The Global Value Chain and Welfare Effects of Tariffs—Counterfactual Analysis of Sino–US Economic and Trade Frictions

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Abstract: This paper aims to study the impact of Sino–US (China–United States) trade frictions on global value chains and welfare changes. We introduce the general equilibrium model for multi-country and multi-sector heterogeneous enterprises and combine it with an input–output structure. The results show that the additional tariffs on China and the US reduce bilateral trade and affect the overall imports and exports of both countries to varying degrees. The results show that the additional tariffs on China and the US affect both countries’ overall imports and exports to varying degrees. The impact of the trade of manufactured goods is greater than that of the trade of intermediate goods. The welfare effect in China has dropped by 0.163%, while the corresponding effect in the US has improved by 0.016%. The main reason for the decline in China’s welfare is the deterioration of the terms of trade. Increased tariffs between China and the US can reduce bilateral trade between the two countries, particularly in intermediate goods, and can cause a reorganization of global value chains in both regions.

Keywords: global value chains; tariffs; world input–output table; general equilibrium model

1. Introduction

The surge of anti-globalization sentiment has led to a slew of remarks and policies targeting China trade, the most recent impact being the outbreak of trade frictions between the US and China in 2018, with tariffs ranging from 5 to 25% on bilateral imports and exports. Even if China and the US temporarily reach a settlement, trade friction and conflict between China and the US will be a long-term issue, which means frequent friction between the two countries will probably become the norm in the future, negatively impacting Sino–US trade and the sustainable development of the global supply chain. Therefore, using counterfactual analysis, we investigate the general equilibrium consequences of Sino–US tariff hikes on global value chains and mutual welfare.

To do this, we need to address two issues: firstly, how to incorporate global value chain (GVC) characteristics into the traditional general equilibrium model; secondly, how to construct a theoretical framework that unifies input–output structures and general equilibrium analysis. Based on Eaton and Kortum (2002) [1] and Caliendo and Parro (2015) [2], we develop a multi-sector, multi-country model featuring intermediate goods, iceberg cost, roundabout production, and input–output linkages. Then, we introduce trade cost functions for intermediate and final goods to construct new equilibrium conditions. Based on the heterogeneity of trade costs, the different trade shares of intermediate and final goods are inscribed in the export sector combined with the basic elements of the input–output table, thus realizing the quantitative analysis of welfare and global value chains.

We re-estimate the different trade elasticities for intermediate and final commodities in our results analysis section and play our model with GVC features to investigate the welfare and GVC impacts of tariffs between China and the US for counterfactual analysis.
The first contribution of our paper highlights a crucial feature of different trade shares and trade elasticities between intermediates and final goods with the incorporation of input–output structures into the quantitative analysis framework of tariff (Johnson and Noguera (2012) [3] shows that the intermediates has accounted for two-thirds of world trade.). We discover that the trade elasticity of intermediate goods differs from the trade elasticity of final goods, with intermediate goods having a larger trade elasticity than final goods. This is because intermediate goods enter and exit the country multiple times and are more sensitive to trade costs than final goods. As a result, the model will be updated to include the heterogeneity of trade elasticity of intermediate and final commodities. The model enables us to distinguish heterogeneous impacts from tariffs on intermediates and final goods. The trade share of final goods is the function of production costs, trade costs, and final goods prices. The imposition of tariffs raises the cost of trade and, if all else is equal, leads to a reduction in trade volumes, which in turn affects trade and welfare and the sustainability of global value chains. Tariff reduction will drop trade costs, thus increasing trade shares of final goods, i.e., ceteris paribus. In contrast, the trade share of intermediates is the function of production costs, trade costs, and intermediates prices. Tariff reduction will decrease intermediates’ prices, thus increasing the trade share of intermediates. However, even though the tax rise shares the same rate, the magnitude of change in the trade volume of intermediate and final items is different due to the varied trade elasticities of intermediate and final goods. Through input–output linkages, it also reduces costs of reproduction and promotes the growth of exports on intermediates and final goods. Theoretically, the imposition of tariffs affects GVCs via changes in exports and imports of corresponding products.

Our model can be combined with the basic elements of the input–output table to achieve a quantitative analysis of GVCs. Based on the equilibrium in relative changes, we obtain trade flows of intermediates and final goods after tariff reduction and then calculate the value-added matrix in world input–output tables. Then, we construct two indexes with global value chain position (upstreamness which we label U) and downstreamness (which we label D) based on Wang et al. (2017) [4]. Upstreamness, proposed by Fally (2012) [5] and Antrás and Chor (2013) [6], is a measure of distance or a lens for a production sector from final consumption corresponding to the weighted-average number of production stages between production and final consumption (We define upstreamness and downstreamness consistent with Antrás and chor (2018) [7]. Upstreamness corresponds to D (distance to final demand) and Downstreamness corresponds to N (embodied production stages) in Fally (2012) [5]). Downstreamness captures the distance or lens of a given sector from the economy’s primary factor of production (or sources of value-added) corresponding to a weighted average of the number of plants sequentially involved in the production of a certain good.

Another contribution of our paper is that we apply our model to the data and investigate the benefits of tariff cuts between the US and China and the corresponding impact on global value chains. By integrating the tariffs imposed at the industry level in China and the US, we create a global input–output table to quantify changes in trade, welfare, and global value chains based on the model. In addition, we will perform a counterfactual study of a full-scale trade war between the US and China (with all tariff lines at 25%). We find that when China and the US have full-scale trade friction, China’s imports of intermediate and final goods from the US decrease by 42.74% and 71.92%, respectively, and total imports decrease by 54.74%; in turn, US imports of the three from China decrease by 37.2%, 67.76%, and 56.24%, respectively. In both China and the US, this leads to a rise in imports from other nations and a drop in exports to other countries. Tariff hikes between the two cause a 0.163% decline in welfare in China, while welfare in the US improves by 0.016%, but real wages in both countries fall. The degradation of China’s welfare is mostly driven by the erosion of trade terms, whereas the US gains from improved trade terms, confirming to some extent the notion of tariff impacts in big nations. The rise in tariffs between the US and China has had a substantial impact on both countries’ value chains,
as evidenced by a decrease in both upstreamness and downstreamness in the US and an increase in upstreamness and a decrease in downstreamness in China. This means that as tariffs between China and the US rise, the US will be forced to take on far more production connections, decreasing the benefits of specialized division of labor and resulting in import substitution of intermediate products to China.

The study is closely related to a series of studies on Sino–US trade friction and the global supply chain. Although there are plenty of academic assessments on Sino–US trade frictions, quantitative studies on the economic impacts of trade policies related to Sino–US trade frictions are still weak. Some recent efforts have been made by some scholars in this area, as Chun Ding Li et al. (2018) [8] assess the evaluation of the effects of policies in response to trade frictions between the US and China based on the general equilibrium theory modeling of trade disputes and trade games. In China and the US, Hongfu Ni, et al. (2018) [9] calculate the cumulative cost of tariffs and simulate the pricing and welfare implications of tariff hikes. Overall, China’s sectors are more affected by the existing tariff regime than those in the US. The tariff rises between the US and China, on the other hand, will result in a bigger price increase in the US than in China, resulting in a larger welfare loss for US people overall than in China. Abiad (2018) [10] shows that if all tariffs are threatened, China’s and the US’ gross domestic product (GDP) will fall by 1% and 2%, respectively, over the next 2 to 3 years. Yuan Zhou et al. (2022) [11] utilized an increase in Sino–US trade conflict as a quasi-natural experiment to examine its influence on total factor productivity (TFP) in China, finding that it has a substantial negative causal effect on TFP in China. Based on micro data of Chinese STI firms, Zhen Xu et al. (2022) [12] empirically analyzed the short-term impact of Sino–US trade frictions on Chinese firm innovation and found that Sino–US trade frictions have a significant impact on science, technology, and innovation (STI) exporters’ innovation, with advanced manufacturing exporters’ innovation being the most obvious in the field of technology. Qing Guo and Weiguang Chen (2019) [13] create five scenarios based on the current state of trade frictions between China and the US and then use the dynamic computable general equilibrium (CGE) model to quantify the economic effect of trade frictions between China and the US using a shock-weighted approach to tariff hikes. The CGE model, on the other hand, has a “black box” problem. Many academics argue that structural models are more effective when it comes to quantitative evaluations. In conclusion, majority of research on the global supply chain has focused on its long-term viability. The structural model approach has fewer parameters and is micro-based, allowing for more accurate and effective analysis and prediction of policies effects to be implemented (Haichao Fan et al., 2020) [14] and is commonly adopted (Alvarez and Lucas, 2007; Ossa, 2014; Di Giovanni et al., 2014; Hsieh and Ossa, 2016; Amiti et al., 2019; Tombe and Zhu, 2019; Caliendo et al., 2020; Caliendo and Parro, 2021) [15–21].

This paper is also closely related to a series of studies measuring the positioning of global value chains. GVC position measures are divided into two types based on the data used, the first being a macro measure based on input–output models, which studies the position of countries or sectors embedded in global value chains. In the framework of an individual country or regional input–output model, Fally (2012) and Antràs and Chor (2013) [5,6] proposed indicators to measure the distance from the production sector to the final consumer, respectively. The latter formalized the concept of upstreamness, i.e., the average stage of production in a given industry to the final consumer. Sectors located relatively upstream sell a smaller proportion of final goods to consumers and most of the products produced are used as intermediate goods for input to other sectors. However, single-country input–output tables fail to take into account the production linkages between countries and have limitations in accurately measuring a country’s position in the GVC. Based on this, Fally and Hillberry (2015) [22] and Miller and Temurshoev (2017) [23] extend upstreamness and downstreamness index measures to global multi-country input–output models. Wang Z. et al. (2017) [24] propose an average production length for the problem of inconsistent measures of upstreamness and downstreamness indexes. The second one is
based on micro customs data and macro input–output tables matching the position of firms
embedded in GVCs, mainly measured by the domestic value-added rate of processing
trade statistics exports.

The rest of the paper is structured as follows. In Section 2, we build the theoretical
model; in Section 3, we illustrate tariff and data description; in Section 4, we apply
the model to assess the impact of tariff reductions on the vertical specialization and position of
global value chains for China and the US; and in Section 5, we provide some conclusions.

2. Theoretical Model

2.1. The General Equilibrium Model

We develop a quantitative general equilibrium model incorporating input–output
linkage, GVC characteristics, and roundabout trade for empirical analysis. There are N
countries and j sectors. We denote countries by m, k, i, j and sectors by s, r. Labor is
mobile within the country but not across countries. Markets are perfectly competitive and
production requires only one factor: labor. We use Z to denote intermediate goods and F
denotes the final goods. Z^F_ij denotes the flow of sectors’ intermediate goods in country
i to country j and sector r for production. It is worth noting that we included a simple
Cobb–Douglas function form; similarly, our model may easily be expanded to a constant
elasticity of substitution (CES) function form. Households. Representative households
maximize utility by consuming final goods.

\[ U(C_j) = \prod_{s=1}^{S} C_j^s a_j^s. \]  

(1)

U(C_j) denotes household preference in country j. C^s_j denotes the consumption of house-
holds in country j for the final goods in sector s. a^s_j denotes the final demand share and
\( \sum_{s=1}^{S} a^s_j = 1 \). Households have two sources of income: labor income (wages) and transfer
payments (Transfer payments arise from the collection of tariffs by the government, which
transfers the revenue from the tariffs to households without compensation as part of their
income to purchase goods for consumption.).

Intermediate goods production. Each sector s produces a continuum of goods \( \omega^s \in [0, 1] \),
and producers use Cobb–Douglas constant-returns-to-scale technology, demanding labor and intermediate inputs from all sectors. The production function of \( \omega^s \) is

\[ a_j^s(\omega^s) = z_j^s(\omega^s) \left[ l_j^s(\omega^s) \right]^{\gamma_j^s} \prod_{r=1}^{R} \left[ M_j^{rs}(\omega^s) \right]^{\gamma_j^r}. \]  

(2)

\( z_j^s(\omega^s) \) denotes productivity of \( \omega^s \) from sector s in country j and, as set by Eaton and
Kortum (2002) [1], the production technology has the Fréchet distribution (The Fréchet
distribution function takes the form \( F(z) = e^{-Tz^{-\theta}} \), \( T_i > 0 \). \( T_i \) is the location parameter of
the distribution, reflecting the average technology level of the country, with the greater \( T_i \)
implies a larger probability that produces any good \( \omega \) with a higher productivity, reflecting
the country’s absolute advantage in producing a continuum of goods. \( \theta > 0 \), \( \theta \) (consistent
for individual countries) is the shape parameter of the distribution, reflecting the variation
within the distribution in cross-country production. Relative productivity heterogeneity
is also an indicator of comparative advantage, with greater \( \theta \) implying less variability.).
\( l_j^s(\omega^s) \) denotes the amount of labor input in production. \( \gamma_j^s \) denotes the share of labor in
total inputs. \( M_j^{rs}(\omega^s) \) denotes the amount of intermediate goods from sector r required for
producing \( \omega^s \). The parameter \( \gamma_j^r \) denotes the share of intermediate inputs from sector r in
total inputs and \( \gamma_j^r = 1 - \sum_{s=1}^{S} \gamma_j^s \).

Based on the assumption of constant returns to scale and perfect competition, firms
set their prices based on unit production costs \( c_j^s / z_j^s(\omega^s) \), and \( c_j^s \) denotes the cost of the input bundle

\[ c_j^s = Y_j^s w_j^s \prod_{r=1}^{R} P_r^{s\gamma_j^r}. \]  

(3)
$Y_i^j$ is a constant and $w_j$ denotes the wage in country $j$. $P_j^{rs}$ denotes the price of intermediate inputs from sector $r$ used by sector $s$ in country $j$.

Composite intermediates production. The composite intermediate goods in country $j$ and sector $s$ consist of two components: the final goods ($C_i^j$) and the intermediate goods ($M_i^j$) inputs. The composite intermediate goods production function is a CES aggregator, as reported in Dixit and Stiglitz (1977) [24].

$$Q_j^s = \left[ \int q_j^s(\omega^s)^{1-1/\sigma^s} d\omega^s \right]^{\sigma^s/(\sigma^s-1)}$$

(4)

$q_j^s(\omega^s)$ denotes demand for intermediates $\omega^s$ from the lowest cost suppliers in sector $s$ of country $j$. The parameter $\sigma^s > 0$ denotes the elasticity of substitution of intermediates. Producers in country $j$ and sector $s$ produce intermediates from the lowest cost suppliers across countries.

$P_j^s$ is the unit price of composite intermediate goods, and $\omega^s$ is the unit price of $p_j^s(\omega^s)$.

$$P_j^s = \left[ \int p_j^s(\omega^s)^{1-1/\sigma^s} d\omega^s \right]^{1/(1-\sigma^s)}$$

(5)

$p_j^s(\omega^s) = c_j^s / z_j^s(\omega^s)$ denotes the lowest price of intermediate goods $\omega^s$.

Trade costs. We assume heterogeneous tariffs $\tau_{ij}^r$ set by specific countries and sectors. $\tilde{\tau}_{ij}^r$ denotes the tariffs imposed by sector $s$ in country $j$ on the imports of intermediate goods from sector $r$ in country $i$ and $\tilde{\tau}_{ij}^F$ denotes the tariffs imposed by sector $s$ in country $j$ on the imports of final goods from sector $r$ in country $i$. The heterogeneity reflects in the input–output linkages and tariff barriers set on intermediates and final goods (according to the theory related to effective tariff rates, a country may impose heterogeneous tariffs on goods with different uses). We then obtain the trade cost of intermediate goods $Z_{ij}^r$ and final goods $P_{ij}^F$ as $\kappa_{ij}^r = \tilde{\tau}_{ij}^r d_{ij}^r$ and $\kappa_{ij}^F = \tilde{\tau}_{ij}^F d_{ij}^F$. We also assume they both satisfy the triangle inequality $\kappa_{ij}^r \kappa_{ij}^s > \kappa_{ij}^r d_{ij}^s$ for the “iceberg cost” (Samuelson, 1954) [25]. The iceberg cost of transporting a unit of final and intermediate goods is the same.).

Prices of intermediate and final products. The unit price of tradable intermediate goods $\omega^r$ produced in country $i$ available in country $j$ is $p_{ij}^r(\omega^r) = c_j^r \kappa_{ij}^s \kappa_{ij}^r / z_j^r(\omega^r)$. The price of intermediate goods in country $j$ is,

$$p_{ij}^r(\omega^r) = \min \left\{ p_{ij}^r(\omega^r) \right\} = \min_i \left\{ c_j^r \kappa_{ij}^s \kappa_{ij}^r / z_j^r(\omega^r) \right\}$$

(6)

According to Equation (5), the price of intermediate goods $P_{ij}^r$ is the weighted price of inputs purchased by sector $s$ in country $j$ from the lowest country-sector suppliers in the world; thus, we set a continuum of commodity $\omega^r$ as a CES function of prices,

$$P_{ij}^r = \left[ \int p_{ij}^r(\omega^r)^{1-1/\sigma^r} d\omega^r \right]^{1/(1-\sigma^r)}$$

(7)

Following Fréchet’s distribution assumption of Eaton and Kortum (2002) [1], the price of intermediate goods $P_{ij}^r$ is (According to Equations (6) and (7), the distribution function of $p_{ij}^r(\omega^r)$ is determined by the distribution of $c_j^r(\omega^r)$). According to the Fréchet distribution function property, Equation (8) can be obtained. $T_i^s$ and $\theta^r$ are the parameters of Fréchet distribution function. Similarly, we suppose that intermediate and final commodities have
distinct trade elasticities, and we designate the intermediate trade elasticity as $\theta^*_i$ and the final trade elasticity as $\theta^*_F$.)

$$P^P_j = A^T \left[ \sum_{i=1}^{I_j} T^r_i \left( c^*_i k^*_j \right)^{-\theta^*_i} \right]^{-1/\theta^*_i} \tag{8}$$

Similarly, the households consume the final goods in sector $r$ and country $j$ at the lowest cost $p^F_{ij}$, which is

$$P^F_j = A^T \left[ \sum_{i=1}^{I_j} T^r_i \left( c^*_i k^*_j \right)^{-\theta^*_F} \right]^{-1/\theta^*_F} \tag{9}$$

Then, the consumer price index of Cobb–Douglas preferences for households is in country $j$.

$$P_j = \prod_{s=1}^{S} \left( \frac{p^F_{js} / \alpha_j}{\alpha_j} \right)^{\kappa_j} \tag{10}$$

Share of expenditure. The input–output table has a distinct variation between final and intermediate goods that a country purchases from the same sector in other countries. Meanwhile, a country purchases different amounts of intermediate and final goods from different industries in a specific country (We can observe the phenomenon easily from input–output tables such as world input–output tables (WIOTs)). The heterogeneity of trade costs for products with different uses determines a country’s share of trade in intermediate and final goods. Country $j$’s total expenditures $X^r_j$ on sector $r$ is divided into expenditures on intermediate and final goods in sector $r$. The share of country $j$’s expenditures on intermediate goods in sector $r$ $\pi^r_{ij}$ is the probability that country $i$ in sector $r$ supplies the goods at the lowest price,

$$\pi^r_{ij} = \Pr \left[ p^r_{ij}(\omega^r) \leq \min p^r_{nj}(\omega^r) \right] \tag{11}$$

Based on Fréchet distribution, the share of expenditures on sector $r$ intermediate goods in country $i$ is $\pi^r_{ij}$ is the one derived from the fact that the probability that $p^r_{ij}(\omega^r)$ is the lowest cost and $\pi^r_{ij} = \Pr \left[ p^r_{ij}(\omega^r) \leq \min p^r_{nj}(\omega^r); n \neq i \right] = \int_0^{\infty} \prod_{n \neq i} \left[ 1 - G_{nj}(p) \right] \ dG_{ij}(p)$. Given $G_{ij}(p) = 1 - e^{-T_i(c, d_{ij})^{-\theta} p^F}$, we can obtain $dG_{ij}(p) = T_i(c, d_{ij})^{-\theta} \theta p^F \ d\phi_j$. Considering the continuum assumption, this probability is also the fraction of goods that country $j$ purchases from country $i$. The same reason leads to the formula for the $\pi^F_{ij}$,

$$\pi^F_{ij} = \frac{T^r_i \left( c^*_i k^*_j \right)^{-\theta^*_F}}{\sum_{i=1}^{I_j} T^r_i \left( c^*_i k^*_j \right)^{-\theta^*_F}} \tag{12}$$

Similarly, the share of expenditures on sector $r$ final goods in country $i$ is

$$\pi^F_{ij} = \frac{T^r_i \left( c^*_i k^*_j \right)^{-\theta^*_F}}{\sum_{i=1}^{I_j} T^r_i \left( c^*_i k^*_j \right)^{-\theta^*_F}} \tag{13}$$

Market clearing. For sector $s$ of country $j$, the total output is equal to the sales of intermediate goods and final goods. The sales of intermediate goods are used as intermediate inputs by producers and sales of final goods are consumed by consumers in all countries
where $I_k$ is the total income of country $k$, including labor income $w_k L_k$, tariff revenue $R_k$, and the trade surplus $D_k$,

$$I_k = w_k L_k + R_k + D_k = w_k L_k + D_k + \sum_{m=1}^{J} \sum_{s=1}^{S} \sum_{r=1}^{I} \frac{\pi_{ji}^{sr}}{1 + \tau_{ji}^{sr}} \gamma_i^{sr} Y_i^{sr} + \sum_{m=1}^{J} \sum_{s=1}^{S} \frac{\pi_{mk}^{sr}}{1 + \tau_{mk}^{sr}} \gamma_k^{sr} Y_k + \sum_{s=1}^{S} \frac{\pi_{si}^{sr}}{1 + \tau_{si}^{sr}} \gamma_i^{sr} I_i + D_j$$

Imports of country $j$ are equal to exports plus the trade surplus expressed as imports of intermediate goods $M_{ij}^{sr}$ and final goods $M_{ij}^{sf}$ (including domestic countries). Exports of country $j$ include exports of intermediate goods $E_{ij}^{sr}$ and final goods $E_{ij}^{sf}$. $D_j$ is the trade surplus.

$$\sum_{j=1}^{J} \sum_{s=1}^{S} \sum_{r=1}^{I} \frac{\pi_{ji}^{sr}}{1 + \tau_{ji}^{sr}} \gamma_j^{sr} Y_j^{sr} + I_j = \sum_{j=1}^{J} \sum_{s=1}^{S} \sum_{r=1}^{I} \frac{\pi_{ji}^{sr}}{1 + \tau_{ji}^{sr}} \gamma_j^{sr} Y_j^{sr} + \sum_{s=1}^{S} \sum_{r=1}^{I} \frac{\pi_{si}^{sr}}{1 + \tau_{si}^{sr}} \gamma_i^{sr} I_i + D_j$$

$M_{ij}^{sr}$ denotes imports of intermediate goods from country $i$ in sector $s$ by country $j$’s sector $r$. $M_{ij}^{sf}$ denotes country $j$’s imports of final goods from country $i$ in sector $s$. The total consumer expenditure on final goods in country $j$ is equal to the sum of all national and sectoral imports of final goods. The total income equals the sum of all national and sectoral imports of final goods.

$$\sum_{j=1}^{J} \sum_{s=1}^{S} M_{ij}^{sf} = I_j, \quad E_{ij}^{sr} = \frac{\pi_{ji}^{sr}}{1 + \tau_{ji}^{sr}} \gamma_j^{sr} Y_j^{sr}$$

Denotes exports of intermediate goods from country $j$ in sector $s$ to country $i$.

Defining equilibrium. Under a tariff $\tau$, the equilibrium of wages and prices satisfies the following equilibrium conditions.

A bundle of costs:

$$c_j^r = Y_j^r w_j \prod_{r=1}^{S} P_{ij}^{sr}$$

The price of intermediate goods:

$$P_{ij}^{sr} = A^r \left[ \sum_{s=1}^{S} T_i^{r} \left( c_j^r k_i^{sr} \right)^{-\theta_{i}^r} \right]^{-1/\theta_{i}^r}$$

The price of the final goods:

$$P_{ij}^{sf} = A^r \left[ \sum_{s=1}^{S} T_i^{r} \left( c_j^r k_i^{sr} \right)^{-\theta_{i}^r} \right]^{-1/\theta_{i}^r}$$

Expenditure shares in intermediate goods:

$$\pi_{ij}^{sr} = \frac{T_i^{r} \left( c_j^r k_i^{sr} \right)^{-\theta_{i}^r}}{\sum_{s=1}^{S} T_i^{r} \left( c_j^r k_i^{sr} \right)^{-\theta_{i}^r}}$$
Expenditure shares in final goods:

\[ \pi_{ij}^F = \frac{T_j^i \left( c_j^{F'} \right)^{-\theta}}{\sum_{i=1}^{J} T_j^i \left( c_j^{F'} \right)^{-\theta}} \]  

(21)

Total output:

\[ Y_j^s = \sum_{s=1}^{S} \sum_{r=1}^{I} \frac{\pi_{ij}^s}{1 + \tau_{jk}} \gamma_{s} r_{k} + \sum_{k=1}^{1} \frac{\pi_{jk}^s}{1 + \tau_{jk}} \alpha_{k}^s \ln k \]  

(22)

Market clearing:

\[ \sum_{i=1}^{I} \sum_{s=1}^{S} \sum_{r=1}^{S} \pi_{ij}^s \gamma_{s} r_{j} + I_j = \sum_{i=1}^{I} \sum_{s=1}^{S} \pi_{ij}^s \gamma_{s} r_{j} + \sum_{s=1}^{S} \sum_{i=1}^{I} \pi_{ij}^s \alpha_{s}^i \ln + D_j \]  

(23)

Defining the changing equilibrium. We define \( \hat{\tau} = \tau' / \tau \), the intermediate goods tariff change \( \tilde{\tau}_{ij}^s \) and the final goods change \( \tilde{\tau}_{ij}^s \), respectively. According to Formula (17)–(23), we further define the changing balance, namely, the trade costs of intermediate products \( \tilde{\tau}_{ij}^s \) and the trade costs of final products \( \tilde{\tau}_{ij}^s \) have changed in the case of the change in the trade cost structure (define \( \hat{\tau} = \tau' / \tau \)), respectively. The equilibrium of wage level and price change is to satisfy the change equilibrium condition according to Equations (17)–(23).

2.2. The Input–Output System Incorporating GVCs Characteristics

We construct a world input–output system to derive the intermediate and final trade flows,

\[ Z_{ij} = \pi_{ij}^s r_{j} \gamma_{s} r_{j} + I_j \]  

(24)

\[ P_{ij}^s = \pi_{ij}^s \alpha_{s}^i \left[ \sum_{r=1}^{I} \gamma_{s} r_{j} - \sum_{i=1}^{I} \sum_{s=1}^{S} r_{ij}^s \right] + D_j \]  

(25)

According to Equations (24) and (25), we construct a new input-output system. Meanwhile, according to Antrás and Chor (2018), upstreamness and downstreamness degree indices are calculated respectively.

2.3. Mechanism for Actual Wage and Welfare Changes

2.3.1. Changes in Real Wages

The real wages can be expressed as the consumer price-adjusted nominal wage \( w_j / P_j \), where \( w_j \) denotes the nominal wage, in Equation (3). \( P_j \) denotes the consumer price index, in Equation (11). A rise in the real wages signifies a gain in buying power since it represents the quantity of a basket of products that can be purchased with wage income. There are two main channels through which real wages can increase: one is a constant nominal wage and a relative decrease in prices; the other is a constant price and a relative increase in nominal wages. We decompose the relative change in real wages \( \tilde{w}_j / P_j \) (the change in real wages in logarithmic form) based on the change in the consumer price index \( P_j \) and the change in nominal wages \( \tilde{w}_j \). We decompose the relative change in real wages \( \tilde{w}_j / P_j \) (the change in real wages in logarithmic form) based on the change in the consumer price index \( P_j \) and the change in nominal wages \( \tilde{w}_j \). (The detailed derivation process is shown in Supplementary Materials).

\[ \ln \frac{\tilde{w}_j}{P_j} = - \sum_{s=1}^{S} \frac{\alpha_{s}^s}{\beta_s} \ln \tilde{\gamma}_{j}^s = - \sum_{s=1}^{S} \frac{\alpha_{s}^s}{\beta_s} \ln \tilde{\gamma}_{j}^s + \sum_{r=1}^{r_{j}} \frac{\beta_{r}^s}{\beta_{r}} \ln \tilde{\gamma}_{j}^s + \sum_{r=1}^{r_{j}} \frac{\beta_{r}^s}{\beta_{r}} \ln \tilde{\gamma}_{j}^s \]  

(26)

Using the decomposition results of Equation (26), we find that the change in real wages can be decomposed into the change in the share of domestic final goods expenditure
in each industry \( \pi_{j}^{sF} \) and the change in the price of intermediate goods inputs relative to the price of final goods in each industry \( \ln \sum_{r=1}^{S} \frac{P_{rs}}{P_{j}} \). This also means that changes in real wages are unrelated to the percentage of domestic intermediate products traded, but solely to the share of domestic final goods traded, which is one of the key contrasts between the conclusions of this research and those of classic trade welfare studies (For example, Arkolakis et al. (2012) [26] and Caliendo and Parro (2015) [2] argue that under a variety of trade models, the percentage of expenditures on domestic products and trade elasticities are the only two statistics that can be used to quantify trade profits. However, none of the discussions of domestic trade shares distinguish between the share of trade in intermediate goods and the share of trade in final goods).

According to the last term of Equation (26) \( \sum_{s=1}^{S} a_{j}^{rs} \ln \sum_{r=1}^{S} \frac{P_{rs}}{P_{j}} \), the final goods tariff reduction leads to a decrease in the price of final goods in sector \( s \) in country \( j \) (a decrease in \( P_{j}^{sF} \)) which, if all other things are equal, leads to an increase in the real wage level and consumers in country \( j \) ultimately benefit from the expansion of imports. However, a decline in \( P_{j}^{sF} \) will also indirectly lead to a decline in the share of domestic final goods expenditure \( \pi_{j}^{sF} \), raising the real wage level.

The impact of tariff reductions on intermediate goods is slightly more complex; on the one hand, a reduction in intermediate goods tariffs will bring about a decrease in the price of imported intermediate goods \( P_{j}^{s} \), as well as an increase in real wages. However, a fall in \( P_{j}^{s} \) will also lead to a fall in domestic production costs (\( \rho_{ij}^{s} \)), which in turn will lead to a rise in the share of domestic final goods expenditures \( \pi_{ij}^{sF} \). As a result, the impact of lower tariffs on imported intermediate items on real wages is determined by how these two pressures interact.

### 2.3.2. Changes in Welfare

Representative consumer benefits in country \( j \) is \( W_{j} = I_{j} / P_{j} \) (Welfare is a measure of how much a country really spends. Tariff transfers occur when the government sets tariffs, and the welfare of a country’s consumers is influenced not just by real wages, but also tariff transfers and trade surpluses.), where \( I_{j} \) denotes total income, which can be obtained by Equation (15). \( P_{j} \) denotes the consumer price index, in Equation (11). We further differentiated the logarithmic form of welfare \( dlnW_{j} \), according to the equilibrium conditions of the model change to obtain the structural decomposition of the change in \( dlnW_{j} \). (The detailed derivation process is shown in Supplementary Materials).

\[
dlnW_{j} = \frac{1}{I_{j}} \sum_{s=1}^{S} \sum_{r=1}^{f} (E_{ij}^{sF} dlnc_{ij}^{s} - M_{ij}^{sF} dlnc_{ij}^{s}) + \frac{1}{I_{j}} \sum_{s=1}^{S} \sum_{r=1}^{f} \alpha_{ij}^{sF} M_{ij}^{sF} (dlnM_{ij}^{sF} - dlnc_{ij}^{s}) + \frac{1}{I_{j}} \sum_{s=1}^{S} \sum_{r=1}^{f} \gamma_{ij}^{sF} M_{ij}^{sF} (dlnM_{ij}^{sF} - dlnc_{ij}^{s})
\]

(27)

According to Equation (29), the welfare change may be split into two primary elements: one being the terms of trade and income impact of final goods, and the other being the terms of trade and income effect of intermediate goods, which is one of the other significant discrepancies between this paper and Caliendo and Parro (2015) [2].

The first term \( \frac{1}{I_{j}} \sum_{s=1}^{S} \sum_{r=1}^{f} (E_{ij}^{sF} dlnc_{ij}^{s} - M_{ij}^{sF} dlnc_{ij}^{s}) \) denotes the final goods terms-of-trade effect. The above equation expresses the difference between the change in the unit cost of exported products \( dlnc_{ij}^{s} \) weighted by the share of revenue of final goods exports \( E_{ij}^{sF} / I_{j} \) from all sectors to all countries in country \( j \), and the change in the unit cost of imported products \( dlnc_{ij}^{s} \) weighted by the share of revenue of final goods imports \( M_{ij}^{sF} / I_{j} \) from all countries and sectors in that country, and is used to portray the impact of tariff
changes (whether final or intermediate goods tariffs) on the terms of the trade of final goods. The second term \( \frac{1}{I_j} \sum_{s=1}^{S} \sum_{i=1}^{I} \tau_{ij}^{FS} M_{ij}^{FS} (d \ln M_{ij}^{FS} - d \ln c_{ij}^{F}) \) stands for the trade volume effect of final goods, which is calculated as the total amount of change in the final goods import trade volume (excluding the effect of import price changes) divided by the revenue share of final goods import tariff revenue from all countries and sectors in country \( j \). It is used to show how changes in the final products’ import volume affect tariff income as a result of tariff modifications (whether final goods tariff or intermediate goods tariff). Similarly, the third \( \frac{1}{I_j} \sum_{s=1}^{S} \sum_{i=1}^{I} \sum_{r=1}^{S} \tau_{ij}^{RS} M_{ij}^{RS} (d \ln M_{ij}^{RS} - d \ln c_{ij}^{R}) \) and fourth term \( \frac{1}{I_j} \sum_{s=1}^{S} \sum_{i=1}^{I} \sum_{r=1}^{S} \tau_{ij}^{RS} M_{ij}^{RS} (d \ln M_{ij}^{RS} - d \ln c_{ij}^{R}) \) depict the impact of tariff increases on the intermediate goods terms of trade and the impact of changes in the volume of intermediate goods imports caused by tariff changes on tariff revenues, respectively.

A drop in import tariffs, according to the theoretical model, will increase the import share. The volume impacts of trade in intermediate and final items are dependent on the change in the import share relative to the price of the imported product, as indicated in terms 2 and 4. As a result, with the price of imported items (i.e., costs) remaining unchanged after tariff prices are removed, tariff reductions on intermediate and final goods will result in a positive change in the income impact, improving welfare. In fact, according to the standard trade model, lowering import tariffs will result in an increase in import supply as well as an increase in the marginal cost of production in the supplying country, increasing the price of imported products excluding the tariff price. However, because the general elasticity of demand is greater than 1 and the magnitude of price change is less than the magnitude of change in the trade volume \( (d \ln M_{ij}^{FS} > d \ln c_{ij}^{F}) \), the tariff reduction will not increase the price of imported products excluding the tariff price.

Unlike the income impact, the tariff increase has the exact opposite effect on the conditions of trade. According to the theoretical and standard models, a country’s unilateral increase in tariffs, which raises the price of imported products excluding tariff prices, will result in negative trade effect terms with no change in the price of exported goods, resulting in a worsening of the terms of trade. Since an increase in import tariffs on final goods does not affect the pricing of a country’s exports, an increase in intermediate goods tariffs will increase the prices of exports manufactured with imported inputs. As a result, raising tariffs on intermediate or final items will have a negative effect on the terms of trade, reducing overall welfare.

The amount of the overall welfare, whether positive or negative, is determined by relative changes in the terms-of-trade impact and the tariff revenue effect, weighted by the percentage of exports and imports in total expenditures.

3. Tariff and Data
3.1. Tariff Description

In the previous section, the WIOTs is used to match the model, so we need to tabularize WIOTs with real data. However, there is no tariff data in the published statistics of WIOD, which means that we need to recompile WIOTs and explains that we can obtain the complete WIOTs of the base period. Data with all 0 are merged appropriately.

Based on the 2016 version released by WIOD, this article focuses on the research of imported intermediate and final goods tariffs from the perspective of value-added. Based on WIOTs in 2014, the tariff rate data are introduced to compile a new WIOTs. It is worth noting that although the intermediate transaction items in the WIOD database are not fully compiled in terms of basic price and compiling different trade costs in the form of value-added is complicated, it is feasible to compile the value-added form of tariff costs directly from the import tariff rates imposed by countries with little inconsistency against the assumptions of the model in this article.

The specific process of compiling the WIOTs of this model is as follows: (1) The main data for compiling the table comes from the import tariff rate of intermediate goods and final goods divided by the industry sectors in WIOD. The WTO tariff database
The required data include sector-level bilateral tariffs (from the TRAINS database of the United Nations Statistics Division (UNSD), ISIC Rev. 3), bilateral trade flows (from the COMTRADE database of the United Nations Statistics Division (UNSD), HS6 code), multi-regional input–output tables (WIOTs, released in 2016, from WIOD), value-added, and total output (both from WIOTs). There are a large number of optional world input–output tables available, and the WIOD database has the benefit of including the most current data, which covers 44 countries and regions (including a row region) with 56 industrial sectors. The tariff data are mainly from WTO, and the missing data are supplemented by the TRAINS tariff database in WITS. If there are still missing data in certain countries in certain years, replace them with the most recent year for which data are available in that country. Similarly, non-most-favored-nation tariffs under preferential trade arrangements are also based on the WTO tariff database and supplemented by the TRAINS tariff database. If there are missing data for certain preferential arrangements in certain years, it will also be replaced with adjacent years with data) are matched and processed. This article has compiled a tariff database that is consistent with the national sector of the world input–output tables of the WIOD 2016 version from 2000 to 2017. Certain improvements have also been made in the selection of tariff rate data. (1) Preferential trade arrangements between countries are considered rather than just the most-favored-nation arrangements when selecting tariff rates. (2) Distinguish the tariff rate between intermediate goods and final goods. The phenomenon of “tariff escalation” generally exists in the practice of tariff policies of various countries, that is, the final products tend to bear higher tariff barriers than intermediate goods when entering the country’s market. For example, in 2014, the average import tariffs on final goods in China, EU countries, Canada, and Turkey were 1.08 times, 1.58 times, 2.27 times, and 2.73 times the average import tariffs on intermediate goods, respectively. Figure 1 shows the industry distribution of bilateral tariffs between China and the United States in 2014 (differentiating intermediate goods and final goods). (2) We can obtain the corresponding import tariff amount by multiplying the tariff rate data of the matching WIOT industry in 2014 by the corresponding intermediate goods (or final goods) of WIOD in 2014. (3) The value-added (or labor factor reward) in this model can be calculated by using the original total output of each industry sector in the WIOD tables minus the intermediate inputs and tariffs imposed by the corresponding industry sector in the WIOTs.

Figure 1. (a) The US tariff levels on Chinese imports in 2014; (b) China’s tariff levels on US imports in 2014. Source: the tariff list published by the Office of the United States Trade Representative and the Ministry of Commerce of the People’s Republic of China. Comparison of weighted import tariffs in China and the US (MFN).

3.2. Data Sources

The required data include sector-level bilateral tariffs (from the TRAINS database of the United Nations Statistics Division (UNSD), ISIC Rev. 3), bilateral trade flows (from the COMTRADE database of the United Nations Statistics Division (UNSD), HS6 code), multi-regional input–output tables (WIOTs, released in 2016, from WIOD), value-added, and total output (both from WIOTs). There are a large number of optional world input–output tables...
tables available, and the WIOD database has the benefit of including the most current year analyzed in this study, 2014, in its database. Because of the scarcity of data, this paper is primarily based on 2014 data as the base model; however, because this paper focuses on the change in welfare effect as a result of increased trade frictions, which is a percentage concept, the use of 2014 data has no significant impact on the conclusion, and the results are credible.

This paper uses data from 51 US states (50 states plus Washington, D.C., where manufacturing value-added as a percentage of GDP was only 0.29% in 2012), 43 other countries (including the rest of the world), and 34 sectors classified according to the WIOD (for which the number of countries and industries is set up according to the principle of maximum segmentation, as required by the inscribed model to collect the required production and trade data). With regards to manufacturing (23 sectors), there are 45 industries in the Naics classification: 22 are in manufacturing and 17 of the remaining 23 are in retail. In the control with WIoD classification, 22 of the manufacturing industry classifications can be controlled one-to-one with Naics classification, in which there are multiple control groups, respectively. There are two groups of two industries in WIoD jointly controlled as a category of Naics, namely r12 and r11 of WIoD jointly controlled with Naics 325 (Naics_id 12), and r20 and r21 of WIoD jointly controlled with Naics 336 (Naics_id 12). There are two sets of WIoDs in which one industry is jointly mapped to multiple industries of Naics, such as r5 of WIoD against two industries of Naics 311–312 and r6 of WIoD against four industries of Naics 313–316. For the first case, we assign the same share to each of the two industries according to the Naics classification industry, and for the second case, there is an accrual. The most essential element of the Naics categorization for the service industry is that the manufacturing sector is more detailed, but the service industry is coarser and the CFS is a commodity flow study, whereas the service business is mostly intangible goods transactions. In contrast, WIoD’s service industry classification is finer, with 33 service industries; thus, our main way of matching is to try to draw a comparison, and then compress the WIoD service industry classification into 11 service industries. Eight of the services in the WIoD can be cross-referenced one-to-one or one-to-many with the Naics classification for 6 services, and the remaining 15 services are divided into five industries: construction and real estate, finance and insurance, utilities, education and health care, arts and entertainment, and other services (which are allocated according to the average value of each industry in each state based on other services).

For the tariff data processing and matching, the following steps are used in this paper. First, missing data from the TRAINS database bilateral sector tariffs (2-decile ISIC Rev. 3 methodology classification, 96 sectors) for 2014 are filled in based on the relevant data for 2013. Second, a weighted average of the import shares of the 43 countries and economies is used to obtain the tariffs at the bilateral level between each country and the world as a whole, as the tariff level of the ROW economies. Third, matching tables are generated by comparing industries from the TRAINS database (two-digit ISIC Rev. 3 Methodological Classification, 96 industries) with industries from the WIoD database (two-digit ISIC Rev. 4 Methodological Classification, 23 tradable industries) according to the ISIC Rev. 3 and ISIC Rev. 4 classifications. Fourth, using industry import shares as weights, bilateral tariffs are calculated for 44 nations and economies (43 countries and 1 ROW (rest of the world)) for 23 tradable sectors defined by WIoD database industries.

3.3. Solving for the Model

We solve the equilibrium in relative changes with $\gamma^r_j$, $\gamma^s_{ij}$, $\pi^{\tau}_ij$, $\pi^{\tau F}_ij$, and $\alpha^r_j$, listed in Table 1.
where the advantages are more substitutable. In this paper, we refer to a new method for estimating discrete parameters proposed by Caliendo and Parro (2015) [2] for parameter estimation. Consider the following three countries: \( h, i, \) and \( n \). Assuming that sector \( j \) goods are transported in one direction (from \( n \) to \( i \), from \( i \) to \( h \), or from \( h \) to \( n \)), and that the same goods are transported from the opposite direction, considering the gravitational equation model of trade and trade costs between the three countries, we can obtain:

\[
\frac{X_{ji}^i X_{ih}^j X_{hn}^j}{X_{ih}^j X_{hi}^i X_{in}^j} = \left( \frac{\kappa_{ni}}{\kappa_{ih} \kappa_{hn}} \right)^{-\theta} \tag{28}
\]

Log linearization of \( \kappa_{ni}^j \) according to the trade cost components:

\[
\ln \kappa_{ni}^j = \ln \tilde{\tau}_{nj}^i + \ln \delta_{ni}^j + \ln \tilde{\tau}_{nj}^i + \ln v_{ni}^j + \mu_h + \delta_i^j + \epsilon_{ni}^j \tag{29}
\]

where \( v_{ni}^j \) captures the effects of distance, language, common border, or free trade agreement symmetric bilateral trade variables; \( \mu_h \) and \( \delta_i^j \) captures importing and exporting country industry fixed effects; and \( \epsilon_{ni}^j \) is a random disturbance term. Substituting Equation (29) into (28) and collapsing it yields:

\[
\ln \left( \frac{X_{ni}^i X_{ih}^j X_{hn}^j}{X_{ih}^j X_{hi}^i X_{in}^j} \right) = -\theta \ln \left( \frac{\tilde{\tau}_{ni}^i \tilde{\tau}_{ih}^j \tilde{\tau}_{hn}^j}{\tilde{\tau}_{ih}^j \tilde{\tau}_{hi}^i \tilde{\tau}_{in}^j} \right) + \tilde{\epsilon}_{ni}^j \tag{30}
\]

where \( \tilde{\epsilon}_{ni}^j \) is the new random perturbation term. According to Equation (30), we estimate the parameters for the full sample, the 99% sample, and the 97% sample using bilateral industry trade data as well as tariff data for 43 representative countries in 2014 to obtain discrete parameters, i.e., trade elasticities, for 23 goods trade industries under the three estimated samples, and the results are presented in Table 2.

| Parameter | Definition | Calculation | Data Sources |
|-----------|------------|-------------|--------------|
| \( \gamma_{ij}^l \) | Share of labor inputs | \( \frac{V_{ij}^l}{Y_{ij}^l} \) | WIOD |
| \( \gamma_{ij}^r \) | Share of intermediates | \( \frac{1}{\sum_{i} \gamma_{ij}^r / Y_{ij}^r} \) | WIOD |
| \( \alpha_{ij}^r \) | Share of final consumption | \( \frac{\sum_{i} p_{ij}^{rF} / \sum_{s} \sum_{i} p_{ij}^{rF}}{} \) | WIOD |
| \( \bar{\tau}_{ij}^r \) | Tariff on intermediates | Data sources | WTO\BACI |
| \( \bar{\tau}_{ij}^{rF} \) | Tariff on final goods | Data sources | WTO\BACI |
| \( \pi_{ij}^r \) | Share of intermediates | \( \frac{Z_{ij}^{rF} (1 + \bar{\tau}_{ij}^r)}{\sum_{s} \tilde{Z}_{ij}^{rF} (1 + \tilde{\tau}_{ij}^r)} \) | WIOD\BACI |
| \( \pi_{ij}^{rF} \) | Share of final goods | \( \frac{\tilde{\tau}_{ij}^{rF} (1 + \bar{\tau}_{ij}^r)}{\sum_{s} \tilde{p}_{ij}^{rF} (1 + \tilde{\tau}_{ij}^r)} \) | WIOD\BACI |

The productivity dispersion parameter \( \theta \) represents a comparative advantage, or trade elasticity, as it reflects the change in trade volume relative to trade costs. Because goods are comparatively more irreplaceable in terms of production efficiency, changes in trade costs are less likely to influence the percentage of traded goods if productivity is more discrete, meaning larger \( \theta \). On the other hand, if productivity is highly concentrated, i.e., the dispersion \( \theta \) is low, small changes in trade costs can translate into large adjustments in the share of traded goods because producers are more likely to change their suppliers. After all, the advantages are more substitutable. In this paper, we refer to a new method for estimating discrete parameters proposed by Caliendo and Parro (2015) [2] for parameter estimation. Consider the following three countries: \( h, i, \) and \( n \).
Table 2. Estimation results of trade elasticity of intermediate goods (final goods).

| Industry                | Full Sample | 99% Sample | 97.5% Sample |
|-------------------------|-------------|------------|--------------|
|                         | θ           | s.e.       | N            | θ           | s.e.       | N            | θ           | s.e.       | N            |
| Crop                    | 3.57        | 0.81       | 247          | 3.07 (1.46) | 1.00 (1.28) | 187 (187)    | 2.86        | 1.05       | 146          |
| Forestry and logging    | 7.43        | 4.73       | 95           | 11.00 (2.77) | 7.61 (9.38) | 46 (18)      | 16.09       | 9.62       | 25           |
| Fishing                 | 2.89        | 3.85       | 135          | 5.84 (4.33) | 4.93 (6.75) | 124 (93)     | 6.44        | 5.31       | 93           |
| Mining and quarrying    | 11.73       | 14.46      | 247          | 8.80 (11.05) | 15.30 (15.50) | 196 (156) | 9.27        | 13.98       | 146          |
| Food products           | 3.64        | 1.44       | 247          | 2.67 (2.42) | 1.68 (1.13) | 187 (187)    | 2.28        | 1.86       | 146          |
| Textiles                | 8.15        | 3.03       | 247          | 2.67 (1.84) | 2.86 (3.88) | 187 (187)    | 3.71        | 2.93       | 146          |
| Fishing                 | 6.96        | 5.38       | 247          | 7.04 (5.18) | 6.28 (7.84) | 187 (187)    | 2.60        | 10.64      | 146          |
| Paper                   | 1.37        | 4.11       | 247          | 1.29 (6.60) | 4.33 (9.53) | 196 (196)    | 0.38        | 4.48       | 146          |
| Printing                | −5.37       | 10.61      | 175          | 10.73 (12.65) | 8.54 (9.97) | 133 (87)     | 12.71       | 9.85       | 79           |
| Coke                    | 48.84       | 8.24       | 235          | 56.17 (51.00) | 9.49 (12.08) | 180 (180)    | 52.45       | 9.59       | 146          |
| Chemicals               | −1.15       | 2.08       | 247          | 6.85 (1.49) | 3.26 (3.77) | 146 (146)    | 6.85        | 3.26       | 146          |
| Pharmaceutical          | −11.06      | 8.74       | 184          | 11.1 (12.55) | 7.80 (10.84) | 144 (181)    | 8.16        | 11.02      | 75           |
| Rubber                  | 0.53        | 2.63       | 247          | 3.29 (8.06) | 2.79 (3.04) | 196 (196)    | 2.23        | 3.09       | 146          |
| Non-metallic mineral    | 4.10        | 3.21       | 247          | 4.33 (11.01) | 3.66 (4.43) | 192 (187)    | 6.47        | 3.82       | 146          |
| Fabricated metal        | −13.39      | 5.69       | 247          | 0.66 (14.86) | 8.57 (8.35) | 146 (152)    | 1.69        | 11.19      | 106          |
| Electronic              | −4.19       | 3.03       | 247          | 6.35 (5.61) | 4.95 (5.17) | 75 (146)     | 6.35        | 4.95       | 75           |
| Electrical equipment    | 1.15        | 2.29       | 241          | 10.73 (11.00) | 4.29 (5.37) | 106 (108)    | 8.74        | 4.44       | 106          |
| Machinery               | 0.15        | 2.94       | 247          | 3.72 (4.62) | 2.83 (4.07) | 196 (187)    | 6.29        | 3.23       | 146          |
| Motor vehicles          | 8.47        | 2.02       | 247          | 10.18 (8.05) | 2.10 (3.27) | 187 (192)    | 9.24        | 2.25       | 146          |
| Other transport         | 2.17        | 3.64       | 237          | 12.71 (9.89) | 6.13 (8.46) | 137 (184)    | 9.48        | 6.36       | 108          |
| Furniture               | 0.74        | 4.73       | 247          | 7.02 (6.87) | 5.67 (8.67) | 187 (187)    | 6.68        | 5.11       | 146          |
| Repair                  | 164.6       | 7.57       | 9            | 148.00 (315.58) | 33.95 (50.11) | 7 (7)        | 132.57      | 103.86     | 5            |
| Population              | 3.74        | 0.59       | 5003         | 4.87 (3.88) | 0.79 (0.93) | 3528 (3497)  | 4.70        | 0.82       | 2754         |

Note: The values in the brackets are the corresponding values of the final goods, and only 99% of the sample data are marked due to space limitations. The baseline estimate is the result of 99% of the sample, controlling for outliers. Since there are fewer observations in the mechanical repair industry which results in abnormal results, we use the overall to replace the mechanical repair industry.

From Table 2, it can be found that the trade elasticity of different types of products is heterogeneous. In general, the trade elasticity of intermediate goods is greater than that of final goods, which is because intermediate goods enter and exit the country multiple times and are more sensitive to trade costs than final goods. In terms of industry distribution, most industries show the same trend overall.

4. Counterfactual Simulation Analysis

This section mainly estimates the trade and welfare effects of additional tariffs on Sino–US trade frictions. We attempt to collect available tariff and trade flow data for our model to maximize the number of countries covered in the estimated sample. Finally, using 2014 as the base year, we selected a basic sample covering 44 countries and regions (43 countries and regions, and a constructed rest of the world), as well as 56 industries (23 tradable industries and 33 non-tradable industries). Based on this sample, we perform a quantitative study on the welfare effect under the Sino–US comprehensive trade friction; in other words, we quantitatively analyze the welfare effect of the two countries imposing 25% additional tariffs on all imported goods under the Sino–US comprehensive trade friction. Trump threatened to increase tariffs on 200 billion Chinese imports from 10 to 25% on 1 January 2019 before an agreement was reached, and did not rule out the possibility of imposing taxes on all remaining Chinese imports in the future. After an agreement is reached, the possibility of imposing a comprehensive 25% tariff still exists for a long time.

4.1. Trade Effect

Table 3 shows the trade effect when China and the US impose 25% additional tariffs on each other’s imports. We can see that the additional tariffs imposed by China and the US have not only greatly reduced the bilateral trade between the two countries, but also impacted the overall imports and exports of both countries to varying degrees. The impact on the final goods trade is greater than the impact on the trade of intermediate goods. Compared with the period when no additional tariffs were imposed, the US’ imports of intermediate and final goods from China decreased by 42.74 and 71.92%, and total imports decreased by 54.74%. China’s imports of intermediate and final goods from the US decreased by 37.2% and 67.76% respectively, with an average reduction of 56.24%. It is
noteworthy that although the US' imports of intermediate and final goods from China are reduced by a larger proportion than China's imports, China's total imports from the US are reduced more than the US due to the different import shares. To further explain, although the trade elasticity of intermediate goods is greater than that of final goods, the additional tariffs on capital goods and intermediate goods can be shared by producers, consumers, and other countries or regions, while final consumer goods are mainly borne directly by residents of the country where the tariff is imposed. Therefore, under the framework of general equilibrium analysis, the reduction in final goods trade is even greater when the tariffs are imposed on both in the same magnitude. A simple analysis of elasticity will lead to the opposite conclusion.

Table 3. Trade Effects of tariffs imposed by China and the US (%).

| Country | China | The US | Other Countries |
|---------|-------|--------|-----------------|
| US imports (intermediate goods, final goods, total imports) | −42.74, −71.92, −54.74 | − | 1.87, 5.33, 3.20 |
| China imports (intermediate goods, final goods, total imports) | − | −37.20, −67.76, −56.24 | −7.86, −6.81, −7.61 |
| US exports (intermediate goods, final goods, total exports) | − | − | −3.22, −4.96, −3.81 |
| China exports (intermediate goods, final goods, total exports) | − | − | 0.48, −3.34, −1.35 |

Under the analysis framework of general equilibrium, the additional tariffs imposed by the two countries will simultaneously affect both countries' imports from other economies in the rest of the world, resulting in a trade diversion effect. The conclusions of this paper have shown that the tariffs imposed by the two countries have had completely different effects on their imports from the rest of the world. Compared with the period when no additional tariffs were imposed, the US imports of intermediate goods from countries other than China increased by 1.87%, final goods imports increased by 5.33%, and total imports increased by 3.2%. The increase in final goods imports was even greater than that of intermediate goods, which is mainly because the additional tariffs imposed by China and the US have forced the US to import intermediate and final goods from other countries to make up for the demand gap created by the blocked imports of Chinese goods, thus deriving a trade diversion effect. However, things are different in China. Compared with the period when no additional tariffs were imposed, China's imports from countries other than the US decreased by 7.86%, 6.81%, and 7.61%, respectively, and the reduction in imports of intermediate goods was greater than that of final goods. This suggests that the additional tariffs imposed will not only reduce China's imports from the US but also imports from other countries. This is determined by China's export-oriented processing trade pattern, in which large quantities of intermediate products are imported for assembly and production of final products for export. The decrease in imports from countries with a large demand for final goods such as the US will inevitably lead to a reduction in China's imports of intermediate goods, which are not only from the US. Therefore, Sino-US trade frictions have also had a certain negative impact on other countries and industries in the upstream and downstream of a certain supply chain through the global value chain.

Additional tariff imposition on imported goods will also lead to reduced exports of China and the US to other countries in the world. Compared with the period before additional tariffs were imposed, US exports of intermediate goods, final goods, and total exports to other countries in the world decreased by 3.22%, 4.96%, and 3.81%, respectively. However, China's final goods exports and total exports decreased by 3.34% and 1.35%, respectively, and exports of intermediate goods to other countries in the world increased by 0.48%. The trade of intermediate goods and the inter-industry linkages make imports and exports closely related under the global value chains. A reduction in imported intermediate
goods, especially high-tech imported intermediate goods from related countries, will reduce the competitiveness of exported intermediate goods and final goods, leading to a decrease in exports of both goods, which is the reason why the US and China’s exports of final goods to other countries in the world have decreased.

Table 4 shows the changes in the export structure of the two countries before and after the additional tariffs imposed by China and the US. These changes indicate that China’s export concentration has declined, while the US has remained almost the same. China’s Herfindahl index dropped from 0.091 before additional tariffs were imposed to 0.081, and export concentration declined. This is due to the relatively large impact of traditional export-oriented industries in trade frictions. Before imposing additional tariffs, China’s export industries were mainly concentrated in the manufacture of electronic and optical products, as well as the manufacture of textiles, wearing apparel, and leather products, and these two industries alone accounted for 42.5% of the total exports. After the additional imposition of tariffs, the export proportions of the above two industries have declined, from 27.41% and 15.09% to 27.21% and 14.04%, respectively, dropping by 0.23 and 1.05%, while the proportions of other industries have increased to varying degrees.

Table 4. Changes in export structure before and after trade frictions.

| Industry              | China before Trade Frictions | China after Trade Frictions | US before Trade Frictions | US after Trade Frictions |
|-----------------------|------------------------------|----------------------------|---------------------------|-------------------------|
|                       | (1)                          | (2)                        | (3)                       | (4)                     |
| Crop                  | 0.72%                        | 0.69%                      | 4.55%                     | 3.98%                   |
| Forestry and logging  | 0.01%                        | 0.00%                      | 0.32%                     | 0.33%                   |
| Fishing               | 0.06%                        | 0.07%                      | 0.19%                     | 0.21%                   |
| Mining and quarrying  | 0.62%                        | 0.67%                      | 3.77%                     | 4.02%                   |
| Food products         | 2.90%                        | 2.84%                      | 7.14%                     | 6.65%                   |
| Textiles              | 15.09%                       | 14.04%                     | 1.12%                     | 1.11%                   |
| Wood                  | 0.91%                        | 0.98%                      | 0.56%                     | 0.57%                   |
| Paper                 | 0.62%                        | 0.64%                      | 2.14%                     | 2.31%                   |
| Printing              | 0.19%                        | 0.20%                      | 0.41%                     | 0.43%                   |
| Coke                  | 1.38%                        | 1.88%                      | 10.80%                    | 11.16%                  |
| Chemicals             | 4.82%                        | 4.86%                      | 10.32%                    | 10.37%                  |
| Pharmaceutical        | 1.01%                        | 1.05%                      | 3.65%                     | 3.86%                   |
| Rubber                | 3.02%                        | 3.04%                      | 2.68%                     | 2.79%                   |
| Non-metallic mineral  | 2.42%                        | 2.46%                      | 0.94%                     | 1.00%                   |
| Basic metals          | 4.29%                        | 4.60%                      | 2.70%                     | 2.98%                   |
| Fabricated metal      | 4.19%                        | 4.23%                      | 3.74%                     | 3.94%                   |
| Electronic            | 27.41%                       | 27.21%                     | 9.55%                     | 9.79%                   |
| Electrical equipment  | 10.80%                       | 11.15%                     | 2.73%                     | 2.78%                   |
| Machinery             | 9.22%                        | 9.29%                      | 9.39%                     | 9.11%                   |
| Motor vehicles        | 2.97%                        | 2.92%                      | 8.77%                     | 8.81%                   |
| Other transport       | 2.62%                        | 2.70%                      | 11.44%                    | 10.68%                  |
| Furniture             | 4.79%                        | 4.45%                      | 3.09%                     | 3.12%                   |
| Repair                | 0.00%                        | 0.00%                      | 0.00%                     | 0.00%                   |
| HH                    | 0.091                        | 0.081                      | 0.034                     | 0.033                   |

4.2. Welfare Effect

Table 5 shows the welfare effects of additional tariffs imposed by China and the US on changes in real wages. We can see that the welfare effect in China has dropped by 0.163%, while the welfare effect in US has improved, rising by 0.016%. However, the real wages of the two countries fell after the additional tariffs were imposed, and the rate of decline in China was also greater than that in the US, with the former falling by 0.239% and the latter falling by 0.168%.
Table 5. The welfare effects of tariffs imposed by China and the US.

| Year | Total Welfare | Terms of Trade of Intermediate Goods | Terms of Trade of Final Goods | Trade Volume of Intermediate Goods | Trade Volume of Final Goods | Changes in Real Wages |
|------|---------------|--------------------------------------|-------------------------------|-----------------------------------|---------------------------|----------------------|
| China | −0.163%       | −0.053%                              | −0.050%                       | −0.030%                           | −0.030%                   | −0.259%              |
| US    | 0.016%        | 0.021%                               | 0.013%                        | −0.004%                           | −0.013%                   | −0.168%              |

We obtain the terms of trade and volume of trade effects for intermediate and final goods by decomposing the welfare effect. Table 5 shows that the main reason for the decline in China’s welfare is the deterioration of the terms of trade; similarly, an improvement in the terms of trade is the main reason for the increased welfare effect of the US. China’s trade effect terms decreased by 0.103% (the trade effect terms of intermediate goods and final goods decreased by 0.0503% and 0.05%, respectively), and the US’ trade effect terms increased by 0.034% (the trade effect terms of intermediate goods and final goods increased by 0.021% and 0.013%, respectively). Therefore, the changes in welfare brought about by trade frictions are mainly determined by the changes in terms of trade between China and the US, where changes in terms of trade of intermediate goods are more significant than those in final goods.

We decompose the effects of the terms of trade between China and the US bilaterally, and further explore the underlying reasons for the changes in the effects of terms of trade. Columns 1 and 2 of Table 6, respectively, show the bilateral decomposition of the effects of trade terms in intermediate and final goods between China and the US. The results of a bilateral decomposition of the terms of trade in intermediate goods show that the US has improved its terms of trade with China and other countries in the world, and the latter is the main reason for its improvement, with an increase of 0.015%. This is consistent with the theoretical expected result of tariffs imposed by major US powers. The deterioration of China’s terms of trade was mainly due to the deterioration of the terms of trade in the world’s final goods, with a reduction of 0.045%. Meanwhile, the changes in the terms of trade in the final goods of the two countries show the same characteristics as the intermediate goods, but the magnitude of the changes is slightly smaller.

Table 6. The bilateral welfare effects of tariffs imposed by China and the US.

| Terms of Trade Effect | Trade Volume Effect | US (China) | World | US (China) | World |
|-----------------------|---------------------|------------|-------|------------|-------|
|                       |                     | (1)        | (2)   | (3)        | (4)   |
| China intermediate goods | −0.007%           | −0.045%    | −0.012% | −0.018%    |       |
| China final goods     | −0.010%            | −0.040%    | −0.026% | −0.004%    |       |
| US intermediate goods | 0.004%             | 0.015%     | −0.005% | 0.002%     |       |
| US final goods        | 0.006%             | 0.008%     | −0.018% | 0.006%     |       |

Columns 4 and 5 of Table 6 show the volume effects of intermediate and final goods, respectively. Additional tariffs imposed can lead to an overall reduction in the volume of trade between China and the US, no matter which country it is. Although increased tariffs will directly cause the trade diversion effect between US and countries other than China, overall, it will reduce the trade volume of intermediate goods by 0.004% and final goods by 0.013% in the US. As far as China is concerned, the volume of trade in intermediate and final goods has shrunk by 0.03%, where the difference is mainly determined by the trade characteristics of China and the US. We further explore the deep-seated reasons for a decrease in the trade volume effect by decomposing the effect of trade volume between China and the US at the bilateral level. Columns 3 and 4 of Table 6, respectively, show the bilateral decomposition results of the trade volume effect of final goods between China and the US. The main reason for the decline in the trade volume of the US can be attributed to the reduction in bilateral trade volume with China, especially the trade volume of final
goods, which was reduced by 0.01%. This is because the US imports from China account for 22% of its total imports (2017, from the Ministry of Commerce of the People’s Republic of China), of which the proportion of final goods is much higher than that of intermediate goods; therefore, the additional imposition of tariffs will result in a sharp fall in final goods imported from China. At the same time, in column 4, an increase in the trade volume of intermediate and final goods of the US with other countries in the world also supports the trade diversion effect to a certain extent. However, the situation in China is slightly different. The additional tariffs have reduced the bilateral final goods trade volume between China and the US by 0.026% and simultaneously reduced the final goods trade volume with other countries in the world by 0.004%. Even worse, they have led to a reduction in the trade volume of intermediate goods with other countries in the world by 0.018%, which is greater than that with the US. This is because China mainly imports intermediate goods from all over the world and then assembles them into final goods for export; thus, a reduction in the trade volume of final goods brought about by additional tariffs will lead to a decline in its imports of intermediate goods worldwide.

We further analyze the industry contribution of the welfare effect. Table 7 shows the industry contribution of the changes in the welfare effect of additional tariffs imposed by China and the US. We can see that the deteriorating terms of trade for China’s intermediate goods are mainly contributed by the four high-end manufacturing industries including electronic and optical products, pharmaceutical products and preparations, electrical equipment and machinery, and equipment manufacturing, which together contribute 45.7%. However, the deteriorating terms of trade of final goods are mainly concentrated in four industries: electronic and optical products, textiles, wearing apparel and leather products, and electrical machinery and equipment, with a contribution rate of 67.7%, reaching two-thirds. These industries are also the most important export industries to the US, so the additional tariffs bring the worst deterioration in the export terms of trade. A reduction in China’s intermediate goods trade volume is mainly concentrated in the electronic and optical products, as well as pharmaceutical products, preparations, and industries, which contributed 55% of the change. The final goods trade volume reduction is mainly concentrated in other transport equipment industries. For the US, whether it is intermediate products or final products, the industries whose terms of trade have improved are mainly those whose terms of trade have deteriorated in China, such as electronic and optical products, machinery and equipment, and other transport equipment industries, which have contributed to 0.78 and 54.95% of terms of trade change in the US’ intermediate and final goods, respectively. A reduction in the trade volume of intermediate goods in the US is mainly concentrated in the electronic and optical products, pharmaceutical products and preparations, as well as machinery and equipment industries, while a reduction in the trade volume of final goods is concentrated in the textiles, wearing apparel and leather products, as well as electronic and optical products.

4.3. The Global Value Chain Effect

Table 8 shows the global value chain effects of additional tariffs imposed by China and the US. It can be found that the additional tariffs imposed by China and the US have different effects on the positions of the two countries’ global value chains. For the US, the increase in tariffs caused its upstreamness and downstreamness to drop by 0.008 and 0.003, respectively, since the upstreamness contains information that products produced by a country or industry are directly sold to other countries or industries as final goods or intermediate inputs, while the downstreamness captures the distance between a country or a given industry and primary factors. This means that on the one hand, the distance between exports of the US and final consumption is shortened, undertaking an increasing number of downstream production stages; on the other hand, the distance between exports of the US and primary production factors is becoming shorter, undertaking more upstream production stages. Taken together, the additional tariffs imposed by the two countries will cause the US to undertake a large number of additional production stages on its
own, thereby reducing the benefits brought by the labor specialization. For China, the upstreamness increased by 0.008, while the downstreamness decreased by 0.005, meaning that the additional imposition of tariffs will increase the distance between China’s exports and final consumption but reduce the burden of final production stages, which may indicate upgrading in terms of indicators on the surface. However, it is actually caused by a decline in the number of final products in export. Meanwhile, the distance between China’s export products and primary factors is becoming shorter, and more domestically produced intermediate products are used in the production of export products, substituting imported intermediates.

### Table 7. Industry contribution of welfare effect.

| Industry               | China Intermediate Goods | China Final Goods | US Intermediate Goods | US Final Goods | China Intermediate Goods | China Final Goods | US Intermediate Goods | US Final Goods |
|------------------------|--------------------------|------------------|-----------------------|----------------|--------------------------|------------------|-----------------------|----------------|
|                        | (1)                      | (2)              | (3)                   | (4)            | (5)                      | (6)              | (7)                   | (8)            |
| Crop                   | 2.02%                    | 1.09%            | 1.46%                 | 1.12%          | 3.85%                    | −0.68%           | 0.31%                 | 0.14%          |
| Forestry and logging   | 0.09%                    | 0.01%            | 1.29%                 | 0.00%          | −0.09%                   | −0.04%           | 0.03%                 | −0.04%         |
| Fishing                | 0.07%                    | 0.12%            | 0.02%                 | 0.11%          | −0.04%                   | 0.17%            | −0.03%                | 0.00%          |
| Mining and quarrying   | 2.61%                    | 0.43%            | 0.21%                 | 0.08%          | −0.10%                   | 0.07%            | 0.00%                 | 0.00%          |
| Food products          | 1.64%                    | 4.79%            | 2.90%                 | 8.89%          | 2.58%                    | 5.92%            | 1.73%                 | 3.88%          |
| Textiles               | 6.88%                    | 20.76%           | 2.26%                 | 1.19%          | 1.67%                    | 9.68%            | 7.06%                 | 42.42%         |
| Wood                   | 2.00%                    | 0.27%            | 0.01%                 | 0.01%          | 0.61%                    | 0.18%            | 0.97%                 | 0.47%          |
| Paper                  | 1.32%                    | 0.20%            | 1.07%                 | 0.05%          | 3.65%                    | 0.46%            | 0.00%                 | 0.00%          |
| Printing               | 0.36%                    | 0.00%            | 0.12%                 | 0.02%          | 0.52%                    | 0.14%            | 0.00%                 | 0.00%          |
| Coke                   | 2.66%                    | 0.58%            | 4.10%                 | 0.00%          | 7.97%                    | 2.81%            | −0.12%                | 0.00%          |
| Chemicals             | 9.39%                    | 0.79%            | 25.90%                | 0.71%          | 16.48%                   | 2.08%            | 17.68%                | 0.52%          |
| Pharmaceutical         | 1.48%                    | 1.20%            | 0.14%                 | 1.94%          | 3.48%                    | 3.20%            | 0.70%                 | 0.00%          |
| Rubber                 | 4.39%                    | 1.46%            | 1.78%                 | 1.12%          | 4.24%                    | 1.54%            | 7.47%                 | 4.64%          |
| Non-metallic Mineral   | 4.78%                    | 0.79%            | 0.69%                 | 0.60%          | 1.43%                    | 0.43%            | 4.08%                 | 3.22%          |
| Basic metals           | 8.88%                    | 0.69%            | 3.66%                 | 0.21%          | 1.30%                    | 0.57%            | 1.31%                 | 1.57%          |
| Fabricated metal       | 6.49%                    | 2.41%            | 0.45%                 | 2.48%          | 5.56%                    | 2.98%            | 12.88%                | 2.42%          |
| Electronic             | 16.88%                   | 26.05%           | 30.71%                | 0.63%          | 16.76%                   | 21.74%           | 20.40%                | 20.69%         |
| Electrical equipment   | 11.00%                   | 9.76%            | 3.20%                 | 6.13%          | 4.67%                    | 4.23%            | 2.87%                 | 7.78%          |
| Machinery              | 8.52%                    | 11.12%           | 10.67%                | 14.46%         | 11.73%                   | 16.00%           | 14.90%                | 0.76%          |
| Motor vehicles         | 4.17%                    | 3.98%            | 1.56%                 | 6.94%          | 9.24%                    | 3.85%            | 6.56%                 | 0.31%          |
| Other transport        | 1.52%                    | 4.85%            | 3.08%                 | 52.22%         | 12.29%                   | 17.21%           | 0.35%                 | 4.10%          |
| Furniture              | 2.86%                    | 8.60%            | 4.70%                 | 3.12%          | 2.38%                    | 7.47%            | 0.94%                 | 7.11%          |
| Repair                 | 0.00%                    | 0.03%            | 0.03%                 | 0.01%          | 0.00%                    | −0.01%           | −0.01%                | −0.01%         |

In the distribution of industry effects, both China and the US show great heterogeneity. For the US, although the overall upstreamness of export products has decreased, the upstreamness of the two high-tech industries, motor vehicles and trailers, and other transport equipment manufacturing has increased, whereas China is an importer of intermediate products in these industries and performs the final assembly. So, the increasing upstreamness can be explained by a reduction in the number of intermediate products directly sold to China by the two industries, which resulted from the increased tariff imposed by China. Except for the crop and animal production industry, the food and beverage industry, and the tobacco industry, almost all the downstreamness of the primary and manufacturing industries in the US decreased. Similarly, the upstreamness of China’s electronic and optical products, electrical equipment, and machinery and equipment industries all increased, while the upstreamness of the motor vehicles and trailers and other transport equipment manufacturing industries declined. However, unlike the US, China is a major exporter of the final products in these industries, so an increase in the upstreamness can be explained by a sharp decline in the export of the final products in these industries; at the same time, the downstreamness of these industries has declined, which also proves that China’s additional tariffs imposition on intermediate products imported from the US has led to the substitution of imported intermediate products in these industries.
Table 8. Global value chain effect of tariffs imposed by China and the US.

| Industry            | U  | D  | U  | D  |
|---------------------|----|----|----|----|
|                     | (1)| (2)| (3)| (4)|
| Crop                |0.001| -0.028| -0.003| 0.010|
| Forestry and logging|0.016| -0.031| -0.004| -0.004|
| Fishing             |-0.007| -0.014| -0.005| -0.003|
| Mining and quarrying|0.010| -0.033| -0.003| -0.004|
| Food products       |-0.001| -0.007| -0.007| 0.004|
| Textiles            |0.043| -0.005| 0.011| -0.012|
| Wood                |0.017| -0.021| 0.000| -0.013|
| Paper               |0.022| -0.018| -0.005| -0.012|
| Printing            |0.001| -0.008| -0.003| -0.012|
| Coke                |-0.006| -0.024| 0.001| -0.001|
| Chemicals           |0.022| -0.035| 0.003| -0.008|
| Pharmaceutical      |-0.003| 0.000| -0.002| -0.012|
| Rubber              |0.030| -0.021| 0.008| -0.017|
| Non-metallic mineral|0.000| -0.017| 0.003| -0.010|
| Basic metals        |0.008| -0.031| -0.005| -0.007|
| Fabricated metal    |0.018| -0.018| 0.002| -0.012|
| Electronic          |0.070| -0.075| -0.008| -0.021|
| Electrical equipment|0.029| -0.075| -0.006| -0.024|
| Machinery           |0.010| -0.016| -0.005| -0.019|
| Motor vehicles      |-0.011| 0.006| -0.013| -0.031|
| Other transport     |-0.015| 0.011| -0.013| -0.022|
| Furniture           |0.117| -0.035| 0.009| -0.014|
| Repair              |0.000| -0.003| 0.000| -0.007|
| Population          |0.008| -0.008| -0.005| -0.003|

5. Conclusions

This study develops a general equilibrium model to quantify tariffs’ welfare and the effects of global value chains under Sino–US trade friction. The model is characterized by distinct trade elasticity and trade cost functions of intermediates and final goods based on Eaton and Kortum (2002) [1] and highlights a crucial feature of different trade shares and heterogeneous impacts from the tariff. Based on the equilibrium in relative changes, we can obtain trade flows of intermediates and final goods after tariffs, which can be combined with the basic elements of the input–output table. This allows us to evaluate the impact of tariffs on global value chain indicators such as the position index. Using the model, we can learn more about the potential channels for the long-term effects of trade frictions. The model can also perform complex trade policy evaluations of global value chain-related issues.

Given the importance of the issue of trade friction between China and the US and the fact that China and the US are the world’s two superpowers, assessing its impacts is economically worthwhile. We estimated the consequences of full-scale trade friction between the two nations, with particular attention paid to the impact on global value chains. China and the US are at the center of Asian and North American manufacturers, with substantial global value chain links between the two nations. Increased tariffs between China and the US can reduce trade between the two countries, particularly in intermediate goods. They can cause a reorganization of global value chains in both regions, with the US becoming more reliant on Mexico and China on Japan and South Korea. Long-term trade frictions between China and the US will put great strain on trade and value chains for both countries and the rest of the world, and the two nations should work more in the future to improve dialogue and resolve trade frictions. In addition, the impact of trade frictions between the two nations on the long-term viability of global value chains should be investigated further.
Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14148280/s1. Section S1. Changes in real wages. Section S2. The derivation of welfare.

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