# The Effect of Tax-Interactions on Optimal Tariffs

*By* KARAM JARAD*

*This paper examines optimal tariffs and tax-interactions by incorporating income taxes and an endogenous labor supply into the Eaton and Kortum quantitative trade model. The study identifies two key mechanisms—the "tax-interaction effect" and the "revenue-recycling effect"—that lead to large deviations from the optimal tariff levels commonly found in the literature. While conventional literature suggests optimal tariff rates of 25%, this analysis reveals that the average optimal tariff is around 36%, with a large variation across countries. Furthermore, tax-interactions lower optimal tariff rates in the presence of retaliatory actions. These findings highlight the complex interplay between income taxes, tariffs, and trade policy, emphasizing the need for considering other tax instruments when assessing the optimal tariff.*

How high should tariffs be? While tariffs distort trade, foreign exporters can bear some of the burden so a country can gain from modest tariffs. This is the subject of a large literature. Moreover, the benefits could be even greater if tariff revenues are used to lower other distortionary taxes. In this study, I specifically look at income taxes as they play the biggest role in distorting labor supply decisions (McDaniel, 2011) and this changes the potential consequences of tariffs. To quantify this, I adapt the Eaton and Kortum (2002) trade model. The Eaton and Kortum (EK) model is a quantitative multi-country trade model that can readily incorporate tariffs, income taxes, and an endogenous labor supply. By simulating a range of unilateral tariff changes, I calculate welfare changes associated with these tariffs and find the welfare-maximizing tariff, commonly referred to as the optimal tariff. My results reveal the following: Firstly, optimal tariffs are, on average, around 36% when countries do not retaliate to other countries' changing their tariffs. This is 11% percentage points higher (or a 44% increase) than what is typically found in the literature. Furthermore, the optimal tariff varies greatly across countries partly due to variations in a country's domestic trade share. Lastly, retaliatory tariff policies compel countries to set lower optimal tariffs, as they can no longer benefit at the expense of others.

A natural question arises: how can income taxes affect optimal tariffs? Figure 1 attempts to answer this by showing the possible effects of interactions between tariffs and income taxes. The interactions stem from two sources, the "tax-interaction effect" and the "revenue-recycling effect". The revenue-recycling effect occurs when an increase in tariffs leads to higher prices, which reduces real wages and subsequently lowers labor supply. However, the increase in government revenue generated by the tariff can then be used to decrease other distortionary taxes which could lead to a higher labor supply. Therefore, the revenue-recycling effect can help to mitigate some of the negative effects associated with a tariff increase. On the other hand, the tax-interaction effect highlights that tariffs are not the only policy measure in place and can interact with other existing policies, such as income taxes. For example, income taxes usually lead to a reduction in the labor supply. If a policymaker decides to increase tariffs, then prices would increase, and this leads to a reduction in real wages which further reduces labor supply similarly to income taxes. As a result, increasing tariffs can exacerbate the effects of other distortionary taxes, a phenomenon often referred to as the "tax-interaction effect". Figure 1 shows the intuition behind the two effects. Labor supply starts at $S_0$; a government policy directed at an increase in tariffs leads to a large shift, caused by the tax-interaction effect, in labor supply to $S_1$. The increase in tariff revenues is used to decrease income taxes (revenue-recycling effect) which will increase labor supply to either $S_{2a}$ or $S_{2b}$, depending on how strongly the labor supply reacts to the

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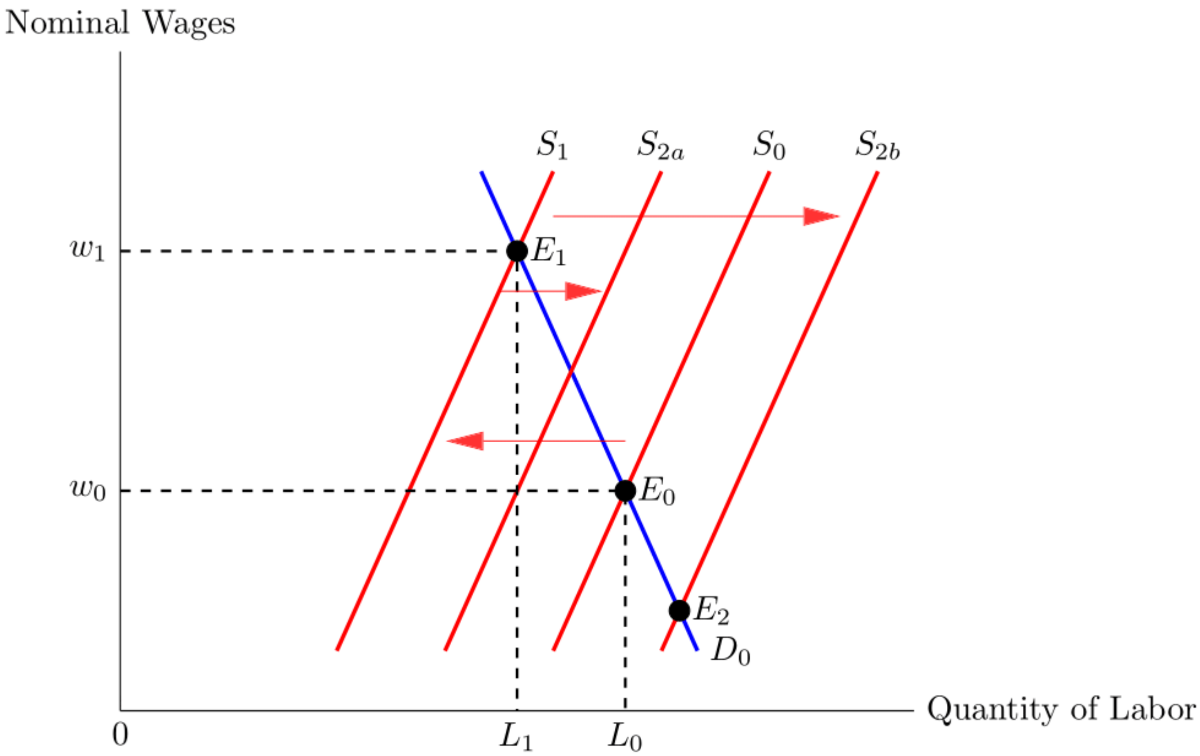


FIGURE 1. REVENUE-RECYCLING AND TAX-INTERACTION EFFECTS

reduction in income taxes[1]. If the revenue-recycling effect is small, supply shifts to $S_{2a}$ and we end up at equilibrium $E_1$, at which nominal wages have increased while labor supply has fallen. On the other hand, a sizeable revenue-recycling effect pushes supply further to $S_{2b}$, which leads to the equilibrium point $E_2$. At this equilibrium, nominal wages have fallen while labor supply has increased. Therefore, the overall effect of an increase in tariffs remains uncertain, since it depends on the relative strength of the tax-interaction effect and the revenue-recycling effect.

To examine the revenue-recycling and tax-interaction effects, I adapt the EK quantitative trade model. EK's seminal work provides economists with a computable general equilibrium trade model that can be used to determine the role that trade plays when productivity changes, analyze the gains from trade, evaluate the effects of a change in tariffs, and, most importantly, estimate optimal tariffs across a broad set of countries. However, the original EK model does not include income taxes and also assumes that the labor supply is fixed. To capture the interaction between tariffs and income taxes, labor supply must be responsive to changes in after-tax wages so that the tax-interaction effect can play a role in influencing the effect of a policy change. Since higher tariffs increase prices which lowers real income, the labor supply is also negatively affected by a rise in tariffs. Therefore, endogenizing the labor supply introduces the tax-interaction effect, a crucial mechanism in determining the trade-off between optimal tariffs and income taxes. To summarize, this study's framework incorporates income taxes and imposes an endogenous labor supply in order to enable tariffs and income taxes interact within the EK model.

With this appended trade model in hand, and data on 42 countries in 2015, I simulate unilateral tariffs

[1]Tariff revenues tend to represent a really small percentage of government revenue (e.g. around 2% for the U.S.). Thus, the generated government revenue will not decrease income tax rates by an extremely amount. However, depending on how large the labor tax base is and how sensitive labor supply is to changes in tax rates, it it safe to assume that even a small change in income taxes can lead to a massive shift in the labor supply.

ranging from 1% to 100%. The results provide welfare changes for each tariff rate. Using these welfare changes, I begin by finding the optimal tariffs, i.e. the tariffs that maximize the welfare of a country if they did not need to worry about retaliatory measures. I find that the optimal tariff rate is, on average, around 36%. This result is 44% higher than what is commonly found in the trade literature. To determine why this is the case, I systematically deconstruct the model to discern the factors contributing to higher optimal tariffs.

My initial intuition is that tariffs impose a greater economic burden than income taxes in a model that allows both to interact, as tariffs are more distortionary when considering a uniformly applied income tax. Williams (1999) shows that changing tariffs, while distortionary income taxes are taken into account, amplifies the welfare effects of tariffs. Specifically, the combined effect of the tax-interaction and revenue-recycling effects results in efficiency gains or losses that are proportional to the effect of tariffs in the absence of income taxes. While Williams argues that the optimal tariff remains unchanged, my findings suggest otherwise. In my analysis, I find that tariff-induced changes in income taxes and lump-sum redistribution of government revenues significantly affect both welfare and labor supply, leading to significantly higher optimal tariffs when tax-interactions are considered.

Lastly, I delve into an analysis of retaliatory optimal tariff policies, also known as Nash tariffs. Nash tariffs refer to the optimal tariffs that countries would set when optimal retaliatory action is taken by other countries. By uncovering the effects of tax-interactions on Nash tariffs, I aim to contribute to the trade war literature. My findings reveal that retaliation leads to a decrease in optimal tariffs, with Nash tariffs averaging around 32%. Furthermore, countries can no longer benefit at the expense of each other with welfare falling for all countries.

## 1. Literature Review

To discuss optimal tariffs, it is necessary to first examine how the literature typically approaches this. The work of Gros (1987) and Helpman and Krugman (1989) establishes that the optimal tariff in a two-country case is equal to the inverse of the trade elasticity, and this finding has been commonly used to calculate optimal tariffs. Interestingly enough, Eaton & Kortum (2002) use their own model to estimate the trade elasticity for the manufacturing sector and find that the trade elasticity ranges between 3.60 and 12.86. Moreover, several authors (Head & Ries, 2001; Bishop, 2006; Broda & Weinstein, 2006; Clausing, 2001; Romalis, 2007; Yi, 2003; Hertel et al., 2003) estimate sectoral trade elasticities and find the values to range between 3 and 30 depending on the sector being examined. More relevant to this paper is the aggregate trade elasticity that is typically found to be around 4 in the literature (Caliendo and Parro, 2015; Hillberry et al., 2005; Costinot & Rodriguez-Clare, 2014). Using Gros's result, this implies that optimal tariff rates are approximately 25%.

However, optimal tariff rates have been shown to be much higher when expanding the framework to a multi-country model. Ossa (2014) estimates optimal tariffs under a multi-country framework without income taxes, but with redistribution of tariff revenues, and finds that optimal tariffs are around 60%. This is significantly higher than the 36% predicted by my multi-country framework. This brings up an important question: why are Ossa's optimal tariffs significantly higher than mine? I argue that the absence of income taxes and tax-interaction effects in Ossa's model incentivizes governments to raise tariffs, as the cost of raising tariff revenues is shifted onto foreign exporters. In contrast, my model incorporates the tax-interaction effect, which increases the welfare cost of an increase in tariffs. As a result, the optimal tariff rate is lower in my model since the combination of tariffs and income taxes leads to a more efficient means of raising government revenues without overly burdening trade through higher tariffs.

To my knowledge, this is the first study that identifies both optimal and Nash tariffs within a trade-focused computable partial equilibrium model that allows for income tax and tariff interactions. The most relevant works to this article are Williams (1999), Alvarez and Lucas (2007), Ossa (2014), Costinot and Rodriguez-Clare (2014), and Caliendo and Parro (2015).

## 2. The Model

In this section, I develop the partial equilibrium model with income taxes, tariffs, and an endogenous labor supply by augmenting on the Ricardian model of EK. The environment is composed of $N$ countries and an infinite number of goods, denoted $j$, that lie in a continuum between 0 and 1. Countries are denoted by $i$ and $n$ where the first subscript of a term refers to an importer while the second is an exporter.

### 2.1. Consumers

There are $L_n$ identical workers that are employed. These workers maximize their utility choosing their labor supply and consuming goods $c_n$ across varieties $j$. Workers earn their income from two sources; they receive wages $w_n$ for supplying their labor and receive a lump-sum transfer from the government, $G_n$. Therefore, the household's budget constraint can be written as follows

$$I_n = (1-t_n)w_nL_n + GR_n, \tag{2.1}$$

where $GR_n$ is the government revenue generated from taxes and tariffs which is transferred lump-sum back to consumers. Preferences are given by

$$U_n = \left(\int c_n(j)^{\frac{\sigma-1}{\sigma}} dj\right)^{\frac{\sigma}{\sigma-1}} - \frac{L_n^B}{B} \tag{2.2}$$

where $\sigma$ is the elasticity of substitution across goods. Households maximize equation (2.2) subject to:

$$\int c_n(j)p_n(j)dj \leq I_n$$

The first order conditions of the households maximization problem are:

$$L_n = \left(\frac{(1-t_n)w_n}{P_n}\right)^{\varepsilon} \tag{2.3}$$

$$c_n(j) = I_nP_n^{-\sigma}(j)P_n^{\sigma-1}$$

where $\varepsilon = \frac{1}{B-1}$ is the elasticity of labor supply and $\varepsilon > 0$. With these first order conditions, it is straightforward to show that welfare is

$$\omega_n = \frac{I_n}{P_n} - \frac{L_n^{\frac{1+\varepsilon}{\varepsilon}}}{\frac{1+\varepsilon}{\varepsilon}} \tag{2.4}$$

### 2.2. Productivity and Prices

In the EK model, producers draw their productivity randomly from a Fréchet probability distribution. Following EK's assumption that productivity is distributed Fréchet, the CDF of firm productivity is given by

$$Pr(\phi_i(j) \leq x) \equiv F_i(x) = e^{(-x/A_i)^{-\theta}}.$$

where $\phi_n(j)$ is the productivity of a firm producing good $j$ in country $n$, $\theta$ determines the variance of the distribution and $A_i$ is the mean of the distribution.

Since firms operate in a perfectly competitive market, selling prices will equal marginal costs $w_n/\phi_n(j)$. Households face two types of trade costs when buying a product. The first type is commonly referred to as "iceberg" trade costs, denoted by $d_{ni}$, where one unit of a tradeable good imported by country $n$ from country $i$ requires $d_{ni} \geq 1$ to be shipped. For domestic trade costs, I set $d_{nn} = 1$. Households also face ad-valorem tariffs $\bar{t}_{ni}$ set on goods imported by country $n$ from $i$. Combining these trade costs gives $\tau_{ni} = (1+\bar{t}_{ni})d_{ni}$. Throughout the rest of this paper, the analysis will revolve around $\bar{t}_{ni}$, as iceberg trade costs are typically assumed to be fixed. Therefore, prices paid by consumers in country n for good j from country i are $p_{ni}(j) = \tau_{ni}w_i/\phi_n(j)$. Since households can select amongst all producers, the actual price paid for good $j$ is the minimum of $p_{ni}(j)$ across all $N$ countries, where

$$p_n(j) = \min_{i\in[1,N]}\{\frac{\tau_{ni}w_i}{\phi_n(j)}\}.$$

Using this distribution, I can explicitly solve for $p_n(j)$ and the aggregate price index $P_n$ which reveals that

$$P_n = \gamma\Phi_n^{-\frac{1}{\theta}},$$

where $\gamma = \Gamma(\frac{1-\sigma}{\theta}+1)^{\frac{1}{1-\sigma}}$, $\Gamma$ is the gamma function, and $\Phi_n = \sum_{k=1}^{N}(\tau_{nk}w_k/A_k)^{-\theta}$. The share of spending $\pi_{ni}$ can also be derived by using the Fréchet distribution of productivity, and is given by:

$$\pi_{ni} = \frac{(\tau_{ni}w_i/A_i)^{-\theta}}{\sum_{k=1}^{N}(\tau_{nk}w_k/A_k)^{-\theta}}$$

### 2.3. *Public Sector*

Governments earn revenue from two sources; taxing workers' earnings $w_nL_n$ at a rate $t_n$ to generate $t_nw_nL_n$, and by setting tariffs $\bar{t}_{ni}$ to earn $\sum_{i=1}\frac{\bar{t}_{ni}}{1+\bar{t}_{ni}}\pi_{ni}X_n$ where $X_n$ is total expenditure of country $n$. Therefore, total government revenue is given by

$$GR_n = t_nw_nL_n + TR_n \tag{2.5}$$

$$TR_n = \sum_{i=1}\frac{\bar{t}_{ni}}{1+\bar{t}_{ni}}\pi_{ni}X_n \tag{2.6}$$

Under this paper's framework, it is assumed that government revenue is redistributed lump-sum back to consumers, and the government balances its budget such that $GS_n = GR_n$.

### 2.4. *Equilibrium Wages*

In a model with taxes, tariffs, and lump-sum redistribution of government revenue, total labor income earned equals the total demand by all countries

$$w_nL_n = \sum_{i=1}^{N}\frac{\pi_{in}}{1+\bar{t}_{in}}X_i. \tag{2.7}$$

To solve for the initial equilibrium, the model requires data on initial levels of labor, taxes, tariffs, total expenditure, expenditure shares, and estimates of $\gamma$ and $\theta$. With the data in hand, the algorithm works as follows: the model is initialised with a guess of a vector of wages $w = (w_1, w_2, ..., w_N)$ and a guess of a vector of tariff revenues $TR = (TR_1, TR_2, ..., TR_N)$. Given these guesses, I can use equations (2.5) and (2.1) to find $GR_n$ and $I_n$. $GR_n$ and $I_n$ are then used to find the model-implied wages and tariff revenues using equations (2.7), and (2.6). If the model-implied wages and tariff revenues differ from the vectors of guesses, this implies that equilibrium has not been reached, forcing the algorithm to adjust the vectors of guesses until they are equal to the model-implied vectors of wages and tariff revenues.

### 2.5. *Solving the Model in Relative Changes*

Dekle, Eaton, and Kortum (2008) developed a procedure that allows economists to find the effect of a change in a policy variable (taxes and tariffs) without the need to estimate parameters that are difficult to identify. This eliminates the requirement to find/use estimates of the iceberg trade costs or the base level of productivity for each country. Therefore, instead of solving for changes caused by a movement from policy $t$ to $t'$, I solve for relative changes defined as $\hat{t} = \frac{t'}{t}$. In other words, I can solve for changes in endogenous variables by simulating a change in taxes and/or tariffs. With this in mind, I will only need data on initial levels of bilateral trade flows, labor supply, taxes, tariffs and estimates of the Frisch, trade, and productivity elasticities. Hence, the equilibrium conditions needed to solve for relative changes are:

Relative change in income:

$$\hat{I}_n = \frac{(1-t'_n)w'_n L'_n + GR'_n}{(1-t_n)w_n L_n + GR_n} \tag{2.8}$$

Relative change in government revenues:

$$\hat{GR}_n = \frac{GR'_n}{GR_n}$$

Relative change in government revenues:

$$\hat{TR}_n = \frac{TR'_n}{TR_n}$$

Relative change in prices:

$$\hat{P}_n = [\sum_{i=1}^{N} \pi_{ni}(\hat{\tau}_{ni}\hat{w}_i/\hat{A}_i)^{-\theta}]^{-\frac{1}{\theta}} \tag{2.9}$$

where $\hat{\tau}_{ni} = \frac{(1+\bar{t}'_{ni})d'_{ni}}{(1+\bar{t}_{ni})d_{ni}}$. Since Iceberg trade costs do not change, this implies that $d'_{ni} = d_{ni}$ and $\hat{\tau}_{ni} = \frac{(1+\bar{t}'_{ni})}{(1+\bar{t}_{ni})}$.

Relative change in expenditure shares:

$$\hat{\pi}_{ni} = \frac{(\hat{\tau}_{ni}\hat{w}_i/\hat{A}_i)^{-\theta}}{\hat{P}_n^{-\theta}} \tag{2.10}$$

Relative change in labor supply:

$$\hat{L}_n = \frac{(1-t'_n)^{\varepsilon}}{(1-t_n)^{\varepsilon}}[\frac{\hat{w}_n}{\hat{P}_n}]^{\varepsilon}$$

Relative change in welfare:

$$\hat{\omega}_n = \frac{\omega'_n}{\omega_n}$$

Relative change in wages[2]:

$$\hat{w}_n = w'_n / w_n. \tag{2.11}$$

An explanation of how these equations are used to find the relative equilibrium can be seen below in section 2.2.6.

### 2.6. *Solving for the Optimal Tax Mix*

Just as a consumer maximizes utility by choosing their optimal consumption bundle assuming a fixed income, the government can find its optimal tax mix by selecting income tax and tariff rates that maximize welfare while keeping government spending fixed. In other words, for a tax policy to be optimal, welfare must increase ($\hat{\omega}_n > 1$) while government spending ($\hat{GS}_n = 1$) does not change. This is done by using two algorithms, an inner and outer algorithm, which are described below.

The inner algorithm begins by solving for initial equilibrium as done in subsection 2.2.4. Next, I simulate unilateral tariff rates (for each country) ranging from 1% to 100%. This can conceptualized as a change in tariff rates from $\bar{t}_n$ to $\bar{t}'_n$. Using this policy change, I can solve for counterfactual changes. To do so, I generate a vector of guesses for $\hat{w}_n, \hat{L}_n$, and $\hat{TR}_n$. Given these vector of guesses, equilibrium conditions (2.9), (2.10) and (2.11) can be used to find the model-implied equilibrium values of $\hat{w}_n, \hat{L}_n$, and $\hat{TR}_n$. If the model-implied values differ from those of the initial guess, I iteratively adjust my vector of guesses until equilibrium is achieved. This provides me with a vector that contains counterfactual equilibrium wages, labor, and tariff revenues for each simulated tariff regime. With this vector, I can then calculate counterfactual government spending for tariffs ranging from 1% to 100%.

The outer algorithm sets a condition on the inner algorithm that requires it to find the corresponding income tax rates that keep government spending fixed (relative to the initial level) in the counterfactual equilibrium, while tariff rates are changing. This is achieved by generating a vector of income tax guesses, $t'_n$, and having the algorithm iteratively solve for the equilibrium tax rates that maintain a fixed level of government spending. The results provide me with an income tax rate for every value of the simulated tariff rates such that $\hat{GS}_n = 1$. Finally, I use these income tax and tariff rates to generate the equilibrium changes in welfare and find the tax mix that provides me with the the largest increase in welfare.

## 3. Evaluating The Model

As outlined in the process of solving for the optimal tax mix, the model requires estimates of the elasticity of labor supply. The literature (Hall (2009); Rogerson & Wallenius (2009); Chetty et al., 2011; Reichling & Whalen, C. (2012); Heathcote et al., (2014); Kaplan, (2012); Peterman, 2016) suggests that macro estimates of the Frisch labor supply elasticity range from 0.2 to 4. I select a value of 2 for $\varepsilon$, as it is represents a reasonable midpoint and does not significantly depart from the implicitly assumed value of zero in trade models. To eliminate the interaction between taxes and tariffs, I exogenize labor supply, ensuring that labor decisions are unaffected by changes in real wages.

### 3.1. *Impact of Endogenizing Labor Supply without Income Taxes on Optimal Tariffs*

I begin my analysis by examining the welfare effects of an endogenous labor supply in an EK model without income taxes and tariffs. To achieve this, I derive welfare changes in an EK model with an endogenous labor supply and find that welfare changes are given by:

$$\hat{\omega}_n = \left(\hat{\pi}_{nn}^{-1/\theta} \hat{A}_n\right)^{1+\varepsilon} = \hat{L}_n^{1+\frac{1}{\varepsilon}} \tag{3.1}$$

[2]It is important to note that in equilibrium, $X_n = I_n$.

On the other hand, a standard EK model finds that welfare changes are equal to:

$$\hat{\omega}_n = \hat{\pi}_{nn}^{-1/\theta} \hat{A}_n \tag{3.2}$$

Since $\varepsilon > 0$, welfare gains ($\hat{\omega}_n > 1$) are always higher with an elastic labor supply while welfare losses ($\hat{\omega}_n < 1$) are more severe with an elastic labor supply. I argue that this is driven by an "expansionary" effect that stems from the implicit assumption that an increase (decrease) in real wages can only increase (decrease) labor supply, implying that the income effect[3] is equal to zero. The expansionary effect reflects a large shift in the production possibilities frontier (PPF) caused by the large increase in labor supply, which leads to the amplification of welfare gains and losses. This simple example provides intuition on how an endogenous labor supply might affect optimal tariffs through welfare changes. Therefore, a more elastic labor supply is expected to amplify the welfare gains and losses caused by changes in tariff rates.

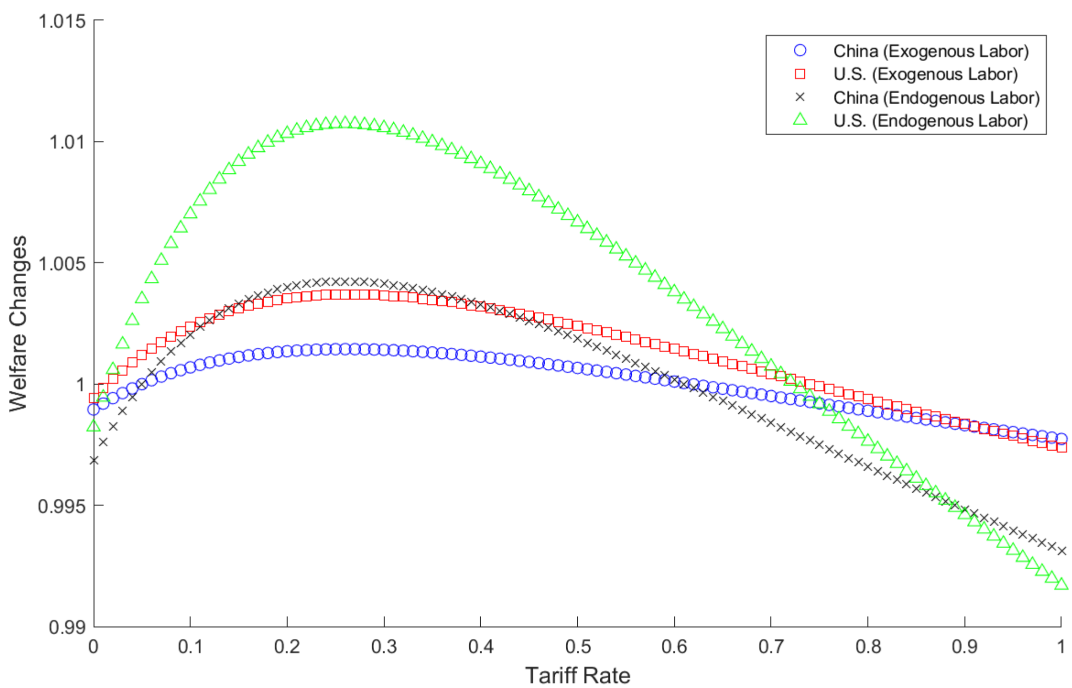


FIGURE 2. OPTIMAL TARIFFS WITHOUT INCOME TAXES

I now turn to analyzing how a responsive labor force affects optimal tariffs under my framework. To determine how an endogenous labor supply affects optimal tariffs, I simulate unilateral tariff rate changes using two restricted models: one with an exogenous labor supply and the other with an endogenous labor supply, and both without income taxes. Studies that use trade models without income taxes and with an exogenous labor supply typically suggest that optimal tariff rates are around 25%. Figure 2 plots U.S. welfare changes associated with changes in the unilateral tariff rates under these two scenarios. Figure 2 confirms the findings from comparing equations (3.1) and (3.2) above, showing that welfare gains (losses) are always higher with an endogenous labor supply. However, optimal tariffs remain unchanged as there is no tax-interaction mechanism to affect optimal tariffs, implying that an elastic labor supply alone does not

[3]The income effect can be built into the utility function $U_n = \frac{C_n^{1-\eta}}{1-\eta} - \frac{L_n^B}{B}$ through $\eta$ which controls the magnitude of the income effect. See Keane (2011) for further clarification.

change optimal tariffs.

### 3.2. *Optimal Tariffs with the Tax-Interaction and Revenue-Recycling Effects*

This subsection explores the interactions between tariffs and income taxes, examining whether the tax-interaction effect and the revenue-recycling effect play a role in influencing optimal tariffs. The revenue-recycling effect occurs when an increase in one tax instrument, such as tariffs, is used to fund a reduction in another distortionary tax instrument. Although income tax revenues are redistributed lump-sum to households, income taxes are still distortionary as they affect labor supply decisions. Therefore, the revenue-recycling effect reduces the burden of an increase in tariffs. Conversely, the tax-interaction effect implies that increasing tariffs exacerbates the distortions already caused by income taxes. Accordingly, the revenue-recycling effect reduces the welfare cost of an increase in tariffs while the tax-interaction effect increases the welfare cost of an increase in tariffs.

To find out whether optimal tariffs change when income taxes and tariffs interact, and to asses which effect dominates, I calibrate the model under two different regimes[4]. The first regime assumes an exogenous labor supply, representing an economy where interactions between income taxes and tariffs are non-existent. The second regime endogenizes labor supply, enabling a mechanism for income taxes and tariffs to interact. The results are presented in table 1. Without tax-interactions, column 3 reveals that optimal tariffs do not vary from the optimal tariffs found commonly in the literature. On the other hand, column 1 reveals that a responsive labor force causes optimal tariffs to change drastically with the average optimal tariff increasing to 36%. Moreover, the optimal tariffs vary greatly across countries now.

TABLE 1—OPTIMAL TARIFFS AND OPTIMAL TAXES UNDER ENDOGENOUS AND EXOGENOUS LABOR SUPPLY REGIMES

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Endogenous Labor Supply | | Exogenous Labor Supply | |
| | Optimal Tariffs | Optimal Taxes | Optimal Tariffs | Optimal Taxes |
| **Country** | | | | |
| BRA | 41% | 10.2% | 25% | 12.0% |
| CAN | 29% | 7.1% | 25% | 8.1% |
| CHN | 38% | 7.8% | 26% | 8.4% |
| FRA | 47% | 13.8% | 25% | 18.6% |
| GBR | 55% | 14.3% | 25% | 20.3% |
| MEX | 30% | 7.9% | 25% | 9.0% |
| ROW | 40% | 12.5% | 25% | 15.6% |
| USA | 36% | 8.5% | 26% | 9.3% |
| Mean | 37% | 12.0% | 25% | 14.5% |

The increase in optimal tariffs implies two things. Firstly, the revenue-recycling effect dominates the tax-interaction effect up to a certain point, the optimal tariff rate. However, the labor supply continues to increase past the optimal tariff rate, as can be seen in figure 3, due to the implicit assumption of the income effect equaling zero as mentioned earlier in subsection 3.3.1. Once the tariff rate exceeds the optimal tariff, the distortions from higher tariffs outweigh the benefits of the revenue recycling effect, leading to welfare losses despite an increase in the labor supply. This indicates that the tax-interaction effect becomes

[4]Optimal tariffs and taxes for all countries can be found in table D1.

stronger at higher tariff rates, reducing the efficiency gains from the revenue-recycling effect and labor supply expansion.

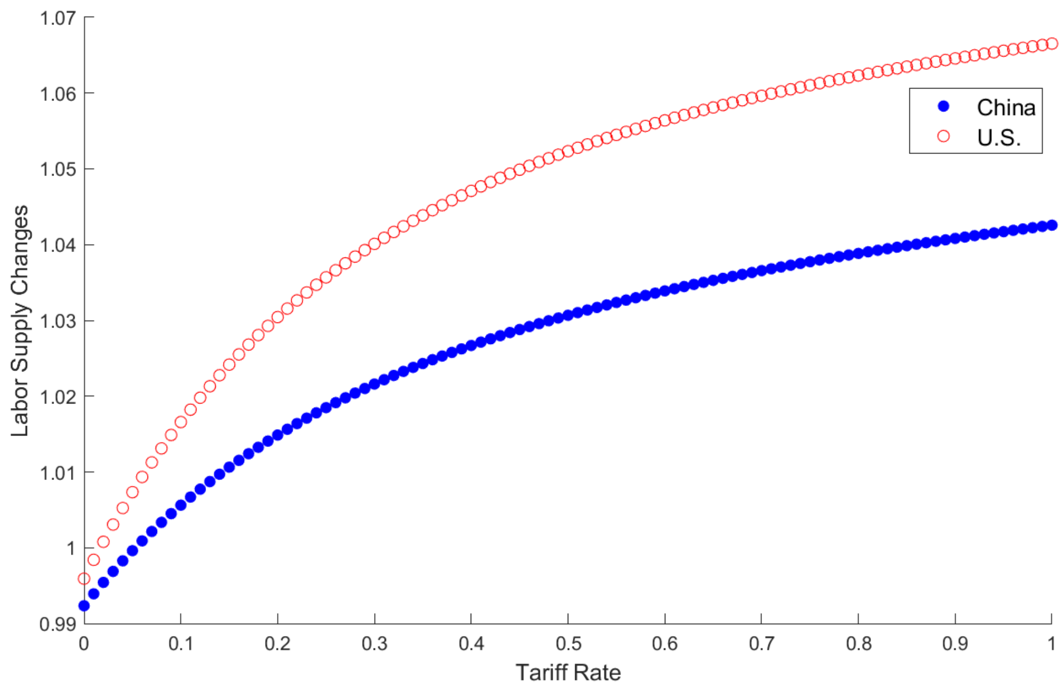


FIGURE 3. CHINA AND U.S. LABOR SUPPLY CHANGES ACROSS TAX REGIMES

Secondly, the increase in optimal tariffs indicates that the welfare benefits of a tariff rate increase are amplified by allowing income taxes and tariffs to interact. Figure 4 shows this for the U.S. and China. In order to break this down further, I use equation (2.4) to find that[5]:

$$\hat{\omega}_n = (\hat{\pi}_{nn}^{-\frac{1}{\theta}} \hat{A}_n) \frac{\hat{L}_n}{\hat{\lambda}_n} \frac{1+\varepsilon(1-\lambda_n')}{1+\varepsilon(1-\lambda_n)} \frac{T_n'}{T_n} \tag{3.3}$$

where $\lambda_n$ represents the share of income that comes from labor earnings, while $1-\lambda_n$ represents the share of income that comes from government lump-sum transfers. To improve readability, let $T_n = 1-t_n$. I also do the same for the regime with an exogenous labor supply to derive the following[6]:

$$\hat{\omega}_n = (\hat{\pi}_{nn}^{-\frac{1}{\theta}} \hat{A}_n) \frac{\hat{L}_n}{\hat{\lambda}_n} \frac{T_n'}{T_n} \tag{3.4}$$

To compare equations (3.3) and (3.4), it is important to understand that $\hat{\pi}_{nn}$, $\hat{L}_n$, $\hat{\lambda}_n$, and $\frac{1+\varepsilon(1-\lambda_n')}{1+\varepsilon(1-\lambda_n)}$ are all endogenous to the model and will differ from equations (3.3) to (3.4), even if we imposed the same tariff and income tax rates. Therefore, to gain a better understanding of why welfare gains are larger with an endogenous labor supply, I simulate changes in tariffs and income taxes such that government spending is unchanged since the sole focus of this paper revolves around the optimal tax mix. In other words, I impose

[5]Derivations shown in appendix section B.
[6]Derivations shown in appendix section B.

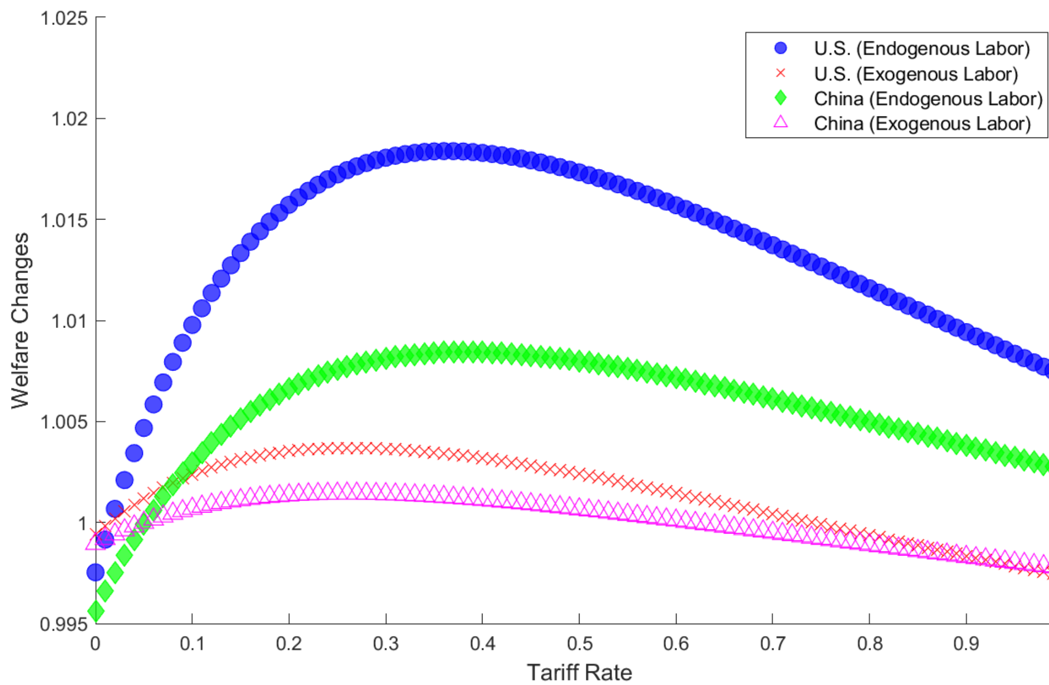


FIGURE 4. OPTIMAL TARIFFS WITH INCOME TAXES

the assumption that $\hat{GS}_n = 1$, and also assume that technology is constant such that $\hat{A}_n = 1$. This is done for both equations (3.3) and (3.4).

I define $\tilde{x}$ as the difference between relative changes found in equation (3.3) and the relative changes found in equation (3.4), such that $\tilde{x} = \hat{x}^{Endogenous} - \hat{x}^{Exogenous}$. The results can be seen in figure 5 below. The differences in changes to the domestic trade shares, income tax rates, and the share of income from labor earnings play a negligible role in determining welfare differences across the two models[7]. The primary factor causing welfare differences, and consequently the increase in optimal tariffs, is the disparity in the relative labor supply. As tariffs rise, $T_n$ increases, which indicates that income taxes are decreasing. With a responsive labor force and the lump-sum redistribution of tax revenues, the labor supply reacts significantly and positively to the decrease in income taxes. This finding is critical for policymakers, as a less responsive labor force would imply lower optimal tariffs, and withholding the generated government revenues from households would similarly lower optimal tariffs.

### 3.3. *Cross-Country Variation in Optimal Tariffs*

With the increase in the optimal tariffs explained, I now turn to examining the cross-country variation in optimal tariffs. This is a particularly interesting result since the literature typically suggests a uniform optimal tariff across countries. A closer examination of the data used for the initial equilibrium reveals two key factors that contribute to this variation: domestic trade shares and initial income taxes. Appendix C presents scatter plots of the optimal tariff rates against these factors. The correlation coefficients are 0.50 between optimal tariffs and domestic trade shares, and 0.55 between optimal tariffs and initial income taxes. These results suggest two main insights. First, countries with higher domestic trade shares tend to have higher optimal tariffs. I argue that this is the case since self-reliance directly influences the magnitude of the

[7]I also looked at changes to $\frac{(1-\lambda_n')}{(1-\lambda_n)}$ and found no significant effect.

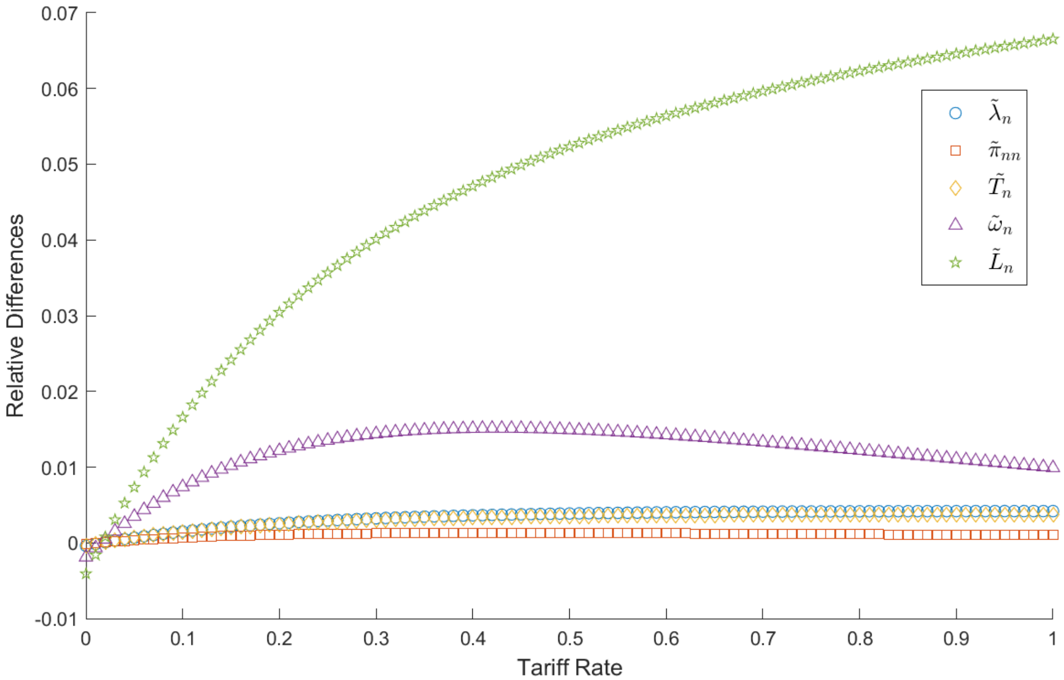


FIGURE 5. RELATIVE CHANGES: ENDOGENOUS VS. EXOGENOUS LABOR SUPPLY

revenue-recycling effect. More self-reliant countries depend less on imports, which allows them to increase tariffs while having a smaller impact on domestic consumption. The generated tariff revenue can be used to reduce income taxes through the revenue-recycling effect, leading to welfare gains. This is mainly due to the fact that self-reliant countries tend to have a larger labor tax base so that even a small reduction in income taxes, financed by an increase in tariff revenues, would lead to large changes in the labor supply and welfare, thereby amplifying the revenue-recycling effect. In other words, the range of tariff rates where the revenue-recycling effect dominates the tax-interaction effect will be bigger for more self-reliant countries.

Second, higher initial income taxes imply higher optimal tariffs. This can be explained through the tax-interaction effect, as countries with higher income taxes will already have significant distortions in the labor supply. Introducing higher tariffs allows policymakers to decrease these distortions by financing a reduction in income taxes, making higher tariffs more appealing. These two insights crucial for policymakers, as they highlight the important role that tax-interactions play in determining optimal tariffs. Developing a better understanding of how both self-reliance and income taxes shape tariff policy will lead to better informed and welfare-enhancing trade policies.

### *3.4. Retaliatory Optimal Tariffs*

The final subsection of this paper examines the concept of ”Nash tariffs”, initially coined by Paul Krugman and later revisited in Ossa’s (2014) work. Nash tariffs account for retaliatory tariff policies by other countries in response to unilateral tariff changes. The calculation is done as follows: first, I calculate optimal tariffs based on actual tariffs; second, I set each country’s unilateral tariffs equal to the optimal tariffs and then re-optimize for the new, mutually reinforcing optimal (Nash) tariffs.

Table 2 presents the Nash tariffs and welfare changes associated with the two regimes that we examined earlier, one that allows tax-interactions and the other that does not. The first key observation to note is that, unlike the scenario’s presented earlier without retaliation, countries can no longer benefit at the expense of others as all countries suffer a welfare loss regardless of whether tax-interactions exist or not (in comparison to the mean welfare changes seen in table D2 in the appendix). Additionally, Nash tariffs are lower than optimal tariffs when labor supply is endogenous, while they are equal to optimal tariffs when labor supply is exogenous. This is evident from the comparison of average optimal tariffs in tables 1 and 2. When the labor supply is exogenous, Nash tariffs equal optimal tariffs as tax-interactions are non-existent, and tariffs are already at this welfare-maximizing rate. On the other hand, Nash tariffs are lower than optimal tariffs (consistent with Ossa's findings) when tax-interactions are considered because governments see that others have already set higher tariffs, lowering the possibility of shifting the burden onto foreign exporters.

TABLE 2—NASH TARIFFS ASSOCIATED WITH TAX-INTERACTIONS

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Endogenous Labor Supply | | Exogenous Labor Supply | |
| | Nash Tariffs | Welfare Change | Nash Tariffs | Welfare Change |
| **Country** | | | | |
| BRA | 36% | 0.9616 | 26% | 0.9907 |
| CAN | 28% | 0.9233 | 25% | 0.9792 |
| CHN | 35% | 0.9875 | 27% | 0.9965 |
| FRA | 40% | 0.9211 | 26% | 0.9870 |
| GBR | 42% | 0.9111 | 27% | 0.9881 |
| MEX | 29% | 0.9101 | 26% | 0.9727 |
| ROW | 36% | 0.9272 | 26% | 0.9829 |
| USA | 33% | 0.9792 | 27% | 0.9954 |
| Mean | 32% | 0.9108 | 26% | 0.9804 |

## 4. Conclusion

In conclusion, this paper explores the intricate relationship between an endogenous labor supply and tax-interactions within a trade model. The inclusion of an endogenous labor supply in a model with tax-interactions results in greater welfare gains and losses. This higlights the importance of analyzing labor supply dynamics in a more comprehensive trade framework.

While the literature typically suggests that optimal tariffs fall between 20% and 25%, my framework reveals that average optimal tariffs are 36%. This discrepancy arises from two key elements. First, endogenizing the labor supply amplifies the welfare effects of tariff rate changes. However, optimal tariffs do not deviate from the typical value of 25% unless income taxes are present, since governments can reduce income taxes through the revenue-recycling effect. Second, the revenue-recycling effect dominates the tax-interaction effect up to the optimal tariff rate. At higher tariff rates, the labor market distortions caused by tariffs outweigh the benefits of revenue recycling, demonstrating that the tax-interaction effect becomes stronger as tariffs increase. Additionally, countries with a less responsive labor force or those withholding from the redistribution of government revenues to households tend to have lower optimal tariffs.

This paper also reveals significant cross-country variation in optimal tariffs, a finding that contrasts with the uniform optimal tariff rate typically presented in the literature. This variation is driven mainly by two factors: domestic trade shares and income tax rates. Countries that are more self-reliant, or have higher domestic trade shares, can impose higher tariffs with less disruption to domestic consumption. For these self-reliant countries, the generated tariff revenue can be used to reduce income taxes, amplifying the welfare gains from the revenue-recycling effect. Additionally, countries with higher initial income taxes tend to have higher optimal tariffs. This is caused by the tax-interaction effect allowing policymakers to decrease labor supply distortions by shifting the government revenue burden onto tariffs. These findings are critical for policymakers, highlighting the significant role of tax-interactions in shaping optimal tariff policy.

Finally, an analysis of retaliatory tariff policies shows that, in contrast to unilateral tariff setting, no country can benefit at the expense of others when retaliation occurs. Moreover, Nash tariffs are lower than optimal tariffs when labor supply is endogenous, but are equal to optimal tariffs when labor supply is exogenous. This is because countries recognize that others have already imposed higher tariffs, which reduces their ability to shift the burden of increasing tariffs onto foreign exporters. In summary, the findings of this paper emphasize the importance of considering tax-interactions, labor supply decisions, and retaliatory tariff policies when formulating optimal trade policy. In other words, this study offers valuable insights for policymakers aiming to achieve welfare-enhancing outcomes in an increasingly complex global trade environment.

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## Data Sources

This appendix section explains the data sources and method for constructing trade shares. The list of countries included in my analysis: Australia, Austria, Belgium, Brazil, Canada, Switzerland, Chile, China, Colombia, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, India, Ireland, Iceland, Israel, Italy, Japan, Korea, Lithuania, Latvia, Luxembourg, Mexico, Netherlands, Norway, New Zealand, Poland, Portugal, Russian Federation, Slovak Republic, Slovenia, Sweden, Turkey, United States, and the rest of the world combined.

### *A1. Bilateral Trade Shares*

The bilateral trade shares are constructed by using data taken from the OECD Inter-Country Input-Output (ICIO) Tables. The database provides data on intermediate use and final demand for 45 industries based on ISIC Revision 4 in 2015. By aggregating all sectors for each country, I calculate the total output imported and exported to each country-pair, which allows me to calculate the bilateral trade shares.

### A2. Tariffs, Labor Force, Taxes, and GDP

Bilateral ad-valorem tariffs data for 2015 are taken from the United Nations Statistical Division-Trade Analysis and Information System (UNCTAD-TRAINS) and World Trade Organization (WTO) databases. My tariff data use a 2-digit aggregation level and an ISIC Revision 3 nomenclature. I chose to use the weighted average effective applied rates as the effective applied rates take any trade agreements into account. Since my framework examines the one-sector case, I use the tariff rates applied on total trade. Data on the labor force, tax rates (as a % of GDP), and GDP are all taken from the World Bank's World Development Indicators database.

## Derivations

### B1. Derivation for welfare changes in a model with endogenous labor supply, no income taxes, and no tariffs.

$$\pi_{ni} = \frac{(\tau_{ni} w_i / A_i)^{-\theta}}{\sum_{k=1}^{N} (\tau_{nk} w_k / A_k)^{-\theta}}$$

$$= \frac{(\tau_{ni} w_i / A_i)^{-\theta}}{P_n^{-\theta}} \gamma^{\theta}$$

Rearranging this gives:

$$\pi_{ni}^{-1/\theta} = \gamma \frac{w_i}{P_n} \frac{\tau_{ni}}{A_i}$$

Setting $n = i$ and rearranging gives:

$$\frac{w_n}{P_n} = \gamma^{-1} \pi_{nn}^{-1/\theta} A_n$$

This result is combined with with equations (2.3) and (2.4), while keeping in mind that there are no income taxes yields the following:

$$L_n = \left(\frac{w_n}{P_n}\right)^{\varepsilon}$$

$$= (\gamma^{-1} \pi_{nn}^{-1/\theta} A_n)^{\varepsilon}$$

$$U_n = \frac{I_n}{P_n} - \frac{L_n^{\frac{1+\varepsilon}{\varepsilon}}}{\frac{1+\varepsilon}{\varepsilon}}$$

$$= \frac{w_n L_n}{P_n} - \frac{L_n^{\frac{1+\varepsilon}{\varepsilon}}}{\frac{1+\varepsilon}{\varepsilon}}$$

Substituting in for $P_n$ using equation (2.3):

$$= \frac{w_n L_n}{w_n L_n^{-1/\varepsilon}} - \frac{L_n^{\frac{1+\varepsilon}{\varepsilon}}}{\frac{1+\varepsilon}{\varepsilon}}$$

$$= L_n^{1+\frac{1}{\varepsilon}} - \frac{L_n^{\frac{1+\varepsilon}{\varepsilon}}}{1+\varepsilon} \varepsilon$$

$$= L_n^{1+\frac{1}{\varepsilon}} (1 - \frac{\varepsilon}{1+\varepsilon})$$

# FIGURES

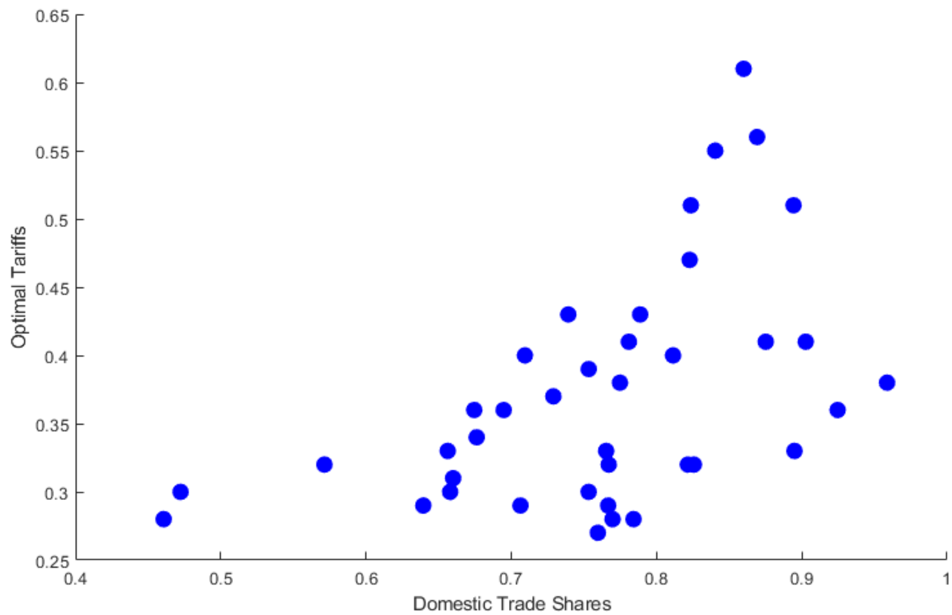


FIGURE C1. SCATTER PLOT OF DOMESTIC TRADE SHARES VS. OPTIMAL TARIFF RATES

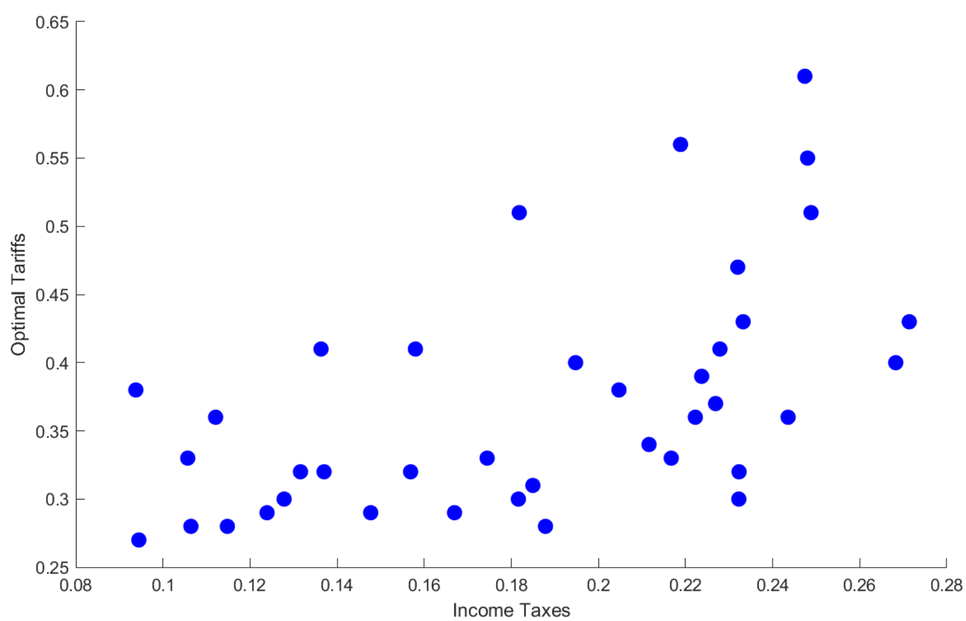


FIGURE C2. SCATTER PLOT OF INCOME TAXES VS. OPTIMAL TARIFF RATES

Therefore, welfare changes can be written as

$$\hat{\omega}_n = \frac{U_n'}{U_n} = \hat{L}_n^{1+\frac{1}{\varepsilon}}$$

$$= \left(\hat{\pi}_{nn}^{-1/\theta}\hat{A}_n\right)^{1+\varepsilon}$$

*C1. Derivation for welfare changes in a model with endogenous labor supply, income taxes, and tariffs.*

$$\omega_n = \frac{I_n}{P_n} - \frac{L_n^{\frac{1+\varepsilon}{\varepsilon}}}{\frac{1+\varepsilon}{\varepsilon}}$$

$$= \frac{I_n}{(1-t_n)w_n L_n^{-\frac{1}{\varepsilon}}} - \frac{L_n^{\frac{1+\varepsilon}{\varepsilon}}}{\frac{1+\varepsilon}{\varepsilon}}$$

$$= L_n^{\frac{1}{\varepsilon}}[\frac{I_n}{(1-t_n)w_n} - \frac{L_n}{\frac{1+\varepsilon}{\varepsilon}}]$$

$$= L_n^{\frac{1}{\varepsilon}}[\frac{w_nL_n(1-t_n)+GR_n}{(1-t_n)w_n} - \frac{L_n}{\frac{1+\varepsilon}{\varepsilon}}]$$

$$= L_n^{\frac{1}{\varepsilon}}[L_n + \frac{GR_n}{(1-t_n)w_n} - \frac{L_n}{\frac{1+\varepsilon}{\varepsilon}}]$$

$$= L_n^{\frac{1}{\varepsilon}}[L_n(1-\frac{\varepsilon}{1+\varepsilon}) + \frac{GR_n}{(1-t_n)w_n}]$$

$$= L_n^{\frac{1}{\varepsilon}}[L_n(\frac{1}{1+\varepsilon}) + \frac{GR_n}{(1-t_n)w_n}]$$

Let $\lambda_n = \frac{(1-t_n)w_nL_n}{I_n}$ and $1-\lambda_n = \frac{GR_n}{I_n}$

$$= L_n^{\frac{1}{\varepsilon}}[L_n(\frac{1}{1+\varepsilon}) + \frac{(1-\lambda_n)I_n}{\lambda_n I_n}L_n]$$

$$= L_n^{\frac{1}{\varepsilon}+1}[\frac{1}{1+\varepsilon} + \frac{(1-\lambda_n)}{\lambda}]$$

$$= L_n^{\frac{1}{\varepsilon}+1}[\frac{\lambda_n + (1-\lambda_n)(1+\varepsilon)}{(1+\varepsilon)\lambda_n}]$$

$$\hat{\omega}_n = \frac{{L_n'}^{\frac{1}{\varepsilon}+1}(\lambda_n' + (1-\lambda_n')(1+\varepsilon))\frac{1}{(1+\varepsilon)\lambda_n'}}{L_n^{\frac{1}{\varepsilon}+1}(\lambda_n + (1-\lambda_n)(1+\varepsilon))\frac{1}{(1+\varepsilon)\lambda_n}}$$

$$= \frac{\hat{L}_n^{\frac{1}{\varepsilon}+1}}{\hat{\lambda}_n}\frac{1+\varepsilon(1-\lambda_n')}{1+\varepsilon(1-\lambda_n)}$$

$$= (\hat{\pi}_{nn}^{-\frac{1}{\theta}}\hat{A}_n)\frac{\hat{L}_n}{\hat{\lambda}_n}\frac{1+\varepsilon(1-\lambda_n')}{1+\varepsilon(1-\lambda_n)}\frac{1-t_n'}{1-t_n}$$

*C2. Derivation for welfare changes in a model with exogenous labor supply, income taxes, and tariffs.*

$$\pi_{ni} = \frac{(\tau_{ni} w_i / A_i)^{-\theta}}{\sum_{k=1}^{N} (\tau_{nk} w_k / A_k)^{-\theta}}$$
$$= \frac{(\tau_{ni} w_i / A_i)^{-\theta}}{P_n^{-\theta}} \gamma^{\theta}$$

Rearranging this gives:

$$\pi_{ni}^{-1/\theta} = \gamma \frac{w_i}{P_n} \frac{\tau_{ni}}{A_i}$$

Setting $n = i$ and rearranging gives:

$$\frac{w_n}{P_n} = \gamma^{-1} \pi_{nn}^{-1/\theta} A_n$$

Multiplying both sides by $\frac{I_n}{w_n}$ yields:

$$\frac{I_n}{P_n} = \gamma^{-1} \pi_{nn}^{-1/\theta} A_n \frac{I_n}{w_n}$$

Using the definition of $\lambda_n$:

$$= \gamma^{-1} \pi_{nn}^{-1/\theta} A_n \frac{I_n}{\lambda_n I_n} (1 - t_n) L_n$$
$$= \gamma^{-1} \pi_{nn}^{-1/\theta} A_n \frac{(1 - t_n) L_n}{\lambda_n}$$

Welfare, $\omega_n$, is given by real income $\omega_n = \frac{I_n}{P_n}$ such that welfare changes can be written as:

$$\hat{\omega}_n = (\hat{\pi}_{nn}^{-\frac{1}{\theta}} \hat{A}_n) \frac{\hat{L}_n}{\hat{\lambda}_n} \frac{1 - t_n'}{1 - t_n}$$

TABLES

TABLE D1—COMPARISON OF OPTIMAL TARIFFS AND INCOME TAXES UNDER ENDOGENOUS AND EXOGENOUS LABOR SUPPLY MODELS

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Endogenous Labor Supply | | Exogenous Labor Supply | |
| | Optimal Tariffs | Optimal Taxes | Optimal Tariffs | Optimal Taxes |
| **Country** | | | | |
| AUS | 56% | 13.2% | 25% | 18.2% |
| AUT | 40% | 16.2% | 25% | 22.3% |
| BEL | 36% | 14.7% | 25% | 20.3% |
| BRA | 41% | 8.2% | 25% | 11.4% |
| CAN | 29% | 7.5% | 25% | 10.3% |
| CHE | 27% | 5.7% | 25% | 7.9% |
| CHL | 33% | 10.5% | 25% | 14.5% |
| CHN | 38% | 5.7% | 26% | 7.8% |
| COL | 41% | 9.5% | 25% | 13.2% |
| CZE | 29% | 8.9% | 25% | 12.3% |
| DEU | 28% | 6.9% | 26% | 9.6% |
| DNK | 0% | 20.5% | 25% | 28.2% |
| ESP | 32% | 8.3% | 25% | 11.4% |
| EST | 33% | 13.1% | 25% | 18.0% |
| FIN | 38% | 12.4% | 25% | 17.0% |
| FRA | 47% | 14.0% | 25% | 19.3% |
| GBR | 55% | 15.0% | 25% | 20.7% |
| GRC | 51% | 15.0% | 25% | 20.7% |
| HUN | 32% | 14.0% | 25% | 19.3% |
| IND | 33% | 6.4% | 25% | 8.8% |
| IRL | 28% | 11.3% | 25% | 15.6% |
| ISL | 37% | 13.7% | 25% | 18.9% |
| ISR | 43% | 14.1% | 25% | 19.4% |
| ITA | 61% | 14.9% | 25% | 20.6% |
| JPN | 0% | 20.1% | 25% | 27.7% |
| KOR | 32% | 7.9% | 25% | 11.0% |
| LTU | 29% | 10.1% | 25% | 13.9% |
| LUX | 30% | 14.0% | 25% | 19.3% |
| LVA | 39% | 13.5% | 25% | 18.6% |
| MEX | 30% | 7.7% | 25% | 10.6% |
| NLD | 34% | 12.8% | 25% | 17.6% |
| NOR | 36% | 13.4% | 25% | 18.5% |
| NZL | 92% | 16.6% | 25% | 22.8% |
| POL | 32% | 9.5% | 25% | 13.1% |
| PRT | 41% | 13.8% | 25% | 19.0% |
| ROW | 40% | 11.8% | 25% | 16.2% |
| RUS | 28% | 6.4% | 25% | 8.9% |
| SVK | 30% | 11.0% | 25% | 15.1% |
| SVN | 31% | 11.2% | 25% | 15.4% |
| SWE | 43% | 16.4% | 25% | 22.6% |
| TUR | 51% | 11.0% | 25% | 15.1% |
| USA | 36% | 6.8% | 26% | 9.3% |
| Mean | 37% | 11.9% | 25% | 14.4% |

TABLE D2—WELFARE CHANGES ASSOCIATED WITH DIFFERENT LABOR SUPPLY ELASTICITIES

| | (1) | (2) | (3) |
|---|---|---|---|
| | Endogenous Labor Supply | Exogenous Labor Supply | |
| | Welfare Change | Welfare Change | Difference |
| **Country** | | | |
| AUS | 1.07 | 1.01 | 0.06 |
| AUT | 1.12 | 1.01 | 0.10 |
| BEL | 1.09 | 1.01 | 0.08 |
| BRA | 1.02 | 1.00 | 0.02 |
| CAN | 1.04 | 1.01 | 0.03 |
| CHE | 1.03 | 1.01 | 0.02 |
| CHL | 1.06 | 1.01 | 0.05 |
| CHN | 1.01 | 1.00 | 0.01 |
| COL | 1.03 | 1.00 | 0.03 |
| CZE | 1.05 | 1.01 | 0.04 |
| DEU | 1.04 | 1.01 | 0.03 |
| DNK | 0.93 | 1.01 | -0.08 |
| ESP | 1.04 | 1.01 | 0.03 |
| EST | 1.08 | 1.01 | 0.06 |
| FIN | 1.07 | 1.01 | 0.06 |
| FRA | 1.08 | 1.01 | 0.07 |
| GBR | 1.09 | 1.01 | 0.09 |
| GRC | 1.10 | 1.01 | 0.09 |
| HUN | 1.09 | 1.02 | 0.07 |
| IND | 1.01 | 1.00 | 0.01 |
| IRL | 1.07 | 1.02 | 0.05 |
| ISL | 1.08 | 1.01 | 0.07 |
| ISR | 1.08 | 1.01 | 0.07 |
| ITA | 1.10 | 1.01 | 0.09 |
| JPN | 0.92 | 1.00 | -0.09 |
| KOR | 1.03 | 1.01 | 0.02 |
| LTU | 1.06 | 1.01 | 0.04 |
| LUX | 1.09 | 1.02 | 0.07 |
| LVA | 1.08 | 1.01 | 0.07 |
| MEX | 1.03 | 1.01 | 0.02 |
| NLD | 1.07 | 1.01 | 0.06 |
| NOR | 1.07 | 1.01 | 0.06 |
| NZL | 1.13 | 1.00 | 0.13 |
| POL | 1.05 | 1.01 | 0.04 |
| PRT | 1.08 | 1.01 | 0.07 |
| ROW | 1.05 | 1.01 | 0.05 |
| RUS | 1.03 | 1.01 | 0.02 |
| SVK | 1.06 | 1.01 | 0.05 |
| SVN | 1.06 | 1.01 | 0.05 |
| SWE | 1.12 | 1.01 | 0.11 |
| TUR | 1.05 | 1.00 | 0.04 |
| USA | 1.02 | 1.00 | 0.01 |
| Mean | 1.06 | 1.01 | 0.05 |