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Abstract

Trade policy uncertainty impacts firm's decisions to enter export markets and make new investments. I extend the trade policy uncertainty literature in a multi-country trade model to evaluate the uncertainty effect on global trade flows. The model introduces two sources of uncertainty; namely a policy change probability and tariff size uncertainty. Using these two sources of uncertainty, I argue that the trade policy uncertainty moderates global trade flows and increases domestic price level due to lack of certainty in price distributions. The framework can be generalized to other uncertainties in trade partners. Finally, the model calibration demonstrates that a moderation of trade flows during the recent trade war period, can be explained by trade policy uncertainty.

Keywords: Trade policy uncertainty, trade flows, sectoral heterogeneity
JEL Codes: F13, F11, F42, F62

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Caught in the Crossfire: How Trade Policy Uncertainty Impacts Global Trade

1 Introduction

Trade policy uncertainty has become a major concern for global trade in the wake of recent economic policy changes like Brexit, trade protectionism measures, China's lockdowns etc. For example, US Trade policy uncertainty index, developed by Bloom et. al. (2016) and Caldara et. al. (2018) rose to its highest level in 2017 as the protectionist measures were discussed. Similar patterns were observed in China, United Kingdom and European Union. This paper introduces trade policy uncertainty in neo-classical multi-country trade models to provide a structural understanding of the uncertainty effect on global trade flows.

Changes in trade policies impacts trade partners in different ways. Generally, higher tariffs moderates trade intensity among trade partners. However, these policy changes introduce uncertainty among trade partners. The effect of uncertainty complicates firms' decision making process. The unavailability of future policy information at the time of planning, triggers uncertainty in the firms' forward looking allocations and thereby, modulates firms' optimal choice. The effect of TPU affects the global trade partners via trade linkages. The trade protectionist measures adopted by the United States, elevated trade policy uncertainty for the trade partners due to lack of clarity in terms of possible tariff sizes and duration of those policies. These trade policies targeted many trade partners, though the majority of these tariffs were targeted towards China. Higher tariffs increased price level of products coming from those targeted countries and thereby, created an opportunity of trade diversion for other trade partners. However, empirical evidence suggests that the effect of those high tariffs moderated global trade and there was no clear winner from the trade war (Fajgelbaum et. al. (2022)). Also, different trade partners experienced different level of trade intensity in those targeted products (Sanyal (2020); Choi & Nguyen (2021)). The direct effect of higher tariffs moderated consumption demand and increased domestic price level in the United States (Waugh (2019); Fajgelbaum et. al. (2020)). The effect on higher tariffs also affected US consumer through global value chain due to higher tariffs on intermediate goods (Bellora and Fontagne (2020)). The impact of trade war also affected export growth of the US through supply chains due to higher trade tariffs (Handley et. al. (2020)). On the other hand, higher tariffs imposed by the US, marginalized the profit margin of the firms in China (Wang et. al. (2020)). Apart from the direct effect of tariffs, the uncertainty reduced trade volume between China and US (Ongan & Gocer, 2020; Yan & Xiao, 2022; Benguria et. al., 2022). Similar effects were observed during the Brexit vote in 2016. Lack of clarity and widespread speculations about future policies increased uncertainty during Brexit. These uncertainty slowed investment momentum and affected productivity (BoE, 2019) and reduced trade volume by 16-20% between EU and UK (Kren & Lawless (2022)). The recent lockdown in China also imparted similar effects on export intensity and global value chain (Nie, 2022).

From the theoretical point of view, multi-country trade models are used to derive the direct effect of tariffs on different trade partners. Changes in the tariff sizes changes the iceberg trade costs and thereby, impacts the price distribution at the originating country. However, these models do not account for the policy uncertainty. This paper provides a generalization of the trade policy uncertainty in multi-country trade models to address the effect of uncertainty on global trade flows and re-allocations. The model uses the multi-country trade set up under perfect competition following Eaton & Kortum (2002) and introduces trade policy uncertainty from two sources - probability of trade policy changes and possible tariff sizes. The firms make their production plans at the beginning of the period when the trade policies are not yet declared. The uncertainty in trade policy affects the trade intensity as the price distribution in the originating country becomes uncertain. The policy uncertainty, thereby, translates to lower than potential trade intensity among trade partners. The proposed model starts with trade policy changes between two countries i.e. higher tariff is proposed by one country on another. Using the probability of trade policy changes and the possible size effect of tariffs, the model provides an analytical derivation of the effect of TPU on global trade and domestic prices. The model is then extended to a generalized scenario where policy uncertainty affects trade cost on all trade partners. Such generalization can be related to China's recent lockdown. Using this generalized set up, the comparative statics of TPU parameters shows similar effect on all trade partners. Later, the quantitative model is calibrated using different scenarios of tariffs sizes and probability of policy changes to demonstrate the effect of TPU.

The paper contributes to two strand of the literature. The first strand addresses trade integration in multi-country multi-sector Ricardian models (Caliendo and Parro 2010; Shikher 2011; Costinot, Donaldson, and Komunjer 2012). Dekle et. al. (2007, 2008) used similar framework to explain the impact of trade balances on factort costs and welfare. Eaton, Kortum, Neiman and Romalis (2011) extended the model framework to explain the role of trade in global recession. Giovanni et. al. (2014) used similar framework to address the welfare implication of trade partners in the wake of China's trade integration and technological changes. Costinot & Rodriguez-Clare (2014) provided survey of findings of global inter-connectedness and sectoral heterogeneity. Similar model set up was used for explaining equity home bias (Hu, 2022), spatial risk sharing (Arora et. al., 2022). This paper provides a generalization of the Eaton and Kortum (EK) framework (2002) with uncertainty in the trade cost. The paper also contributes to the growing literature of trade policy uncertainty. Some of the notable papers in this context are Handley & Limao (2018, 2022), Steinberg (2015, 2018) and Caldara et. al. (2018). Compared to these papers, my paper addresses the trade policy uncertainty in multi-country and multi-sector set up and analyzes the impact of the uncertainty on trade flows and global re-allocations.

The remaining of the paper is organized as follows - Section 2 provides the model details with analytical derivations, Section 3 details the calibration approach, Section 4 summarizes the findings of the model simulations followed by concluding remarks in Section 5.

2 Model

2.1 Set up

The model uses Ricardian trade model set up with multiple countries and multiple sectors following Eaton & Kortum (2002). There are N countries (for simplicity, I assume that country 1 is United States and Country 2 is China). There are J traded sectors and one non-traded sector in each country. The production process happen in two stages. In the first stage, each country produces intermediate goods using labor, capital and other intermediate inputs. In the second stage, the final goods are produced using intermediate goods.

The markets are perfectly competitive and international trade is costly. The price charged by the each country is a markup on the unit cost of production adjusting for the trade cost. The final price distribution in any country is derived from the minimum price offered by all trade partners. The capital and labor endowment in each country is fixed. The firms choose factors of production depending upon the final demand of each sector. The productivity distribution follows Frechet distribution.

I assume iceberg trade cost between any two countries. The trade policy changes the trade cost. For simplicity, I assume that possible trade policy changes increases the trade cost on imports from Country 2 to Country 1 [1]). The trade policy uncertainty has two components - the probability of trade policy change and possible size of tariffs.

The firms make production plans at the beginning of the period before the trade policy is announced and allocates the factors of production (labor, capital ands intermediate goods)

[1] I am going to generalize this assumption in the next section

based on perception of final demand under uncertainty. I assume that the factor allocations are subject to adjustment costs and hence, cannot be modified after realization of the trade policy. This creates a wedge between potential trade diversion and actual trade diversion on account of higher tariffs imposed by Country 1.

2.2 Firms

The production process happens in two stages. The first stage is the production of intermediate goods. I assume that the cost function of each intermediate goods is Cobb-Douglas with labor wage, capital rent and cost of other intermediate goods. The subscripts (i,k etc.) represent countries and superscript (j,l) represent sectors.

$$C_i^j = \left(w_i^{\alpha_j} r_i^{1-\alpha_j} \right)^{\beta_j} \left(\prod_{j=1}^{J+1} (p_i^k)^{\gamma_{jk}} \right)^{1-\beta_j} \tag{1}$$

where α_j is the share of labor wage in value added and β_j is the share of value added in sector j. I assume that these shares are constant across countries. However, I will run robustness checks by relaxing this assumption (i.e. α_j and β_j varies across countries).

The unit cost of production of a intermediate good is $C_i^j / Z_i^j(q)$ where $Z_i^j(q)$ is the productivity of country i in sector j. I assume that $Z_i^j(q)$ follows Frechet distribution with scale parameter T_i^j and shape parameter θ. Higher value of T_i^j implies greater absolute comparative advantages of country i in sector j.

Following perfect competition and costly trade, the price charged by country i on country k in sector j ($p_{ki}^j(q)$) is a mark-up on the unit price of production.

$$p_{ki}^j(q) = \frac{C_i^j}{z_i(q)} d_{ki}^j \tag{2}$$

where d_{ki}^j is the iceberg trade cost to export to Country k from Country i. I assume that the trade cost varies across sectors and origin-destination pair.

In the second stage, the final good is produced by the aggregating the intermediate goods using a CES aggregator.

$$Q_n^j = \left[\int_0^1 Q_n^j(q)^{\frac{\epsilon-1}{\epsilon}} dq \right]^{\frac{\epsilon}{\epsilon-1}} \tag{3}$$

where ϵ is the elasticity of substitution between varieties.

2.3 Trade policy uncertainty

The firms are making their production plan at the beginning of the year. They allocate labor and capital in each sector at the beginning of the period based on their assessment of the final demand in each sector. The final demand of each sector depends upon the trade cost in each sector. We assume that the trade cost between Country 1 and Country 2 in sector j (d_{12}^j) is unknown at the beginning of the year. The unknown value of d_{12}^j imbibes uncertainty in the final price distribution of Sector j in Country 1. As the demand of sector j in Country 1 responds to the unknown trade cost, the trade partners' allocation decision is affected by the trade policy uncertainty.

In order to model the trade policy uncertainty, I introduce two components namely (i) the probability of trade policy changes ($(1-\chi)$) and (ii) Distribution F(.) over all possible values of trade cost d_{12}^j [2]. Higher values of χ implies lower chance of trade policy changes. Further, I assume that the trade cost D_{12}^j [3] follows uniform distribution over d_{12}^j and some bounds D^j (invariant across products) where d_{12}^j is the existing iceberg trade cost between country 1 and country 2 and D^j is the upper bound of tariffs in sector j. One can relate the value of D^j as the bounded tariffs, China's pre-WTO accession tariffs or column 2 tariffs in sector j. The assumption of uniform distribution is driven the non-informative property of the uniform distribution i.e. each value over the support of F(.), is equally probable. This assumption can be generalized. [4] To avoid any such assumptions, I stick to uniform

[2]This specification provides mechanism to decompose the size effect of the tariffs and the uncertainty around policy changes which is helpful to generalize the model

[3]I used D_{12}^j in place of d_{12}^j to highlight the stochastic process of trade cost

[4]Any parametric choice of tariff distribution necessarily entails some assumptions about the possible

distribution to model the tariff size uncertainty.

Following the assumptions of TPU, the new tariff D^j_{12} follows a mixture of distributions

$$D^j_{12}\big|_{\text{Under TPU}} \begin{cases} = d^j_{12} & \text{if no change in trade policy}(Pr = \chi) \\ \sim U(d^j_{12}, D^j) & \text{Otherwise}(Pr = 1-\chi) \end{cases} \tag{4}$$

where $U(d^j_{12}, D^j)$ is the uniform distribution between d^j_{12} and D^j.

2.4 Price distribution under TPU

Under TPU, the export price distribution of country 2 to country 1 in sector j is given by

$$\begin{aligned} G^j_{12}(p) &= \mathbf{P}\left[p^j_{12} \le p\right] \\ &= \mathbf{P}\left[\frac{C^j_2}{Z^j_2(q)} D^j_{12} \le p\right] \\ &= 1 - \chi exp\left[-T^j_2\left(C^j_2 d^j_{12}\right)^{-\theta} p^\theta\right] - (1-\chi)\frac{1}{D^j - d^j_{12}} \int_{d^j_{12}}^{D^j} exp\left[-T^j_2\left(C^j_2 h\right)^{-\theta} p^\theta\right] dh \end{aligned} \tag{5}$$

The probability distribution of price p^j_{12} is given by

$$\begin{aligned} g^j_{12}(p) = {}& \chi\theta p^{\theta-1}\left[T^j_2\left(C^j_2 d^j_{12}\right)^{-\theta}\right] exp\left[-T^j_2\left(C^j_2 d^j_{12}\right)^{-\theta} p^\theta\right] \\ &+ \frac{1-\chi}{D^j - d^j_{12}} \int_{d^j_{12}}^{D^j} \theta p^{\theta-1}\left[T^j_2\left(C^j_2 h\right)^{-\theta}\right] exp\left[-T^j_2\left(C^j_2 h\right)^{-\theta} p^\theta\right] dh \end{aligned} \tag{6}$$

The distribution of price of sector j in Country 1, then, includes the mixture of distribution as follows

tariff sizes and their likelihood.

$$
\begin{aligned}
G_1^j(p) &= \mathbf{P}\Big[\min_{i=1(1)N} p_{1i}^j(q) \le p\Big] \\
&= 1 - \mathbf{P}\Big[\min_{i=1(1)N} p_{1i}^j(q) > p\Big] \\
&= 1 - \chi exp\Bigg[-\Phi_1^j p^{-\theta}\Bigg] - \frac{1-\chi}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j} exp\Bigg[-\Phi_1^j(h)p^{\theta}\Bigg]dh
\end{aligned} \tag{7}
$$

where $\Phi_1^j(h) = \sum_{i\neq 2}^N T_i^j\Big(C_i^j d_{1i}^j\Big)^{-\theta} + T_2^j\Big(C_2^j h\Big)^{-\theta}$ is the market access for any trade cost (h) from stochastic distribution of trade cost.

The final price of sector j in Country 1 is given by

$$
P_1^j = \Gamma\Bigg[\chi\Big(\Phi_1^j\Big)^{-\frac{1}{\theta}} + \frac{1-\chi}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j}\Big(\Phi_1^j(h)\Big)^{-\frac{1}{\theta}}dh\Bigg] \tag{8}
$$

where Γ is a constant.

The market access of country 1 deteriorates to $\Phi_1^j\big|_{\text{TPU}}$

$$
\Phi_1^j\big|_{\text{TPU}} = \chi\Phi_1^j + \frac{1-\chi}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j}\Phi_1^j(h)dh \tag{9}
$$

Given the uncertainty in the price distribution in Country 1, the export share of each trade partner i in Country 1 is given by

$$
\pi_{1i}^j = \begin{cases}
\chi\frac{T_i^j\left(C_i^j d_{1i}^j\right)^{-\theta}}{\Phi_1^j} + \frac{1-\chi}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j}\frac{T_i^j\left(C_i^j d_{1i}^j\right)^{-\theta}}{\Phi_1^j(h)}dh & \text{if } i \neq 2 \\
\chi\frac{T_2^j\left(C_2^j d_{12}^j\right)^{-\theta}}{\Phi_1^j} + \frac{1-\chi}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j}\frac{T_2^j\left(C_2^j h\right)^{-\theta}}{\Phi_1^j(h)}dh & \text{if } i = 2
\end{cases} \tag{10}
$$

2.5 Effect of trade policy uncertainty on price and trade

The comparative statics with respect to TPU parameters $(1-\chi)$ and D^j on price level of country 1 shows the effect of the change in TPU. First, the comparative statics with respect to D^j indicates that increase in the upper bound of the tariff size distribution increases overall price level of the sector j in Country 1 (from Eq. 11) As tariffs become higher on Country 2, the trade cost increases and the the market access declines.

$$\begin{aligned}\frac{\partial}{\partial D^j} P_1^j &= \frac{1-\chi}{D^j - d_{12}^j}\left[(\Phi_1^j(D^j))^{-\frac{1}{\theta}} - \frac{1-\chi}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j} (\Phi_1^j(h))^{-\frac{1}{\theta}} dh\right] \\ &\geq \frac{1-\chi}{D^j - d_{12}^j}(\Phi_1^j(D^j))^{-\frac{1}{\theta}}[1-(1-\chi)] \text{ (Due to convexity)} \\ &\geq 0\end{aligned} \tag{11}$$

The comparative statics of prices with respect to the probability of trade policy changes $(1-\chi)$ also indicates increase in price in distribution in Country 1. When the probability of trade policy changes is high (i.e. $(1-\chi)$ is high), then the relative contribution of the higher tariff reduces market access and the price level increases (from Eq. 12).

$$\frac{\partial}{\partial(1-\chi)} P_1^j = \left[\frac{1}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j} \left(\Phi_1^j(h)\right)^{-\frac{1}{\theta}} dh - \left(\Phi_1^j\right)^{-\frac{1}{\theta}}\right] \geq 0 \tag{12}$$

(due to convexity)

Next, I conduct the comparative statics of trade share with D^j and $(1-\chi)$. I define the trade diversion intensity in following way

$$\begin{aligned}\Delta\pi_{1i}^j &= \pi_{1i}^j\big|_{\text{TPU}} - \pi_{1i}^j \\ &= (1-\chi)T_i^j\left(C_i^j d_{1i}^j\right)^{-\theta}\left[\frac{1}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j}\frac{1}{\Phi_1^j(h)}dh - \frac{1}{\Phi_1^j}\right]\end{aligned} \tag{13}$$

Clearly, higher value of $\Delta\pi_{1i}^j$ indicates greater trade diversion possibility. Comparative statics of $\Delta\pi_{1i}^j$ with respect to TPU parameters is presented in Eq. 14 and Eq. 15. The trade intensity increases due to the increases in $(1-\chi)$ and D^j. Following the expression of trade share (Eq. 10), any increase in the trade cost improves the trade share of other trade partners other than Country 2 (i.e. trade diversion increases).

$$\frac{\partial}{\partial(1-\chi)}\Delta\pi_{1i}^{j} = T_i^j\left(C_i^j d_{1i}^j\right)^{-\theta}\left[\frac{1}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j}\frac{1}{\Phi_1^j(h)}dh - \frac{1}{\Phi_1^j}\right] \geq 0 \tag{14}$$

$$\frac{\partial}{\partial D}\Delta\pi_{1i}^{j} = (1-\chi)T_i^j\left(C_i^j d_{1i}^j\right)^{-\theta}\frac{1}{D^j - d_{12}^j}\left[\frac{1}{\Phi_1^j(D^j)} - \frac{1}{D^j - d_{12}^j}\int_{d_{12}^j}^{D^j}\frac{1}{\Phi_1^j(h)}dh\right] \geq 0 \tag{15}$$

However, the increase in trade diversion intensity can not be fully achieved due to the trade policy uncertainty. For instance, if the actual trade cost d_{12}^j increases to d_{12}^{j*} after the trade policy is announced, then the trade share of other countries ($i \neq 2$) increases to

$$\pi_{1i}^j = \frac{T_i^j(C_i^j d_{1i}^j)^{-\theta}}{\Phi_1^{j*}} \tag{16}$$

where $\Phi_1^{j*} = \sum_{k\neq 2}^{N} T_k^j(C_k^j d_{1k}^j)^{-\theta} + T_2^j(C_2^j d_{12}^{j*})^{-\theta}$ is the new market access term under the proposed trade cost d_{12}^{j*}.

The difference between trade share under new tariff (from Eq. 16) and the expected trade share under TPU (from Eq. 10) can be expressed as follows

$$\begin{aligned}\Delta\pi_{1i}^{j*} &= \pi_{1i}^j\big|_{\text{TPU}} - \pi_{1i}^{j*} \\ &= \kappa\left[\chi\underbrace{\left(\frac{1}{\phi_{1i}^j} - \frac{1}{\phi_{1i}^{j*}}\right)}_{\text{Non-TPU Diff}(<0)} + (1-\chi)\underbrace{\left(\frac{1}{D - d_{12}^j}\int_{d_{12}^j}^{D}\frac{1}{\Phi_1^j(h)}dh - \frac{1}{\Phi_{1i}^{j*}}\right)}_{\text{TPU Diff} \lesseqgtr 0}\right]\end{aligned} \tag{17}$$

The trade difference expression (Eq. 17) provides a decomposition of the trade share difference of two terms - the first term is the difference of trade share possibility under the new tariffs under no uncertainty and the second term is the difference of the new trade share possibility with expected trade share under uncertainty. The contribution of each term is weighted by the probability of trade policy changes. Clearly, the first term is negative as the trade share is expected to increase for other trade partners ($i \neq 2$) due to higher tariffs on country 2. On the other hand, the second term adjusts the trade diversion intensity depending on the distribution of tariff sizes. The effect of the TPU difference (from Eq. 17) can be positive or negative given the relative size of exact tariff realization with respect to the belief about the highest trade cost value. The bounds of the TPU difference can be derived as the market share term $\Phi_1^j(h)$ is convex in nature with respect to h. These bounds are given by

$$\left(\frac{1}{\phi_{1i}^j} - \frac{1}{\phi_{1i}^{j*}}\right) \leq \left(\frac{1}{D - d_{12}^j}\int_{d_{12}^j}^{D} \frac{1}{\Phi_1^j(h)}dh - \frac{1}{\Phi_{1i}^{j*}}\right) \leq \left(\frac{1}{\phi_{1i}^j(D)} - \frac{1}{\phi_{1i}^{j*}}\right) \tag{18}$$

Eq. 18 provides the range of values of the trade share difference. When the difference $\Delta\pi_{1i}^{j*}$ is positive (opportunity gained), trade diversion happens as the trade partners align their production plan according to a higher possible trade cost and greater chance of trade policy changes. The difference becomes negative (opportunity lost) if the trade partners underweight the possibility of trade war and/or assumes a muted tariff increase on Country 2.

2.6 Household and Equilibrium

The utility of households in each country is a CES aggregator of the traded goods and non-traded goods.

$$U_n = \left(\sum_{j=1}^{J} \omega_j^{\frac{1}{\eta}} (Y_n^j)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}\epsilon_n} \left(Y_n^{J+1}\right)^{1-\epsilon_n} \tag{19}$$

where η is the elasticity of substitution among the traded goods and ϵ_n is the expenditure share of traded goods. ω_j is the preference parameter of sector j good.

The budget constraint of the households is given by

$$\sum_{j=1}^{J+1} P_n^j Y_n^j = w_n L_n + r_n K_n \tag{20}$$

Following standard derivations, the expression of the consumer price index of country n is given by

$$P_n = B_n \left(\sum_{j=1}^{J} \omega_j (p_n^j)^{1-\eta} \right)^{\frac{1}{1-\eta}\epsilon_n} \left(p_n^{J+1} \right)^{1-\epsilon_n} \tag{21}$$

The competitive equilibrium of this model is the prices, factor allocations and trade shares such that (i) given prices, the firms optimize their factor allocations and the output equates with production function (ii) given prices, the consumer optimizes their utility given budget constraint (iii) price level is such that factor market and goods market clear and (iv) balance trade happens [5]. Here, the price components include the prices of traded and non-traded goods ($\{p_n^j\}$ (for j = 1(1)J+1)), wage rate w_n, rental rate of capital r_n and aggregate prices P_n. The factor allocations are given by $\{K_n^j, L_n^j\}$, the final demand allocations is Y_n^j and final production is Q_n^j. These price distributions, factor allocations should satisfy the following equilibrium conditions

3 Generalization of the model

3.1 Trade war with retaliation

The framework can be extended to trade war with retaliation where Country 1 imposes higher tariffs on Country 2 and Country 2 retaliates with higher tariffs on Country. The

[5] Here, the tariffs increases the revenue of the countries and thereby, the trade is not likely to be balance under higher trade cost. However, unbalanced trade will open up the role of financial sectors and thereby, will complicate the model framework. Further, the trade policy uncertainty will not have any implications on financial markets. Hence, we assume that the trade balance of each country is provided to the firms lump sum tax/ subsidy. The effect of trade policy uncertainty is not impacted due to the lump sum tax/subsidy on firms

difference with this scenario is that the tariff distribution d_{21}^j follows stochastic distribution with upper bound of D^{j*} and a probability of trade policy changes $(1-\mu)$. Following similar derivations, the trade cost distribution under TPU from country 2,becomes

$$D_{21}^j\big|_{\text{Under TPU}} \begin{cases} = d_{21}^j & \text{if no change in trade policy}(Pr = \mu) \\ \sim U(d_{21}^j, D^{j*}) & \text{Otherwise}(Pr = 1-\mu) \end{cases} \tag{22}$$

The price of sector j goods in country 2 becomes

$$P_2^j = \Gamma\left[\mu\left(\Phi_2^j\right)^{-\frac{1}{\theta}} + \frac{1-\mu}{D_1 - d_{21}^j}\int_{d_{21}^j}^{D_1}\left(\Phi_2^j(h)\right)^{-\frac{1}{\theta}} dh\right] \tag{23}$$

The market access of Country 2 becomes

$$\Phi_2^j\big|_{\text{TPU}} = \mu\Phi_2^j + \frac{1-\mu}{D_1 - d_{21}^j}\int_{d_{21}^j}^{D_1}\Phi_2^j(h)dh \tag{24}$$

Lastly, the trade share in Country 2 becomes

$$\pi_{2i}^j = \mu\frac{T_i^j\left(C_i^j d_{2i}^j\right)^{-\theta}}{\Phi_2^j} + \frac{1-\mu}{D_1 - d_{21}^j}\int_{d_{21}^j}^{D_1}\frac{T_i^j\left(C_i^j d_{2i}^j\right)^{-\theta}}{\Phi_2^j(h)}dh \tag{25}$$

Using similar comparative statics, higher value of D^{j*} and $(1-\mu)$ leads to higher value of P_2^j and increases trade share of other trade partners $(i \neq 1)$. However, the trade share may not reach the full potential with respect to the actual tariff realization depending upon the realization of trade cost after tariff changes and the belief about the upper bound of the tariff sizes.

3.2 COVID lockdown in China

The above framework can be extended to model different scenarios. I extend the model to capture the COVID lockdown scenario in China. Spike in COVID cases in major cities of China lead to a strict lockdown which restricted the transportation and economic activities.

This scenario can be modelled with the assumption of higher trade cost (i.e. D^j is very high) and the probability of trade policy changes $(1-\mu)$ being very high. Here, the distribution of the trade costs under TPU is expressed as

$$D^j_{2i}\big|_{\text{Under TPU}} \begin{cases} = d^j_{2i} & \text{if no change in trade policy}(Pr = \mu) \\ \sim U(d^j_{2i}, D^{j**}) & \text{Otherwise}(Pr = 1-\mu) \end{cases} \tag{26}$$

Since the trade costs of each trade partners with Country 2 (i.e. China) follows stochastic distribution, the distribution of prices of traded sectors can be derived as (given $\mu = 0$ i.e. trade policy changes with certainty)

$$P^j_2 = \left(\prod_{i=1}^{N} \frac{1}{D^{j**} - d^j_{2i}}\right)\left(\prod_{i=1}^{N} \int_{d^j_{2i}}^{D^{j**}} \left(T^j_i (C^j_i h)\right)^{-\theta} dh\right) \tag{27}$$

Clearly, the effect of trade policy uncertainty is more severe in this context as the trade cost with all trade partners become uncertain.

4 Calibration

Having shown the effect of TPU parameters on the trade share and price distribution, I move to calibration of the model using two stage approaches.

In the first stage, I estimate the non-TPU parameter (i.e. all parameters except D^j and $(1-\chi)$) using Levchenko and Zhang (2011) approach. The approach estimates (i) productivity parameters T^j_n and θ (ii) trade costs under no uncertainty d^j_{ik} (iii) production function parameters (iv) labor and capital endowments and elasticity & preference parameters [6]. These parameters are estimated using annual data from 2012-2016 period. I choose the time frame to avoid any influence of trade policy uncertainty [7]. I select 62 countries for the model parameters. A list of countries is provided in Appendix 1. The sectors correspond to 2-digit

[6] I skip the details of these parameter estimation. For details, refer to Levchenko & Zhang (2011) and Giovanni et. al. (2014)

[7] The trade policy uncertainty index remained low during this time

ISIC codes (Rev 3). These sectors are

Table 1: Sectors covered

Food - Beverage (15)	Tobacco products (16)
Textiles (17)	Wearing apparels (18)
Leather and products (19)	Wood products (20)
Paper and products (21)	Printing (22)
Coke, refined petroleum (23)	Chemical and products (24)
Rubber and products (25)	NMMP (26)
Basic metal (27)	Fabricated metal (28)
Office, accounting (29)	Electrical machinery (31)
Medical precision (33)	Transport equipment (34)
Furniture (36)	Services (non-traded) (4A)

The second part involves TPU parameters D^j and $(1-\chi)$. These parameters are tested using different choices of tariff upper bounds and probability of policy changes. The possible values of D^j is drawn from (i) bounded tariffs under MFN agreements (ii) Highest value of Pre-WTO accession tariffs and (iii) maximum value of Column 2 tariffs. These values are represent the highest tariffs agreed under MFN agreements or highest tariffs imposed by the United States in different occasions. We assume that the trade partners form their belief about the possible tariff sizes based on the benchmark tariff rates from these references. Lastly, I calibrate the model with different values of $(1-\chi)$ between 0.1 and 0.9 [8].

[8] For the calibration purpose, I only considered one sided tariffs imposed by the United States on China

5 Findings

5.1 Non-TPU parameter estimates and goodness of fit

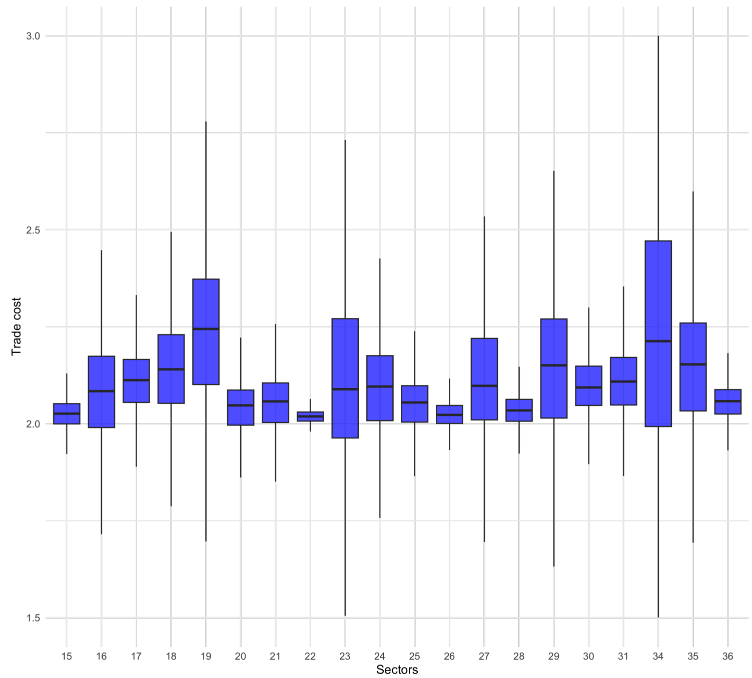
The first round of parameter estimation provides an estimate of the non-TPU parameters. The estimate of absolute comparative advantages in each sector provides an overview about the heterogeneity of the sectors in terms of comparative advantages (refer to Table 2).

Table 2: Estimate of T_i^j

ISIC	Min	Q1	Median	Mean	Q3	Max	ISIC	Min	Q1	Median	Mean	Q3	Max
15	0.00	0.03	0.05	0.08	0.08	1.06	16	0.00	0.01	0.01	0.11	0.03	3.23
17	0.00	0.03	0.05	0.08	0.07	1.10	18	0.00	0.01	0.02	0.05	0.04	1.00
19	0.00	0.00	0.00	0.02	0.01	1.17	20	0.00	0.02	0.04	0.08	0.06	1.27
21	0.00	0.03	0.05	0.09	0.08	1.22	22	0.00	0.01	0.02	0.05	0.03	1.05
23	0.01	0.05	0.09	0.16	0.13	1.51	24	0.00	0.02	0.03	0.06	0.04	1.06
25	0.00	0.03	0.05	0.08	0.07	1.19	26	0.00	0.02	0.03	0.06	0.04	1.20
27	0.01	0.05	0.08	0.11	0.12	1.12	28	0.00	0.02	0.03	0.06	0.05	1.05
29	0.00	0.01	0.02	0.05	0.04	0.98	30	0.00	0.03	0.05	0.10	0.07	1.76
31	0.00	0.03	0.05	0.08	0.07	1.11	34	0.00	0.03	0.06	0.10	0.09	1.27
35	0.00	0.02	0.04	0.08	0.05	1.18	36	0.93	0.94	0.98	0.99	1.04	1.08

The trade cost estimates d_{ik}^j distribution, derived using the gravity equation, highlights the variation in trade cost across different traded sectors. The variation, represented in boxplot, varies between (1.5,3.0) for all sectors with major variation observed in transport equipment (ISIC = 34) and coke & refined petroleum products (ISIC = 23) (Fig. 1)

Figure 1: Trade cost estimates



Trade costs are estimated using gravity equations by incorporating bilateral country attributes

Using the estimated parameters, the wage and rental rate of capital are derived using LZ (2011) and the goodness of fit of these prices indicates a close fit of the data moments with the model predictions (Table 3)

Table 3: Moment matching between model and data using 2012-2016 annual data

	Model	**Data**
Wage values		
Mean	0.34	0.42
Median	0.32	0.29
Percentile(25th)	0.15	0.11
Percentile(75th)	0.44	0.60
Correlation	0.78	
Rental rate		
Mean	0.78	0.86
Median	0.45	0.66
Percentile(25th)	0.25	0.31
Percentile(75th)	0.74	0.90
Correlation	0.78	
Trade share π_{ni} $(n \neq i)$		
Mean	0.0238	0.0205
Median	0.0015	0.0021
Correlation	0.65	
Own trade share π_{ni} $(n = i)$		
Mean	0.5898	0.6256
Median	0.6342	0.7635
Correlation	0.64	

5.2 TPU parameters and scenario analysis

Using the baseline parameters, different scenarios are constructed to incorporate the trade policy uncertainty in the model. These scenarios were derived using different values of

TPU parameters, χ and D^j. The choice of D^j, i.e. the upper bound of tariff, can be benchmarked against the higher tariff episodes. Some examples include the tariff levels under no-cooperation (i.e. US tariff on Cuba, North Korea etc.), higher tariffs imposed on China during pre-WTO accession period or upper bound of tariffs negotiated by the US on China. For calibration purpose, the higher tariff levels are set from the bounded tariff limits which were negotiated by the United States with China under trade agreements. These tariffs varied across different sectors. The scenarios were developed using values from the tariff distribution (Table 4 provides the variation in these tariff levels).

Table 4: US import tariffs

	Max	**Min**
1930 - 1950	65%	15%
1950 - 1990	15%	8%

The probability of trade policy changes, χ is calibrated over range of values varying over 0.05 to 0.95. Low values of χ represent lower chance of trade dispute whereas higher values of χ represent imminent threat of trade dispute. Lastly, the combination of discretize values of D^j and χ created different TPU scenarios. The model prediction are generated using the baseline non-TPU parameters and the choice of TPU parameters from each scenario. These predictions were matched with actual trade share data during the recent US trade dispute period. The targeted bilateral trade data is collected from WITS at ISIC 2 digit level for 2019 to capture the trade dispute outcomes. The bilateral trade shares are compared between data and model predictions using trade share ratio, defined as below

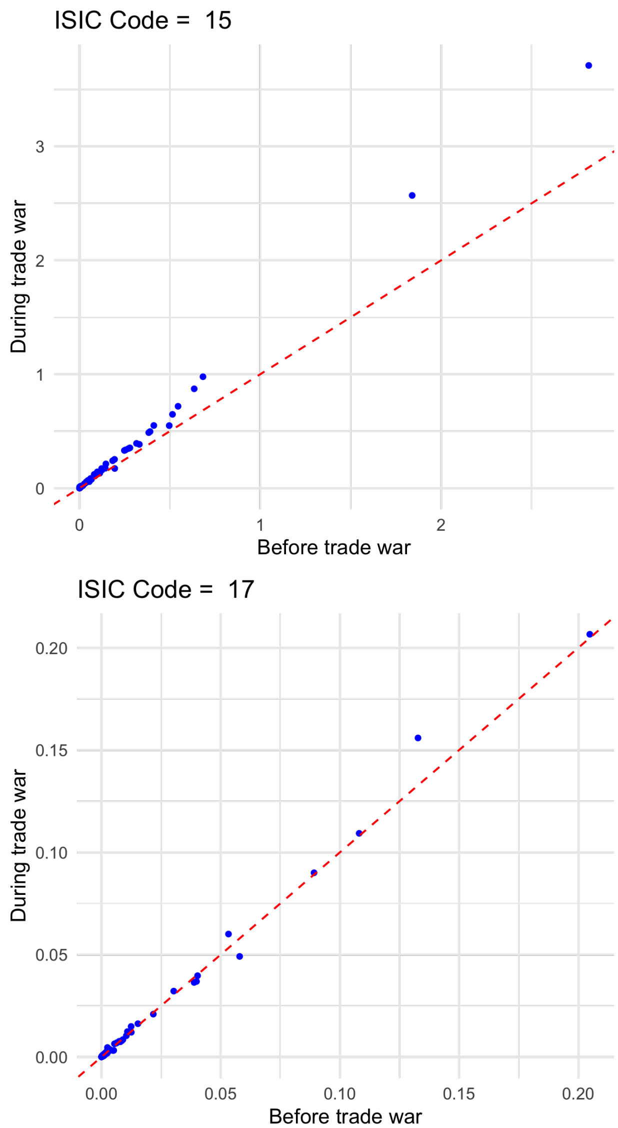
$$DD_i^j = \left(\frac{\pi_{1i}^{j,After}}{\pi_{12}^{j,After}} \right) \text{ and } \left(\frac{\pi_{1i}^{j,Before}}{\pi_{12}^{j,Before}} \right) \tag{28}$$

where $After$ stand for 2019 and $Before$ represents the average trade share between 2016-2017. Higher value of DD_i^j represents greater trade intensity from trade partner i to US (Country = 1) compared to trade intensity with China in the same sector. If DD_j^i increases in the after trade dispute period, it provides evidence towards possible trade diversion after higher tariffs were imposed on China [9]. Apart from the trade share, the consumer price predictions are matched for the US and China with the post trade dispute data.

The model predictions are generated using the trade share equation and price distribution are generated by simplifying the TPU equations in incomplete Gamma format (Refer to Appendix for the simplified version of these equations). The scatter plot of trade share from before and after trade dispute period provides a glimpse of heterogeneity in trade re-allocations after the trade dispute. Fig 9 plots the average trade share ratio of other trade partners (excluding China). The horizontal axis is the average trade share over 2016-17 and the vertical axis is the trade share in 2019. The plots are fitted with a 45 degree line - any point on the dotted red line represents no change in relative trade share after the trade dispute (The plots are shown for ISIC 15-18 in the main text, other plots are available in Appendix).

[9] One of the limitation of this ratio based measure is that D_i^j is always 1 for China. Recent literature shows that the effect of higher tariffs on China moderated the bilateral trade volume between US and China. However, I do not compare the moderation of trade volume from China in this paper

Figure 2: Trade share ratio plots (from data)



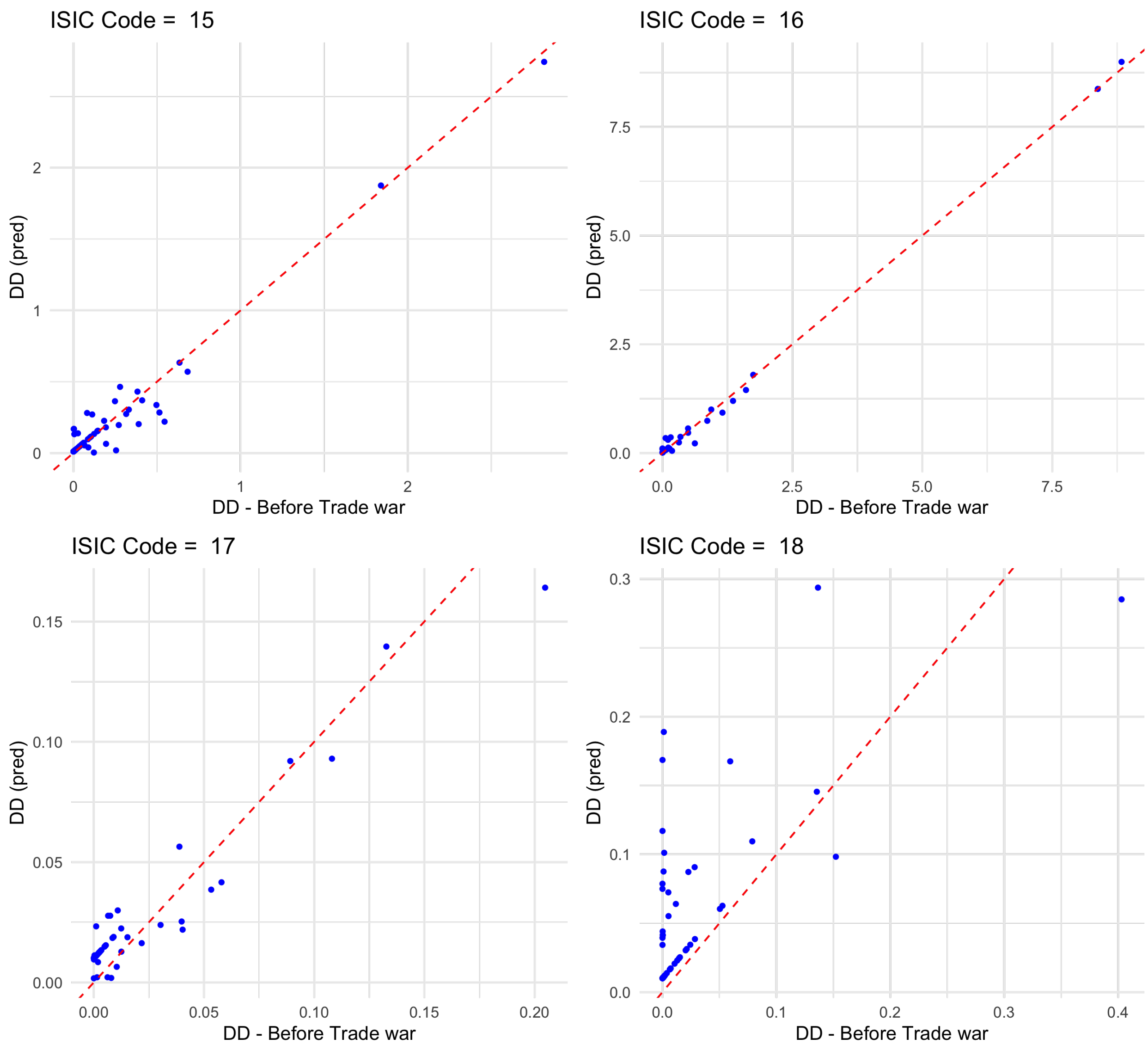
The trade shares ratios are defined across ISIC sectors using UN Comtrade data; "Before trade war" period is 2016-2017 and "During trade war" is 2019 data. The industry labeling is not incorporated in the chart for better readability. Please refer to Table 1 for sectors

Following Fig. 9, the trade share ratios increased for ISIC Code 15 (Food and Beverages) which implies trade diversion across all trade partners. However, such broad-based trade diversion intensity did not happen for other industry segments. In fact, the heterogeneity in the trade diversion is visible in tobacco products (ISIC = 16), wearing apparels (ISIC = 18), printing (ISIC = 22), chemical and products (ISIC = 24), non-metallic mineral products

(ISIC = 26) and basic metals (ISIC = 27).

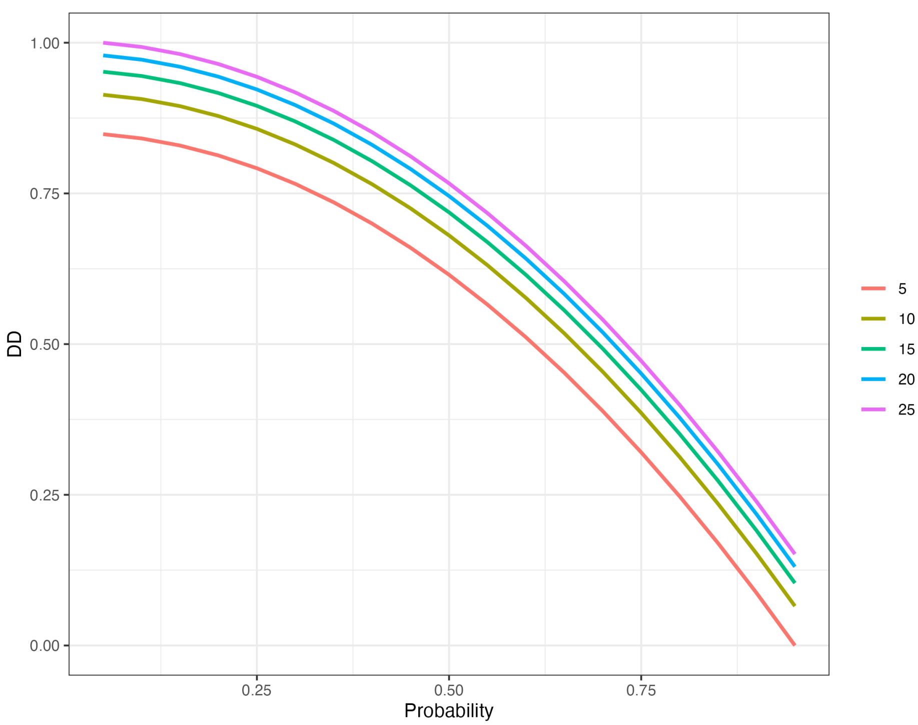
I plot the trade share ratio for the before trade dispute period from the model prediction and data. Fig. 3 provides scatter plot of the trade share prediction against the observed variation from data. The predicted values fall close to the red dotted line which implies that the model predictions match with data.

Figure 3: Trade share prediction before trade war



Next, I predict the trade share to the United States using different values of probability and tariff sizes (χ and D^j) and calculate the ratio measures DD. The average trade share ratio is plotted against the tariff size brackets and trade policy change probability. The trade diversion intensity, measured by DD, remains high when the probability of tariff changes are high (the plot uses χ in the horizontal axis which represents the probability of no change in tariffs). The trade diversion intensity increases with the probability of trade diversion. The prediction is intuitive - as the trade partners starts believing in imminent trader dispute, they make their production plan accordingly and the trade diversion happens more intensely to other trade partners. The trade diversion intensity increases with the higher bounds of tariff sizes. As the trade partners expect large tariff changes on Country 2, the high trade cost offsets the relative comparative advantages of Chinese firms and creates opportunity for other trade partners to increase their export to the United States (refer to Figure 4.

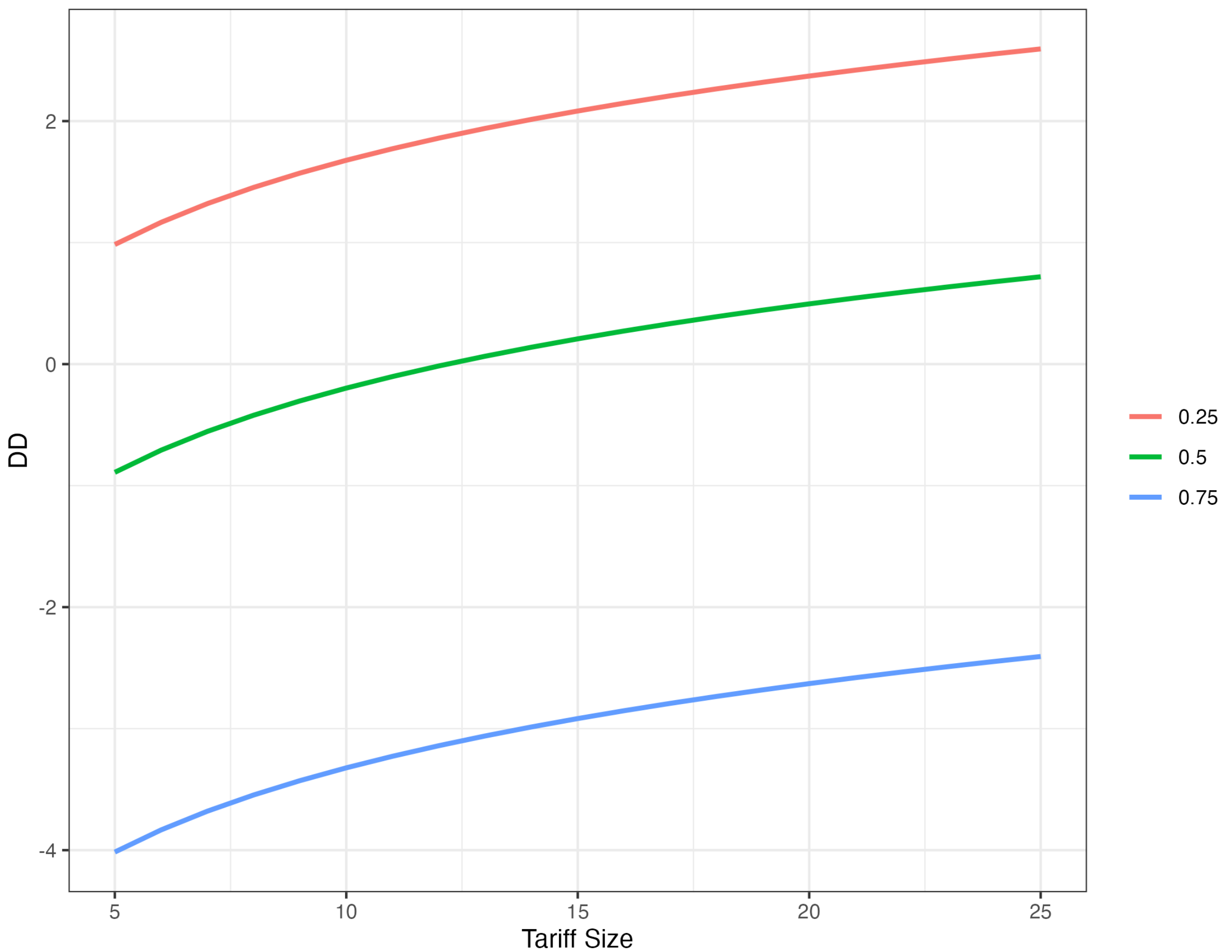
Figure 4: Trade share ratio under different Tariff brackets



(Different colors represents trade diversion intensity under different tariff size brackets in percentages)

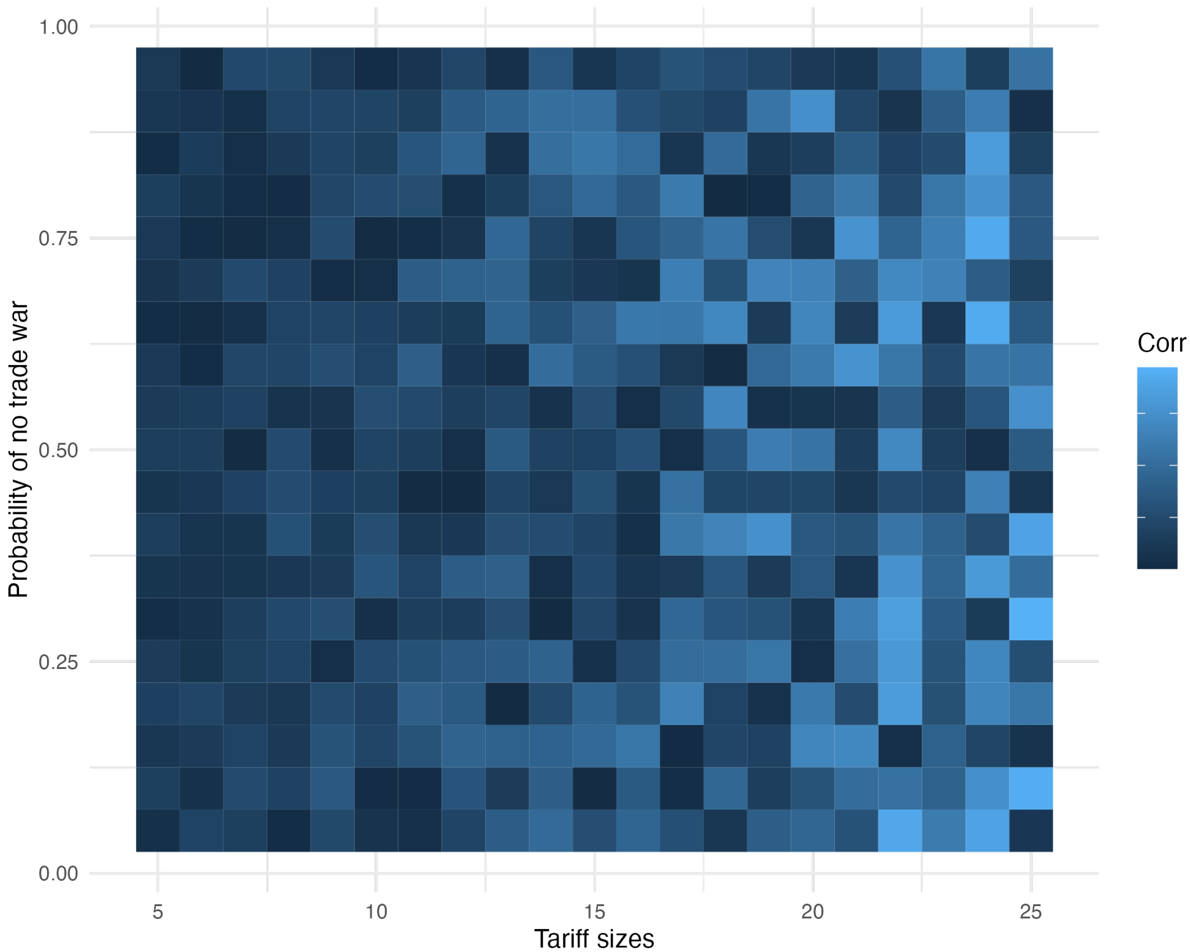
Next, the average prediction of trade diversion (DD) is plotted against the tariff sizes for different beliefs on uncertainty about trade policy changes. Here, the trade diversion intensities increases with the tariff sizes. Such increasing pattern in trade diversion intensity reflects the increase in trade partners' assessment about the final export demand to the US under different beliefs about the trade policy changes (refer to Figure 5.

Figure 5: Trade share ratio under different Probability brackets



I compare the prediction of trade diversion intensity from the model with the patterns observed from data. For that, the trade diversion ratio is calculated from bilateral trade flows data for 2019 data. The predictions are matched against the trade shares from the data and correlation between the model the model predictions and the actual realizations are calculated for each scenarios. The correlation increases with tariff sizes and probability of trade dispute. For relatively lower tariff level, the correlation is highest when the belief about the tariff dispute is very high (refer to Figure 6) (please refer to the annex for the prediction accuracy across various tariff size brackets and probability brackets).

Figure 6: Correlation of trade diversion intensity - prediction and realization



The correlation pattern provides some intuition behind the trade partners' belief about the trade dispute between US and China. The trade partners factored in higher tariff scenario under trade dispute. The rationale behind such belief of high tariff can be drawn from the average tariff on China before WTO accession. The higher correlation values at high tariff sizes reveals that the trade partners believed very high tariffs drawing from the pattern of higher tariffs on China since 1980. At such higher tariffs, the correlation is high at relatively lower probability of trade dispute. Combining these two outcomes, the trade partners appear to be less certain about the implementation of higher tariffs but they were near certain about very high tariff values.

6 Concluding remarks

I asses the impact of trade policy uncertainty on the global trade flows. Previous literature has demonstrated that the policy uncertainty affects firms' decision to enter a new export market, leading to attenuation of new investment and technology upgrades. In this paper, I extend the trade policy uncertainty to a multi-country multi-sector trade model to demonstrate the effect of policy uncertainty on global trade flows. Uncertainty arises from two sources: the probability of trade policy change and the uncertainty around the tariff sizes. The framework assumes that the trade partners make their production plan at the beginning of the period when there is lack of clarity about the trade dispute. They have their belief about possible trade dispute which leads to uncertainty around the price distribution and the final demand. The trade partners' belief is modeled by assuming a uniform distribution on tariffs and probability of trade policy changes. Given the uncertainty, the trade partners decides the trade intensity by factoring in their assessment of final demand and prices.

I assess the effect of trade policy uncertainty using an analytical solution and full scale calibration of the model under different scenarios. The analytical solution establishes that the trade policy uncertainty moderates the trade diversion intensity and increases the price distribution in the destination market. The effect depends upon the stochastic distribution of the tariff sizes and the probability of trade policy changes. The calibration of the structural model is done by estimating the model parameters in two stages. The paper uses the recent US-China trade war to demonstrate the effectiveness of the proposed framework in explaining the global trade flows after the US imposed higher tariffs on China and other trade partners. In the first stage, the trade model parameters, not pertaining to uncertainty components, are estimated from bilateral trade data before the recent trade disputes of the United States. In the second stage, the trade policy uncertainty is introduced in the model using different assumptions on the tariff sizes and probability of trade policy changes. Lastly, the model prediction under different assumptions of trade policy uncertainty parameters, are matched with the trade flows data and changes in price movements.

The paper observes that trade diversion intensity increases with the belief about the upper bound of tariff level and the probability of the trade dispute. As the trade partners plan for the possible tariff imposition with certainty, they plan their production accordingly. The effect of trade policy uncertainty and the adjustment cost of production plans creates a wedge among trade partners in terms of trade diversion intensity. The model prediction are matched with the trade diversion pattern from post-trade war period. The correlation between the model prediction and realization provides an intriguing pattern about the trade partners' belief. The trade partners belief aligned with the possibility of higher tariffs imposition but they were uncertain about the implementation of higher tariffs.

The paper contributes to the increasing literature of trade policy uncertainty and Ricardian trade models by introducing the effect of trade policy uncertainty on global trade flows. The generalization proposed in this paper, adds more flexibility in the multi-country trade models by relaxing the assumption of fixed trade cost. The approach can be generalized to different situations like Brexit uncertainty or uncertainty around the lockdown measures imposed by China. The model is capable of generating the disruptions in trade intensity due to global events leading to uncertain trade environments. The main driver of the trade policy uncertainty is drawn from the belief about the trade dispute and uncertainty about the possible tariff sizes. The beliefs can be generalized to introduce heterogeneity in the country level experience of trade diversion.

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7 Appendix

7.1 Simplifying TPU equations using incomplete Gamma

Export price distribution of Country 2 to Country 1

$$G_{12}^j(p) = 1 - \chi exp\Bigg[- T_2^j \Big(C_2^j d_{12}^j \Big)^{-\theta} p^\theta \Bigg] - (1-\chi) \frac{\theta}{(D - d_{12}^j)(T_2(C_2^j)^{-\theta} p^\theta)} \Bigg[\Gamma(d_{12}^\theta) - \Gamma(D^\theta) \Bigg] \tag{29}$$

Price distribution in Country 1

$$G_1^j(p) = 1 - \chi exp\Bigg[- \Phi_1^j p^\theta \Bigg] - \frac{1-\chi}{D - d_{12}^j} \frac{\theta}{(T_2(C_2^j)^{-\theta} p^\theta)} \Bigg[\Gamma(d_{12}^\theta) - \Gamma(D^\theta) \Bigg] \Phi_{1,-2}^j \tag{30}$$

Price in Country 1

$$P_1^j = \Gamma \Bigg[\chi \Big(\Phi_1^j \Big)^{-\frac{1}{\theta}} + \frac{1-\chi}{D - d_{12}^j} \int_{d_{12}^j}^{D} \Big(\Phi_1^j(h) \Big)^{-\frac{1}{\theta}} dh \Bigg] \tag{31}$$

Export share

$$\frac{\pi_{1i}^j}{\pi_{12}^j} = \frac{\chi \frac{T_i^j \left(C_i^j d_{12}^j \right)^{-\theta}}{\Phi_1^j} + \frac{1-\chi}{D-d_{12}^j} \int_{d_{12}^j}^{D} \frac{T_i^j \left(C_i^j d_{12}^j \right)^{-\theta}}{\Phi_1^j(h)} dh}{\chi \frac{T_2^j \left(C_2^j d_{12}^j \right)^{-\theta}}{\Phi_1^j} + \frac{1-\chi}{D-d_{12}^j} \int_{d_{12}^j}^{D} \frac{T_2^j \left(C_2^j h \right)^{-\theta} dh}{\Phi_1^j(h)} dh} \tag{32}$$

7.2 Trade share ratio across industry segments

Figure 7: Trade share ratio plots (from data)

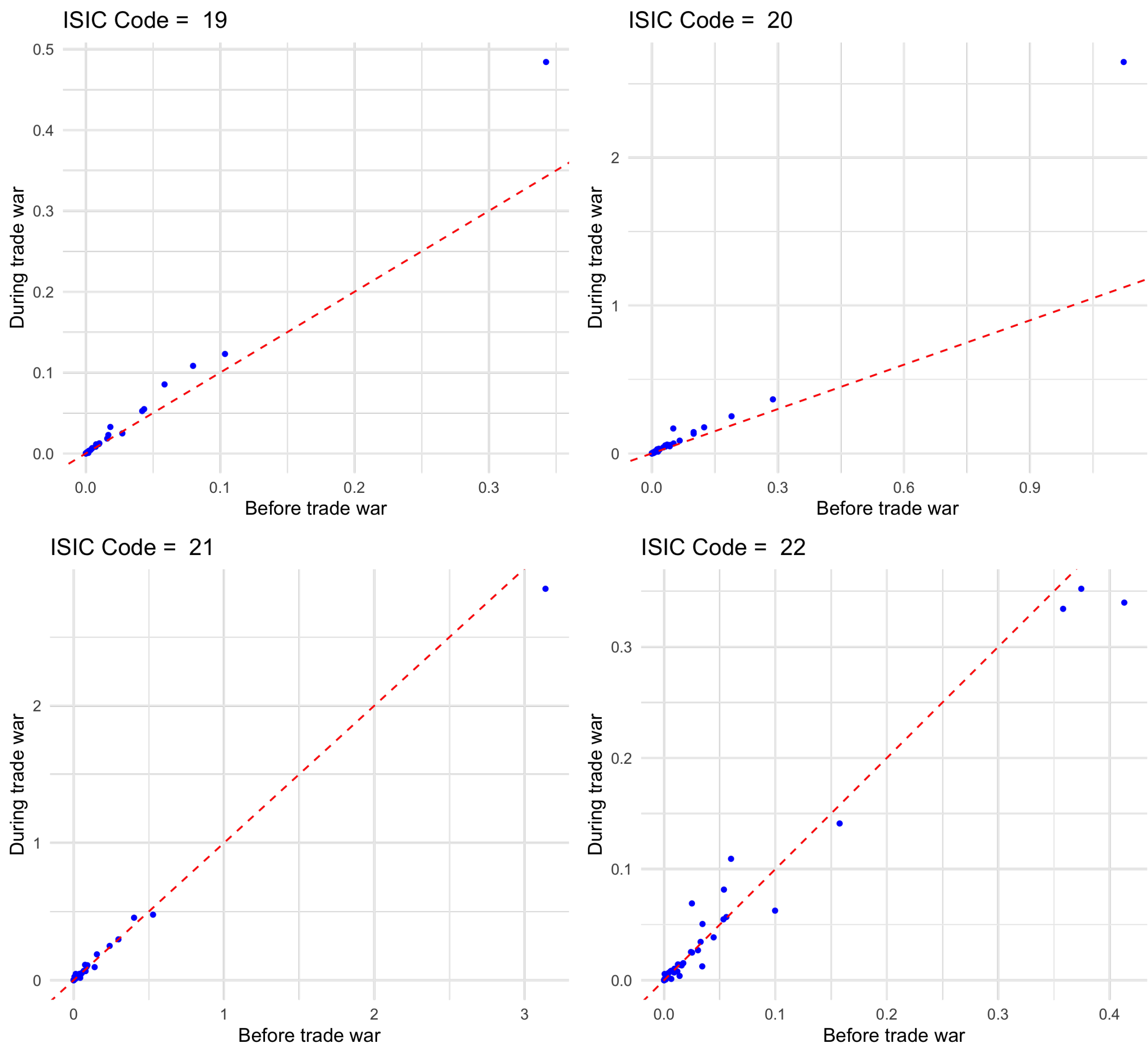

Figure 8: Trade share ratio plots (from data)

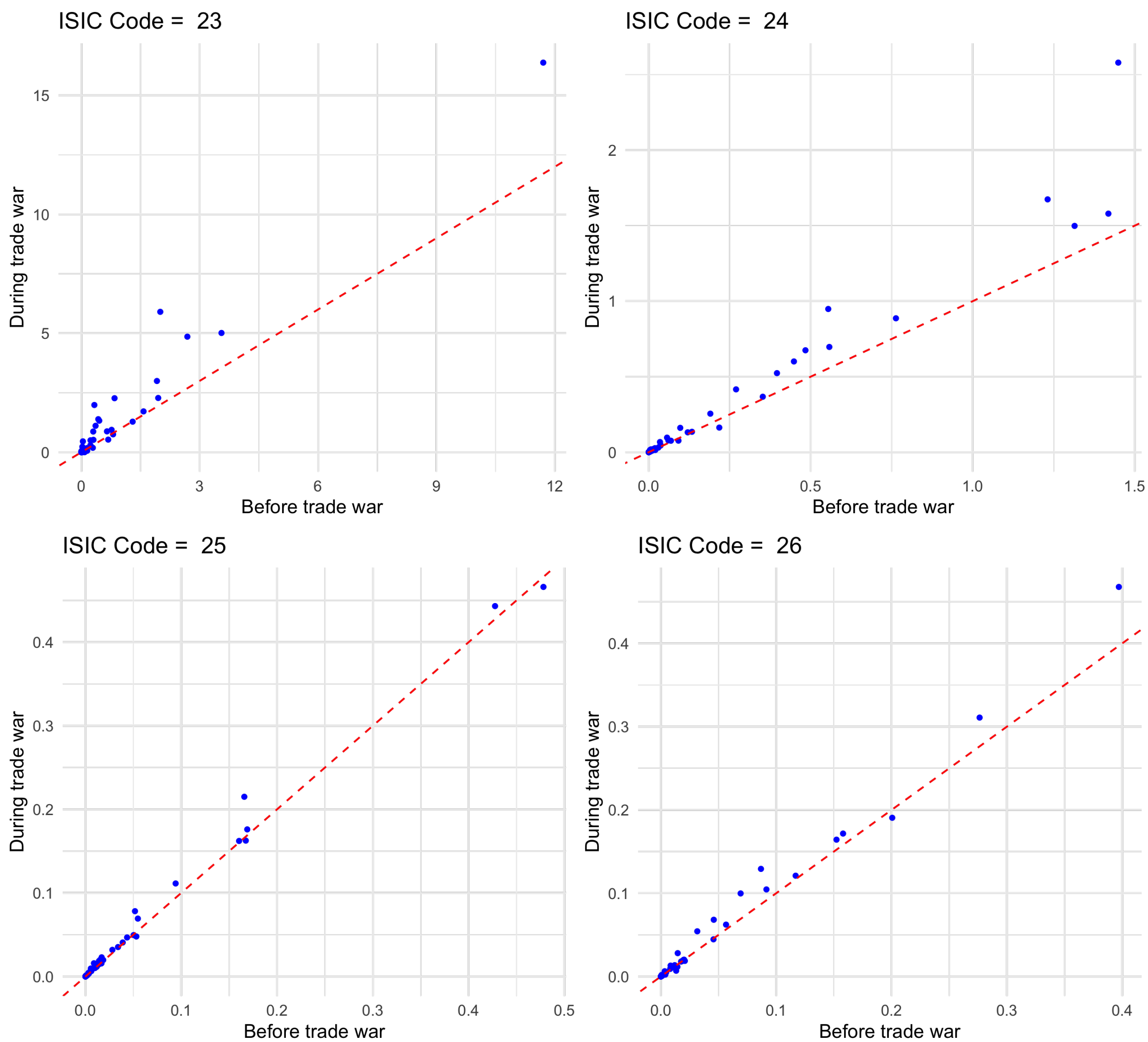

Figure 9: Trade share ratio plots (from data)