_s}{E_s}\right)\hat{P}_{Ms}. \tag{C.9}$$

Next, given that $P_{Ms} = \left(\sum_{g\in\mathcal{G}_s} a_{Mg}p_{M_g}^{1-\eta}\right)^{\frac{1}{1-\eta}}$, the import price index in sector s changes according to:

$$\hat{P}_{Ms} = \sum_{g\in G_s}\left(\frac{p_{Mg}m_g}{P_{Ms}M_s}\right)\hat{p}_{Mg}, \tag{C.10}$$

and by $p_{Mg} = \left(\sum_i a_{ig}p_{ig}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$, the product-level import price index changes according to:

$$\hat{p}_{Mg} = \sum_{i\in\mathcal{I}_g}\left(\frac{p_{ig}m_{ig}}{p_{Mg}m_g}\right)\hat{p}_{ig}. \tag{C.11}$$

Further, from (3.6), (3.5), and (3.3), we have:

$$\begin{aligned}\hat{m}_{ig} &= \hat{m}_g + \sigma\hat{p}_{Mg} - \sigma\hat{p}_{ig} \\ &= \hat{M}_s + \eta\hat{P}_{Ms} + (\sigma-\eta)\,\hat{p}_{Mg} - \sigma\hat{p}_{ig} \\ &= \hat{E}_s + (\kappa-1)\,\hat{P}_s + (\eta-\kappa)\,\hat{P}_{Ms} + (\sigma-\eta)\,\hat{p}_{Mg} - \sigma\hat{p}_{ig}.\end{aligned} \tag{C.12}$$

From the foreign export supply (3.9) and the price relationship (3.7), we also have:

$$\hat{m}_{ig} = \frac{1}{\omega^*}\left(\hat{p}_{ig} - \frac{d\tau_{ig}}{1+\tau_{ig}}\right). \tag{C.13}$$

Combining (C.12) and (C.13), it follows that:

$$\hat{p}_{ig} = \frac{\omega^*}{1+\omega^*\sigma}\left(\hat{E}_s + (\kappa-1)\hat{P}_s + (\eta-\kappa)\hat{P}_{Ms} + (\sigma-\eta)\hat{p}_{Mg}\right) + \frac{1}{1+\omega^*\sigma}\frac{d\tau_{ig}}{1+\tau_{ig}}. \tag{C.14}$$

Lastly, recall the definition of tariff revenue,

$$R = \sum_{s\in\mathcal{S}} \sum_{g\in G_s} \sum_{i\in\mathcal{I}_g} \tau_{ig} p^*_{ig} m_{ig}. \tag{C.15}$$

Taking the second-order total differentiation gives:

$$\begin{aligned} dR &= \sum_s \sum_g \sum_i \left(p^*_{ig} m_{ig} d\tau_{ig} + \tau_{ig} m_{ig} dp^*_{ig} + \tau_{ig} p^*_{ig} dm_{ig}\right) \\ &\quad + \frac{1}{2} \sum_s \sum_g \sum_i \left(2m_{ig} dp^*_{ig} d\tau_{ig} + 2p^*_{ig} dm_{ig} d\tau_{ig} + 2\tau_{ig} dp^*_{ig} dm_{ig}\right) \\ &= \sum_s \sum_g \sum_i p^*_{ig} m_{ig} d\tau_{ig} + \sum_s \sum_g \sum_i \tau_{ig} p^*_{ig} m_{ig} \left(\hat{p}^*_{ig} + \hat{m}_{ig}\right) + \sum_s \sum_g \sum_i d\tau_{ig} p^*_{ig} m_{ig} \left(\hat{p}^*_{ig} + \hat{m}_{ig}\right) \\ &\quad + \frac{1}{2} \sum_s \sum_g \sum_i \tau_{ig} d^2 \left(p^*_{ig} m_{ig}\right). \end{aligned} \tag{C.16}$$

It follows that:

$$\hat{R} = \sum_s \sum_{g\in G_s} \sum_i \frac{p^*_{ig} m_{ig}}{R} d\tau_{ig} + \sum_s \sum_{g\in G_s} \sum_i \frac{p^*_{ig} m_{ig}}{R} \left(\tau_{ig} + d\tau_{ig}\right) \left(\hat{p}^*_{ig} + \hat{m}_{ig}\right) + \frac{1}{2} \sum_s \sum_{g\in G_s} \sum_i \frac{\tau_{ig}}{R} d^2 \left(p^*_{ig} m_{ig}\right). \tag{C.17}$$

We set the last term $\tau_{ig} d^2 \left(p^*_{ig} m_{ig}\right)$ to 0, provided that the initial tariffs τ_{ig} are reasonably small. Using the solutions for $\hat{p}_{ig}$ and $\hat{m}_{ig}$ from equations (C.14) and (C.13), in addition to (3.7), we get:

$$\begin{aligned} \hat{R} &= \sum_s \sum_{g\in G_s} \sum_i \left(\tau_{ig} + d\tau_{ig}\right) \frac{p^*_{ig} m_{ig}}{R} \frac{1+\omega^*}{1+\omega^*\sigma} \left(\hat{E}_s + (\kappa-1)\hat{P}_s + (\eta-\kappa)\hat{P}_{Ms} + (\sigma-\eta)\hat{p}_{Mg}\right) \\ &+ \sum_s \sum_{g\in G_s} \sum_i \left(1 - \tau_{ig} \frac{\sigma-1}{1+\omega^*\sigma}\right) \frac{p^*_{ig} m_{ig}}{R} \frac{d\tau_{ig}}{1+\tau_{ig}} \\ &- \sum_s \sum_{g\in G_s} \sum_i \frac{p_{ig} m_{ig}}{R} \sigma \frac{1+\omega^*}{1+\omega^*\sigma} \left(\frac{d\tau_{ig}}{1+\tau_{ig}}\right)^2. \end{aligned} \tag{C.18}$$

Sector and Region Demand Shifters

The third set of equations characterizes the sector and region level expenditure shifters $\{\hat{E}_s, \hat{X}_r\}$ given $\{\hat{R}, \hat{p}_s, \hat{\phi}_s, \hat{w}_r^{NT}, \hat{w}_{sr}\}$. The expenditure in sector s is defined as $E_s = P_s C_s + P_s I_s$, and from (3.8) we have $P_s C_s = \beta_s X$, where X is the total national expenditure, defined as $X = Y + R + D$, where D is the trade deficit. We assume that the national trade deficit is determined by factors outside the model and remains unchanged. Thus, it follows that:

$$\begin{aligned} \hat{E}_s &\equiv \frac{P_s C_s}{E_s}\hat{X} + \left(1 - \frac{P_s C_s}{E_s}\right)\widehat{P_s I_s}, &\text{(C.19)}\\ \hat{X} &= \frac{Y}{X}\hat{Y} + \frac{R}{X}\hat{R}. &\text{(C.20)} \end{aligned}$$

Since we assume that the non-tradable sectors use only labor as input, this implies that the national income equals $Y = \sum_{r\in\mathcal{R}} P_{NT,r}Q_{NT,r} + \sum_{s\in\mathcal{S}} (1-\alpha_{Is})\, p_s Q_s$. Hence,

$$\hat{Y} = \sum_{r\in\mathcal{R}} \left(\frac{P_{NT,r}Q_{NT,r}}{Y}\right)\hat{X}_r + \sum_{s\in\mathcal{S}} (1-\alpha_{Is}) \left(\frac{p_s Q_s}{Y}\right) \sum_{r\in\mathcal{R}} \left(\frac{p_s Q_{sr}}{p_s Q_s}\right) \left(\hat{p}_s + \hat{Q}_{sr}\right). \tag{C.21}$$

The total demand for intermediates of sector s is defined as:

$$P_s I_s = \sum_{s'\in\mathcal{S}} \alpha^s_{s'} p_{s'} Q_{s'},$$

so that

$$\widehat{P_s I_s} = \sum_{s'\in\mathcal{S}} \alpha^s_{s'} \sum_{r\in\mathcal{R}} \frac{p_{s'}Q_{s'r}}{P_s I_s}\left(\hat{p}_{s'} + \hat{Q}_{s'r}\right). \tag{C.22}$$

Using (3.14) for Q_{sr}, we have:

$$\hat{p}_s + \hat{Q}_{sr} = \frac{1}{\alpha_{Ks}}\hat{p}_s - \frac{\alpha_{Is}}{\alpha_{Ks}}\hat{\phi}_s - \frac{\alpha_{Ls}}{\alpha_{Ks}}\hat{w}_{sr}. \tag{C.23}$$

By (3.8), we have $P_{NT,r}Q_{NT,r} = \beta_{NT}X_r$. Thus, using (3.18), the change of expenditures in region r can be expressed as:

$$\hat{X}_r = \frac{\sum_{s\in\mathcal{S}} \frac{p_s Q_{sr}}{X_r}\left(1-\alpha_{Is}\right)\left(\hat{p}_s + \hat{Q}_{sr}\right) + \frac{b_r R}{X_r}\hat{R}}{1-\frac{P_{NT,r}Q_{NT,r}}{X_r}}. \tag{C.24}$$

C.2.2 Implementation

We use the 2017 Chinese input-output (IO) tables, China Labor Statistical Yearbook of 2017, and the Chinese customs data for 2017, as documented in Appendix C.1, to parameterize the allocation shares. We basically follow the same steps as in Fajgelbaum et al. (2020) to construct the shares. Differences in the Chinese context are highlighted below. The share of expenditures on the non-tradable good is set at $\beta_{NT} = 0.6$, such that the model matches the observed 18% share of imports in GDP. Implementing the system also requires information on labor income and employment shares by regions. We allocate the sectoral labor compensation (from the IO tables) across Chinese provinces using the sector-province labor compensation shares (from China Labor Statistical Yearbook of 2017). All 31 provinces have positive employment in both tradable and non-tradable sectors. Finally, for information on import and export flows by variety, we reconcile the sector-level trade flows from the IO tables and the variety-level trade flows from the customs data, by allocating the sector-level import and export flows (from the IO tables) across varieties using the import and export shares at the variety level within each GB/T-2 sector (observed in the Chinese customs data).

C.2.3 Trade Diversion Impacts

Note that the change in Chinese imports from a trading partner i across all products in sector s is:

$$\widehat{\sum_{g\in\mathcal{G}_s} p^*_{ig}m_{ig}} = \sum_{g\in\mathcal{G}_s}\left(\frac{p^*_{ig}m_{ig}}{\sum_{g\in\mathcal{G}_s} p^*_{ig}m_g}\left(\hat{p}^*_{ig} + \hat{m}_{ig}\right)\right), \tag{C.25}$$

and across all tradable sectors is:

$$\sum_{s\in\mathcal{S}}\widehat{\sum_{g\in\mathcal{G}_s} p^*_{ig}m_{ig}} = \sum_{s\in\mathcal{S}}\sum_{g\in\mathcal{G}_s}\left(\frac{p^*_{ig}m_{ig}}{\sum_{s\in\mathcal{S}}\sum_{g\in\mathcal{G}_s} p^*_{ig}m_{ig}}(\hat{p}^*_{ig}+\hat{m}_{ig})\right). \tag{C.26}$$

By aggregating across trading partners within a set of countries $i \in \mathcal{I}_o$, the corresponding expressions are:

$$\sum_{i\in\mathcal{I}_o}\widehat{\sum_{g\in\mathcal{G}_s} p^*_{ig}m_{ig}} = \sum_{i\in\mathcal{I}_o}\sum_{g\in\mathcal{G}_s}\left(\frac{p^*_{ig}m_{ig}}{\sum_{i\in\mathcal{I}_o}\sum_{g\in\mathcal{G}_s} p^*_{ig}m_{ig}}(\hat{p}^*_{ig}+\hat{m}_{ig})\right), \tag{C.27}$$

$$\sum_{s\in\mathcal{S}}\widehat{\sum_{i\in\mathcal{I}_o}\sum_{g\in\mathcal{G}_s} p^*_{ig}m_{ig}} = \sum_{s\in\mathcal{S}}\sum_{i\in\mathcal{I}_o}\sum_{g\in\mathcal{G}_s}\left(\frac{p^*_{ig}m_{ig}}{\sum_{s\in\mathcal{S}}\sum_{i\in\mathcal{I}_o}\sum_{g\in\mathcal{G}_s} p^*_{ig}m_{ig}}(\hat{p}^*_{ig}+\hat{m}_{ig})\right). \tag{C.28}$$

Next, using (3.10), we have:

$$\begin{aligned}
\hat{x}_{ig} &= -\sigma^*\hat{p}^X_{ig} = -\sigma^*\hat{p}_s, \qquad \text{for } i \neq US; \\
\hat{x}_{ig} &= -\sigma^*\left(\frac{d\tau^*_{ig}}{1+\tau^*_{ig}} + \hat{p}_s\right), \qquad \text{for } i = US.
\end{aligned}$$

Thus, for each $s \in S$ and destination $i \neq US$, the change in Chinese exports is:

$$\begin{aligned}
\widehat{EX}_{-US,s} &= \sum_{i\neq US}\widehat{\sum_{g\in\mathcal{G}_s} p^X_{ig}x_{ig}} = \sum_{i\neq US}\sum_{g\in\mathcal{G}_s}\left(\frac{p^X_{ig}x_{ig}}{\sum_{i\neq US}\sum_{g\in\mathcal{G}_s} p^X_{ig}x_{ig}}(\hat{p}^X_{ig}+\hat{x}_{ig})\right) \\
&= \sum_{i\neq US}\sum_{g\in\mathcal{G}_s}\left(\frac{p^X_{ig}x_{ig}}{\sum_{i\neq US}\sum_{g\in\mathcal{G}_s} p^X_{ig}x_{ig}}(1-\sigma^*)\hat{p}_s\right),
\end{aligned} \tag{C.29}$$

and for $i = US$:

$$\begin{aligned}
\widehat{EX}_{US,s} &= \widehat{\sum_{g\in\mathcal{G}_s} p^X_{ig}x_{ig}} = \sum_{g\in\mathcal{G}_s}\left(\frac{p^X_{ig}x_{ig}}{\sum_{g\in\mathcal{G}_s} p^X_{ig}x_{ig}}(\hat{p}^X_{ig}+\hat{x}_{ig})\right) \\
&= \sum_{g\in\mathcal{G}_s}\left(\frac{p^X_{ig}x_{ig}}{\sum_{g\in\mathcal{G}_s} p^X_{ig}x_{ig}}\left((1-\sigma^*)\hat{p}_s - \sigma^*\frac{d\tau^*_{ig}}{1+\tau^*_{ig}}\right)\right).
\end{aligned} \tag{C.30}$$

The change in Chinese exports of all tradable sectors can be similarly aggregated from the sector-level exports.