Trade Wars and Trade Talks with Data*

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Abstract

What are the optimal tariffs of the US? What tariffs would prevail in a worldwide trade war? How costly would be a breakdown of international trade policy cooperation? And what is the scope for future multilateral trade negotiations? I address these and other questions using a unified framework which nests traditional, new trade, and political economy motives for protection. I find that US optimal tariffs average 60 percent, world trade war tariffs average 58 percent, the welfare losses from a breakdown of international trade policy cooperation average 3.5 percent, and the possible welfare gains from future multilateral trade negotiations average 0.3 percent.

JEL classification: F11, F12, F13

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1 Introduction

I propose a flexible framework for the quantitative analysis of noncooperative and cooperative trade policy. It is based on a multi-country multi-industry general equilibrium model of international trade featuring inter-industry trade as in Ricardo (1817), intra-industry trade as in Krugman (1980), and special interest politics as in Grossman and Helpman (1994). By combining these elements, it takes a unified view of trade policy which nests traditional, new trade, and political economy motives for protection. Specifically, it features import tariffs which serve to manipulate the terms-of-trade, shift profits away from other countries, and channel profits towards politically influential industries.

I use this framework to provide a first comprehensive quantitative analysis of noncooperative and cooperative trade policy. To this end, I calibrate it to perfectly match industry-level trade and tariffs of the main players in recent GATT/WTO negotiations. I begin with an investigation of unilateral trade policy: What are the optimal tariffs of the US and how powerful are the traditional, new trade, and political economy motives for protection? I then turn to an examination of multilateral trade policy: What tariffs would prevail in a worldwide trade war and how costly would be a breakdown of international trade policy cooperation? What tariffs would result from efficient trade negotiations and how much scope is there for future mutually beneficial trade liberalization?

With respect to unilateral trade policy, I find that US optimal tariffs vary widely across industries and trading partners and average 60 percent. They would increase real income in the US by 2.4 percent and decrease real incomes elsewhere by 1.3 percent on average. In the US, imports would fall by 37 percent and a reallocation of resources to more profitable industries would increase profits by 5.0 percent. In other countries, imports would fall by 10 percent on average, and a reallocation of resources to less profitable industries would decrease profits by 1.6 percent on average. Traditional terms-of-trade effects and new trade profit shifting effects are the key driving forces behind these results.

With respect to multilateral trade policy, I find that world trade war tariffs vary widely across industries, countries, and trading partners and average 58 percent. This is roughly in line with the noncooperative tariffs observed following the Smoot-Hawley Tariff Act of

1930. They would substantially decrease real income in all countries with the average loss amounting to 3.5 percent. They would also induce a sharp drop in imports in all countries with the average decline equaling 58 percent. I also find that factual tariffs are close to efficient tariffs in the sense that a mutually beneficial move from factual tariffs to efficient tariffs would only increase real incomes by 0.3 percent on average.

I am unaware of any quantitative analysis of noncooperative and cooperative trade policy which is comparable in terms of its scope. I believe that this is the first quantitative framework which nests traditional, new trade, and political economy motives for protection. Likewise, there is no precedent for estimating noncooperative and cooperative tariffs at the industry level for the major players in recent GATT/WTO negotiations. The surprising lack of comparable work is most likely rooted in long-binding methodological and computational constraints. In particular, widely accepted calibration techniques of general equilibrium trade models have only become available quite recently following the seminal work of Eaton and Kortum (2002). Also, the calculation of disaggregated noncooperative and cooperative tariffs is very demanding computationally and was simply not feasible without present-day algorithms and computers.

The most immediate predecessors are Perroni and Whalley (2000), Broda et al (2008), and Ossa (2011). Perroni and Whalley (2000) provide quantitative estimates of noncooperative tariffs in a simple Armington model which features only traditional terms-of-trade effects. Ossa (2011) provides such estimates in a simple Krugman (1980) model which features only new trade production relocation effects. Both contributions allow trade policy to operate only at the most aggregate level so that a single tariff is assumed to apply against all imports from any given country.[1] Broda et al (2008) provide detailed statistical estimates of the inverse export supply elasticities faced by a number of non-WTO member countries. The idea is to test the traditional optimal tariff formula which states that a country's optimal tariff is equal to the inverse export supply elasticity it faces in equilibrium.[2]

[1] Neither contribution computes cooperative tariffs. The work of Perroni and Whalley (2000) is in the computable general equilibrium tradition and extends an earlier contribution by Hamilton and Whalley (1983). It predicts implausibly high noncooperative tariffs of up to 1000 percent. See also Markusen and Wigle (1989).

[2] This approach is not suitable for estimating the optimal tariffs of WTO member countries. This is because such countries impose cooperative tariffs so that the factual inverse export supply elasticities they face are not informative of the counterfactual inverse export supply elasticities they would face if they imposed optimal tariffs under all but the most restrictive assumptions.

The paper further relates to an extensive body of theoretical and quantitative work. The individual motives for protection are taken from the theoretical trade policy literature including Johnson (1953-54), Venables (1987), and Grossman and Helpman (1994).[3] The analysis of trade negotiations builds on a line of research synthesized by Bagwell and Staiger (2002). My calibration technique is similar to the one used in recent quantitative work based on the Eaton and Kortum (2002) model such as Caliendo and Parro (2011). However, my analysis differs from this work in terms of question and framework. In particular, I go beyond an investigation of exogenous trade policy changes by emphasizing noncooperative and cooperative tariffs.[4] Also, I take a unified view of trade policy by nesting traditional, new trade, and political economy effects.

My application focuses on 7 regions and 26 manufacturing industries in the year 2005. The regions are Brazil, China, the EU, India, Japan, the US, and a residual Rest of the World and are chosen to comprise the main players in recent GATT/WTO negotiations. I need data on trade flows and tariffs as well as estimates of two sets of structural parameters. I construct the matrix of trade flows from United Nations trade data, NBER production data, and World Bank production data. I take the matrix of tariffs from an extension of United Nations tariff data. I use US estimates of the elasticities of substitution by Broda and Weinstein (2006) and US estimates of the influence of lobbies from Goldberg and Maggi (1999) for my benchmark calculations but also provide extensive sensitivity checks. A detailed discussion of the data including the applied aggregation, extrapolation, and matching procedures can be found in the appendix.

The remainder of the paper is organized as follows. In the next section, I lay out the basic setup, characterize the equilibrium for given tariffs, demonstrate how to compute the general equilibrium effects of tariff changes, and discuss the welfare effects of tariff changes. I then turn to US optimal tariffs, world trade wars, and world trade talks.

[3]The analyzed profit shifting effect is more closely related to the production relocation effect in Venables (1987) than the classic profit shifting effect in Brander and Spencer (1981). This is explained in more detail in footnote 10. See Mrazova (2010) for a recent treatment of classic profit shifting effects in the context of GATT/WTO negotiations.

[4]Existing work typically focuses on quantifying the effects of exogenous tariff changes. Caliendo and Parro (2011), for example, analyze the effects of the North American Free Trade Agreement. One exception can be found in the work of Alvarez and Lucas (2007) which includes a short discussion of optimal tariffs in small open economies.

2 Analysis

2.1 Basic setup

There are N countries indexed by i or j and S industries indexed by s. Consumers have access to a continuum of differentiated varieties. Preferences over these varieties are given by the following utility functions:

$$U_j = \prod_s \left(\sum_i \int_0^{M_{is}} x_{ijs} \left(\nu_{is}\right)^{\frac{\sigma_s - 1}{\sigma_s}} \, d\nu_{is} \right)^{\frac{\sigma_s}{\sigma_s - 1}\mu_{js}} \tag{1}$$

where x_{ijs} is the quantity of an industry s variety from country i consumed in country j, M_{is} is the mass of industry s varieties produced in country i, $\sigma_s > 1$ is the elasticity of substitution between industry s varieties, and μ_{js} is the fraction of country j income spent on industry s varieties.

Each variety is uniquely associated with an individual firm. Firms are homogeneous within industries and their technologies are summarized by the following inverse production functions:

$$l_{is} = \sum_j \frac{\theta_{ijs} x_{ijs}}{\varphi_{is}} \tag{2}$$

where l_{is} is the labor requirement of an industry s firm in country i featuring iceberg trade barriers θ_{ijs} and a productivity parameter φ_{is}. Each firm has monopoly power with respect to its own variety and the number of firms is given exogenously.[5]

Governments can impose import tariffs but do not have access to other policy instruments.[6] I denote the ad valorem tariff imposed by country j against imports from country i in industry s by t_{ijs} and make frequent use of the shorthand $\tau_{ijs} \equiv t_{ijs} + 1$ throughout. Government

[5] The model can also be solved and calibrated with free entry and fixed costs of production. I focus on a version without free entry for two main reasons. First, because it features positive profits and therefore lends itself more naturally to an analysis of political economy considerations. Second, because it rules out corner solutions with zero production in some sectors so that it can be implemented using a much simpler algorithm. See footnote 10 for a further discussion of the model with free entry.

[6] This restriction is motivated by the fact that import tariffs have always been by far the most important trade policy instruments in practice. However, it would be easy to extend the framework to also include export subsidies, import quotas, or voluntary export restraints. See Bagwell and Staiger (2009a, 2009b) for a discussion of the importance of this restriction for the theory of trade agreements in a range of simple new trade models.

preferences are given by the following objective functions:

$$G_j = V_j + \sum\nolimits_s \lambda_{js} \frac{\pi_{js}}{P_j} \tag{3}$$

where $V_j \equiv \frac{X_j}{P_j}$ is the welfare of country j, X_j is total expenditure or income in country j, P_j is the ideal price index in country j, $\lambda_{js} \geq 0$ is the political economy weight of industry s in country j, and π_{js} are the profits of industry s in country j.[7]

Notice that governments simply maximize welfare if the political economy weights are zero. The interpretation of the political economy weights is that one dollar of profits in industry s of country j counts $1 + \lambda_{js}$ as much as one dollar of wage income or tariff revenue in the government's objective function. This formulation of government preferences can be viewed as a reduced form representation of the "protection for sale" theory of Grossman and Helpman (1994). I compute the political economy weights based on US estimates of Goldberg and Maggi (1999) using a procedure which I explain in detail in the appendix. In essence, I divide industries into politically organized and politically unorganized ones and set their political economy weights to $\lambda_{is} = 0.017$ and $\lambda_{is} = 0$, respectively.[8]

2.2 Equilibrium for given tariffs

Utility maximization implies that firms in industry s of country i face demands

$$x_{ijs} = \frac{(p_{is}\theta_{ijs}\tau_{ijs})^{-\sigma_s}}{P_{js}^{1-\sigma_s}} \mu_{js} X_j \tag{4}$$

where p_{is} is the ex-factory price of an industry s variety from country i and P_{js} is the ideal price index of industry s varieties in country j. Also, profit maximization requires that firms in industry s of country i charge a constant mark-up over marginal costs

$$p_{is} = \frac{\sigma_s}{\sigma_s - 1} \frac{w_i}{\varphi_{is}} \tag{5}$$

[7] As in most trade models, welfare is the same as real income if nominal income is deflated by the ideal price index. This is because the ideal price index is a unit expenditure function and utility only depends on consumption. Nominal income consists of labor income, profits, and tariff revenue.

[8] In order to clearly expose the novel features of my framework, I deliberately abstract from intermediate goods or nontraded goods, which is in line with much of the theoretical trade policy literature. The idea is that intermediate goods tend to magnify the effects of trade policy while nontraded goods tend to dampen the effects of trade policy so that omitting both seems like a reasonable first pass.

where w_i is the wage rate in country i.

The equilibrium for given tariffs can be characterized with four condensed equilibrium conditions. The first condition follows from substituting equations (2), (4), and (5) into the relationship defining industry profits $\pi_{is} = M_{is}\left(\sum_j p_{is}\theta_{ijs}x_{ijs} - w_i l_{is}\right)$:

$$\pi_{is} = \frac{1}{\sigma_s}\sum\nolimits_j M_{is}\tau_{ijs}^{-\sigma_s}\left(\frac{\sigma_s}{\sigma_s - 1}\frac{\theta_{ijs}}{\varphi_{is}}\frac{w_i}{P_{js}}\right)^{1-\sigma_s}\mu_{js}X_j \tag{6}$$

The second condition combines equations (2), (4), and (5) with the requirement for labor market clearing $L_i = \sum_s M_{is}l_{is}$:

$$w_i L_i = \sum\nolimits_s \pi_{is}\left(\sigma_s - 1\right) \tag{7}$$

The third condition results from substituting equation (5) into the formula for the ideal price index $P_{js} = \left(\sum_i M_{is}\left(p_{is}\theta_{ijs}\tau_{ijs}\right)^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}}$:

$$P_{js} = \left(\sum\nolimits_i M_{is}\left(\frac{\sigma_s}{\sigma_s - 1}\frac{w_i\theta_{ijs}\tau_{ijs}}{\varphi_{is}}\right)^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}} \tag{8}$$

And the final condition combines equations (4) and (5) with the budget constraint equating total expenditure to labor income, plus tariff revenue, plus aggregate profits:

$$X_j = w_j L_j + \sum\nolimits_i\sum\nolimits_s t_{ijs}M_{is}\left(\frac{\sigma_s}{\sigma_s - 1}\frac{\theta_{ijs}}{\varphi_{is}}\frac{w_i}{P_{js}}\right)^{1-\sigma_s}\tau_{ijs}^{-\sigma_s}\mu_{js}X_j + \sum\nolimits_s \pi_{js} \tag{9}$$

Conditions (6) - (9) represent a system of $2N\left(S+1\right)$ equations in the $2N\left(S+1\right)$ unknowns w_i, X_i, P_{is}, and π_{is} which can be solved given a numeraire. An obvious problem, however, is that this system depends on the set of unknown parameters $\{M_{is}, \theta_{ijs}, \varphi_{is}\}$ which are all difficult to estimate empirically.

2.3 General equilibrium effects of tariff changes

I avoid this problem by computing the general equilibrium effects of counterfactual tariff changes using a method inspired by Dekle at al (2007). In particular, conditions (6) - (9) can be rewritten in changes as

$$\sum_j \alpha_{ijs} \left(\widehat{\tau}_{ijs}\right)^{-\sigma_s} \left(\widehat{P}_{js}\right)^{\sigma_s - 1} \widehat{X}_j = \widehat{\pi}_{is} \left(\widehat{w}_i\right)^{\sigma_s - 1} \tag{10}$$

$$\widehat{w}_i = \sum_s \delta_{is} \widehat{\pi}_{is} \tag{11}$$

$$\widehat{P}_{js} = \left(\sum_i \gamma_{ijs} \left(\widehat{w}_i \widehat{\tau}_{ijs}\right)^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}} \tag{12}$$

$$\widehat{X}_j = \frac{w_j L_j}{X_j} \widehat{w}_j + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j} \widehat{t}_{ijs} \left(\widehat{w}_i\right)^{1-\sigma_s} \left(\widehat{P}_{js}\right)^{\sigma_s - 1} \left(\widehat{\tau}_{ijs}\right)^{-\sigma_s} \widehat{X}_j + \sum_s \frac{\pi_{js}}{X_j} \widehat{\pi}_{js} \tag{13}$$

where a "hat" denotes the ratio between the counterfactual and the factual value, $\alpha_{ijs} \equiv T_{ijs} / \sum_n T_{ins}$, $\gamma_{ijs} \equiv \tau_{ijs} T_{ijs} / \sum_m \tau_{mjs} T_{mjs}$, $\delta_{is} \equiv \sum_j \frac{\sigma_s - 1}{\sigma_s} T_{ijs} \Big/ \sum_t \sum_n \frac{\sigma_t - 1}{\sigma_t} T_{int}$, and $T_{ijs} \equiv M_{is} \left(\frac{\sigma_s}{\sigma_s - 1} \frac{\theta_{ijs}}{\varphi_{is}} \frac{w_i}{P_{js}}\right)^{1-\sigma_s} \tau_{ijs}^{-\sigma_s} \mu_{js} X_j$ is the factual value of industry s trade flowing from country i to country j evaluated at world prices.

Equations (10) - (13) represent a system of $2N(S+1)$ equations in the $2N(S+1)$ unknowns $\widehat{w}_i$, $\widehat{X}_i$, $\widehat{P}_{is}$, $\widehat{\pi}_{is}$. Crucially, their coefficients depend on σ_s and observables only so that the full general equilibrium response to counterfactual tariff changes can be computed without further information on any of the remaining model parameters. Moreover, all required observables can be inferred directly from widely available trade and tariff data since the model requires $X_j = \sum_i \sum_s \tau_{ijs} T_{ijs}$ and $w_j L_j = X_j - \sum_i \sum_s t_{ijs} T_{ijs} - \sum_s \pi_{js}$, where $\pi_{js} = \frac{1}{\sigma_s} \sum_j T_{ijs}$ in this constant markup environment.

Notice that this procedure also ensures that the counterfactual effects of tariff changes are computed from a reference point which perfectly matches industry-level trade and tariffs. Essentially, it imposes a restriction on the set of unknown parameters $\{M_{is}, \theta_{ijs}, \varphi_{is}\}$ such that the predicted T_{ijs} perfectly match the observed T_{ijs} given the observed τ_{ijs} and the estimated σ_s. It is important to emphasize that the restriction on $\{M_{is}, \theta_{ijs}, \varphi_{is}\}$ does not deliver estimates of $\{M_{is}, \theta_{ijs}, \varphi_{is}\}$ given the high dimensionality of the parameter space. To obtain estimates of $\{M_{is}, \theta_{ijs}, \varphi_{is}\}$, one would have to reduce this dimensionality, for example, by imposing some structure on the matrix of iceberg trade barriers.[9]

One issue with equations (10) - (13) is that they are based on a static model which does

[9] I do not further pursue an estimation of $\{M_{is}, \theta_{ijs}, \varphi_{is}\}$ in this paper, since the model relates T_{ijs} and $\{M_{is}, \theta_{ijs}, \varphi_{is}\}$ with a standard gravity equation whose empirical success is widely known.

not allow for aggregate trade imbalances thereby violating the data. The standard way of addressing this issue is to introduce aggregate trade imbalances as constant nominal transfers into the budget constraints. However, this approach has two serious limitations which have gone largely unnoticed by the literature. First, the assumption of constant aggregate trade imbalances leads to extreme general equilibrium adjustments in response to high tariffs and cannot be true in the limit as tariffs approach infinity. Second, the assumption of constant nominal transfers implies that the choice of numeraire matters since real transfers then change with nominal prices.

To circumvent these limitations, I first purge the original data from aggregate trade imbalances using my model and then conduct all subsequent analyses using this purged dataset. The first step is essentially a replication of the original Dekle et al (2007) exercise using my setup. In particular, I introduce aggregate trade imbalances as nominal transfers into the budget constraint and calculate the general equilibrium responses of setting those transfers equal to zero which allows me to construct a matrix of trade flows featuring no aggregate trade imbalances. I discuss this procedure and its advantages as well as the first-stage results in more detail in the appendix.

As an illustration of the key general equilibrium effects of trade policy, the upper panel of Table 1 summarizes the effects of a counterfactual 25 percentage point increase in the US tariff on pharmaceuticals or cosmetics. Pharmaceutical products have a relatively low elasticity of substitution of 1.98 while cosmetic products have a relatively high elasticity of substitution of 13.49. The first column gives the predicted percentage change in the US wage relative to the numeraire. As can be seen, the US wage is predicted to increase by 0.15 percent if the tariff increase occurs in pharmaceuticals and is predicted to increase by 0.08 percent if the tariff increase occurs in cosmetics.

The second column presents the predicted percentage change in the quantity of US output in the protected industry and the third column the simple average of the predicted percentage changes in the quantity of US output in the other industries. Hence, US output is predicted to increase by 3.77 percent in pharmaceuticals and decrease by an average 0.06 percent in all other industries if the tariff increase occurs in pharmaceuticals. Similarly, US output is predicted to increase by 4.03 percent in cosmetics and decrease by an average 0.12 percent in all other industries if the tariff increase occurs in cosmetics.

Intuitively, a US import tariff makes imported goods relatively more expensive in the US market so that US consumers shift expenditure towards US goods. This then incentivizes US firms in the protected industry to expand which bids up US wages and thereby forces US firms in other industries to contract. Even though it is not directly implied by Table 1, it should be clear that mirroring adjustments occur in other countries. In particular, firms in the industry in which the US imposes import tariffs contract which depresses wages and allows firms in other industries to expand.

2.4 Welfare effects of tariff changes

Given the general equilibrium effects of tariff changes, the implied welfare effects can be computed from $\widehat{V}_j = \widehat{X}_j / \widehat{P}_j$, where $\widehat{P}_j = \Pi_s \left(\widehat{P}_{js} \right)^{\mu_{js}}$ is the change in the aggregate price index. This framework features both traditional as well as new trade welfare effects of trade policy. This can be seen most clearly from a log-linear approximation around factuals. As I explain in detail in the appendix, it yields the following relationship for the welfare change induced by tariff changes, where $\frac{\Delta V_j}{V_j}$ is the percentage change in country j's welfare and so on:

$$\frac{\Delta V_j}{V_j} \approx \sum_i \sum_s \frac{T_{ijs}}{X_j} \left(\frac{\Delta p_{js}}{p_{js}} - \frac{\Delta p_{is}}{p_{is}} \right) + \sum_s \frac{\pi_{js}}{X_j} \left(\frac{\Delta \pi_{js}}{\pi_{js}} - \frac{\Delta p_{js}}{p_{js}} \right) + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j} \left(\frac{\Delta T_{ijs}}{T_{ijs}} - \frac{\Delta p_{is}}{p_{is}} \right) \tag{14}$$

The first term is a traditional terms-of-trade effect which captures changes in country j's real income due to differential changes in the world prices of country j's production and consumption bundles. Country j benefits from an increase in the world prices of its production bundle relative to the world prices of its consumption bundle because its exports then command more imports in world markets. The terms-of-trade effect can also be viewed as a relative wage effect since world prices are proportional to wages given the constant markup pricing captured by formula (5).

The second term is a new trade profit shifting effect which captures changes in country j's real income due to changes in country j's aggregate profits originating from changes in industry output. It takes changes in industry profits, nets out changes in industry prices, and then aggregates the remaining changes over all industries using profit shares as weights. These remaining changes are changes in industry profits originating from changes in industry output since industry profits are proportional to industry sales in this constant markup environment.[10]

The last term is a combined trade volume effect which captures changes in country j's real income due to changes in country j's tariff revenue originating from changes in import volumes. It takes changes in import values, nets out changes in import prices, and then aggregates the remaining changes over all countries and industries using tariff revenue shares as weights. These remaining changes are changes in import volumes since changes in import values can be decomposed into changes in import prices and import volumes.[11]

As an illustration, the lower panel of Table 1 reports the welfare effects of the counterfactual 25 percentage point increase in the US tariff on pharmaceuticals or cosmetics and decomposes them into terms-of-trade and profit shifting components following equation (14). As can be seen, US welfare increases by 0.08 percent if the tariff increase occurs in pharmaceuticals but decreases by 0.01 percent if the tariff increase occurs in cosmetics. The differential welfare effects are due to differential profit shifting effects. While the terms-of-trade effect is positive in both cases, the profit shifting effect is positive if the tariff increase occurs in pharmaceuticals and negative if the profit increase occurs in cosmetics.

The positive terms-of-trade effects are a direct consequence of the increase in the US relative wage identified above. The differential profit shifting effects are the result of cross-industry differences in markups which are brought about by cross-industry differences in the

[10]This profit shifting effect is more closely related to the production relocation effect from Venables (1987) than the classic profit shifting effect from Brander and Spencer (1981). It can be shown that in a version of the model with free entry and fixed costs of production, the equivalent of equation (14) would be $\frac{\Delta V_j}{V_j} \approx \sum_i \sum_s \frac{T_{ijs}}{X_j}\left(\frac{\Delta p_{js}}{p_{js}} - \frac{\Delta p_{is}}{p_{is}}\right) + \sum_i \sum_s \frac{\tau_{ijs} T_{ijs}}{X_j} \frac{1}{\sigma_s - 1} \frac{\Delta M_{is}}{M_{is}} + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j}\left(\frac{\Delta T_{ijs}}{T_{ijs}} - \frac{\Delta p_{is}}{p_{is}}\right)$, where the second term can now be interpreted as a production relocation effect. Essentially, tariffs lead to changes in industry output at the intensive margin without free entry and at the extensive margin with free entry.

[11]Readers familiar with the analysis of Flam and Helpman (1987) may wonder why decomposition (14) does not reveal that tariffs can also be used to partially correct for a domestic distortion brought about by cross-industry differences in markups. The reason is simply that this decomposition only captures first-order effects, while the Flam and Helpman (1987) corrections operate through second-order adjustments in expenditure shares. As will become clear in the discussion of efficient tariffs, they always push governments to impose somewhat higher tariffs on higher elasticity goods in an attempt to counteract distortions in relative prices. While I take this force into account in all my calculations, I only emphasize it in the discussion of efficient tariffs, as the key channels through which countries can gain at the expense of one another are terms-of-trade and profit shifting effects.

elasticity of substitution. Since the quantity of US output always increases in the protected industry but decreases in other industries, the change in profits which is due to changes in industry output is always positive in the protected industry but negative in other industries. The overall profit shifting effect depends on the net effect which is positive if the tariff increase occurs in a high profitability industry such as pharmaceuticals and negative if it occurs in a low profitability industry such as cosmetics.[12]

Notice that the overall welfare effects are smaller than the sum of the terms-of-trade and profit shifting effects in both examples. One missing factor is, of course, the trade volume effect from equation (14). However, this effect is approximately zero in both examples since the loss in tariff revenue due to a decrease in import volumes in the protected industry is approximately offset by the gain in tariff revenue due to an increase in import volumes in other industries.[13] The discrepancy therefore largely reflects the fact that equation (14) only provides a rough approximation if tariff changes are as large as 25 percentage points since it is obtained from a linearization around factuals.[14]

2.5 US optimal tariffs

The above discussion suggests that governments have incentives to use import tariffs to increase relative wages generating a positive terms-of-trade effect and induce entry into high-profitability industries generating a positive profit shifting effect. However, these incentives combine with political economy considerations as governments also seek to protect high λ_{is} industries to channel profits to politically influential special interest groups. I compute optimal tariffs using the Su and Judd (forthcoming) method of mathematical programming with equilibrium constraints, as I explain in detail in the appendix. Essentially, it involves maximizing the government's objective function (3) subject to the equilibrium conditions (10) - (13), which ensures relatively fast convergence despite the high dimensionality of the optimization

[12] As is easy to verify, equations (5) and (11) imply that $\sum_s \frac{\pi_{js}}{X_j}\left(\frac{\Delta\pi_{js}}{\pi_{js}} - \frac{\Delta p_{js}}{p_{js}}\right) = 0$ if $\sigma_s = \sigma$ for all s so that there is then no profit shifting effect.

[13] The volume of overall US imports falls as a consequence of the higher tariffs in pharmaceuticals and cosmetics. The reason that tariff revenue still remains largely unchanged is that US tariffs on pharmaceuticals and cosmetics are relatively small compared to US tariffs in other industries.

[14] In particular, the overall reduction in imports associated with the increase in tariffs also reduces the import shares which leverage the improvement in relative world prices. This effect does not appear in equation (14) since changes in import shares are second order effects.

problem.

Figure 1a summarizes the optimal tariffs of the US taking as given all other countries' factual tariffs. It ranks all industries by elasticity of substitution and plots the optimal tariff of the US with respect to all trading partners against the industry rank. As can be seen, optimal tariffs vary widely across industries and are strongly decreasing in the elasticity of substitution, as one would expect given the profit shifting motive for protection. There is also some variation across trading partners although it is much less pronounced. At 59 percent, the average US optimal tariff imposed against Brazil is the lowest. At 63 percent, the average US optimal tariff imposed against China is the highest. The average US optimal tariff imposed against all trading partners combined is 60 percent.

Figure 2a illustrates the changes in the value of US imports corresponding to US optimal tariffs. It ranks all industries by elasticity of substitution and plots the predicted change in US imports with respect to all trading partners against the industry rank. As a consequence of the tilted tariff schedule, US imports fall in most industries but increase sharply in the highest elasticity industries. US relative wages rise faster than US tariffs in the highest elasticity industries so that importing effectively becomes more attractive in these industries. There is again relatively little variation across trading partners. At -44 percent, US imports from Japan fall the most. At -33 percent, US imports from China fall the least. Overall, US imports fall by 37 percent.[15]

Figure 3a highlights the changes in the quantity of US production corresponding to US optimal tariffs. It ranks all industries by elasticity of substitution and plots the predicted change in US shipments with respect to all trading partners against the industry rank. It also includes changes in US domestic shipments and changes in US total shipments by industry. US shipments to trading partners fall across the board mirroring the decline in US imports. This decline is particularly pronounced in high elasticity industries. US total shipments increase in low elasticity industries but decrease in high elasticity industries, as one would expect given the profit shifting motive for protection. Overall, the reallocation of resources towards high

[15] Changes in the value of imports can be computed at various levels of aggregation from $\widehat{T}_{ijs} = (\widehat{w}_i)^{1-\sigma_s} \left(\widehat{P}_{js}\right)^{\sigma_s - 1} (\widehat{\tau}_{ijs})^{-\sigma_s} \widehat{X}_j$, $\widehat{T}_{ij} = \sum_s \frac{T_{ijs}}{\sum_t T_{ijt}} \widehat{T}_{ijs}$, and so on.

profitability industries increases total US profits by 5.0 percent.[16]

The first column of Table 2a lists the welfare effects corresponding to US optimal tariffs. As can be seen, US optimal tariffs are predicted to increase US real income by 2.4 percent and decrease real incomes elsewhere by 1.3 percent on average. The US can gain at the expense of other countries because the terms-of-trade and profit shifting effects have a beggar-thy-neighbor character, which can be seen immediately from the second and third column of Table 2a. The variation in the welfare losses of other countries largely reflects variation in their trade openness. With import shares of 32 and 24 percent, China and the Rest of the World are the most open economies in the sample which explains why they lose most. With import shares of 11 and 12 percent, the EU and Japan are the least open economies in the sample which explains why they lose least.

To provide more perspective on these results, I have also computed the optimal tariffs of all other countries, following the same procedure I applied for the US. As one would expect, optimal tariffs are positively related to country size even though the relationship is not particularly strong. India's optimal tariffs are the lowest and average 56 percent. The Rest of the World's optimal tariffs are the highest and average 63 percent. While all countries can gain considerably by imposing optimal tariffs, the international externalities they impose vary substantially with country size. With an average welfare loss of -0.04 percent, India's optimal tariffs cause the least harm. With an average welfare loss of -1.9 percent, the Rest of the World's optimal tariffs cause the most harm.[17]

Table 3a returns to the US optimal tariffs and illustrates their sensitivity to alternative assumptions on the elasticities of substitution. The first row simply restates the key results from the benchmark analysis, which is based on the estimates of Broda and Weinstein (2006), as detailed in the appendix. The following rows then recalculate everything using proportionately scaled versions of the Broda and Weinstein (2006) estimates, where the scaling is such that the elasticities average to the value displayed in the first column. The specific range is

[16] Shipments are defined as $Q_{ijs} = \frac{T_{ijs}}{p_{is}}$. Changes in shipments can be computed from $\widehat{Q}_{ijs} = \frac{\widehat{T}_{ijs}}{\widehat{w}_i}$. Changes in total profits induced by the reallocation of resources across sectors can be computed from $\frac{\widehat{\pi}_i}{\widehat{w}_i} = \sum_j \sum_s \frac{\pi_{ijs}}{\sum_n \sum_t \pi_{int}} \widehat{Q}_{ijs}$.

[17] Specifically, the average optimal tariffs, changes in own welfare, and average changes in others' welfare are 57.4%, 1.6%, and -0.1% for Brazil, 55.7%, 3.1%, and -0.6% for China, 60.9%, 1.4%, and -1.6% for the EU, 56.0%, 1.4%, -0.0% for India, 59.0%, 1.3%, and -0.6% for Japan, and 63.2%, 2.8%, and -1.9% for the Rest of the World. All results are rounded to the number of digits shown.

chosen to correspond to the range of aggregate trade elasticities suggested by Simonovska and Waugh (2011).[18] As can be seen, the optimal tariffs are strongly decreasing in the average elasticity. Intuitively, lower elasticities give the US more monopoly power in world markets which it optimally exploits through higher tariffs.

Table 4a explores the sensitivity of the results to alternative assumptions on the political economy weights. The first row again restates the key results from the benchmark analysis, which is based on the political economy weights of Goldberg and Maggi (1999), as explained in the appendix. It also adds some further detail to the earlier discussion by quoting separate average optimal tariffs for politically organized and politically unorganized industries. The following rows then recalculate everything for proportionately scaled versions of the Goldberg and Maggi (1999) estimates, where the scaling is such that the political economy weights in organized industries equal the value shown in the first column. To accommodate a wide range of beliefs on the quantitative importance of special interest politics, I consider alternative political economy weights going all the way up to 75 percent.[19]

As can be seen, an increase in the political economy weights is mainly reflected in an increase in the average tariffs imposed by organized relative to unorganized industries and does not affect the aggregate outcomes very much. Intuitively, political economy forces mainly govern the distribution of rents within the economy and therefore have little effect on the economy as a whole. Notice that channelling profits to politically influential industries requires channelling sales to politically influential industries which can be achieved either by increasing tariffs in such industries or by decreasing tariffs in other industries. The latter approach has the advantage of also lowering the aggregate price index and is therefore pursued by the government since interest groups are assumed to care about real profits according to the government objective function (3).

While the Broda and Weinstein (2006) elasticities are typically accepted as the industry standard, the Goldberg and Maggi (1999) weights are sometimes viewed as implausibly small.

[18] The trade elasticities are the partial equilibrium elasticities of trade flows with respect to trade costs and equal $1 - \sigma_s$ here. Simonovska and Waugh (2011) obtain their results in the context of an Eaton and Kortum (2002) model, which means that their results do not exactly apply here. However, it is now well-understood that different gravity models share similar aggregate behaviors so that I still use their numbers as rough bounds.

[19] Notice that there is only a minimal difference between the results with original and no political economy effects. The reason that average optimal tariffs are still higher in organized industries even without any political economy effects is that the elasticities tend to be lower in these industries.

I have therefore also considered calibrating the weights to match a given cross-industry distribution of optimal tariffs, as seems generally possible in light of the results in Table 4a. However, the difficulty is that most countries set tariffs in GATT/WTO negotiations so that their factual tariffs are not informative of their optimal tariffs without strong assumptions on the nature of the negotiation process.[20] Moreover, the aggregate outcomes seem fairly robust along the political economy dimension so that the main promise of such a calibration would have been the novel estimates of the weights per se which are not really what I am after in this paper.

2.6 World trade wars

The above discussion of US optimal tariffs assumes that other countries do not retaliate which allows the US to benefit considerably at their expense. I now turn to an analysis of the Nash equilibrium in which all countries retaliate optimally. The Nash tariffs are such that each government chooses its tariffs to maximize its objective function (3) given the tariffs of all other governments as well as conditions (10) - (13). They can be computed by iterating over the algorithm used to compute optimal tariffs, as I discuss in detail in the appendix. I refer to optimal tariffs without retaliation as optimal tariffs and optimal tariffs with retaliation as Nash tariffs throughout. I have experimented with many different starting values without finding any differences in the results which makes me believe that the identified Nash equilibrium is unique.[21]

Figure 1b provides a summary of the world Nash tariffs. It ranks all industries by elasticity of substitution and plots the average Nash tariff imposed by each country against the industry rank. As can be seen, the average Nash tariffs are quite similar to US optimal tariffs. At 55 percent, the average Nash tariffs imposed by China are the lowest. At 62 percent, the average Nash tariffs imposed by the Rest of the World are the highest. The average across all Nash tariff is 58 percent which is remarkably close to the average tariff of 50 percent typically

[20] Of course, one could follow Broda et al (2006) and restrict attention to non-WTO member countries. However, these countries tend to be rather special politically so that identifying political economy weights from them seems problematic. For instance, Russia and Iran are currently the biggest non-WTO member countries.

[21] This is, of course, subject to the well-known qualification that complete autarky is also always a Nash equilibrium.

reported for the trade war following the Smoot-Hawley tariff Act of 1930.[22] This trade war is the only full-fledged trade war in economic history and therefore the only benchmark available to me. Of course, it can only serve as a rough reference point given the differences in the set of players and the timing of the experiment.

In order to compare the effects of world Nash tariffs to the effects of US optimal tariffs, I now again focus on the US and present the Nash equilibrium analogs to Figures 2a and 3a. Figure 2b is the Nash equilibrium analog to Figure 2a. It illustrates the changes in the value of US imports corresponding to world Nash tariffs. It ranks all industries by elasticity of substitution and plots the predicted change in US imports with respect to all trading partners against the industry rank. As can be seen, the US import responses to world Nash tariffs summarized in Figure 2b are largely a magnified version of the US import responses to US optimal tariffs summarized in Figure 2a. At -65 percent, US imports from the EU fall the most. At -55 percent, US imports from Japan fall the least. Overall, US imports fall by 62 percent as a consequence of world Nash tariffs which is almost twice the response predicted as a consequence of US optimal tariffs.

Figure 3b is the Nash equilibrium analog to Figure 3a. It highlights the changes in the quantity of US production corresponding to world Nash tariffs. It ranks all industries by elasticity of substitution and plots the predicted change in US shipments with respect to all trading partners against the industry rank. It also includes the changes in US domestic shipments as well as changes in US total shipments by industry. As can be seen, the response of US shipments exhibits less cross-industry dispersion under world Nash tariffs than under US optimal tariffs. Since this is particularly true with regards to US total shipments, the US is less successful at reallocating resources towards high profitability industries in the Nash equilibrium. This reflects the fact that all countries attempt to promote their high profitability industries at the same time. Overall, the reallocation of resources towards high profitability industries increases total US profits by 0.5 percent under world Nash tariffs which is only one tenth of the effect under US optimal tariffs.

[22] See, for example, Bagwell and Staiger (2002: 43). The average Nash tariff imposed by the US is 58 percent and therefore 2 percentage points lower than the average optimal tariff imposed by the US. Intuitively, Nash tariffs tend to be smaller than optimal tariffs because lower trade volumes mean that there is less scope for benefitting from unilateral trade policy interventions.

Table 2b lists the welfare effects of world Nash tariffs. As can be seen, the US is no longer able to gain at the expense of other countries and welfare falls across the board with the average loss equaling -3.5 percent. Intuitively, each country now increases its import tariffs in an attempt to induce favorable terms-of-trade, profit shifting, and political economy effects. The end result is a large drop in trade volumes which leaves all countries worse off. Similar to the variation in the welfare effects of US optimal tariffs, the variation in the welfare effects of world Nash tariffs on China, the EU, Japan, the Rest of the World, and now also the US is largely due to variation in their trade openness. In contrast, the large negative welfare effects on Brazil and India are mainly explained by their highly protectionist factual trade policies. With average tariffs of 27 percent and 12 percent, India and Brazil have by far the most protectionist factual trade policies in the sample which means that they increase their tariffs by less than other countries when moving to Nash tariffs.

Tables 3b and 4b illustrate the sensitivity of world Nash tariffs to alternative assumptions on the elasticities of substitution and the political economy weights in exactly the same fashion as explained earlier for Tables 3a and 4a. As can be seen, world Nash tariffs are strongly decreasing in the elasticity of substitution just like US optimal tariffs. Also, an increase in the political economy weights is again mainly reflected in an increase in the average tariffs imposed by organized relative to unorganized industries and does not affect the aggregate outcomes very much. Table 4b thereby confirms an observation made in conjunction with Table 4a: If the cross-industry distribution of noncooperative tariffs was observable, it seems that the political economy weights could be chosen to get the model predictions close to that distribution without changing the aggregate results very much.

2.7 World trade talks

The inefficiency of the Nash equilibrium creates incentives for international trade policy cooperation. I now turn to an analysis of such cooperation by characterizing the outcome of efficient multilateral trade negotiations. As will become clear shortly, there is an entire efficiency frontier so that I have to take a stance on the specific bargaining protocol. I adopt one in the spirit of symmetric Nash bargaining according to which all governments evenly split all efficiency gains. In particular, I begin by solving max $\widehat{G}_1$ s.t. $\widehat{G}_j = \widehat{G}_1 \; \forall \; j$ starting at *Nash* tariffs, thereby invoking the same threat point as most of the theoretical literature. However, I then also consider the outcome of max $\widehat{G}_1$ s.t. $\widehat{G}_j = \widehat{G}_1 \; \forall \; j$ starting at *factual* tariffs to quantify the scope for future mutually beneficial trade liberalization. As before, I defer a detailed discussion of the algorithm to the appendix.

Figure 1c provides a summary of the world cooperative tariffs resulting from trade negotiations starting at Nash tariffs. It ranks all industries by the elasticity of substitution and plots the average cooperative tariff imposed by each country against the industry rank. As can be seen, world cooperative tariffs are negative in the lowest elasticity industries and increase strongly with the elasticity of substitution. There is also substantial variation across countries with China clearly standing out. The cross-industry variation in the cooperative tariffs counteracts distortions in relative prices originating from cross-industry variation in markups. The cross-country variation in the cooperative tariffs induces terms-of-trade effects which replicate international side payments and ensure that all efficiency gains are split equally as required by the bargaining protocol.

To better understand the cross-industry variation in cooperative tariffs, notice that the equilibrium in this economy is efficient as long as relative prices equal relative marginal costs.[23] If markups are the same across industries, this is the case without policy intervention so that free trade is then first-best. If markups differ across industries, however, relative prices are distorted without policy intervention but can be fully corrected by taxing imports and domestic sales in the high elasticity industries and subsidizing imports and domestic sales in the low elasticity industries. This is also what governments attempt in the cooperative equilibrium with the important difference that they are given no access to domestic policy instruments so that they have to approximate the first-best allocation with the help of only trade policy instruments. This is similar to the point of Flam and Helpman (1987).

To better understand the cross-country variation in cooperative tariffs, notice that a combination of import tariffs and import subsidies can induce terms-of-trade effects which replicate international side payments. As an illustration, consider the case of the US and China. If the

[23] To see this, consider the effects of a fully symmetric increase in markups starting at the efficient benchmark where prices equal marginal costs. On the demand side, consumption would be unchanged for all varieties since relative prices would be unchanged and profits would be fully redistributed to consumers. On the supply side, output would be unchanged for all varieties since there is a fixed number of firms, a fixed supply of workers, and wages adjust to ensure full employment.

US imposes an across-the-board import tariff, this improves the US terms-of-trade but also increases the prices of Chinese goods relative to US goods in the US market with the opposite occurring in China. If China now responds with the right across-the board import subsidy, it is possible to further improve the US terms-of-trade but now decrease the prices of Chinese goods relative to US goods in the US market back to their original level with the opposite occurring in China. In this situation, China would then effectively make a side payment to the US. This is essentially the point of Mayer (1981).

The fact that China's cooperative tariffs are so far below all other countries' cooperative tariffs therefore implies that China effectively makes large side payments as a result of efficient trade negotiations. The reason is simply that China is by far the most open economy in the sample which means that it stands to gain most from a cooperative approach and therefore needs to make large international transfers to ensure that all countries eventually gain the same. Of course, the cross-country variation in cooperative tariffs also depends critically on the specific bargaining protocol. For example, an increase in China's bargaining weight would reduce the side payments required from China and would therefore change the cross-country distribution of cooperative tariffs in China's favor while leaving the cross-industry distribution of cooperative tariffs unchanged.

In order to compare the effects of world cooperative tariffs to the effects of US optimal tariffs and world Nash tariffs, I now again focus on the US and present the cooperative equilibrium analogs to Figures 2a/b and 3a/b. An important difference, however, is that Figures 2a/b and 3a/b depict all changes relative to factual tariffs whereas I now illustrate everything relative to Nash tariffs. Figure 2c is the cooperative equilibrium analog to Figures 2a/b. It illustrates the changes in the value of US imports corresponding to world cooperative tariffs. It ranks all industries by elasticity of substitution and plots the predicted change in US imports with respect to all trading partners against the industry rank. As can be seen, a move from world Nash tariffs to world cooperative tariffs leads to a substantial rise in US imports which is particularly pronounced in low elasticity industries.

Figure 3c is the cooperative equilibrium analog to Figures 3a/b. It ranks all industries by elasticity of substitution and plots the predicted change in US shipments with respect to all trading partners against the industry rank. It also includes changes in US domestic shipments and changes in US total shipments by industry. US shipments to trading partners rise across the board mirroring the increase in US imports. This rise is particularly pronounced in low elasticity industries. Perhaps surprisingly, US total shipments do not rise much in low elasticity industries compared to high elasticity industries even though this is part of what governments attempt to achieve. The reason is that the lack of domestic policy instruments limits the governments' ability to fully correct the cross-industry distortions in relative prices. While import tariffs can deal with the cross-industry distortion in relative prices among imported goods, they cannot deal with the cross-industry distortion in relative prices among domestic goods. Moreover, they themselves introduce cross-country distortions in relative prices which governments seek to avoid.

The first column of Table 2c lists the welfare effects of moving from world Nash tariffs to world cooperative tariffs. Since changes in government welfare are the same by construction and the Goldberg and Maggi (1999) political economy weights are small, changes in representative agent welfare are also almost the same. The relative wage changes correspond to the terms-of-trade changes which replicate international transfers as discussed above. As can be seen, China's relative wages fall the most by far which implies that China has to make the largest side payments by far. The fact that changes in industry output have increased profits in almost all countries follows from the heavily tilted tariff schedule which effectively shifts consumer expenditure to high-profitability industries. While much of the consumer expenditure is taxed away in high-elasticity low-profitability industries, large subsidies add to consumer expenditure in the low-elasticity high-profitability industries, thereby expanding high-profitability industries across the world.

To quantify the gap between factual tariffs and efficient tariffs, I have performed two additional calculations. First, I computed the welfare changes of moving from factual tariffs to efficient tariffs, where efficient tariffs solve max $\widehat{G}_1$ s.t. $\widehat{G}_j = \widehat{G}_1 \; \forall \; j$ starting at *Nash* tariffs, just as above. At -3.4 percent and -1.5 percent, China and India would lose the most. At 1.4 percent and 1.0 percent, the EU and Japan would gain the most.[24] This finding lends support to the common conjecture that developing countries have been favored in past trade

[24] Specifically, real income changes by 0.5% for Brazil, -3.4% for China, 1.4% for the EU, -1.5% for India, 1.0% for Japan, -0.7% for the Rest of the World, and 0.8% for the US. All results are rounded to the number of digits shown.

negotiations. Second, I computed the welfare changes of moving from factual tariffs to efficient tariffs, where efficient tariffs now solve max $\widehat{G}_1$ s.t. $\widehat{G}_j = \widehat{G}_1 \ \forall\ j$ starting at *factual* tariffs. I find that such mutually beneficial trade liberalization would only increase real incomes by 0.3 percent or 0.4 percent in each country, which implies that factual tariffs are relatively close to efficient tariffs in a welfare sense.[25] The main reason is that factual tariffs are still high only in emerging economies such as India and Brazil, which do not matter so much to the world as a whole.[26]

Tables 3c and 4c illustrate the sensitivity of world cooperative tariffs to alternative assumptions on the elasticities of substitution and the political economy weights in exactly the same fashion as explained earlier for Tables 3a and 4a. Here, I return to the case where efficient tariffs solve max $\widehat{G}_1$ s.t. $\widehat{G}_j = \widehat{G}_1 \ \forall\ j$ starting at Nash tariffs and where all welfare effects are computed relative to Nash tariffs as well. Table 3c reveals that the average world cooperative tariff is closer to zero the higher is the elasticity of substitution which simply reflects the fact that mark-up distortions are less severe the smaller the degree of monopoly power. Table 4c shows that the political economy weights matter somewhat more for the aggregate results pertaining to world cooperative tariffs, than they did in the case of US optimal tariffs or world Nash tariffs. The reason is that the cooperative way of increasing real profits in politically organized industries, which is to cross-subsidize imports in these industries, entails significant distortions.

3 Conclusion

I proposed a flexible framework for the quantitative analysis of noncooperative and cooperative trade policy which nests traditional, new trade, and political economy motives for protection. I used this framework to address some natural questions emerging from the qualitative trade policy literature. I began with an investigation of unilateral trade policy: What are the

[25] Specifically, real income changes by 0.3% for Brazil, 0.3% for China, 0.4% for the EU, 0.3% for India, 0.4% for Japan, 0.3% for the Rest of the World, and 0.3% for the US. All results are rounded to the number of digits shown. The cross-industry distribution of efficient tariffs looks virtually identical to the one displayed in Figure 1c.

[26] Specifically, the average factual tariff is 12% for Brazil, 4% for China, 2% for the EU, 27% for India, 1% for Japan, 6% for the Rest of the World, and 2% for the US. All results are rounded to the number of digits shown.

optimal tariffs of the US and how powerful are the traditional, new trade, and political economy motives for protection? I then turned to an examination of multilateral trade policy: What tariffs would prevail in a worldwide trade war and how costly would be a breakdown of international trade policy cooperation? What tariffs would result from efficient trade negotiations and how much scope is there for future mutually beneficial trade liberalization?

The interpretation of my results depends on whether the framework is taken as a maintained or tested hypothesis. In the former case, they can be viewed as answers to questions of immediate policy relevance: for example, as revealing what would have happened if a trade war had broken out in the wake of the recent financial crisis; or as suggesting how much there is to gain from future multilateral trade negotiations. In the latter case, they can be interpreted as suggestive of the plausibility of some of the leading models of trade policy making: for example, as demonstrating that the predicted tariffs are roughly in line with the noncooperative tariffs observed following the Smoot-Hawley Tariff Act of 1930; or as showing that the underlying trade policy externalities can be sufficiently strong to plausibly justify a lengthy process of multilateral trade negotiations.

Given the near-absence of prior quantitative analyses of noncooperative and cooperative trade policy, the framework could be extended in many ways and used to address a whole host of related questions emerging from the large qualitative trade policy literature. As one of many examples, one could restrict multilateral trade negotiations to abide by the GATT/WTO principles of reciprocity and nondiscrimination as formalized by Bagwell and Staiger (1999) and ask whether they are helpful or harmful for achieving and maintaining global efficiency. This could entail a quantitative analysis of the long-standing debate associated with Bhagwati (1991) of whether free trade agreements, which are allowed under GATT/WTO rules as an important exception to the principle of nondiscrimination, represent building-blocks or stumbling-blocks on the way towards full multilateral cooperation.

4 Appendix

4.1 Data

The data on international trade flows is from the UN-Comtrade database which covers most countries in the world. It is originally at the HS 6-digit level and I convert it to the SITC-Rev2 4-digit level using an NBER concordance which I downloaded from Jon Haveman's website at Maclester College. I then aggregate it to the 2-digit level by summing over all relevant industries. I impute domestic trade flows using US shipment data from the NBER-CES manufacturing industry database which is originally at the SIC 4-digit level as well as worldwide value added data from the World Bank-WDI database which is at the country level. The NBER-CES manufacturing data is only available until the year 2005 which is why I choose this year for my analysis. I use the following procedure to impute domestic trade flows:

First, I convert the US shipment data to the SITC-Rev2 4-digit level using a concordance between SIC 4-digit codes and SITC-Rev2 4-digit codes constructed by matching concordances from Feenstra (1996) and Pierce and Schott (2010). Second, I merge the US shipment data with the US trade data and compute the US industry expenditure shares which I subsequently apply to all other countries. Third, I compute total expenditures for all countries from total shipments, minus total exports, plus total imports. I impute total shipments for all countries other than the US by dividing value added by 0.312 which is the number for value added reported by Dekle et al (2007). Fourth, I compute domestic trade flows for all countries other than the US by multiplying the expenditure shares with total expenditures and subtracting industry imports. Finally, I aggregate the domestic trade flows to the 2-digit level by summing over all relevant industries.

The tariff data was generously provided to me by John Romalis. It is a carefully cleaned version of the TRAINS-UN data which gives applied tariffs in ad valorem terms. Applied tariffs are either the most-favored nation tariffs or preferential tariffs if exceptions such as free trade agreements apply. It is originally at the SITC-Rev2 4-digit level and I aggregate it to the 2-digit level by averaging over all relevant tariffs using trade weights.

The elasticities are taken from Broda and Weinstein (2006). I use the SITC-Rev3 3-digit level elasticities computed for the period 1990-2001 for the US. I aggregate these elasticities to the 2-digit level by averaging over all relevant industries. The SITC-Rev2 and SITC-Rev3 codes are very similar at the 2-digit level. Since elasticities tend to decrease with the level of aggregation, this procedure is likely to generate elasticities which are somewhat too high. I have therefore also experimented with the elasticity estimation technique suggested by Caliendo and Parro (2011). However, my tariff data does not contain enough variation for this technique to deliver significant results.

The political economy weights are constructed based on the estimates of Goldberg and Maggi (1999) for the US. Their Table B1 provides a list of unorganized industries at the SIC 3-digit level which I aggregate to the SITC-Rev2 2-digit level using the same concordance I used for the US shipment data. I then rank the SITC-Rev2 2-digit level industries by how many unorganized SIC 3-digit level industries they contain and impose the share of unorganized industries from Table B1. I finally set $\lambda_{is} = \left(1 - \bar{\beta}\right) / \bar{\beta}$ in all organized industries and $\lambda_{is} = 0$ in all unorganized industries, where $\bar{\beta} = 0.9837$ is the average "implied β" from their Table 1. I apply the same political economy weights in all countries.

I focus on 7 regions and 26 manufacturing industries. The 7 regions are Brazil, China, the EU, India, Japan, the US, and a residual Rest of the World and are chosen to comprise the main players in recent GATT/WTO negotiations. The 26 manufacturing industries are all SITC-Rev2 2-digit manufacturing industries other than those from section 8 ("Miscellaneous manufactured articles"). I drop the manufacturing industries from section 8 only to somewhat contain the computational intensity of the analysis. The average tariff across all countries and industries included in the sample is 7.6 percent and the median is given by 3.9 percent. The average elasticity of substitution across all industries included in the sample is 3.9 percent and the median is given by 2.5 percent.

4.2 Elimination of aggregate trade imbalances

To purge the trade data of aggregate trade imbalances, I essentially replicate the original Dekle et al (2007) exercise using my model. In particular, I introduce aggregate trade imbalances as nominal transfers into the budget constraints and allow them to change exogenously so that equation (13) becomes

$$\widehat{X}_j = \frac{w_j L_j}{X_j}\widehat{w}_j + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j}\widehat{t}_{ijs}\left(\widehat{w}_i\right)^{1-\sigma_s}\left(\widehat{P}_{js}\right)^{\sigma_s - 1}\left(\widehat{\tau}_{ijs}\right)^{-\sigma_s}\widehat{X}_j + \sum_s \frac{\pi_{js}}{X_j}\widehat{\pi}_{js} - \frac{NX_j}{X_j}\widehat{NX}_j \tag{15}$$

where $NX_i \equiv \sum_j \sum_s (T_{ijs} - T_{jis})$ is taken from the data. I then use equations (10), (11), (12), and (15) to solve for the general equilibrium effects $\widehat{w}_i, \widehat{X}_i, \widehat{P}_{is}, \widehat{\pi}_{is}$ resulting from setting $\widehat{NX}_j = 0$ while keeping all tariffs unchanged. I finally use these general equilibrium effects to calculate the effects on trade flows using the relationship $\widehat{T}_{ijs} = \left(\widehat{w}_i\right)^{1-\sigma_s}\left(\widehat{P}_{js}\right)^{\sigma_s - 1}\widehat{X}_j$, which delivers a trade matrix without aggregate trade imbalances.

Aggregate trade imbalances are quite large in the raw data. In particular, exports minus imports as a ratio of exports plus imports equal 10 percent for Brazil, 12 percent for China, 8 percent for the EU, -17 percent for India, 46 percent for Japan, -11 percent for the Rest of the World, and -20 percent for the US. The predicted changes in exports and imports resulting from an elimination of aggregate trade imbalances are -12 percent and 7 percent for Brazil, -9 percent and 15 percent for China, -9 percent and 7 percent for the EU, 13 percent and -21 percent for India, -28 percent and 94 percent for Japan, 9 percent and -14 percent for the Rest of the World, and 17 percent and -23 percent for the US.

As indicated in the main text, calculating the counterfactual effects of trade policy changes using the purged data and equations (10), (11), (12), and (13) has two main advantages over the standard approach which would call for using the raw data and equations (10), (11), (12), and (15) with aggregate net exports kept unchanged. First, the assumption of constant aggregate trade imbalances leads to extreme general equilibrium adjustments in response to high tariffs and cannot be true in the limit as tariffs approach infinity. Second, the assumption of constant nominal transfers implies that the choice of numeraire matters since real transfers then change with nominal prices.

While the first point should be obvious, the second point may not be immediately clear. To see the problem, notice that country j's real income depends on $\frac{NX_j}{P_j}$ in the presence of aggregate trade imbalances if they are introduced as nominal transfers into the budget constraints. If NX_j is held fixed, changes in real income therefore depend on changes in P_j which, in turn, depend on the choice of numeraire. As a result, changes in all real variables then depend on the choice of numeraire which can be a serious problem. Notice that NX_j can generally not be held fixed in real terms since it also has to satisfy the global adding up constraint $\sum_j NX_j = 0$. Notice also that the numeraire is not an issue in the original Dekle et al (2008) exercise since aggregate net exports are then set equal to zero anyway.

4.3 Algorithm

As indicated in the main text, calculating disaggregated noncooperative and cooperative tariffs is very intensive computationally due to the high dimensionality of the problem which has been a major barrier to progress in the area. I overcome this barrier with a combination of modern computing power and an efficient algorithm based on the idea of mathematical programming with equilibrium constraints as formulated in Su and Judd (forthcoming). Using a high-end desktop computer and standard MATLAB software, it takes about 3 days to calculate all results which are reported in the paper.

I compute US optimal tariffs by maximizing the government's objective function (3) subject to the equilibrium conditions (10) - (13) using the algorithm suggested by Su and Judd (forthcoming). To minimize the dimensionality of the problem, I do not literally use equations (10) - (13) but substitute first for $\widehat{\pi}_{is}$ using equation (10) and then for $\widehat{P}_{js}$ using equation (12). As an alternative, I have also experimented with computing optimal tariffs directly from the first-order conditions which can also be manipulated in the spirit of Dekle et al (2008). However, I eventually abandoned this approach since it did not sufficiently improve performance to justify the substantial added complication.

I compute world Nash tariffs using a similar approach as Perroni and Whalley (2000) and Ossa (2011). Starting at factual tariffs, I let one country impose its optimal tariffs, then let the next country impose its optimal tariffs given the first country's optimal tariffs, and so on, until the solution converges in the sense that no country has an incentive to deviate from its tariffs. I have experimented with many different starting values without finding any differences in the result which makes me believe that the identified Nash equilibrium in unique. This is, of course, subject to the well-known qualification that complete autarky is also always a Nash equilibrium.

I compute world cooperative tariffs by maximizing $\widehat{G}_1$ subject to the equilibrium conditions

(10) - (13) as well as the condition that $\widehat{G}_j = \widehat{G}_1$ for all j using again the algorithm suggested by Su and Judd (forthcoming). I either start from Nash tariffs or factual tariffs and again substitute first for $\widehat{\pi}_{is}$ using equation (10) and then for $\widehat{P}_{js}$ using equation (12) to reduce the dimensionality of the problem. As discussed in the main text, there is an entire frontier of efficient tariffs due to the existence of de facto side payments and restricting $\widehat{G}_j = \widehat{G}_1$ for all j can be thought of as finding the point on that frontier which also lies on a 45 degree line from the origin.

4.4 Derivations

4.4.1 Derivation of equation (14)

Equilibrium conditions (8) and (9) can be approximated as

$$\frac{\Delta P_{js}}{P_{js}} \approx \sum_i \frac{\tau_{ijs} T_{ijs}}{X_j} \left(\frac{\Delta w_i}{w_i} + \frac{\Delta \tau_{ijs}}{\tau_{ijs}} \right) \tag{16}$$

$$\frac{\Delta X_j}{X_j} \approx \frac{w_j L_j}{X_j} \frac{\Delta w_j}{w_j} + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j} \left(\frac{\Delta t_{ijs}}{t_{ijs}} + \frac{\Delta T_{ijs}}{T_{ijs}} \right) + \sum_s \frac{\pi_{js}}{X_j} \frac{\Delta \pi_{js}}{\pi_{js}} \tag{17}$$

These approximations imply

$$\frac{\Delta P_j}{P_j} \approx \sum_i \sum_s \frac{T_{ijs}}{X_j} \frac{\Delta p_{is}}{p_{is}} + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j} \frac{\Delta p_{is}}{p_{is}} + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j} \frac{\Delta t_{ijs}}{t_{ijs}} \tag{18}$$

$$\frac{\Delta X_j}{X_j} \approx \sum_i \sum_s \frac{T_{ijs}}{X_j} \frac{\Delta p_{js}}{p_{js}} + \sum_s \frac{\pi_{js}}{X_j} \left(\frac{\Delta \pi_{js}}{\pi_{js}} - \frac{\Delta p_{js}}{p_{js}} \right) + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j} \frac{\Delta T_{ijs}}{T_{ijs}} + \sum_i \sum_s \frac{t_{ijs} T_{ijs}}{X_j} \frac{\Delta t_{ijs}}{t_{ijs}} \tag{19}$$

which immediately combines to equation (14) since $\frac{\Delta V_j}{V_j} \approx \frac{\Delta X_j}{X_j} - \frac{\Delta P_j}{P_j}$. Notice that changes in profits which are due to changes in prices are attributed to the terms-of-trade effect. Notice also that changes in the price index which directly result from changes in tariffs cancel with changes in tariff revenue which directly result from changes in tariffs.

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TABLE 1: Effects of 25 percentage point increase in US tariff

	General equilibrium effects		
	Δ US wage	Δ US production (protected)	Δ US production (other)
Pharm.	0.15%	3.77%	-0.06%
Cosm.	0.08%	4.03%	-0.12%
	Welfare effects		
	Δ US welfare	Terms-of-trade effect	Profit shifting effect
Pharm.	0.08%	0.03%	0.07%
Cosm.	-0.01%	0.02%	-0.02%

Notes: The entries under "General equilibrium effects" are the percentage change in the US wage relative to the numeraire (column 1), the percentage change in the quantity of output in the US pharmaceutical or cosmetics industry (column 2), and the average of the percentage changes in the quantity of output in the other US industries (column 3). The entries under "Welfare effects" are the percentage change in US welfare (column 1), the component due to terms-of-trade effects (column 2), and the component due to profit shifting effects (column 3). The values in column 2 and 3 do not add up to the value in column 1 because they are computed using equation (14) which is a linear approximation. Here, all changes are computed relative to factual tariffs.

TABLE 2a: Effects of US optimal tariffs

	Δ welfare	Δ wage	Δ profits	Δ imports
Brazil	-1.0%	-2.4%	-1.0%	-10.3%
China	-1.8%	-2.7%	-3.2%	-7.6%
European Union	-0.8%	-2.5%	-1.1%	-12.2%
India	-1.0%	-2.8%	-1.1%	-7.8%
Japan	-0.7%	-2.9%	-0.8%	-11.1%
Rest of World	-2.4%	-2.6%	-2.6%	-13.2%
United States	2.4%	15.9%	5.0%	-36.9%

TABLE 2b: Effects of world Nash tariffs

	Δ welfare	Δ wage	Δ profits	Δ imports
Brazil	-2.8%	-2.7%	0.6%	-58.6%
China	-6.5%	-1.3%	-4.1%	-58.2%
European Union	-2.0%	3.8%	-1.7%	-63.2%
India	-4.7%	-7.1%	-0.9%	-45.8%
Japan	-2.3%	4.1%	-2.9%	-60.3%
Rest of World	-3.9%	1.3%	0.1%	-60.8%
United States	-2.5%	1.9%	0.5%	-62.0%

TABLE 2c: Effects of world cooperative tariffs

	Δ welfare	Δ wage	Δ profits	Δ imports
Brazil	3.4%	5.2%	0.5%	223.2%
China	3.3%	-10.2%	11.3%	165.2%
European Union	3.4%	4.3%	2.7%	223.7%
India	3.4%	2.8%	-1.4%	168.8%
Japan	3.4%	-0.3%	4.1%	190.4%
Rest of World	3.4%	-2.8%	2.1%	198.2%
United States	3.4%	1.0%	0.9%	201.5%

Notes: The entries are the percentage change in real income (column 1), the percentage change in the nominal wage normalized such that the average change is equal to zero (column 2), the percentage change in total profits due to changes in industry output (column 3), and the percentage change in the value of imports (column 4). All changes are computed relative to factual tariffs in Table 2a and Table 2b but relative to Nash tariffs in Table 2c.

TABLE 3a: Sensitivity of US optimal tariffs w.r.t σ_s

Original Broda and Weinstein (2006) elasticities		
average σ_s	average US tariff	Δ US welfare
3.9	60.0%	2.4%
Proportionately scaled Broda and Weinstein (2006) elasticities		
average σ_s	average US tariff	Δ US welfare
3.5	71.6%	3.0%
4.5	49.3%	2.0%
5.5	37.5%	1.5%
6.5	30.5%	1.2%

TABLE 3b: Sensitivity of world Nash tariffs w.r.t σ_s

Original Broda and Weinstein (2006) elasticities		
average σ_s	average tariff	Δ average welfare
3.9	57.9%	-3.5%
Proportionately scaled Broda and Weinstein (2006) elasticities		
average σ_s	average tariff	Δ average welfare
3.5	68.6%	-4.2%
4.5	47.8%	-2.9%
5.5	36.3%	-2.2%
6.5	29.3%	-1.8%

TABLE 3c: Sensitivity of world cooperative tariffs w.r.t σ_s

Original Broda and Weinstein (2006) elasticities		
average σ_s	average tariff	Δ average welfare
3.9	-4.9%	3.4%
Proportionately scaled Broda and Weinstein (2006) elasticities		
average σ_s	average tariff	Δ average welfare
3.5	-6.7%	4.2%
4.5	-3.5%	2.7%
5.5	-2.0%	2.0%
6.5	-1.4%	1.6%

Notes: The entries are the average elasticity of substitution (column 1), the average US optimal tariff, world Nash tariff, or world cooperative tariff (column 2), and the percentage change in US real income resulting from US optimal tariffs, average percentage change in world real income resulting from world Nash tariffs, or average percentage change in world real income resulting from world cooperative tariffs (column 3). All changes are computed relative to factual tariffs in Table 3a and Table 3b but relative to Nash tariffs in Table 3c.

TABLE 4a: Sensitivity of US optimal tariffs w.r.t λ_{is}

Original Goldberg and Maggi (1999) political weights				
λ_{is}	average US tariff			Δ US welfare
organized	all	organized	other	
0.0166	60.0%	65.7%	50.8%	2.4%
Proportionately scaled Goldberg and Maggi (1999) political weights				
λ_{is}	average US tariff			Δ US welfare
organized	all	organized	other	
0.0000	61.2%	65.8%	53.8%	2.4%
0.2500	55.5%	63.8%	42.1%	2.4%
0.5000	52.5%	63.1%	35.6%	2.4%
0.7500	50.9%	63.5%	30.9%	2.3%

TABLE 4b: Sensitivity of world Nash tariffs w.r.t λ_{is}

Original Goldberg and Maggi (1999) political weights				
λ_{is}	average tariff			Δ average welfare
organized	all	organized	other	
0.0166	57.9%	63.4%	49.1%	-3.5%
Proportionately scaled Goldberg and Maggi (1999) political weights				
λ_{is}	average tariff			Δ average welfare
organized	all	organized	other	
0.0000	58.2%	63.2%	50.2%	-3.5%
0.2500	57.5%	65.6%	44.5%	-3.5%
0.5000	58.2%	69.4%	40.3%	-3.6%
0.7500	60.4%	74.1%	38.4%	-3.8%

TABLE 4c: Sensitivity of world cooperative tariffs w.r.t λ_{is}

Original Goldberg and Maggi (1999) political weights				
λ_{is}	average tariff			Δ average welfare
organized	all	organized	other	
0.0166	-4.9%	-6.3%	-2.6%	3.4%
Proportionately scaled Goldberg and Maggi (1999) political weights				
λ_{is}	average tariff			Δ average welfare
organized	all	organized	other	
0.0000	-4.7%	-6.0%	-2.6%	3.4%
0.2500	-8.6%	-12.1%	-2.8%	3.0%
0.5000	-11.3%	-16.5%	-2.7%	2.6%
0.7500	-12.8%	-19.0%	-2.6%	2.2%

Notes: The entries are the political economy weight in organized industries (column 1), the average US optimal tariff, average world Nash tariff, or average world cooperative tariff across all industries (column 2), the average US optimal tariff, world Nash tariff, or world cooperative tariff across organized industries (column 3), the average US optimal tariff, world Nash tariff, or world cooperative tariff across non-organized industries (column 4), and the percentage change in US real income resulting from US optimal tariffs, the average percentage change in world real income resulting from world Nash tariffs, or the average percentage change in world real income resulting from world cooperative tariffs (column 5). All changes are computed relative to factual tariffs in Table 4a and Table 4b but relative to Nash tariffs in Table 4c.

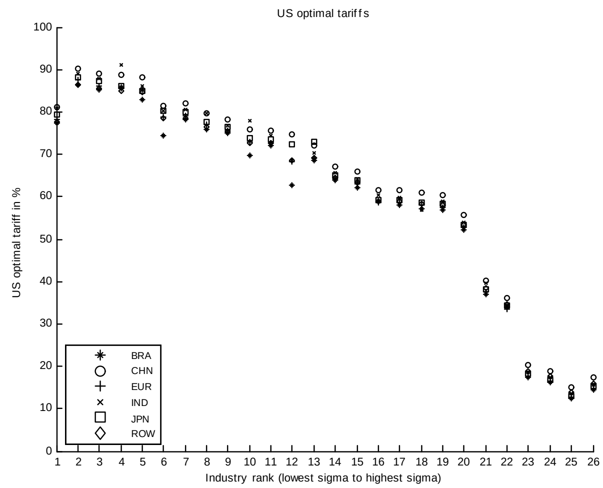

Figure 1a: US optimal tariffs by industry

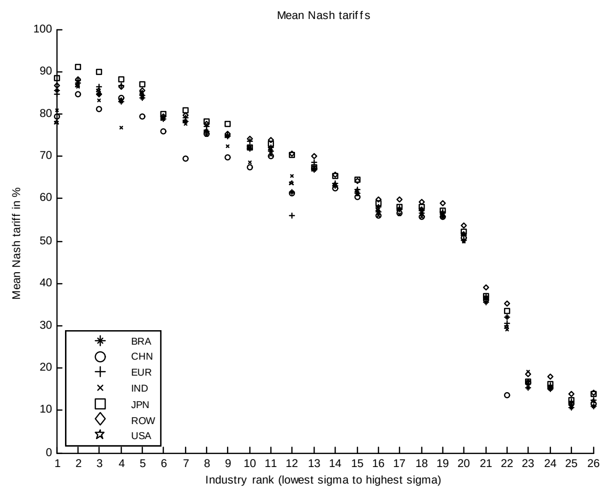

Figure 1b: Mean Nash tariffs by industry

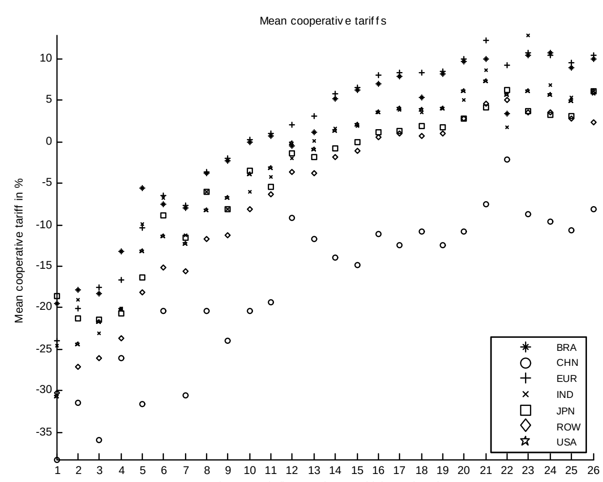

Figure 1c: Mean cooperative tariffs by industry

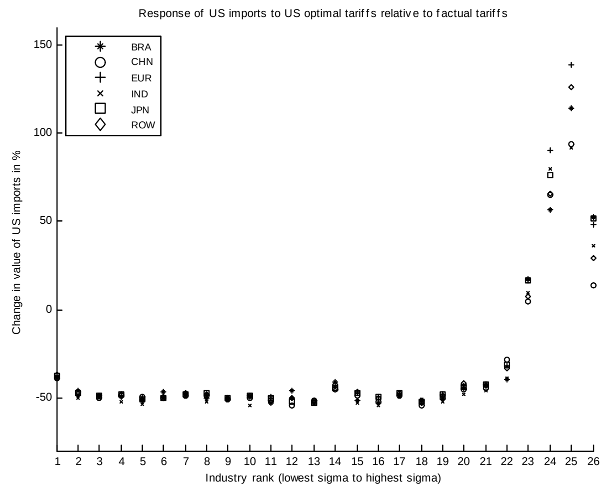

Figure 2a: Response of US imports to US optimal tariffs by industry

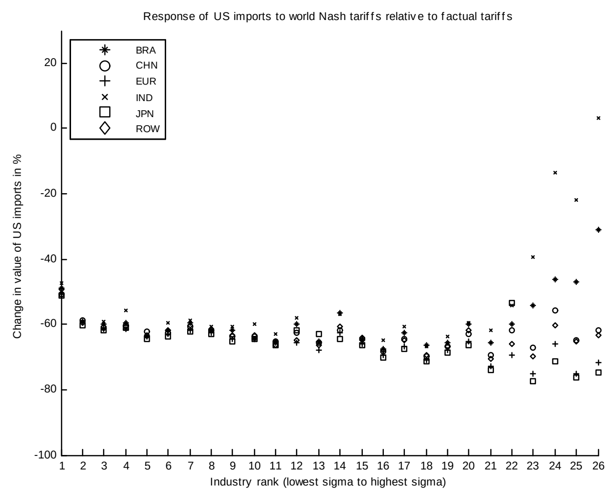

Figure 2b: Response of US imports to world Nash tariffs by industry

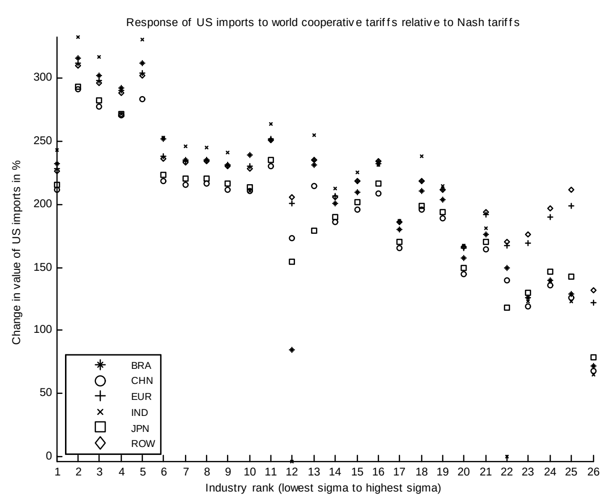

Figure 2c: Response of US imports to world cooperative tariffs by industry

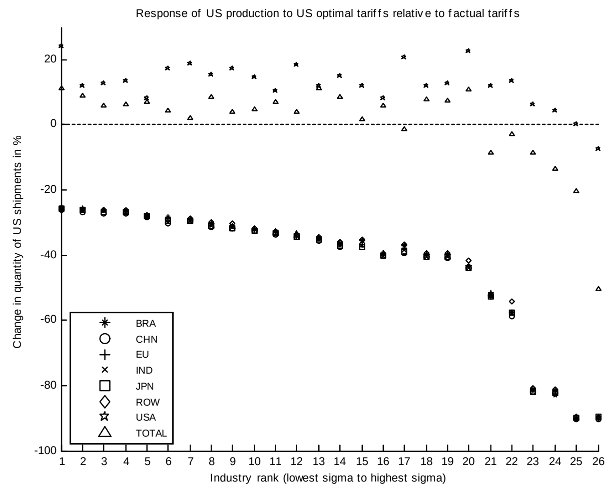

Figure 3a: Response of US production to US optimal tariffs by industry

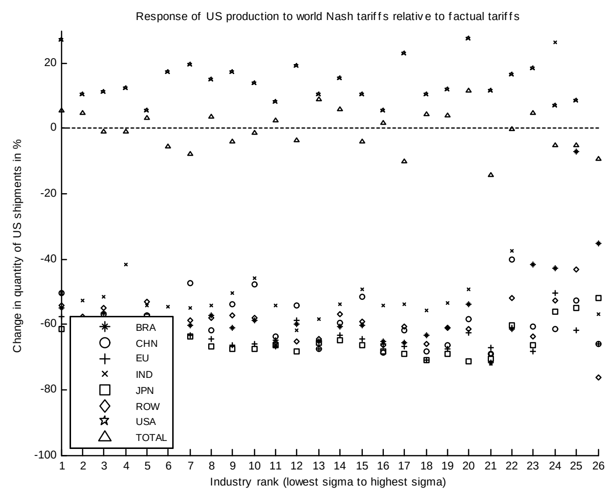

Figure 3b: Response of US production to world Nash tariffs by industry

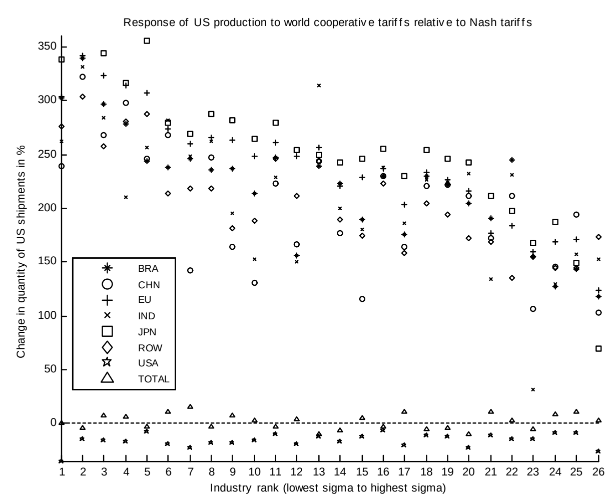

Figure 3c: Response of US production to world cooperative tariffs by industry