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# **HOW PROTECTIONISM HARMS WORKERS UNDER OLIGOPOLY**

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# How Protectionism Harms Workers Under Oligopoly

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## Abstract

I study welfare and distributional effects of import tariffs in a two-country asymmetric general oligopolistic equilibrium trade model. Tariffs have an anti-competitive effect that reduces labor demand because firms want to shorten supply. Unilaterally increasing the import tariff in absence of foreign retaliation raises domestic welfare at the foreign country's expense, but comes at the cost of favoring profit recipients as compared to workers, whose real wages fall. Only if initial symmetric tariffs are low, the tariff-increasing government could use its rising tariff revenue to neutralize the distributional effect or the negative effect on workers, an action the other country could never take because its tariff revenue declines. If supporting workers is the policy objective, tariffs do not appear to be a suitable tool under oligopoly and need to be accompanied by transfer payments or even profit taxation.

**JEL-Codes:** F13, E25, F12, J23, L13.

**Keywords:** Trade Policy, labor share, general oligopolistic equilibrium, labor demand, strategic trade.

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# 1 Introduction

Currently, there is a public debate on the effectiveness of import tariffs as a tool to improve the economic situation of workers.<sup>1</sup> We know from perfect competition that in absence of foreign retaliation a large country can improve its welfare via its terms of trade by setting a positive import tariff. Evidence of rising profit shares in the global economy, however, strongly suggests a growing importance of large firms' market power.<sup>2</sup> The optimal tariff argument has been transferred to the case of oligopolistic competition in partial equilibrium.<sup>3</sup> To determine whether workers actually benefit from such policies, we need to consider distributional effects and, thus, turn to a general equilibrium. This raises the question whether a country can still benefit from unilaterally increasing its import tariffs in general oligopolistic equilibrium. To answer it, we need to incorporate country asymmetries with regard to tariff rates in a general oligopolistic equilibrium model.<sup>4</sup>

I show that even for the best possible case of no foreign retaliation, while a country can raise its real income by means of import tariffs, the real income of workers falls. To reach the policy objective of raising workers' economic welfare, trade policy needs to be combined with social policy. Even when lump-sum transfers to workers are feasible without causing distortions, the marginal rise in tariff revenue will be large enough to compensate the marginal loss in real labor income only up to certain initial symmetric tariff rates. Thus, extensive trade policy with this objective additionally needs to integrate profit taxation, which might be distortionary in its own right.

With oligopolistic competition, import tariffs have an anti-competitive effect that reduces labor demand because firms want to shorten supply. Consequently, wages fall in general equilibrium. Accordingly, import tariffs by itself are no suitable policy tool for improving the situation of workers. If there is foreign retaliation, symmetric countries set

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<sup>1</sup>See, for example, Polaski et al. (2020), Ernst et al. (2019) or the intention to "put American workers first" by Trump (2018).

<sup>2</sup>See, for example, Barkai (2020), De Loecker et al. (2020), Autor et al. (2020) as well as Shepotylo and Vakhitov (2020).

<sup>3</sup>See, for example, Brander and Spencer (1984). The approach to transfer it to general oligopolistic equilibrium by Colacicco (2012) is discussed later on in this chapter.

<sup>4</sup>In the GOLE context, this implies allowing the countries' marginal utilities of income to differ.

identical tariffs in Nash equilibrium and tariff revenue is never sufficient to compensate labor income – especially not relative to rising profit income. Empirical evidence supports such a negative effect of import tariffs on labor income.<sup>5</sup> Furceri et al. (2019) empirically analyze effects of tariffs for 151 countries from 1963 to 2014 and find that tariffs increase income inequality. This is in line with my result of a falling ratio of labor to profit income, if profit income recipients are richer than workers *ex ante*.

I analyze unilateral and non-cooperative trade policy in a two-country asymmetric general oligopolistic equilibrium (AGOLE) trade model based on Quint and Rudsinske (2020a). Import tariffs act as a trade barrier, such that cross-country strategic competition is reduced and firms want to produce less. A general equilibrium is necessary to capture the negative wage effects related to this. At the same time, the general equilibrium opens a cross-country demand channel that causes asymmetric income and price effects in the two countries. While firms from both countries increase nominal markups when tariffs reduce cross-border competition, the tariff-increasing country gains a part of the foreign firms' markup adjustment in the form of tariff revenue. Thus, strategic competition among oligopolists causes foreign firms to bear a part of the tariff burden, in order to artificially inflate their foreign prices by reducing exports less than they would in absence of market power, thereby limiting their domestic supply. Without foreign retaliation, increasing the import tariff from a symmetric starting point raises domestic welfare at the other country's expense. However, this comes at the cost of favoring profit recipients as compared to workers, whose real wages fall. For small initial symmetric tariffs, the protectionist government can use its tariff revenue to neutralize this distributional effect, the other government cannot. As the model does not feature any aggregate gains from trade, the non-cooperative Nash equilibrium is at prohibitive symmetric tariffs. Thus, free trade agreements can be desirable from a social welfare perspective even without gains from trade as they lower firms' market power and raise the labor share under oligopolistic competition.

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<sup>5</sup>Giovannetti et al. (2020) show that tariff protection lowered real wages in Egypt. Xu and Ouyang (2017) find that tariff reductions increased wages in China.

The paper is related to several strands of the literature. First, it extends the literature on optimal tariffs<sup>6</sup> to the case of general oligopolistic equilibrium. Fleming (1956) analyzes optimal tariffs for the case of two countries with differing but exogenous marginal utilities of income. While this stresses the role that country differences play, it does not reflect possible endogenous effects of trade policy on the marginal utility of income as present in this paper. When trade policy is able to shift real income between countries, this is likely to affect the marginal utility of income. With a decreasing marginal utility of consumption, higher consumption causes additional income to buy less utility at constant prices. A surge in domestic prices, which I show is a side effect of strategic import tariffs in general oligopolistic equilibrium, intensifies this channel.

Second, the paper is related to the literature on import tariffs under oligopoly as well as to the literature on the influence of import tariffs on the factor income distribution. Brander and Spencer (1992) show that tariffs distort pro-competitive effects of intraindustry trade in a reciprocal dumping model as described by Brander (1981). This is an important channel that transfers to the broader general equilibrium model presented here. However, a pronounced difference to their model is that marginal costs are no longer constant but endogenously affected by trade policy. Accordingly, domestic tariffs affect sales in the foreign country as well. When foreign firms export less due to a rise in tariffs, they want to reduce production. In general equilibrium, this pushes down wages until full employment is restored, which results in higher sales by foreign firms in the foreign country. This effect on the factor income distribution is present in Bastos and Kreickemeier (2009), who model a specific symmetric tariff within a general oligopolistic equilibrium model that features labor unions. They find that a marginal decline in symmetric tariffs increases wages, decreases profits and does not affect prices and welfare. This corresponds to my results for symmetric tariffs, which is not surprising as tariffs are the sole source of asymmetry in

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<sup>6</sup>Kaldor (1940) and De Scitovszky (1942) formalize that at least in absence of foreign retaliation it can be optimal for a country to charge positive import duties. Bond (1990) generalizes the optimal tariff argument for a large economy from two-goods to higher dimensions. Gros (1987) shows that even for a small economy a positive tariff can be optimal under product differentiation and monopolistic competition. Felbermayr et al. (2013) extend this to the case of a large one-sector economy with heterogeneous firms and preferences that exhibit a constant elasticity of substitution.

the model. To analyze strategic trade policy, we have to allow countries to set different tariffs and then check how the factor income distribution is affected.

Their model is based on Neary (2016), who proposes a trade model for the case of general oligopolistic equilibrium (GOLE), where countries are symmetric in every characteristic necessary to ensure that their marginal utilities of income are identical. This allows to analyze strategic interactions among firms in a general equilibrium setting. The existing literature on tariffs in GOLE focuses on symmetric tariffs, which does not allow to study the strategic dimension of unilateral trade policy and the effects of asymmetric tariff rates.<sup>7</sup> Colacicco (2012) analyzes strategic trade policy in a GOLE-style framework, but only models the demand-side of one country, such that a cross-country demand channel is ruled out by definition.<sup>8</sup> Although a vast literature on optimal tariffs exists, the influence of strategic interactions among large firms in a general equilibrium setting and the ability of governments to tackle tariff-induced distributional effects have not been analyzed adequately.

In Quint and Rudsinske (2020a) we extend the GOLE to feature asymmetric countries with segmented markets (AGOLE), which allows analysis of a wider variety of topics.<sup>9</sup> As the AGOLE allows to include asymmetric import tariffs, unilateral trade policy can be studied in this framework. Trade in the AGOLE model with a featureless economy, i.e. the same technology in all sectors, behaves similarly as in the partial oligopolistic equilibrium model of Brander and Krugman (1983). Strategic considerations among firms give rise to two-way trade in homogeneous goods. With positive tariffs in the AGOLE, marginal costs are higher for exporting, which pushes down markups on foreign relative to domestic sales *ceteris paribus*. Therefore, firms sell more domestically and reduce exports.

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<sup>7</sup>Zhang (2017) analyses a symmetric reduction in trade costs between two trading partners in a GOLE model with product differentiation. Fujiwara and Kamei (2018) focus on the effects of a symmetric tariff reduction in a GOLE model with an explicit division of labor. They find differences in the effects on productivity in trading and non-trading industries.

<sup>8</sup>He assumes that the total produced quantity in both countries will be supplied to and consumed in the home country. This rules out any strategic considerations of companies with regard to their supply decision over the home and the foreign market. Furthermore, the home country by definition has to run a trade balance deficit.

<sup>9</sup>In Quint and Rudsinske (2020b), for example, we apply the AGOLE model to the case of tax-motivated transfer pricing.

The paper is structured as follows. I introduce the theoretical model and the solution strategy in chapter 2. In chapter 3, I present the effects of symmetric import tariffs as a benchmark to stress the role of the cross-country demand channel in the asymmetric case. I present the welfare and distributional effects of unilaterally raising the import tariff in chapter 4, where I also derive the non-cooperative Nash equilibrium tariffs. The final chapter concludes, while most proofs are deferred to the appendix.

## 2 Theoretical Model

I adapt a two-country model of international trade in general oligopolistic equilibrium developed by Neary (2016) and extended by Quint and Rudsinske (2020a) for the case of asymmetric countries with segmented markets. In the following, I will only present the expressions for the country Home in most cases. Expressions for Foreign are analogous. Variables referring to Foreign will be marked with an asterisk.

### 2.1 Demand and Supply

Each country is inhabited by one representative consumer. Her continuum-quadratic preferences are additively separable and she inelastically supplies  $L$  units of labor to a perfectly competitive labor market.

$$U[\{y(z)\}] = \int_0^1 u[y(z)]dz \quad \text{where} \quad u[y(z)] = ay(z) - 1/2 by(z)^2,$$

with  $\frac{\partial U}{\partial y(z)} > 0$  and  $\frac{\partial^2 U}{\partial y(z)^2} < 0$ . Here,  $y(z)$  is the amount of consumption of a homogeneous good produced in sector  $z \in [0, 1]$  and  $a$  as well as  $b$  are parameters with  $a, b > 0$ .  $a$  and  $b$  are identical in both countries. The representative consumer is indifferent between domestic goods and imports in each sector  $z$ .

The yet to be determined wage rate will result in a wage income of  $wL$ . Additionally, aggregate profits ( $\Pi$ ) and tariff revenues ( $T$ ) are disbursed to the representative consumer.



Accordingly, her income is given by

$$I = wL + \Pi + T. \quad (1)$$

With price  $p(z)$  per unit of the good in sector  $z$ , the budget constraint is

$$\int_0^1 p(z)y(z)dz \leq I. \quad (2)$$

Utility function and budget constraint lead to the utility maximization problem represented by the Lagrangian:  $\max_{y(z), \forall z} \mathcal{L} = \int_0^1 (ay(z) - 1/2 by(z)^2) dz + \lambda \left( I - \int_0^1 p(z)y(z)dz \right)$ . The first order condition then gives  $0 = a - by(z) - \lambda p(z)$  for all sectors  $z$  with  $\lambda$  being the Lagrange-parameter and therefore the marginal utility of income. The inverse Frisch demand follows straightforwardly and is given by

$$p(z) = \lambda^{-1} \frac{\partial u[y(z)]}{\partial y(z)} = 1/\lambda [a - by(z)]. \quad (3)$$

The inverse demand functions (3) negatively depend on the marginal utility of income. A higher value of  $\lambda$  in equilibrium, *ceteris paribus*, indicates a lower equilibrium demand for goods.

The producers aim to maximize their profits given the demand and the import tariffs. Analogously to Neary (2016), firms are assumed to have market power in their respective markets. However, they do not have a deliberate influence on aggregate economic factors like  $\lambda$  and  $w$ , because a continuum of sectors exists and jointly determines those factors.

In their profit maximization, the firms have to take the tariff into account. They determine their domestic supply and their export supply separately. I assume that  $n$  firms exist in Home in each sector  $z$  and that there are neither fixed costs of production nor transport costs. The firms play a static one-stage game where they compete in Cournot competition over output in the Home and Foreign market. They take the consumers' demand as given and perceive the inverse demand as linear – irrespective of the functional form of  $\lambda$  – as companies by assumption do not have an individual influence outside their

own sector.

Production occurs with constant returns to scale and common technology in each sector  $z$ , such that cost  $c(z)$  in sector  $z$  are linear in output. Labor is the only factor of production. Labor  $L$  moves freely across sectors within a country, but not across national borders, such that the wage rate is determined at the country level by combining the inelastically supplied labor  $L$  and the demand for labor resulting from the companies' production.

The sector-specific common unit-labor requirement is  $\gamma(z)$ . The unit-cost function for sector  $z$  is then given by  $c(z) = w\gamma(z)$  where  $w$  is the national wage. To keep the model as simple as possible, I only consider the case of identical technology across sectors and countries  $\gamma(z) = 1 \forall z$  so we can drop the index  $z$ , although there is still a continuum of now identical sectors. Thus, the model does not capture a Ricardian-style technological comparative advantage as it did in Neary (2016). Trade in this setting is always of intra-industry type and caused solely by strategic considerations among oligopolists. As companies remain small in the large, they do not take their effect on wages into account when maximizing their profits. Therefore, marginal costs are constant and equal across the countries where they sell the good.

Because all sectors in a country are identical, they have identical prices. Accordingly, there is no endogenously changing price heterogeneity that could affect the utility of the representative consumer as in Neary (2016). With a strictly increasing marginal utility of consumption, this implies a strictly monotonic relationship between consumption (or real income) and welfare defined as utility of the representative consumer. Thus, for the direction of effects these terms can be used interchangeably.

Before firms and consumers act, the national government sets an import tariff denoted by  $t$ , which uniformly applies to all sectors. Tariffs are specific, so they accrue per unit of imported goods. Profits of one Home firm are given by  $\pi = (p - c)y_h + (p^* - c - t^*)y_f$ , where  $y_h$  is domestic and  $y_f$  is export supply.

## 2.2 Cournot Equilibrium

For solving the Cournot equilibrium we take the demand parameters  $\lambda^{(*)}$  and the wages  $w^{(*)}$  as exogenously given. One country's demand for goods from a specific sector is given by equation (3). All companies active in that sector compete in Cournot competition to satisfy this demand simultaneously.

Firms will maximize their profits by choosing the amount of goods to produce and sell given the demand, the tariffs, and the other companies' supply.

$$\begin{aligned} \max_{y_h, y_f} \pi &= [p - w] y_h + [p^* - w - t^*] y_f \\ &\text{with } p = 1/\lambda[a - by] \text{ and } p^* = 1/\lambda^*[a - by^*], \end{aligned}$$

where  $p$  and  $p^*$  are the inverse demand functions in Home and Foreign, and  $y$  describes the total supply of the good in Home and  $y^*$  in Foreign.  $y_i$  denotes the supply of one company producing in Home (no asterisk) to country  $i$ , whereas  $y_i^*$  denotes the supply of one company producing in Foreign ( $^*$ ) to country  $i$ , where  $i$  is either the country Home ( $h$ ) or Foreign ( $f$ ).

Bearing in mind that companies from the same country are symmetric, the first order conditions from the firms' profit maximization over their supplied quantities can be rearranged to

$$\begin{aligned} w &= \frac{1}{\lambda} (a - b(n^* y_h^* + (n+1)y_h)), \\ w + t^* &= \frac{1}{\lambda^*} (a - b(n^* y_f^* + (n+1)y_f)). \end{aligned} \tag{4}$$

They can be transformed into reaction functions to the supply of Foreign companies in the respective markets.

$$y_h = \frac{a - \lambda w - b n^* y_h^*}{b(n+1)} \tag{5}$$

$$y_f = \frac{a - \lambda^*(w + t^*) - b n^* y_f^*}{b(n+1)} \tag{6}$$

The equation for supply to Foreign shows the expected negative effect of the foreign import tariff.

Combining the reaction functions, we obtain the Cournot-Nash-equilibrium supply for Home (Foreign) companies  $y_i$  ( $y_i^*$ ) in both markets. The equilibrium supply of each individual company to the Home market is

$$y_h = \frac{a + \lambda \{n^*(w^* + t) - (n^* + 1)w\}}{b(n + n^* + 1)} \quad (7)$$

$$y_h^* = \frac{a + \lambda \{nw - (n + 1)(w^* + t)\}}{b(n + n^* + 1)}. \quad (8)$$

The supplied quantities in Foreign are analogous:

$$y_f^* = \frac{a + \lambda^* \{n(w + t^*) - (n + 1)w^*\}}{b(n + n^* + 1)} \quad (9)$$

$$y_f = \frac{a + \lambda^* \{n^*w^* - (n^* + 1)(w + t^*)\}}{b(n + n^* + 1)}. \quad (10)$$

This leads us to total production by Home firms  $\bar{y} = n(y_h + y_f)$  and total supply to the Home market  $y = ny_h + n^*y_h^*$ :

$$\begin{aligned} \bar{y} &= \frac{n}{b(n + n^* + 1)} \{2a + (\lambda + \lambda^*)(n^*w^* - (n^* + 1)w) + \lambda n^*t - \lambda^*(n^* + 1)t^*\} \\ y &= \frac{a(n + n^*) - \lambda(nw + n^*(w^* + t))}{b(n + n^* + 1)}. \end{aligned}$$

## 2.3 Labor Market and General Equilibrium

With the Cournot-Nash-equilibrium supply derived above, we can now turn to the clearing of the labor market. Inelastic labor supply amounts to  $L^{(*)}$  units in the respective countries. Labor demand depends on the total equilibrium production  $\bar{y}$  in the respective country and is given by  $L^D = \bar{y}$ . In equilibrium demand has to equal supply, such that  $L = \bar{y}$ . In combination with the analogously defined equilibrium on the Foreign labor market, wages

in both countries are defined as:

$$w = \frac{1}{\bar{\lambda}} \left\{ 2a - b \left[ \frac{n+1}{n} L + L^* \right] - t^* \lambda^* \right\} \quad (11)$$

$$w^* = \frac{1}{\bar{\lambda}} \left\{ 2a - b \left[ \frac{n^*+1}{n^*} L^* + L \right] - t \lambda \right\}, \quad (12)$$

where  $\bar{\lambda} = \lambda + \lambda^*$ . For equal labor endowment and industrial structure across countries, wages are equal if  $t = t^* = 0$ . The wage is reduced when the trading partner charges an import tariff.<sup>10</sup>

I normalize the aggregate marginal utility of income to unity, i.e.  $\bar{\lambda} = 1$ . Hence, the aggregate marginal utility of income is used as numéraire. This translates into the relationship between  $\lambda$  and  $\lambda^*$  that  $\lambda^* = 1 - \lambda$ . Additionally, we know that both marginal utilities of income will lie between zero and one because both have to be positive.

In equilibrium the model is characterized by nine equations in nine endogenous variables. The Cournot equilibrium quantities ((7) – (10)) determine the supply of each multinational company to each country. The labor market clearing in each country determines the wage rate ((11) and (12)). The prices are given by the representative consumers' inverse demand functions ((3) for Home, analogously for Foreign).

We can now use the budget constraint of the representative consumer as ninth equation to attain an implicit solution for the equilibrium marginal utility of income in Home. The budget constraint is given by

$$p \cdot (n y_h + n^* y_h^*) = w L + n \pi + T$$

This can be rearranged to obtain that the Home balance of payments (BoP) has to be zero in equilibrium:

$$BoP = (n^* t y_h^* - n t^* y_f) + (n p^* y_f - n^* p y_h^*) = 0 \quad (13)$$

The left term in parentheses is the capital balance, which in this model is the Home

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<sup>10</sup>We know this because  $\lambda > 0$  and  $\lambda^* > 0$  have to hold in any case.

tariff revenue minus the Foreign tariff revenue. The right term in parentheses depicts the trade balance, i.e. Home export value minus Home import value. This allows for trade imbalances if these imbalances are offset by capital transfers resulting from differing tariff payments of the companies across countries. Note that according to Walras' law the Foreign BoP will automatically be zero, if the Home BoP is.

We can now further simplify the system of equations by expressing all endogenous variables in terms of exogenous parameters and  $\lambda$  only.<sup>11</sup> These formulations can then be inserted in the balance of payments condition such that we only have one equation in one variable left.

Without loss of generality Home is the high-tariff country, i.e.  $0 \leq t^* \leq t$ . For simplicity, assume  $n = n^* = 1$  and  $L = L^* = 1/2$ . To ensure a positive marginal utility of consumption and positive quantities in absence of tariffs in any case, assume  $2/3 a < b < a$ .<sup>12</sup>

For the admissible range  $\lambda \in (0, 1)$  there exists one unique solution to the balance of payments condition under these assumptions if the tariffs are not too large. A tariff upper bound is obviously needed to ensure positive quantities and prices.<sup>13</sup>

**Lemma 1** (Existence and Uniqueness). *There exists a solution to the condition of an even balance of payments (13) in  $\lambda \in (0, 1)$ , which is unique if  $t = t^* \leq b \vee 0 \leq t^* \leq t < \bar{t}$ .*

*Proof.* See appendix. □

Unfortunately, we cannot determine the equilibrium marginal utility of income  $\hat{\lambda}$  in closed form if  $t \neq t^*$ , as in the equilibrium condition (13) it is derived from a quintic polynomial. According to Abel's impossibility theorem, there is no solution to this polynomial in radicals. However, it is possible to determine derivatives of  $\hat{\lambda}$  with respect to exogenous parameters by implicitly differentiating the equilibrium condition given by equation (13).

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<sup>11</sup>See the appendix for these equations.

<sup>12</sup>A positive marginal utility of consumption requires  $a > b$  in equilibrium. To ensure that this condition holds I take the most extreme case where  $y = L + L^* = 1$ . This leads to  $b < a$ . More generally, one needs  $b < a/(L+L^*)$ . This also assures positive wages at  $t = 0$ , which require  $b < 2a((n+1/n)L + L^*)$ . It is shown in the supplement that  $2/3 a < b$  is a sufficient condition for quantities to be positive for all admissible values of  $\lambda$  in absence of tariffs, i.e.  $t = t^* = 0$ .

<sup>13</sup>We will see later on that  $b$  is the prohibitive symmetric tariff, while due to complexity  $\bar{t}$  is chosen as a sufficient but not a necessary upper bound for the higher Home tariff when tariffs are asymmetric.

### 3 Symmetric Tariffs

When countries are completely symmetric, their marginal utilities of income need to be equal to one another. With  $1 = \lambda + \lambda^*$ , this boils down to  $\lambda = 1/2$  irrespective of the symmetric tariff rates. This makes the analysis of the symmetric case much easier. All prices and quantities are equal in both countries. Without any tariffs and fully symmetric countries, the model collapses to the case of no market segmentation. Symmetric tariffs do not distort the symmetry of the equilibrium. However, they do have an impact on international trade and the within-country income distribution.

**Proposition 1** (Effects of Symmetric Tariffs). *Rising symmetric tariffs reduce international trade and wages, and increase profits. Thus, the labor-profit ratio falls. The gain in tariff revenue is neither sufficient to offset the negative effect on labor income in absolute terms nor relative to profit incomes, if  $t > 0$ .*

*Proof.* See appendix. □

Because of the tariff barrier, firms want to export less. Thus, they want to reduce production. In order to restore labor market equilibrium, wages have to fall. Due to lower wage costs, firms supply more to their country of origin. Equilibrium prices are not affected, such that with the fall in wage costs profits grow. As prices and consumption are not affected, also the representative consumer's income has to be unaffected. The fall in wage income has to account for both the rise in profit income and the surge in tariff revenue. Thus, the labor share of income decreases while the profit share increases.

In absence of good opportunities for governments to gain revenue, it can be interesting for them to cooperatively gain or even maximize tariff revenue at  $t = b/2$ .<sup>14</sup> However, for  $t > 0$  the marginal gain in tariff revenue ( $\frac{1}{4} - \frac{t}{2b}$ ) is not even sufficient to offset the negative marginal effect on labor income in absolute terms ( $-\frac{1}{4}$ ) and especially not relative to profit incomes that marginally rise by  $\frac{t}{2b}$ . The terms show that the rise in tariff revenue is maximal at the initial zero-tariff situation with  $\frac{1}{4}$ , which exactly offsets the negative

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<sup>14</sup>See proof of proposition 1 in the appendix.

effect on labor income. If the tariffs rise symmetrically, the effect on labor income remains constant, but there is a rising positive effect on profit incomes which directly reduces the marginal increase in tariff revenue. At maximal tariff revenue with  $t = \frac{b}{2}$ , profit income has grown by  $\frac{b}{16}$ ,<sup>15</sup> labor income has fallen by  $\frac{b}{8}$ <sup>16</sup> and tariff revenue has increased by what is left from the labor income reduction after accounting for rising profits, i.e.  $\frac{b}{8} - \frac{b}{16} = \frac{b}{16}$ . At that point as compared to  $t = 0$ , profit income has increased by 25% and labor income has dropped by  $\frac{100}{8\frac{a}{b}-6}\%$ , which is larger the closer  $b$  is to  $a$ , i.e. the more the marginal utility of consumption reacts to a rise in consumption. Remember that we have  $\frac{2}{3}a < b < a$ . For a medium value of  $b = \frac{4}{5}a$  wages would have fallen by 25%. As prices are not affected by symmetric tariffs, the result holds both in nominal and real terms. In that setting, moving to the prohibitive tariff  $t = b$  would result in a 50% loss of labor income accompanied by a 100% rise in profit income as compared to free trade with the ratio of labor to profit income falling by 75% from 2 to  $\frac{1}{2}$ . Figure 1 plots the development of aggregate profit income, tariff revenue and aggregate labor income for symmetric tariffs beginning from free trade ( $t = 0$ ), over revenue-maximizing symmetric tariffs ( $t = b/2$ ) up to prohibitive tariffs ( $t = b$ ) for the case of  $b = 1$ .<sup>17</sup> The three sources of income always add up to zero because symmetric tariffs do not change aggregate income when there are no gains from trade.

To give the reader some intuition about the mechanisms that determine the general equilibrium, I decompose the model's operating principle into two fundamental conditions, which is analogous to Quint and Rudsinske (2020a). The consumption indifference condition (CI) states that for utility maximization the origin of the product is inconsequential. The representative consumer is indifferent between products in the same sector that are produced in Home and in Foreign. The market indifference condition (MI) states that in equilibrium firms have to be indifferent between selling the marginal unit in Home or in Foreign. We can plot these two conditions in a box diagram with the Home origin (0)

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<sup>15</sup>As the marginal change is linear in  $t$  starting from 0, we can calculate the area of the triangle, which is  $\frac{1}{2}$  times the last marginal increase ( $\frac{1}{4}$ ) times the last tariff ( $\frac{b}{2}$ ).

<sup>16</sup>This follows from the constant  $-\frac{1}{2}$  over the interval 0 to  $\frac{b}{2}$  for  $L = \frac{1}{2}$ .

<sup>17</sup> $b$  is only a scale parameter here and does not change economic intuitions.



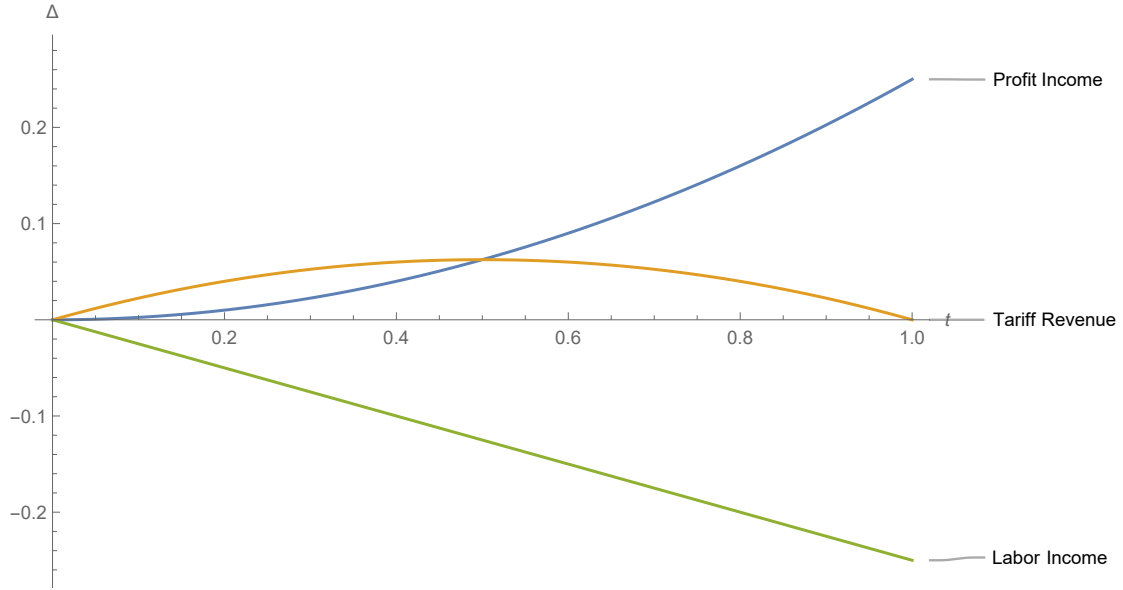


Figure 1: Income Differences Compared to  $t = 0$  (for  $b = 1$ )

in the lower left corner and the Foreign origin ( $0^*$ ) in the upper right corner. The usual notation applies.

The CI is easily derived from the budget constraint.

$$I = p(y_h + y_h^*)$$

$$CI : y_h = \frac{I}{p} - y_h^*$$

It gives us a function with perfect substitutability between Home and Foreign goods from the consumer's perspective, for whom real income  $I/p$  is exogenous. Thus, the slope of the CI line is  $-1$  and an increase in real income in Home shifts it towards the upper-right corner. In our initial equilibrium with  $I/p = L/n = 1/2$  the intercept is exactly in the upper left corner of the graph. The same can analogously be done for the Foreign representative consumer giving us exactly the same line in the graph.

The MI can be derived from the fact that the marginal revenues of a firm need to be equal in both markets in equilibrium. This follows straightforwardly from the profit

maximization in equations (4) and (5) and can be rearranged to

$$\frac{1}{\lambda}(a - b\bar{y}) = \frac{1}{\lambda}by_h + \frac{1}{\lambda^*}(a - b\bar{y}^* - by_f) - t^*$$

and

$$\frac{1}{\lambda}(a - b\bar{y}) = \frac{1}{\lambda}by_h^* + \frac{1}{\lambda^*}(a - b\bar{y}^* - by_f^*) + t.$$

Because these equations have the same left-hand side, we can set the right-hand sides equal, rearrange, and get

$$\frac{t + t^*}{b} = \frac{y_h - y_h^*}{\lambda} + \frac{y_f^* - y_f}{\lambda^*}.$$

This shows that the lower  $b$  and the higher the tariffs, the more has to be consumed from domestic producers on each market, where markets are weighted with their demand aggregator ( $\lambda^{-1}$ ).  $b$  is a parameter from the quadratic sub-utility, where lower  $b$  means that marginal utility of consumption is decreasing slower in consumption. From inverse Frisch demand we know that with lower  $b$  prices will react less strongly to consumption changes. In that case prices will react less to the direct supply effect of the tariffs and thus dampen it less, such that the equilibrium quantity reactions are larger. Using the normalization  $\lambda = 1 - \lambda^*$ , as well as  $y_f + y_h = L/n = L^*/n^* = y_h^* + y_f^*$  this equation can be rearranged to get a function that we can use to illustrate the equilibrium:

$$MI : y_h(y_h^*) = \frac{t + t^*}{b}\lambda(1 - \lambda) + y_h^*$$

The line has a slope of +1, which in our diagram again is the same from Foreign's perspective. The first term on the right-hand side is exogenous from the firm's perspective as it entails the demand aggregator  $\lambda$ , and the model parameters  $b, t$ , and  $t^*$ .

Figure 2 shows the symmetric-tariff equilibrium at the intersection of MI and CI. Without any tariffs we are in point A and both markets are identical from the perspective of all firms. With symmetric but positive tariffs, each firm's domestic market will become relatively more attractive *ceteris paribus*, such that the MI line shifts towards the upper

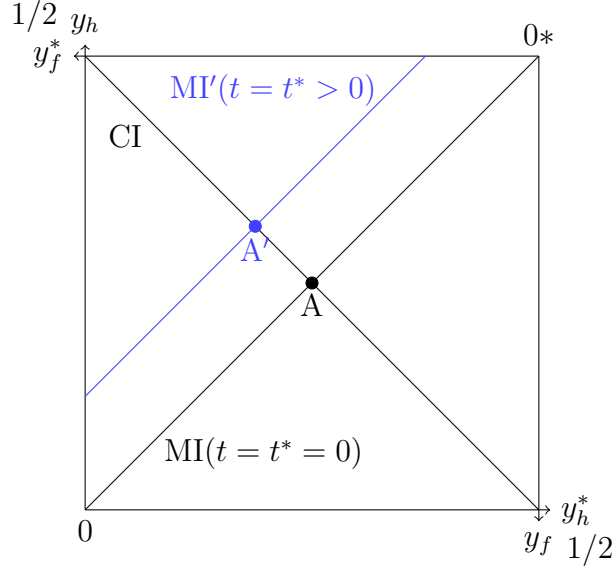


Figure 2: Symmetric Equilibrium with  $t = t^*$

left corner where international trade decreases. The CI line does not move, which shows us that countries are still doing equally well from a welfare perspective. We can use this graphical depiction later to illustrate the effects of asymmetric tariffs on the consumers and producers. The main point I will stress is that with asymmetric tariffs the CI line shifts and affects the general equilibrium outcome. Also the shift of the MI line will be affected if the countries' marginal utilities of income become asymmetric with an asymmetric tariff, which changes the equilibrium value of  $\lambda$ .

There is no distortion in production across sectors in the featureless economy, such that welfare, real income and consumption do not change. Also the cross-country demand channel (the CI curve) is switched off as long as both countries are fully symmetric. This is a benchmark scenario that we can use to better understand the mechanisms at work and to compare the effects of asymmetric tariffs in the next chapter with, where the cross-country demand channel comes into play.

## 4 Asymmetric Tariffs

Let us now allow tariffs to be asymmetric. This enables us to analyze the effects of an marginally increasing Home tariff while keeping the Foreign tariff fixed and equal to the

initial tariff in Home for simplicity.<sup>18</sup> Accordingly, Foreign does not engage in retaliation so far. First, we need to determine the effect of an increase in  $t$  on the equilibrium marginal utility of income  $\hat{\lambda}$ .

**Lemma 2** (Effect of Unilateral Tariff on  $\hat{\lambda}$ ). *A unilateral increase in  $t$  decreases the marginal utility of income  $\hat{\lambda}$  in the high-tariff country, if  $t^* = t < b \vee 0 \leq t^* \leq t < \bar{t}$ .*

*Proof.* See appendix. □

A first intuition for this result is that domestic tariff revenue rises, which increases domestic income. With higher income, ceteris paribus, the marginal utility of income falls. There is also a general equilibrium price effect affecting this outcome, which follows shortly.

With this result at hand, we can now turn to the analysis of the effects that a unilaterally increasing Home tariff has. Tariffs make it less attractive to sell abroad. When Foreign firms want to reduce exports following a tariff increase in Home, Home firms will react and fill this supply gap by shifting supply from Foreign to Home. While firms from both countries raise nominal markups when tariffs reduce cross-border competition, the tariff-increasing country Home gains a part of Foreign firms' markup adjustment in the form of tariff revenue. Strategic competition among oligopolists causes Foreign firms to bear a part of the tariff burden. They do this in order to artificially inflate their prices in Foreign by limiting their supply. As production is fixed in general equilibrium, this involves reducing exports less than they would in absence of market power. Consequently, their export price is artificially low, which benefits Home via the terms of trade. One important difference to a case of a large country reaping rents from a foreign monopolist is that the Home oligopolists sell identical products, such that strategic competition gives rise to supply and production reactions in both countries.

Home real income rises at the cost of Foreign. With increasing demand in Home, and symmetrically decreasing demand in Foreign, Foreign exports fall less than Home

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<sup>18</sup>Note that the propositions in this chapter do not change fundamentally for  $t > t^*$ , which I show in extensions 1 and 2 in the supplement as general as possible given the model's complexity.

exports thereby enabling Home to consume more. This cross-country demand channel is an essential mechanism to explain how asymmetric tariffs affect welfare in general oligopolistic equilibrium. It captures the standard terms-of-trade effect that is known from other settings. Because Home demand is higher due to the increased tariff revenue, prices increase in Home relative to Foreign.

**Lemma 3** (Asymmetric Price Reaction). *When Home raises its tariff at  $t = t^*$ , prices increase in Home and decrease in Foreign.*

*Proof.* See appendix. □

As exporting is less attractive with the higher Home tariff, Foreign firms want to produce less. Additionally, in presence of higher trade barriers Home oligopolists experience growing market power domestically and want to artificially reduce supply to benefit from higher prices, which in equilibrium with fixed labor supply pushes down wages and thus firms' cost. This way, the rising market power comes with higher nominal markups, which explain the growing nominal profits at constant sales, that we find in both countries for  $t > 0$ . With a fixed labor supply but decreasing labor demand as a result of firms wanting to reduce production, nominal wages are affected. They decrease in Foreign, are unaffected in Home if  $t^* = 0$  and decrease in Home if  $t^* > 0$ .

Also real wages fall in both countries with rising trade barriers in place. Nominal profits rise in both countries. Due to the asymmetric price reactions, real profits (in domestic prices) increase in Foreign. They decrease in Home for low initial tariffs and rise for high initial tariffs. The labor-profit ratio always declines in Foreign, and in Home as well if  $t > 0$ . This leads to rising inequality if ex ante profit income recipients are richer than workers. Foreign tariff revenue is diminished. Even the rise in Home tariff revenue is too low to neutralize the distributional effect or to compensate workers in Home in nominal

and even more so in real terms, if the initial symmetric tariffs are too high.<sup>19</sup>

**Proposition 2** (Income and Distribution). *When Home raises its tariff at  $t = t^*$ , real wages decrease in both countries, while real profits increase in Foreign. The reaction of Home real profits is negative for low and positive for high initial tariffs. The labor-profit ratio always declines in Foreign, and also in Home if  $t > 0$ . Only up to certain initial symmetric tariffs, Home could use its rising tariff revenue to neutralize the distributional effect or the negative effect on labor income, Foreign can never do that because its tariff revenue declines.*

*Proof.* See appendix. □

If a country raises its tariff from a symmetric starting point, its consumption rises due to the cross-country demand channel and international trade declines. When both countries start at zero tariffs, it is always optimal for each of them to deviate and increase its tariff unilaterally. The unilaterally optimal tariff without Foreign retaliation is lower than prohibitive.<sup>20</sup> A welfare benefit from an increasing tariff goes hand in hand with a loss abroad, because it is a simple reallocation of consumption. Thus, the other country is always better off with catching up to the same tariff. With equal tariffs, both countries have the same welfare again – and again an incentive to deviate upwards. This stops when trade has come to a halt. Thus, prohibitive symmetric tariffs are the unique Nash-equilibrium and we already know that it benefits profit recipients as compared to workers. Accordingly, even without gains from trade free trade agreements can be desirable from a social welfare or industrial policy perspective as they lower effective market power and raise the labor share.

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<sup>19</sup>To compensate the marginal distributional effect or the marginal real labor income effect with the marginal rise in tariff revenue, initial symmetric tariffs need to be below certain thresholds, that are both lower than  $b/3$ , which is a third of the prohibitive symmetric tariff and lower than the revenue maximizing symmetric tariff  $b/2$ . The threshold is higher for the real labor income effect if  $a$  is large relative to  $b$ , which implies that the distributional effect of a unilateral tariff increase is the first that cannot be compensated anymore when initial symmetric tariffs would rise. If  $a$  is small relative to  $b$ , prices react more strongly to growing Home consumption, such that the real wage effect is harder to compensate.

<sup>20</sup>Due to the model's complexity, the optimal unilateral tariff cannot be derived in closed form. I show this even for the extremely simple case of  $a = 1, b = 4/5, t^* = 0$  in the proof of proposition 3 in the supplement, where I also prove that the resulting optimal tariff is, nevertheless, strictly positive and benefits the tariff-imposing country.

**Proposition 3** (Trade, Welfare and Nash-Equilibrium). *When Home raises its tariff at  $t = t^*$ , consumption increases in Home and decreases in Foreign due to changing terms of trade, while the total quantity traded internationally declines. There exists a unique Nash-equilibrium with prohibitive tariffs.*

*Proof.* See appendix. □

World welfare in this setting is not affected by tariffs as there are no gains from trade. When there are comparative advantages, it is likely that the Nash-equilibrium tariff would not be prohibitive but still positive to balance the positive and negative effects of unilateral deviations. In that case, any tariffs and accordingly the Nash-equilibrium outcome would be detrimental from the world's welfare perspective.

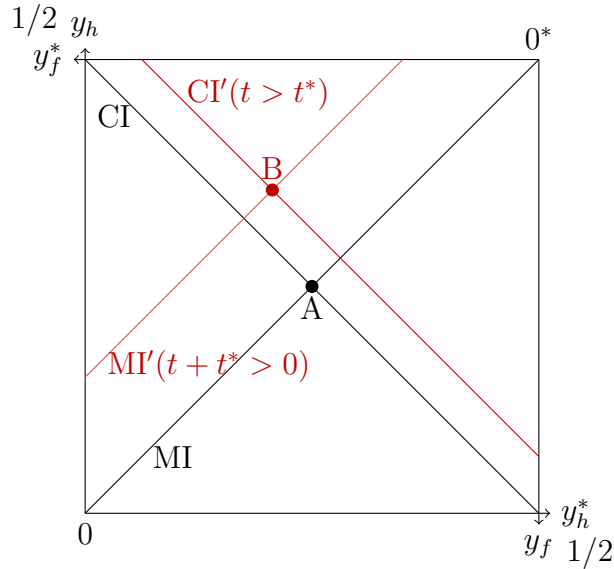


Figure 3: Asymmetric Equilibrium with  $t > t^* = 0$

Figure 3 shows the new equilibrium in point B with a positive tariff in Home and  $t^* = 0$ . Exporting is less attractive with the tariff, such that the MI curve shifts upwards. Firms need to export less to be indifferent between both markets again. This is also true for Home firms, which are not charged a tariff here, because they face growing competition on the Foreign market from Foreign firms that have reduced their exports in favor of domestic supply. At the same time, Home gains tariff income that is partly absorbed from Foreign profits. This cross-country income reallocation increases real income in Home at

the cost of Foreign and gives rise to the cross-country demand channel. As Home now consumes more, the CI curve shifts upwards, though less than the MI curve, such that also Foreign exports unequivocally decrease if  $t$  does not get too large.<sup>21</sup>

## 5 Conclusion

We have analyzed the welfare and distributional effects of unilateral import tariffs in general oligopolistic equilibrium. Import tariffs reduce cross-country strategic competition. To optimize profits, firms want to produce less. They reduce their labor demand such that wages have to fall to restore full employment. A unilaterally higher import tariff can increase welfare, but comes at the cost of favoring profit recipients as compared to workers. The ratio of labor to profit income declines in both countries. With oligopoly, import tariffs have a strong distributional effect that governments should take into account, although tariff revenue alone can be too low to neutralize it.

The AGOLE framework allows to show that even though unilaterally raising the tariff can increase real income in absence of foreign retaliation, trade policy needs to be accompanied by social policy measures or even by profit taxation when the policy objective is to improve the situation of workers in a globalizing world. Possible inefficiencies of profit taxation or lump-sum transfers should be considered jointly with trade policy in order to reach a particular policy objective. In this respect, import tariffs do not appear to be a suitable tool for improving the situation of workers in presence of large firms with market power.

For future work it could be interesting to integrate a Ricardian comparative advantage in order to analyze how a counteracting gains from trade channel would affect the countries' tariff setting. Asymmetries in countries' labor endowment and market concentration could result in asymmetric optimal tariffs, which might be useful in bridging the gap between the theoretical and the empirical literature on 'trade wars'. Likewise, the introduction of

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<sup>21</sup>An in-depth analysis is provided in extension 1 in the supplement. From proposition 3 follows that at least for small deviations of  $t$  from  $t^*$  the MI shift has to be the larger one as the reduction in the exported quantity is larger for Home firms.



labor market imperfections might be insightful. Furthermore, export subsidies or other forms of trade policy could be analyzed in the AGOLE framework.

## Appendix

### Endogenous Variables Depending on $\lambda$

I present these equations in a more general way without applying the assumptions on  $L^{(*)}$  and  $n^{(*)}$ . Still  $0 \leq t^* \leq t$ . The supplied quantities are

$$\begin{aligned} y_h &= \lambda \frac{L}{n} + \frac{(1-2\lambda)a + (\lambda - \lambda^2)(n^*t + (n^* + 1)t^*)}{b(n + n^* + 1)} \\ y_f &= (1-\lambda) \frac{L}{n} + \frac{(2\lambda-1)a - (\lambda - \lambda^2)(n^*t + (n^* + 1)t^*)}{b(n + n^* + 1)} \\ y_h^* &= \lambda \frac{L^*}{n^*} + \frac{(1-2\lambda)a - (\lambda - \lambda^2)(nt^* + (n + 1)t)}{b(n + n^* + 1)} \\ y_f^* &= (1-\lambda) \frac{L^*}{n^*} + \frac{(2\lambda-1)a + (\lambda - \lambda^2)(nt^* + (n + 1)t)}{b(n + n^* + 1)}. \end{aligned}$$

The prices are given by

$$\begin{aligned} p &= \frac{a(2(n + n^*) + 1/\lambda) - (1-\lambda)(nt^* - n^*t)}{n + n^* + 1} - b(L + L^*) \\ p^* &= \frac{a(2(n + n^*) + 1/(1-\lambda)) - \lambda(n^*t - nt^*)}{n + n^* + 1} - b(L + L^*) \end{aligned}$$

and wages are

$$\begin{aligned} w &= \frac{1}{\lambda} \left\{ 2a - b \left[ \frac{n+1}{n} L + L^* \right] - t^*(1-\lambda) \right\} \\ w^* &= \frac{1}{\lambda} \left\{ 2a - b \left[ \frac{n^*+1}{n^*} L^* + L \right] - t\lambda \right\}. \end{aligned}$$

### Proof of Lemma 1 (Existence and Uniqueness)

*Proof.* In equilibrium, the balance of payments has to be equal to zero.

$$BoP \equiv (n^*ty_h^* - nt^*y_f) + (np^*y_f - n^*py_h^*) = 0$$

The usual assumptions apply. I show in the supplement, that the limits of the  $BoP$  for the most extreme admissible  $\lambda$ s are

$$\begin{aligned}\lim_{\lambda \rightarrow 0^+} BoP &= -\infty < 0 \\ \lim_{\lambda \rightarrow 1^-} BoP &= +\infty > 0.\end{aligned}$$

Furthermore, the  $BoP$  is differentiable with respect to  $\lambda$  for  $\lambda \in (0, 1)$ , which implies continuity. Therefore, at least one solution for the above equation exists in  $\lambda \in (0, 1)$ . Uniqueness is sufficiently ensured, if the derivative of the balance of payments with respect to  $\lambda$  is strictly positive for  $\lambda \in (0, 1)$ . The balance of payments can be rearranged to

$$BoP = \frac{1}{9b} \left( x_1 + x_2\lambda - x_3\lambda^2 + (t^* - t)^2\lambda^3 + a^2 \frac{1 - 2\lambda^2}{\lambda(\lambda - 1)} \right)$$

with

$$\begin{aligned}x_1 &= \frac{1}{2} \left( -12a^2 + 2a(12b + 4t + 5t^*) - 9b(b + t^*) \right) \\ x_2 &= \frac{1}{2} \left( 32a^2 - 2a(24b + t + 17t^*) + b(18b - 3t + 21t^*) - 2t(4t - t^*) + 10t^{*2} \right) \\ x_3 &= (t^* - t)(-8a + 6b + 3t + 6t^*)\end{aligned}$$

Hence, the derivative is given by

$$\frac{\partial BoP}{\partial \lambda} = \frac{1}{9b} \left( x_2 - 2x_3\lambda + 3(t^* - t)^2\lambda^2 + a^2 \frac{1 - 2\lambda + 2\lambda^2}{\lambda^2(\lambda - 1)^2} \right),$$

where

$$a^2 \frac{1 - 2\lambda + 2\lambda^2}{\lambda^2(\lambda - 1)^2} > 0.$$

We can calculate the global minimum of the quadratic part  $x_2 - 2x_3\lambda + 3(t^* - t)^2\lambda^2$ , which is at  $\lambda_{min} = \frac{-8a+6b+6t^*+3t}{3(t^*-t)}$ . Then we add this global minimum to the "rest"  $a^2 \frac{1-2\lambda+2\lambda^2}{\lambda^2(\lambda-1)^2}$ , which is always positive, and derive an upper bound  $\bar{t}$  for the Home tariff, such that this sum

(a lower bound for the derivative) is always positive under our usual assumptions, which sufficiently ensures uniqueness. I show in the supplement with mathematical software that uniqueness is guaranteed for  $t = t^* \leq b$ , for  $0 \leq t^* \leq t < \bar{t}$  and for  $0 \leq t^* < t \leq \bar{t}$ .

$$\bar{t} = \frac{10a - 9b}{18} + \frac{\sqrt{44a^2 - 28ab + 15b^2}}{6\sqrt{3}}$$

This is a sufficient and no necessary condition in several ways. Note that we demand the "rest" of the function  $\frac{\partial BOP}{\partial \lambda}$  for all possible  $\lambda$  to be at least as large as the global minimum of the quadratic part, even if that global minimum is not at an equilibrium value of  $\lambda$  or not even within the allowed range of  $\lambda$ . I choose this procedure for simplicity because it allows to derive one specific upper bound on  $t$ , while a more general approach results in a plethora of possible upper bounds depending in its functional forms on the values of the other parameters.  $\square$

## Proof of Proposition 1 (Effects of Symmetric Tariffs)

In the symmetric case we have  $\lambda = 1/2$  and  $t = t^*$ . I prove in the supplement, that indeed  $\lambda$  does not change with  $t$ . The usual assumptions from the main text apply. We can simplify the equilibrium prices and quantities:

$$\begin{aligned} p = p^* &= 2a - b \\ \frac{\partial p}{\partial t} &= 0 \\ w = w^* &= \frac{4a - 3b - t}{2} \\ \frac{\partial w}{\partial t} &= -\frac{1}{2} < 0 \\ y_h = y_f^* &= \frac{b + t}{4b} \\ \frac{\partial y_h}{\partial t} &= \frac{1}{4b} > 0 \\ y_f = y_h^* &= \frac{b - t}{4b} \\ \frac{\partial y_f}{\partial t} &= -\frac{1}{4b} < 0 \end{aligned}$$

$$\begin{aligned}
\pi = \pi^* &= \frac{b^2 + t^2}{4b} \\
\frac{\partial \pi}{\partial t} &= \frac{2t}{4b} > 0 \\
T = T^* &= \frac{(b-t)t}{4b} \\
\frac{\partial T}{\partial t} &= \frac{1}{4} - \frac{2t}{4b}
\end{aligned}$$

$\frac{\partial T}{\partial t} > 0$  for  $t < b/2$  and  $\frac{\partial T}{\partial t} < 0$  for  $t > b/2$ , such that  $t^{rm} = b/2 < \bar{t}$  is the revenue maximizing symmetric tariff. At this tariff, we have  $y_h = \frac{3}{8}$  and  $y_f = \frac{1}{8}$  as compared to both being  $\frac{1}{4}$  without tariffs. This shows that at this point the tariff has reduced international trade by 50%, which can be called a tariff of substantial size. Thus,  $\bar{t}$  is not critically low.

$t = b$  is the prohibitive tariff, where international trade becomes zero. Higher symmetric tariffs would result in negative traded quantities, which we rule out by assumption. The prohibitive tariff can be higher than  $\bar{t}$  in some cases, but remember that  $\bar{t}$  is a sufficient and no necessary upper bound.

## Proof of Lemma 2 (Effect of Unilateral Tariff on $\lambda$ )

*Proof.* The derivative can be obtained by implicit differentiation using the BoP, i.e.  $\frac{\partial \lambda}{\partial t} = -\frac{\partial BoP/\partial t}{\partial BoP/\partial \lambda}$ . From the proof of lemma 1 we know that  $\partial BoP/\partial \lambda$  is positive for  $0 \leq t^* \leq t < \bar{t}$ . The same holds for  $\partial BoP/\partial t$  if  $0 < \lambda \leq 1/2$  (confirmation is provided in the supplement):

$$\frac{\partial BoP}{\partial t} = \frac{1}{18b} \left( 3b\lambda(-1 + 4\lambda) - 2a(-4 + \lambda + 8\lambda^2) + 2(-1 + \lambda)\lambda(t^* - 2t\lambda + 2t(4 + \lambda)) \right) > 0$$

Accordingly,  $\frac{\partial \lambda}{\partial t}$  is negative, which is why the assumption of  $\lambda \leq 1/2$  is valid because with  $t = t^*$  we start from  $\lambda = 1/2$  and it declines thereafter in  $t$ .

$$\begin{aligned}
\frac{\partial \lambda}{\partial t} = & ((-1 + \lambda)^2 \lambda^2 (b(3 - 12\lambda)\lambda + 2a(-4 + \lambda + 8\lambda^2) - 2(-1 + \lambda)\lambda(t^* - 2t^*\lambda + 2t(4 \\
& + \lambda)))) / (-2a(-1 + \lambda)^2 \lambda^2 (24b + t + t^*(17 - 16\lambda) + 16t\lambda) + a^2(2 - 4\lambda + 36\lambda^2)
\end{aligned}$$

$$-64\lambda^3 + 32\lambda^4) + (-1 + \lambda)^2\lambda^2(18b^2 - 3b(t - 8t\lambda + t^*(-7 + 8\lambda)) + 2(t^{*2}(5 - 12\lambda + 3\lambda^2) + t^2(-4 + 6\lambda + 3\lambda^2) - t^*t(1 - 6\lambda + 6\lambda^2))))$$

For a marginal increase in one of the initially symmetric tariffs, i.e. at  $t = t^*$ , the same holds as long as we are below the prohibitive tariff  $b$  (see supplement). In this quasi-symmetric case we get a closed-form result for the derivative, i.e.  $\frac{\partial \lambda}{\partial t} = \frac{-3a-3b/2+9t/2}{48a^2-2a(24b+18t)+18b^2+18bt}$ , because we know that we start at  $t = t^*$  and  $\lambda = 1/2$  which allows to get rid of the complexity problem of not having a closed-form expression for  $\lambda$ .  $\square$

### Proof of Lemma 3 (Asymmetric Price Reaction)

*Proof.* Taking the derivatives of the equilibrium price equations with respect to  $t$  leads to

$$\begin{aligned}\frac{\partial p}{\partial t} &= \frac{1}{3} \left( 1 - \lambda + \frac{\partial \lambda}{\partial t} (t^* - t - \frac{a}{\lambda^2}) \right), \\ \frac{\partial p^*}{\partial t} &= \frac{1}{3} \left( -\lambda + \frac{\partial \lambda}{\partial t} (t^* - t - \frac{a}{(\lambda - 1)^2}) \right).\end{aligned}$$

Evaluating them at  $t = t^*$  with  $\lambda = 1/2$  and the respective term for  $\frac{\partial \lambda}{\partial t}$  gives us a positive expression for Home and a negative one for Foreign as confirmed with mathematical software in the supplement.  $\square$

### Proof of Proposition 2 (Income and Distribution)

*Proof.*

$$\begin{aligned}\frac{\partial w}{\partial t} &= t^* \frac{\partial \lambda}{\partial t} \\ \frac{\partial w^*}{\partial t} &= -\lambda - t \frac{\partial \lambda}{\partial t}\end{aligned}$$

Taking the derivatives of the equilibrium nominal wages (formulas given above) and also of real wages (given in the supplement) with respect to  $t$  and evaluating them at  $t = t^*$  with

$\lambda = 1/2$  and the respective term for  $\frac{\partial \lambda}{\partial t}$  gives us negative expressions for nominal wages (no reaction in Home if  $t^* = 0$ ), with Foreign wages falling more strongly, and negative expressions for real wages, which fall more strongly in Home, as shown in the supplement with mathematical software.

The same procedure is then applied to profits. For strictly positive tariffs I show in the supplement that nominal profits rise in both countries, but stronger in Home. Real profits rise in Foreign. They fall in Home for low and rise for high initial symmetric tariffs with  $b/8 < t = t^* = 2(2a - b) - \sqrt{16a^2 - 16ab + 3b^2} < b/3$  being the cutoff where the reaction is zero, which is positive and smaller than the revenue maximizing symmetric tariff  $b/2$ .

The labor-profit ratio is  $\frac{Lw}{n\pi}$ . Taking the derivatives of it for both countries with respect to  $t$  and evaluating them at  $t = t^*$  with  $\lambda = 1/2$  and the respective term for  $\frac{\partial \lambda}{\partial t}$  gives us negative expressions for both countries (no reaction for Home if initially  $t = t^* = 0$ ). This is straightforward because in both countries nominal wages are falling and nominal profits are rising. The decline is larger in Home for small but positive initial tariffs and larger in Foreign for high initial tariffs, as shown in the supplement with mathematical software.

Furthermore, I show in the supplement that Foreign tariff revenue decreases in  $t$  starting from a symmetric-tariff equilibrium, while Home revenue rises (equations given below) up to a certain initial tariff, and I compare the marginal (nominal and real) tariff revenue change in Home with the marginal change in (nominal and real) Home labor income. I also check up to which initial symmetric tariffs the marginal rise in Home tariff revenue is sufficient to keep the Home labor-profit ratio at its initial level by means of transfers to workers, i.e.  $t = t^*$  for which  $\frac{wL}{n\pi} = \frac{\frac{\partial wL}{\partial t} + \frac{\partial T}{\partial t}}{\frac{\partial \pi}{\partial t}}$  holds. The marginal rise in tariff revenue has to overcompensate the marginal fall in labor income in a certain proportion relative to the marginal rise in profit income. For the labor-profit ratio to remain unchanged, this proportion is exactly the initial labor-profit ratio. Up to certain initial symmetric tariffs (not determinable in closed-form) that are lower than  $b/3$ , and thus the revenue maximizing symmetric tariff  $b/2$ , the marginal rise in Home nominal tariff revenue is large enough to offset the marginal distributional effect, i.e. to restore the old labor-profit-ratio, and the marginal rise in Home real tariff revenue is large enough to offset the marginal negative

effect on Home real labor income, if non-distortionary transfer payments to workers are possible. Up to certain initial symmetric tariffs, that are lower than the prohibitive but can sometimes be higher than the revenue maximizing symmetric tariffs, the marginal rise in Home nominal tariff revenue is larger than the marginal loss in nominal Home labor income.

$$\begin{aligned}\frac{\partial(ty_h^*)}{\partial t} &= \frac{\lambda}{2} + \frac{a(1-2\lambda) - (t^* + 2t)(\lambda - \lambda^2)}{3b} \\ &\quad + t \left( \frac{\frac{\partial\lambda}{\partial t}}{2} + \frac{2(\lambda^2 - \lambda) - \frac{\partial\lambda}{\partial t}(2a + (t^* + 2t)(1 - 2\lambda))}{3b} \right) \\ \frac{\partial(t^*y_f)}{\partial t} &= \frac{-t^*}{2} \frac{\partial\lambda}{\partial t} + \frac{\lambda^2 - \lambda + \frac{\partial\lambda}{\partial t}(2a - (2t^* + t)(1 - 2\lambda))}{3b}\end{aligned}$$

□

### Proof of Proposition 3 (Trade, Welfare, Nash-Equilibrium)

*Proof.*

$$\frac{\partial(y_f + y_h^*)}{\partial t} = \frac{\lambda^2 - \lambda + \frac{\partial\lambda}{\partial t}(2\lambda - 1)(t^* + t)}{b}$$

Taking the derivative of the sum of Home and Foreign exports with respect to  $t$  and evaluating it at  $t = t^*$  with  $\lambda = 1/2$  and the respective term for  $\frac{\partial\lambda}{\partial t}$  gives us  $-\frac{1}{4b} < 0$ .

Taking the derivative of Home's terms of trade with respect to  $t$  and evaluating it at  $t = t^*$  with  $\lambda = 1/2$  and the respective term for  $\frac{\partial\lambda}{\partial t}$  gives us a positive expression as shown in the supplement with mathematical software.

Taking the derivatives of the equilibrium export quantities with respect to  $t$  leads to

$$\begin{aligned}\frac{\partial y_f}{\partial t} &= \frac{-1}{2} \frac{\partial\lambda}{\partial t} + \frac{1}{3b} \left( -\lambda + \lambda^2 + \frac{\partial\lambda}{\partial t}((t + 2t^*)(2\lambda - 1) + 2a) \right) < 0, \\ \frac{\partial y_h^*}{\partial t} &= \frac{1}{2} \frac{\partial\lambda}{\partial t} + \frac{1}{3b} \left( -2(\lambda - \lambda^2) + \frac{\partial\lambda}{\partial t}((2t + t^*)(2\lambda - 1) - 2a) \right) < 0,\end{aligned}$$

Evaluating them at  $t = t^*$  with  $\lambda = 1/2$  and the respective term for  $\frac{\partial\lambda}{\partial t}$  gives us negative

expressions for export supplies, with Home exports decreasing more strongly than Foreign exports, as confirmed in the supplement with mathematical software.

$$\frac{\partial(y_h^* - y_f)}{\partial t} = \frac{\lambda^2 - \lambda + \frac{\partial \lambda}{\partial t} (3b - 4a + (2\lambda - 1)(t - t^*))}{3b}$$

Welfare is strictly increasing in consumption (or real income), which is given by  $y_h + y_h^* = 1/2 - y_f + y_h^*$  in Home. Thus, for the direction of its change we can focus on the change in the difference of exports  $y_h^* - y_f$ . In the supplement I show in detail that there is a positive welfare effect from an increasing tariff for Home if the initially symmetric tariffs are below the prohibitive level  $b$ .

It follows that whenever a country has the lower tariff than the other country, its welfare and consumption would be higher when increasing the tariff to the level of the other country – resulting again in identical welfare in both countries, while before welfare was lower in the low-tariff country. Thus, also for the low tariff country it would be optimal to increase the tariff at least up to this level. Accordingly, in this zero-sum consumption-game there can be no Nash-equilibrium where otherwise symmetric countries differ in their consumption level, because the low-consumption country could always set the same tariff as the other country, which results in identical consumption. At identical tariffs, it would again be beneficial for both to increase the tariff further as long as there are exports that yield tariff revenue. This shows that a locally stable equilibrium exists at symmetric prohibitive tariffs  $t = t^* = b$ , where no country has an incentive to marginally deviate anymore. Confirmation is provided in the supplement. However, the possibility remains, that for a certain  $t$  there exists another  $t^* < t \leq b$  at which both countries have the same welfare, i.e. export the same quantity, as well. I prove in the supplement that there exists no such  $t^* \neq b$ , which guarantees the uniqueness of the Nash-equilibrium at  $t = t^* = b$ .  $\square$



## Supplement

The supplement (Mathematica Notebook) is available from the author upon reasonable request.

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