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? What are the gains from international trade policy cooperation? And what gains can be expected from future reciprocal 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 66 percent, world trade war tariffs average 63 percent, the welfare gains from international trade policy cooperation average 4.4 percent, and there is almost no scope for future reciprocal trade negotiations.

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1 Introduction

I propose a flexible framework for the quantitative analysis of unilateral and multilateral 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 address some natural questions emerging from the qualitative trade policy literature. 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 what would they imply for welfare, trade, production, and profits around the world? 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 what are the implied gains from international trade policy cooperation? What tariff changes correspond to the GATT/WTO principle of reciprocity and what gains can be expected from future reciprocal trade negotiations?[1]

With respect to unilateral trade policy, I find that US optimal tariffs vary widely across industries and trading partners and average 66 percent. They would increase real income in the US by 2.6 percent and decrease real income in the other countries by 1.6 percent on average. In the US, imports would fall by 27 percent on average and a reallocation of resources to more profitable industries would increase profits by 4.2 percent on average. In the other countries, imports would fall by 12 percent on average and a reallocation of resources to less

[1] The principle of reciprocity is one of the central pillars of the GATT/WTO system which I explain in detail later on.

profitable industries would decrease profits by 1.8 percent on average. Traditional terms-of-trade effects and new trade profit-shifting effects are the key driving forces behind these results. Political economy effects are only of limited quantitative importance.

With regard to multilateral trade policy, I find that the world trade war tariffs vary widely across industries, countries, and trading partners and average 63 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 4.1 percent. I also find that tariff changes which correspond to the GATT/WTO principle of reciprocity can be characterized by a simple formula which is easy to implement in practice. While this formula identifies a number of industries in which there is still scope for future reciprocal trade negotiations, it also suggests that the overall gains from such negotiations would be quite small.

I am unaware of any quantitative analysis of unilateral and multilateral trade policy which is of similar scope as the one provided here. I believe that this is the first quantitative framework which nests traditional, new trade, and political economy motives for protection. I also believe that this is the first study which provides estimates of optimal and noncooperative 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 optimal and noncooperative tariffs is very demanding computationally and was simply not feasible without present-day 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 optimal and 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.[2] 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.[3]

The paper further relates to an extensive body of theoretical and quantitative work. The traditional, new trade, and political economy motives for protection are borrowed from the theoretical trade policy literature including Johnson (1953-54), Venables (1987), and Grossman and Helpman (1994).[4] The analysis of the GATT/WTO principle of reciprocity builds on the pioneering work of Bagwell and Staiger (1999). 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 line of work in terms of framework and question. In particular, I take a unified view of trade policy by nesting traditional, new trade, and political economy effects. Also, I go beyond an investigation of exogenous trade policy changes by emphasizing optimal and noncooperative tariffs.[5]

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

[2] 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.

[3] 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.

[4] 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 12. See Mrazova (2010) for a recent treatment of classic profit shifting effects in the context of GATT/WTO negotiations.

[5] 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.

on trade flows and tariffs as well as estimates of two sets of structural parameters. I construct the matrix of international and domestic 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 estimates of the elasticities of substitution by Broda and Weinstein (2006) and estimates of the influence of lobbies as well as the lobbying status of industries from Goldberg and Maggi (1999). 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 tariff changes, 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 Nash tariffs, and GATT/WTO negotiations.

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:

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

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:

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

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.[6]

Governments can impose import tariffs but do not have access to other policy instruments.[7] 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 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.[8]

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

[6] 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 12 for a further discussion of the model with free entry.

[7] This restriction is motivated by the fact that import tariffs have always been by far the most important trade policy instrument 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.

[8] 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.

(1994). I compute the political economy weights based on the estimates of Goldberg and Maggi (1999) using a procedure which I explain in detail in the appendix.[9]

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

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

where w_i is the wage rate in country i.

It is useful to characterize the equilibrium for given tariffs 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 $L_i = \sum_s M_{is}l_{is}$:

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

[9] In order to clearly expose the novel features of my framework, I deliberately abstract from many bells and whistles which can be found in other quantitative work. For example, I do not allow for 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.

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, minus aggregate net exports which are treated as a parameter in this static environment:[10]

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

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}. It can be solved given a numeraire and I normalize $\sum_j w_j L_j = 1$ throughout.

2.3 General equilibrium effects of tariff changes

An advantage of this characterization is that the general equilibrium effects of counterfactual tariff changes can now be computed using a method inspired by Dekle at al (2007). In particular, conditions (6) - (9) can be rewritten in changes as

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

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

[10] Treating the aggregate trade balance as a parameter is standard in the quantitative trade literature. The idea is that it is determined by intertemporal saving and investment decisions which do not respond to trade policy. One problem is that this dichotomy cannot hold in the limit as tariffs approach prohibitive levels because the aggregate trade balance then also has to go to zero. As a result, a more realistic specification may involve a negative relationship between the absolute value of the aggregate trade balance and tariffs. Since the details of this relationship are far from clear, it would be ideal to explore a number of alternative specifications. Unfortunately, this is very difficult in practice since it takes about two months until all algorithms converge. I therefore stick to the standard assumption and point out where and how it affects my results.

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

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

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 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 $X_j = \sum_i \sum_s \tau_{ijs} T_{ijs}$, $w_j L_j = X_j - \sum_i \sum_s t_{ijs} T_{ijs} - \sum_s \pi_{js}$, and $NX_i = \sum_j \sum_s (T_{ijs} - T_{jis})$, where $\pi_{js} = \frac{1}{\sigma_s} \sum_j T_{ijs}$ in this constant markup environment. Notice that this procedure ensures that the model perfectly matches all observed trade flows and tariffs by default.[11]

As an illustration, the upper panel of Table 1a summarizes the key general equilibrium 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 US tariff is low in both industries, averaging close to 0 percent in pharmaceuticals and close to 1 percent in cosmetics. 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 0.20 percent if the tariff increase occurs in pharmaceuticals and is predicted to increase by 0.18 percent if the tariff increase occurs in cosmetics.

[11] Essentially, the calibration technique imposes a restriction on the set of 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.

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 4.13 percent in pharmaceuticals and decrease by an average 0.12 percent in all other industries if the tariff increase occurs in pharmaceuticals. Similarly, US output is predicted to increase by 9.27 percent in cosmetics and decrease by an average 0.29 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.

2.4 Welfare effects of tariff changes

Given the general equilibrium effects of counterfactual 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 with aggregate net exports set to zero. 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 consumption bundle relative to the world prices of its production 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 pricing 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.[12]

The last term is a combined tariff revenue 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.

As an illustration, the lower panel of Table 1a reports the welfare effects of the counterfactual 25 percentage point increase in the US tariff on pharmaceuticals or cosmetics discussed above and decomposes them into terms-of-trade and profit shifting components along the lines of equation (14). As can be seen, US welfare increases by 0.07 percent if the tariff increase occurs in pharmaceuticals but decreases by 0.03 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

[12] 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.

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 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.[13]

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 tariff revenue 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.[14] 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.[15]

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}

[13] 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.

[14] 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.

[15] 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.

industries to channel profits to politically influential lobbies. The optimal tariffs of a government maximize that government's objective function (3) subject to conditions (10) - (13). They can be computed using a simple iterative algorithm which I discuss in detail in the appendix.

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 62 percent, the average US optimal tariff imposed against Brazil is the lowest. At 69 percent, the average US optimal tariff imposed against Japan is the highest. The average US optimal tariff imposed against all trading partners combined is 66 percent.

The quantitative effect of political economy forces is very limited. In particular, the simple average of the difference between the optimal tariffs summarized in Figure 1a and the optimal tariffs obtained by setting all political economy weights equal to zero is only 0.35 percentage points with the maximum difference being only 1.15 percentage points. This is mainly due to the small political economy weights which are constructed based on estimates by Maggi and Goldberg (1999) using a procedure which I discuss in detail in the appendix. An apparent alternative would have been to recalibrate the political economy weights given the trade and tariff data at hand. However, the difficulty is that most countries set tariffs cooperatively in GATT/WTO negotiations so that factual tariffs are not informative of optimal tariffs without strong assumptions on the nature of the negotiation process.[16]

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

[16] Of course, one could follow Broda et al (2006) and restrict attention to non-WTO member countries only. 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.

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 -33 percent, US imports from the Rest of the World fall the most. At -14 percent, US imports from Brazil fall the least. Overall, US imports fall by 27 percent.[17]

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 as well as 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 profitability industries increases total US profits by 4.2 percent.[18]

The first column of Table 2a lists the welfare effects corresponding to US optimal tariffs. As can be seen, US real income is predicted to increase by 2.6 percent at the expense of all other countries. 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. This can be seen from the second and third columns of Table 2a. While US wages are predicted to rise by 21.9 percent relative to the numeraire, the wages of the other countries are predicted to fall by an average 5.6 percent relative to the numeraire. And while total US profits are predicted to increase by 4.2 percent due to the reallocation of resources towards high profitability industries, total profits

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

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

in the other countries are predicted to fall by an average 1.8 percent due to the reallocation of resources towards low profitability industries.

China and Japan are predicted to suffer most severely from US optimal tariffs. Chinese exports account for 36 percent of Chinese sales which makes China by far the most open economy in the sample. This implies that US optimal tariffs hit China particularly hard which explains the large adverse relative wage and profit shifting effects. The Japanese aggregate trade surplus accounts for 14 percent of Japanese sales which makes Japan by far the largest net exporter in the sample. The percentage drop in Japanese imports must therefore far exceed the percentage drop in Japanese exports in order to keep Japanese net exports unchanged. As a consequence, Japanese imports must become much more expensive relative to Japanese exports which explains the large drop in Japanese relative wages.[19,20]

2.6 World Nash tariffs

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 using a simple iterative algorithm which 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.

Figures 4a and 4b provide a summary of the world Nash tariffs. Figure 4a ranks all industries by elasticity of substitution and plots the average Nash tariff imposed by each country against the industry rank. Figure 4b ranks all industries by elasticity of substitution and plots the average Nash tariff faced by each country against the industry rank. As can

[19] Of course, this depends crucially on the assumption that aggregate trade balances are exogenous. If they were allowed to be decreasing in the tariffs, the Japanese wage adjustments would be less pronounced. See footnote 10 for a detailed discussion of the assumption of constant aggregate trade balances.

[20] The percentage changes in the value of imports and exports are reported in the last two columns of Table 2a. The percentage drop in imports exceeds the percentage drop in exports whenever a country runs an aggregate trade surplus and vice versa. Overall, world trade is predicted to fall by 17 percent.

be seen, the average Nash tariffs are quite similar across countries.[21] The average across all Nash tariffs is 63 percent which is remarkably close to the average tariff of 50 percent typically 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 these world Nash tariffs to the US optimal tariffs discussed above, I now again focus on the US and present the Nash equilibrium analogs to Figures 1a - 3a. Figure 1b is the Nash equilibrium analog to Figure 1a. It ranks all industries by elasticity of substitution and plots the US Nash tariff with respect to all trading partners against the industry rank. As can be seen, the pattern of US Nash tariffs is very similar to the pattern of US optimal tariffs. However, each US Nash tariff exceeds the corresponding US optimal tariff as one might intuitively expect. At 75 percent, the average US Nash tariff imposed against Brazil is the lowest. At 92 percent, the average US Nash tariff imposed against Japan is the highest. The average across all US Nash tariffs is 82 percent and therefore exceeds the average across all US optimal tariffs by 16 percentage points.

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 -64 percent, US imports from the Rest of the World fall the most. At -19 percent, US imports from Japan fall the least. Overall, US imports fall by 48 percent as a consequence of world Nash tariffs which is almost twice the

[21] The EU imposes the lowest average Nash tariffs (56 percent) and the US imposes the highest average Nash tariffs (82 percent). At the same time, the US faces the lowest average Nash tariffs (58 percent) and Japan faces the highest average Nash tariffs (70 percent).

[22] See, for example, Bagwell and Staiger (2002: 43). There is a small number of zeros in the matrix of trade flows. Since the corresponding Nash tariffs can be set to arbitrary values, I do not include them in the calculation of any averages.

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 1.2 percent under world Nash tariffs which is less than one third of the effect under US optimal tariffs.

The first column of 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. 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. However, there are still substantial adjustments in wages and profits as can be seen from columns 2 and 3 of Table 2b. As a consequence, there are sizeable differences in the overall welfare effects across countries. At -0.5 percent, the US loses the least. At -8.6 percent and -9.1 percent, China and Japan lose the most. On average, welfare falls by 4.1 percent.

The reasons why China and Japan are predicted to suffer so severely from protectionism are the same as before. China is by far the most open economy in the sample so that world Nash tariffs induce large adverse relative wage and profit shifting effects. Japan is by far the largest net exporter in the sample so that the large contraction in trade volumes requires a large reduction in Japanese relative wages to keep Japanese net exports unchanged. The story for the US is the mirror image of the story for Japan. The US aggregate trade deficit accounts for 33 percent of US imports making the US by far the largest net importer in the sample. The percentage drop in US exports must therefore far exceed the percentage drop in US imports to keep US net imports unchanged. As a consequence, US exports must become much more expensive relative to US imports which explains the large increase in US relative wages.[23,24]

2.7 GATT/WTO negotiations

The welfare losses from world Nash tariffs can be viewed as the welfare gains from international trade policy cooperation.[25] The primary forum for international trade policy cooperation is the GATT/WTO. In a nutshell, GATT/WTO regulations require countries to impose tariffs according to the principle of nondiscrimination and change tariffs according to the principle of reciprocity. While the principle of nondiscrimination simply prohibits imposing different tariffs against different trading partners, the principle of reciprocity is much more loosely defined. In particular, countries are encouraged to liberalize reciprocally in trade negotiations in the sense that they make tariff concessions of equal value. Similarly, countries are entitled to retaliate reciprocally in trade disputes in the sense that they remove tariff concessions of equal value.[26]

I interpret this definition of the principle of reciprocity as referring to an ideal of mutual tariff changes which have no terms-of-trade and profit shifting effects. Formally, such tariff changes can be found by imposing the restrictions $\sum_i \sum_s \frac{T_{ijs}}{X_j} \left(\frac{\Delta p_{js}}{p_{js}} - \frac{\Delta p_{is}}{p_{is}} \right) = 0$ and

[23] Again, this depends crucially on the assumption that aggregate trade balances are exogenous. If they were allowed to be decreasing in the tariffs, the Japanese and US wage adjustments would be less pronounced. See footnote 10 for a detailed discussion of the assumption of constant aggregate trade balances.

[24] The percentage changes in the value of imports and exports are reported in the last two columns of Table 2b. The percentage drop in imports exceeds the percentage drop in exports whenever a country runs an aggregate trade surplus and vice versa. Overall, world trade is predicted to fall by 57 percent.

[25] Of course, the welfare gains are the inverse of the welfare losses strictly speaking. They amount to 3.4% for Brazil, 9.4% for China, 2.4% for the European Union, 2.8% for India, 10.1% for Japan, 2.3% for the Rest of the World, 0.5% for the US, and 4.4% on average.

[26] These principles as well as their numerous exceptions are discussed in detail in Bagwell and Staiger (2002). One particularly important exception is that GATT/WTO members are allowed to sign free trade agreements in spite of the principle of nondiscrimination.

$\sum_s \frac{\pi_{js}}{X_j}\left(\frac{\Delta\pi_{js}}{\pi_{js}} - \frac{\Delta p_{js}}{p_{js}}\right) = 0$ on the equilibrium conditions (10) - (13). I view this as a natural extension of the interpretation adopted by Bagwell and Staiger (1999) which implies that reciprocal tariff changes have no terms-of-trade effects.[27] By precluding countries from gaining at the expense of one another through terms-of-trade and profit shifting effects, the principle of reciprocity represents a force towards international trade policy cooperation. In particular, it tends to incentivize countries to offer tariff concessions and deter countries from withdrawing tariff concessions in anticipation of the resulting trade volume effects.

Notice that there are at least as many tariffs as restrictions even if the principle of nondiscrimination is imposed so that the set of reciprocal tariff changes is typically not unique. A particularly intuitive formula characterizing nondiscriminatory and reciprocal tariff changes can be obtained by imposing $\frac{\Delta p_{is}}{p_{is}} = \frac{\Delta\pi_{is}}{\pi_{is}} = 0$ in a version of the model in which tariffs are treated as a component of iceberg trade barriers. As I explain in detail in the appendix, this yields

$$\frac{\Delta\tau_{vs}}{\tau_{vs}} \approx \sum_{j\neq v}\left(\frac{T_{vjs}}{\sum_{n\neq v}T_{vns}}\right)\left(\frac{\sum_{n\neq v}T_{vns}}{\sum_{m\neq v}T_{mvs}}\right)\left(\frac{T_{jjs}\,/\sum_m T_{mjs}}{T_{vvs}\,/\sum_m T_{mvs}}\right)\frac{\Delta\tau_{js}}{\tau_{js}} \tag{15}$$

where τ_{js} denotes the nondiscriminatory tariff imposed by country j in industry s. This is a system of N equations in N tariff changes whose coefficients are in terms of observable trade flows only. Given one country's tariff change in a particular industry, it uniquely pins down the necessary responses of all other countries in the same industry since one of the equations is always linearly dependent.

The first term captures that country v needs to respond more to a tariff change by country j the larger is the share of country v's exports going to country j. The second term captures that country v needs to respond more to a tariff change by any country the larger are country

[27] Bagwell and Staiger (1999) interpret the principle of reciprocity as referring to an ideal of mutual tariff changes which bring about changes in the volume of each country's imports that are of equal value to changes in the volume of its exports. They demonstrate that this ideal can eliminate all terms-of-trade effects which is also true in the environment discussed here. In particular, their interpretation implies $\sum_{j\neq i}\sum_s p_{js}dQ_{jis} = \sum_{j\neq i}\sum_s p_{is}dQ_{ijs}$. Also, differentiating the trade balance condition yields $\sum_i\sum_s (p_{js}dQ_{jis} + Q_{jis}dp_{js}) = \sum_i\sum_s (p_{is}dQ_{ijs} + Q_{ijs}dp_{is})$. If aggregate trade imbalances are set equal to zero, these relationships combine to $\sum_i\sum_s \frac{T_{ijs}}{X_j}\left(\frac{dp_{js}}{p_{js}} - \frac{dp_{is}}{p_{is}}\right) = 0$.

v's exports relative to country v's imports overall. The final term captures that country v needs to respond more to a tariff change by country j the more open country v is relative to country j. This term is a measure of how open country v is relative to country j since the numerator is the share of country j's purchases from itself and the denominator is the share of country v's purchases from itself.

While this formula is derived in a version of the model in which tariffs are treated as a component of iceberg trade barriers, it performs well in the full model featuring tariff revenue. This is illustrated in Table 1b which revisits the effects of a counterfactual 25 percentage point increase in the US tariff on pharmaceuticals or cosmetics discussed above. The key difference is that the US trading partners are now assumed to respond reciprocally to the US tariff increase according to formula (15).[28] As can be seen, the US is now predicted to lose from the tariff increase in both industries since the terms-of-trade and profit shifting effects are all but eliminated. This is because US wages and US production respond much less to the US tariff increase given the retaliatory responses of the US trading partners.

Table 3a reports the combined effects of the largest possible tariff cuts in all industries which are consistent with formula (15). It is based on the assumption that countries do not impose import subsidies so that the largest possible tariff cuts in a given industry are always such that one country completely eliminates its tariffs in that industry. As can be seen, the predicted welfare gains and trade responses are small suggesting that there is little scope for future reciprocal trade liberalization. The reason is that the EU, Japan, and the US already impose low tariffs in most industries so that there is little room for further reciprocal tariff cuts. The largest reciprocal tariff cuts are possible in textiles but also only average to 3.29 percent. No tariff cuts at all are possible, for example, in road vehicles since Japan's tariff is already at 0.00 percent in that industry.[29]

[28] The specific tariff increases in pharmaceuticals and cosmetics required by formula (15) are 4% and 23% for Brazil, 11% and 24% for China, 31% and 59% for the EU, 71% and 51% for India, 13% and 12% for Japan, and 7% and 10% for the Rest of the World.

[29] Complete trade liberalization in all countries and industries is not a likely outcome of multilateral trade negotiations because it does not lead to Pareto gains. At -1.3%, India is predicted to lose the most because its average factual tariff is the highest in the sample (27.0%). At 0.6%, Japan is predicted to gain the most

3 Conclusion

I proposed a flexible framework for the quantitative analysis of unilateral and multilateral 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 optimal tariffs of the US and what would they imply for welfare, trade, production, and profits around the world? 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 what are the implied gains from international trade policy cooperation? What tariff changes correspond to the GATT/WTO principle of reciprocity and what gains can be expected from future reciprocal trade negotiations?

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 the GATT/WTO could implement the principle of reciprocity in future trade disputes. 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.

A direct test of the framework's quantitative predictions is challenging given that most countries now impose cooperative tariffs as a result of GATT/WTO negotiations. One approach would be to collect detailed historic trade and tariff data and see if the framework can not only match the average but also the distribution of tariffs observed during the trade

because its average factual tariff is the lowest in the sample (1.5%). The interested reader can find a summary of all associated effects in Table 3b.

war following the Smoot-Hawley Tariff Act of 1930. Another approach would be to focus on non-tariff barriers like Goldberg and Maggi (1999) or non-WTO member countries like Broda et al (2006) and assume that they are not subject to the constraints imposed by international trade policy cooperation. Yet another approach would be to impose more structure on the nature of GATT/WTO negotiations such as Bagwell and Staiger (2011) and focus on the tariff changes resulting from WTO-accessions.

These approaches could be the basis of rewarding future work. Besides, the framework could also be extended in many ways and used to address a whole host of related questions emerging from the large qualitative literature on GATT/WTO negotiations. As one of many examples, GATT/WTO members are allowed to sign free trade agreements as an important exception to the principle of nondiscrimination. Bagwell and Staiger (1999) have pointed out that this can limit the effectiveness of the principle of reciprocity as a force towards international trade policy cooperation since insiders can then gain at the expense of outsiders through trade diversion effects. The framework could be used to quantify the efficiency costs free trade agreements impose through such effects.

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. Because the data gives applied tariffs and these tariffs are aggregated using trade weights, the resulting tariff matrix is inconsistent with the GATT/WTO principle of nondiscrimination. I therefore further average these tariffs across trading partners for the calculations shown in Tables 1b, 3a, and 3b. Omitting this step would only slightly alter the results presented in these tables.

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 6.5 percent. The average elasticity of substitution across all industries included in the sample is 3.9 percent.

4.2 Algorithm

The algorithm I use to compute US optimal tariffs and world Nash tariffs is a straightforward extension of the iterative algorithm used by Perroni and Whalley (2000) and Ossa (2011). In particular, I use four interrelated programs. The first program calculates the optimal tariff of country i against country j in industry s given all other tariffs using a standard optimization software. The second program calculates the optimal tariffs of country i against country j in all industries by iterating the first program across all industries until the solution converges. The third program calculates the optimal tariffs of country i against all trading partners in all industries by iterating the second program across all trading partners until the solution converges. The fourth program calculates the Nash tariffs by iterating the third program across all countries until the solution converges. I have experimented with all programs using a large number of simplified examples and found that they reliably converge to the same solution. With the actual data the Nash algorithm takes about two months to run.

4.3 Derivations

4.3.1 Derivation of equation (14)

If $NX_j = 0$, 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.

4.3.2 Derivation of equation (15)

Treating τ_{ijs} as a component of iceberg trade barriers yields the following versions of equilibrium conditions (10) - (13):

$$\sum_j \alpha_{ijs} \left(\widehat{\tau}_{ijs}\right)^{1-\sigma_s} \left(\widehat{P}_{js}\right)^{\sigma_s - 1} \widehat{X}_j = \widehat{\pi}_{is} \left(\widehat{w}_i\right)^{\sigma_s - 1} \tag{20}$$

$$\widehat{w}_i = \sum_s \delta_{is} \widehat{\Pi}_{is} \tag{21}$$

$$\widehat{P}_{js} = \left(\sum_i \widetilde{\gamma}_{ijs} \left(\widehat{w}_i \widehat{\tau}_{ijs} \right)^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}} \tag{22}$$

$$\widehat{X}_j = \frac{w_j L_j}{X_j} \widehat{w}_j + \sum_s \frac{\pi_{js}}{X_j} \widehat{\pi}_{js} - \frac{NX_j}{X_j} \tag{23}$$

where α_{ijs} and δ_{is} are defined as before and $\widetilde{\gamma}_{ijs} \equiv T_{ijs} / \sum_m T_{mjs}$. The only differences are that price changes are now weighted by import shares net of tariffs in condition (22) and that expenditure changes no longer include changes in tariff revenue in equation (23). Imposing $\frac{\Delta p_{is}}{p_{is}} = \frac{\Delta \pi_{is}}{\pi_{is}} = 0 \Longleftrightarrow \widehat{w}_i = \widehat{\pi}_{is} = 1$ and setting $NX_j = 0$ implies that these conditions reduce to

$$\sum_j \alpha_{ijs} \left(\widehat{\tau}_{ijs}\right)^{1-\sigma_s} \left(\widehat{P}_{js}\right)^{\sigma_s - 1} = 1 \tag{24}$$

$$\widehat{P}_{js} = \left(\sum_i \widetilde{\gamma}_{ijs} \left(\widehat{\tau}_{ijs}\right)^{1-\sigma_s}\right)^{\frac{1}{1-\sigma_s}} \tag{25}$$

which can be approximated as

$$\sum_j \alpha_{ijs} \left(\frac{\Delta P_{js}}{P_{js}} - \frac{\Delta \tau_{ijs}}{\tau_{ijs}}\right) \approx 0 \tag{26}$$

$$\frac{\Delta P_{js}}{P_{js}} \approx \sum_i \widetilde{\gamma}_{ijs} \frac{\Delta \tau_{ijs}}{\tau_{ijs}} \tag{27}$$

Combining these approximations and imposing nondiscrimination then yields equation (15).

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TABLE 1a: Effects of 25 percentage point increase in US tariff without reciprocity

General equilibrium effects			
	Δ US wage	Δ US production (protected)	Δ US production (other)
Pharm.	0.20%	4.13%	-0.12%
Cosm.	0.18%	9.27%	-0.29%
Welfare effects			
	Δ US welfare	Terms-of-trade effect	Profit shifting effect
Pharm.	0.07%	0.05%	0.06%
Cosm.	-0.03%	0.04%	-0.05%

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

General equilibrium effects			
	Δ US wage	Δ US production (protected)	Δ US production (other)
Pharm.	0.02%	-3.26%	0.08%
Cosm.	0.06%	1.36%	-0.04%
Welfare effects			
	Δ US welfare	Terms-of-trade effect	Profit shifting effect
Pharm.	-0.04%	0.00%	-0.01%
Cosm.	-0.02%	0.00%	-0.01%

Notes: The entries under "General equilibrium effects" are the predicted percentage change in the US wage relative to the numeraire (column 1), the predicted percentage change in the quantity of output in the US pharmaceutical or cosmetics industry (column 2), and the simple average of the predicted percentage changes in the quantity of output in the other US industries (column 3). The entries under "Welfare effects" are the predicted 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. All entries are rounded to the number of digits shown.

TABLE 2a: Effects of US optimal tariffs

	Δ welfare	Δ wage	Δ profits	Δ imports	Δ exports
Brazil	-1.2%	-4.7%	-1.2%	-10%	-8%
China	-2.7%	-5.7%	-4.0%	-10%	-8%
European Union	-1.0%	-5.4%	-1.1%	-13%	-11%
India	-0.4%	-5.0%	-0.8%	-7%	-10%
Japan	-2.3%	-7.3%	-1.7%	-19%	-7%
Rest of World	-2.2%	-5.6%	-1.9%	-14%	-18%
United States	2.6%	21.9%	4.2%	-27%	-41%

TABLE 2b: Effects of world Nash tariffs

	Δ welfare	Δ wage	Δ profits	Δ imports	Δ exports
Brazil	-3.3%	-7.8%	0.4%	-60%	-49%
China	-8.6%	-10.2%	-5.7%	-62%	-49%
European Union	-2.4%	-5.0%	-1.6%	-66%	-56%
India	-2.7%	-8.0%	1.3%	-36%	-51%
Japan	-9.1%	-21.4%	-7.3%	-84%	-31%
Rest of World	-2.3%	6.9%	1.2%	-55%	-69%
United States	-0.5%	19.7%	1.2%	-48%	-73%

Notes: The entries are the percentage change in real income (column 1), the percentage change in the nominal wage relative to the numeraire (column 2), the percentage change total profits due to changes in industry output (column 3), the percentage change in the value of imports (column 4), and the percentage change in the value of exports (column 5). All entries are rounded to the number of digits shown.

TABLE 3a: Effects of reciprocal trade liberalization

	Δ welfare	Δ wage	Δ profits	Δ imports	Δ exports
Brazil	0.01%	0.00%	0.00%	1.12%	0.92%
China	0.01%	0.00%	0.00%	0.73%	0.57%
European Union	0.00%	0.00%	0.00%	0.84%	0.72%
India	0.08%	0.00%	0.01%	1.37%	1.94%
Japan	0.00%	0.00%	0.00%	1.34%	0.49%
Rest of World	0.01%	0.00%	0.00%	0.57%	0.72%
United States	0.00%	0.00%	0.00%	0.46%	0.70%

TABLE 3b: Effects of complete trade liberalization

	Δ welfare	Δ wage	Δ profits	Δ imports	Δ exports
Brazil	-0.4%	-3.0%	-0.4%	27%	22%
China	0.3%	-0.1%	0.4%	7%	5%
European Union	0.2%	0.7%	0.2%	9%	7%
India	-1.3%	-8.4%	-2.1%	34%	48%
Japan	0.6%	1.6%	0.5%	10%	4%
Rest of World	-0.6%	-1.7%	-0.6%	9%	12%
United States	0.2%	0.4%	0.1%	5%	8%

Notes: The entries are the percentage change in real income (column 1), the percentage change in the nominal wage relative to the numeraire (column 2), the percentage change total profits due to changes in industry output (column 3), the percentage change in the value of imports (column 4), and the percentage change in the value of exports (column 5). All entries are rounded to the number of digits shown.

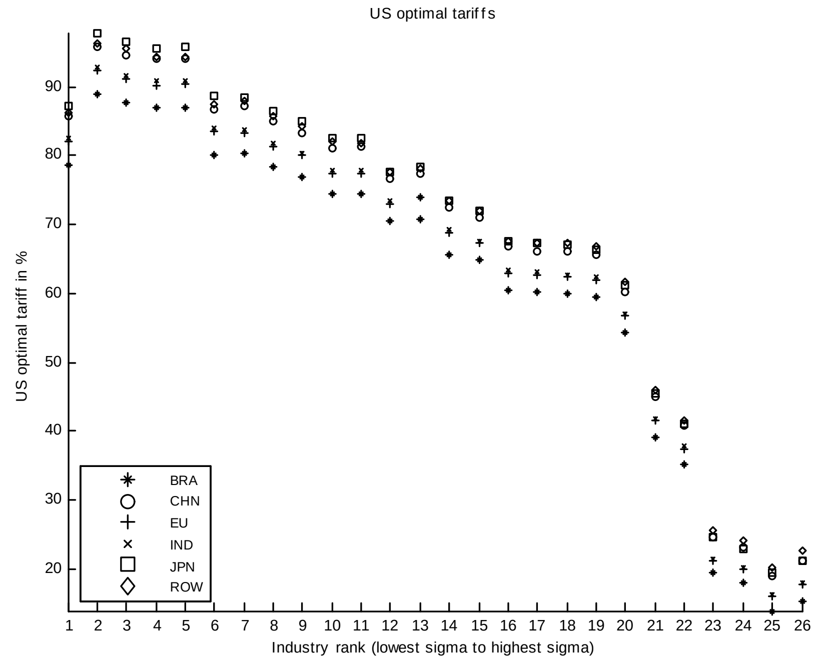

Figure 1a: US optimal tariffs by industry

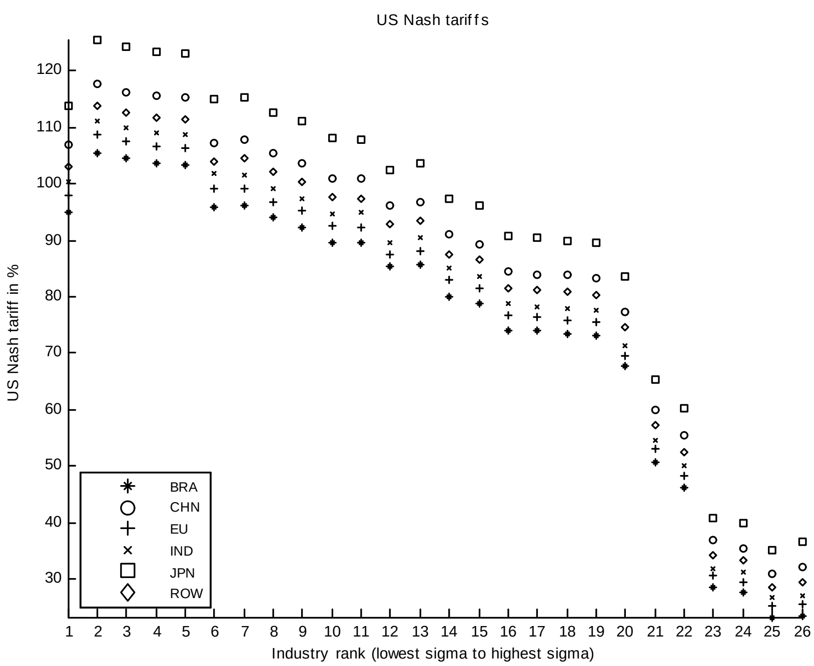

Figure 1b: US Nash tariffs by industry

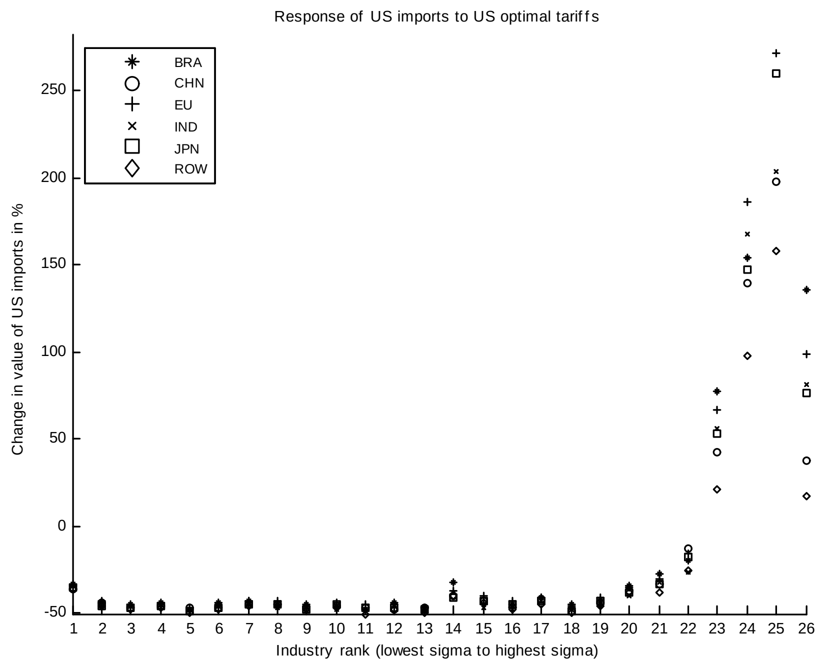

Figure 2a: Response of US imports to US optimal tariffs by industry

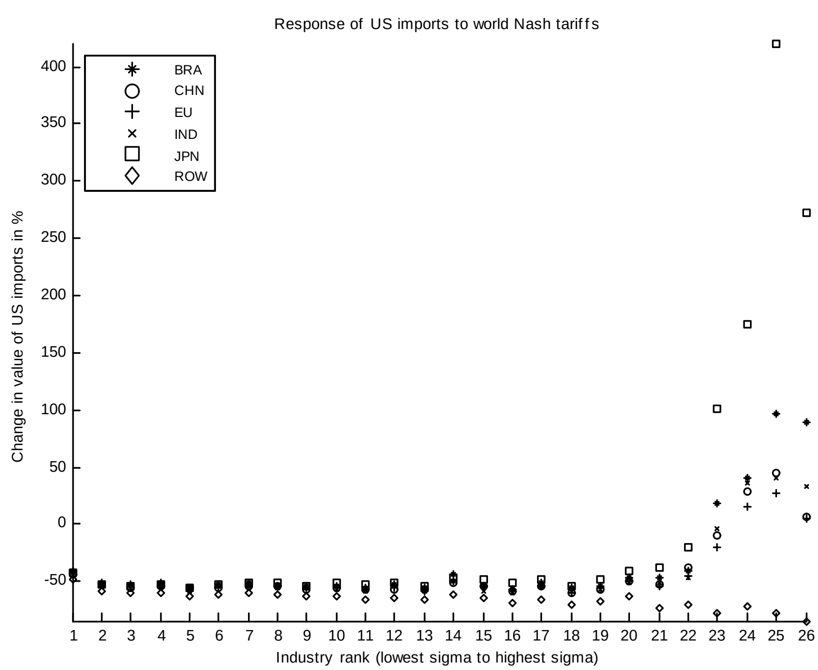

Figure 2b Response of US imports to world Nash tariffs by industry

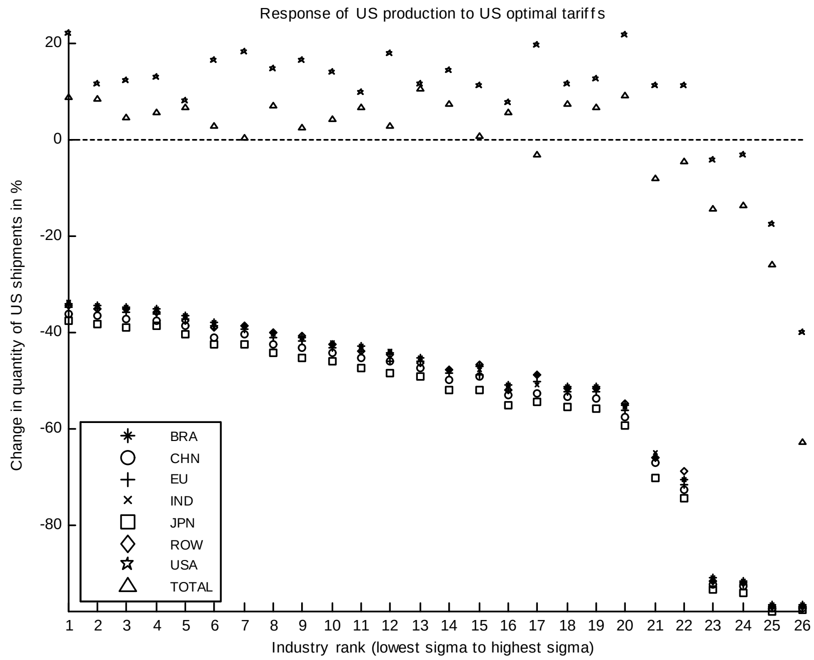

Figure 3a: Response of US production to US optimal tariffs by industry

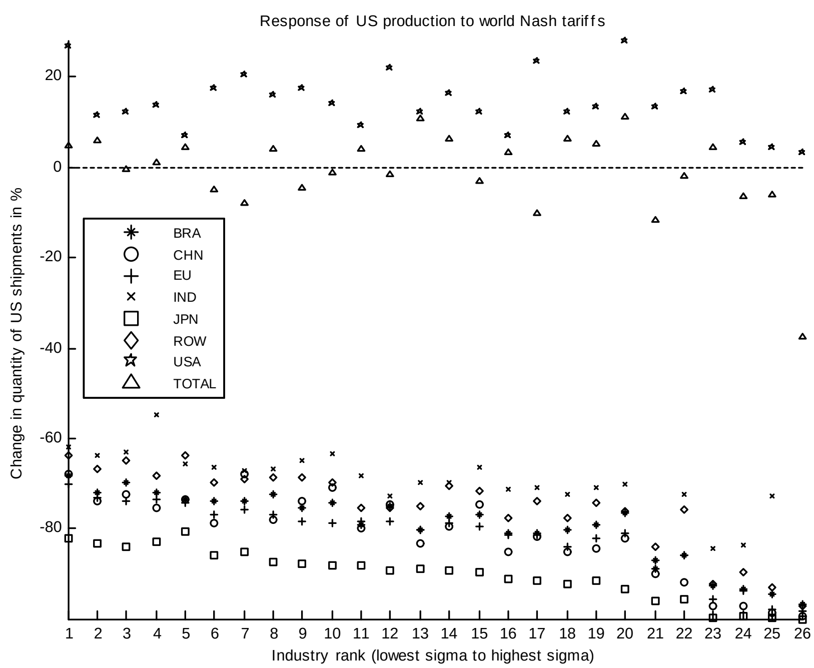

Figure 3b: Response of US production to world Nash tariffs by industry

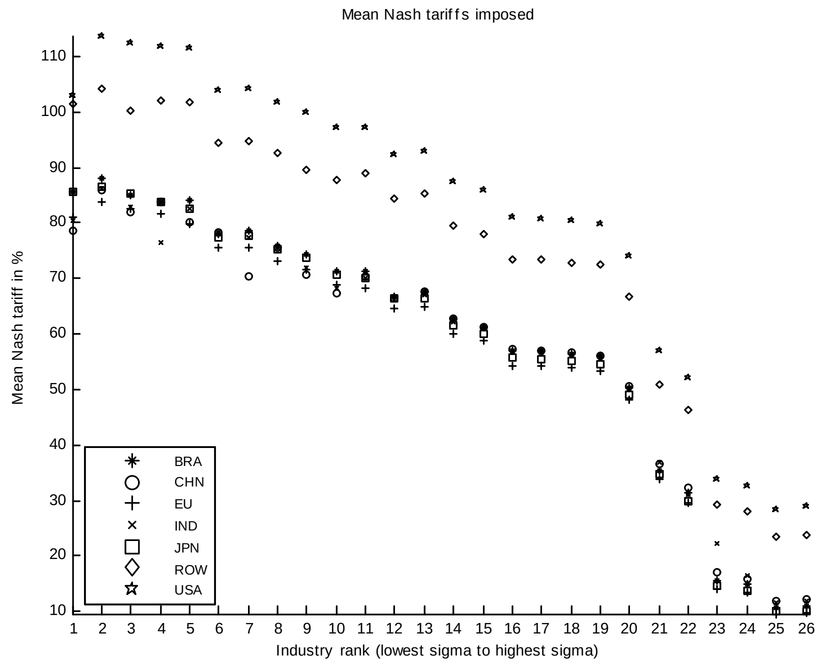

Figure 4a: Mean Nash tariffs imposed by industry

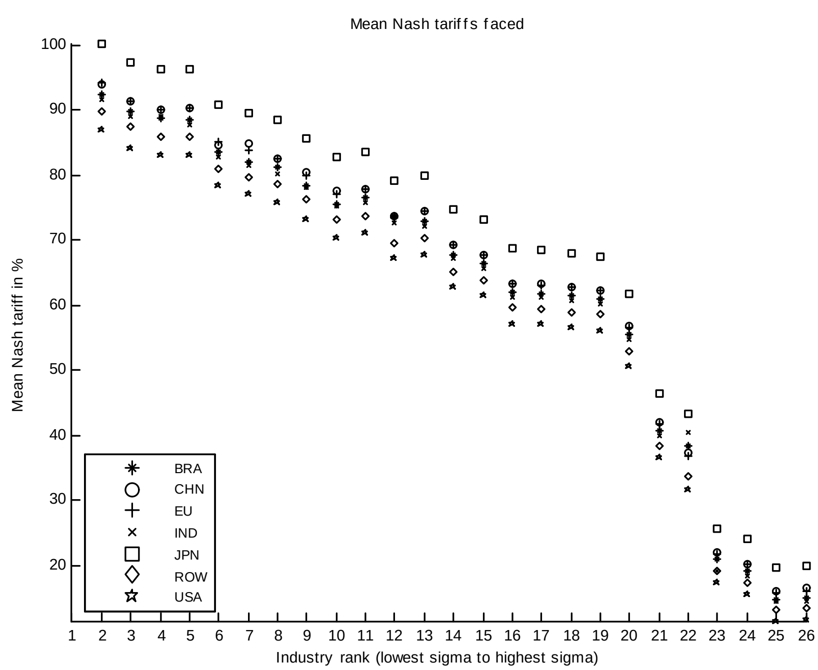

Figure 4b: Mean Nash tariffs faced by industry