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Optimal and threshold tariffs, trade balance and welfare in a small open Ricardian economy

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Abstract

This paper draws on a Ricardian model for a small open economy and derives the welfare implications of tariffs. By focusing on three key parameters – (i) the expenditure share on imports, (ii) the degree of tariff pass-through, and (iii) the proportion of tariff revenues spent domestically – the model provides closed-form expressions for welfare, optimal tariff rates, and threshold tariff levels. The analysis explains why the marginal effectiveness of increasing tariff rates declines and might even become negative as well as why real wage income typically diverges from total income when tariff revenues are saved rather than spent. The results indicate that high pass-through of tariffs substantially limits potential welfare gains from tariffs even at the optimal rate. Improvements in the trade balance only arise when tariff revenues are not fully recycled into domestic demand. However, welfare is also lower when the optimal tariff rate is applied in such a case. The framework captures mechanisms consistent with more complex trade models and highlights the narrow range of conditions under which tariff policy can yield positive welfare outcomes.

Keywords: Ricardian trade model, optimal tariffs, pass-through, trade balance

JEL classification: F13, F17

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1 Introduction

Tariff hikes have once again become an important policy tool in international trade. Applied general equilibrium studies – such as Caliendo & Parro (2015) – and input-output analyses find that tariff increases imposed by an economy such as the US have negative but relatively modest effects. Three features of these results recur. Real income falls because tariffs raise the price index as they are passed through to consumer prices, yet welfare may nonetheless improve for the tariff-imposing country on account of higher tariff revenues. The marginal effect of further tariff increases diminishes. Further, the reduction in trade deficits that is often invoked to justify tariffs is poorly captured, since standard trade models assume balanced trade or constant trade imbalances at the country level, though not necessarily bilaterally.

Whether tariffs raise welfare depends on the degree of pass-through. Gains arise when foreign suppliers absorb part of the tariff by lowering their export prices, so that the terms of trade improve.[1] This paper studies this mechanism in a general equilibrium setting for a small open Ricardian economy with full specialisation into imported and domestically produced exported products. We derive results first under constant expenditure shares and then generalise to variable shares that respond to the relative price changes induced by tariffs.

Our departure from the literature is to model pass-through as an exogenous parameter, which as a special case can be interpreted as the foreign supply elasticity. Retaliation and strategic trade policy are left aside. The resulting framework is analytically tractable, and the mechanisms it isolates carry over to richer general equilibrium models that account for further second-round effects. In particular, it explains why the marginal effect of tariffs declines in such frameworks and shows how an optimal tariff rate – or the absence thereof – may emerge.[2]

We obtain five results. First, the effects of tariffs on real wages and welfare become increasingly negative as pass-through rises; under full pass-through, tariffs always reduce welfare despite rising tariff revenues. Second, under partial pass-through, we derive a simple formula for the welfare-maximising tariff rate, which depends on the expenditure share of imported products, the pass-through rate, and the share of tariff revenues used for demand; this corresponds to the finding in Gros (1987). Third, we identify a threshold tariff rate beyond which even partial pass-through implies negative welfare consequences, a margin not usually treated explicitly in the literature. Fourth, we trace the declining marginal effect of tariffs to the concave shape of the tariff revenue function. Fifth, allowing for tariff revenues to be saved rather than spent, we delineate the trade-off between welfare gains and improvements in the trade balance. We then apply the framework to recent trade patterns and tariff schedules, which allows us to quantify the effects of recent tariff hikes and to compute optimal and threshold tariff rates for individual countries.

The paper is structured as follows: Section 2 reviews the relevant literature. Section 3 introduces the analytical framework and derives the implications of tariffs for real income, welfare, and the trade balance.[3] Section 4 discusses optimal and threshold tariffs, and Section 5 adds considerations regarding trade balance effects. Section 6 examines the implications of expenditure shares that change with relative prices, using a constant elasticity of substitution (CES) demand system. Section 7 brings the model insights to data, and Section 8 concludes. Detailed technical derivations are presented in Appendix B.

[1] For a detailed discussion, see Chapter 7 in Feenstra (2015).

[2] Generally, the optimal tariff rate balances the gains from terms-of-trade improvements and tariff revenues against the reduced trade volume, resulting in welfare losses.

[3] In Section A, we set up the Ricardian framework using a standard textbook approach and illustrate the implications of tariff hikes graphically, considering various cases regarding tariff pass-through to consumer prices.

2 Related literature

The proposition that a country with market power in world markets can raise its own welfare by restricting trade is among the oldest results in the theory of commercial policy. Bickerdike (1906, 1907) established it in its modern form: starting from free trade, an infinitesimally small import or export duty generates a first-order gain through the improvement in the terms of trade, while the associated distortion of the volume of trade is only second-order. The argument was immediately recognised as analytically sound and immediately distrusted on other grounds. Edgeworth (1908), reviewing it sympathetically, accepted the logic while warning that it was too dangerous to be placed in the hands of practical policy. That ambivalence of a valid theoretical case for intervention coupled with unease about its use has shaped the literature ever since.

The argument was recovered for modern welfare economics by Kaldor (1940) and Scitovszky (1942), who restated it within the apparatus of offer curves and compensation tests, and then extended beyond the two-good case by Graaff (1949), who characterised the structure of optimal tariffs when many goods are traded and showed that the optimal rate varies across goods with the relevant elasticities. Thus, the principal objection to the Bickerdike argument was no longer its internal validity but its strategic incompleteness: a country that exploits its market power invites retaliation, and a presumption had formed that the resulting tariff war would leave all participants worse off than under free trade.

Johnson (1953) is the decisive response to that objection and the pivot of the subsequent literature. Analysing the tariff war as an equilibrium in reaction curves rather than as a unilateral deviation from free trade, he showed that the pessimistic presumption does not hold in general: depending on the configuration of import demand elasticities, a country may emerge from a full retaliatory equilibrium better off than it was under free trade. The result rested on a tractable class of preferences yielding constant elasticities, which raised the natural question of whether the conclusions were artefacts of that specification. Gorman (1958) addressed precisely this concern, showing how the preferences Johnson had employed could be used to approximate more general preference structures and thereby supplying the theoretical warrant for Johnson's exercise.

A second line of work turned from the properties of the tariff-war equilibrium to the prior question of whether such an equilibrium exists at all. Johnson's diagrammatic treatment presupposed a well-defined equilibrium of the tariff game. Kuga (1973) recast the problem as a non-cooperative game embedded in a general equilibrium exchange economy and brought fixed-point methods to bear on it. Otani (1980) is generally credited with settling the existence question in general equilibrium settings. The issue proved more delicate than it first appeared: establishing the existence of an equilibrium with positive trade, rather than one that collapses to autarky, remained an active question much later, as in Wong (2004).

With those foundations in place, attention shifted to the comparative statics of the tariff war and, in particular, to the determinants of who gains from it. Riezman (1982) examined tariff retaliation from an explicitly strategic standpoint, while Thursby & Jensen (1983) relaxed the Nash conjecture in favour of a conjectural variations approach, showing that the equilibrium outcome depends materially on what each government believes about the other's response. Kennan & Riezman (1988) posed the question whether large countries win tariff wars directly and found that size confers an advantage but not an unconditional one. Syropoulos (2002) returned to the same question with a more general treatment of how country size operates, distinguishing the several channels through which it affects the retaliatory equilibrium. Dixit (1987) provides the natural synthesis of this body of work and draws out its implications for the design of trade agreements.

That last theme defines a further branch. Mayer (1981) made the pivotal move of treating the non-cooperative tariff equilibrium not as the object of interest but as the disagreement point from which two governments bargain towards a mutually preferred outcome, thereby connecting the retaliation literature to cooperative bargaining theory and to the analysis of negotiated trade liberalisation. Grossman & Helpman (1995) embedded a political-economy model of domestic tariff formation in the two-country strategic setting, characterising both the non-cooperative outcome and the negotiated one when governments respond to organised interests rather than to aggregate welfare. Bagwell & Staiger (1999) provided the most influential rationale for the institutional structure of the GATT/WTO, arguing that the terms-of-trade externality is the fundamental problem trade agreements solve and that reciprocity and non-discrimination can be understood as instruments for internalising it. Bond & Park (2002) address the dynamics of agreements between asymmetric countries and the role of gradual liberalisation.

A parallel applied literature has sought to attach numbers to these arguments. Hamilton & Whalley (1983) extended the earlier constant-elasticity calculations of Johnson and Gorman by adopting more flexible functional forms and incorporating production, computing optimal tariffs with and without retaliation and concluding that observed protection lies well below optimal levels and that the scope for retaliation is potentially large. Perroni & Whalley (2000) turned the same machinery to an institutional puzzle, computing post-retaliation Nash tariffs to argue that the asymmetric concessions observed in regional agreements between large and small countries are better understood as insurance purchased by the smaller party against the larger party's exercise of market power than as liberalisation in the conventional sense. Ossa (2014) represents the current state of this line, nesting traditional, new trade, and political-economy motives for protection in a single quantitative framework and finding both optimal and trade-war tariffs in excess of 60%, with welfare losses from a breakdown of cooperation substantially exceeding the gains available from further negotiation. The magnitudes produced by this literature have themselves become a subject of debate, with the widespread Armington assumption of national product differentiation identified as a source of upward bias in computed optimal tariffs.

The empirical evidence on whether governments in fact exploit market power is mixed. Broda et al. (2008) find that tariffs are systematically higher on goods for which countries face lower export supply elasticities, which is consistent with the deliberate exercise of market power. Magee & Magee (2008) reach a more sceptical conclusion regarding the United States, arguing that its market power is considerably more limited than the theoretical literature typically assumes. Ludema & Mayda (2013) examine the terms-of-trade channel in the context of WTO membership and find support for its relevance to negotiated outcomes.

Finally, a substantial body of work has examined how the classical results survive changes in the underlying trade model. On the goods dimension, Bond (1990) characterises optimal tariff structures in higher-dimensional settings, while Opp (2010) and Costinot et al. (2015) analyse optimal and retaliatory policy in Ricardian environments with a continuum of goods, where the pattern of comparative advantage itself shapes the optimal instrument. On market structure, Gros (1987) established that the case for positive tariffs survives — and is strengthened in some respects — under monopolistic competition with intra-industry trade, and Haaland & Venables (2016) revisit optimal policy in this class of models. The introduction of firm heterogeneity following Melitz (2003) has prompted a further reassessment: Felbermayr et al. (2013) compute optimal tariffs and the welfare costs of tariff wars in that setting, Costinot et al. (2020) derive optimal policy from the underlying micro-level distribution of firms, and Ara (2024) extends this line further.

3 The model

3.1 Free trade equilibrium

The starting point of the analysis is a free trade equilibrium in a Ricardian model with two industries for a small open economy (i.e. world prices p_1 and p_2 are assumed to be given for this economy). Specialisation is driven by differences between the relative world price of good 1 and the relative autarky price, the latter being determined by labour productivity in both industries. Without loss of generality, we assume that $p_1/p_2 > p_1^a/p_2^a$ (where p_i^a denotes autarky prices). The country is therefore completely specialised in the production of good 1, which is also exported.[4]

In this free trade equilibrium, the country produces $q_1 = \varphi_1 \cdot h$, where φ_1 denotes labour productivity in industry 1 and h is labour endowment. Due to complete specialisation, production in industry 2 equals $q_2 = 0$. Assuming full employment, nominal income is given by $y = w \cdot h = p_1 \cdot q_1$, where w denotes the wage rate in the free trade equilibrium. The latter follows from $w \cdot h = p_1 \cdot \varphi_1 \cdot h$, resulting in $w = p_1 \cdot \varphi_1$.[5] The relative price of exports (i.e. the terms of trade) equals the relative world price of good 1 (i.e. p_1/p_2).

For simplicity, we assume a Cobb-Douglas demand system. Demand for the two products is then given by $f_1 = \alpha_1 \cdot \frac{y}{p_1}$ and $f_2 = \alpha_2 \cdot \frac{y}{p_2}$, where α_i for $i = 1, 2$ denotes the (constant) expenditure shares, with $0 < \alpha_i < 1$ and $\alpha_1 + \alpha_2 = 1$. These shares α_i can be interpreted as expenditure shares in total income or the share of world income the country can attract when specialising in good i.[6] The underlying utility function is $u = \left(\frac{f_1}{\alpha_1}\right)^{\alpha_1} \cdot \left(\frac{f_2}{\alpha_2}\right)^{\alpha_2}$. Given this Cobb-Douglas utility function, the price index in free trade is the geometric average of world prices weighted by expenditure shares (i.e. $p = p_1^{\alpha_1} \cdot p_2^{\alpha_2}$). Real labour income corresponds to the maximum utility level in this equilibrium (i.e. $u = y/p$).[7]

Exports are given by production minus domestic demand, $x_1 = q_1 - f_1$, in industry 1; imports in industry 2 equal demand, thus $m_2 = f_2$ (because $q_2 = 0$). As usual in such a model set-up, trade is balanced since total income equals total expenditures; formally,

$$tb = (p_1 \cdot q_1 - p_1 \cdot f_1) - p_2 \cdot f_2 = w \cdot h - (p_1 \cdot f_1 + p_2 \cdot f_2) = 0$$

3.2 Tariffs and pass-through

Let us now analyse the impacts of tariffs in this standard Ricardian model.[8] We begin by introducing the modelling strategy for the pass-through effect. Second, we derive the tariff revenue function and show that it is concave and bounded above. Third, we discuss the effects on nominal income and expenditures and, fourth, the implications for the demand for both products. Fifth, by defining the price index including tariffs, we can study the effects on real income and welfare. These results are then used in the subsequent sections to derive the optimal and threshold tariff rates as well as to explore the implications for the trade balance. Finally, we generalise the model structure by introducing CES demand.

Let $t \geq 0$ denote the tariff rate on the imported product.[9] The price at which foreign exporters serve the market depends on the rate of pass-through, which is parametrised by $0 \leq \lambda \leq 1$, indicating that about λ of the tariff increase is pass-through to consumers.[10] The world price at the border before the tariff is p_2. This price may become lower after the introduction of the tariff and is modelled as $p_2 \cdot (1 + t)^{\lambda - 1}$.

[4] An alternative interpretation in a model with a range of products is that this constitutes the range of exported products due to comparative advantages.

[5] Alternatively, one could model this as the wage rate in autarky (in the national currency) converted by the exchange rate under free trade.

[6] In a typical model with a continuum of products α_i can also be interpreted as the share of imported or domestically produced products.

[7] The Cobb-Douglas assumption implies own-price elasticities $\varepsilon_{ii} = -1$, cross-price elasticity $\varepsilon_{ij} = 0$, income elasticity $\varepsilon_{\cdot m} = 1$, and elasticity of substitution $\sigma = 1$. Results for a more flexible CES demand structure are discussed in Section 6.

[8] Technical details for all steps are provided in Appendix Section B.

[9] Opp (2010) and Costinot et al. (2015) show that in the context of a canonical Ricardian model with a continuum of products the optimal import tariffs should be uniform.

[10] The pass-through may depend on various factors including the foreign supply conditions, domestic market conditions or exchange rate movements. As for the first factor, denote $\lambda = \frac{\sigma - 1}{\sigma}$ where $\sigma \geq 1$ is the foreign supply elasticity. Then $\lambda - 1 = -\frac{1}{\sigma}$ and the price at border therefore is given by $p_2 \cdot (1 + t)^{-\frac{1}{\sigma}}$ and the price the consumers face is $p_2 \cdot (1 + t)^{\frac{\sigma - 1}{\sigma}}$. A foreign supply elasticity of $\sigma = 1$ implies no pass-through as $\lambda = 0$, whereas full pass-through would occur for $\sigma \to \infty$ as in this case $\lambda \to 1$.

Thus, for $\lambda = 1$, the world price at the border does not change, whereas for $\lambda = 0$, the world price at the border decreases proportionally to the tariff. Consumers must pay this price plus the tariff and therefore face the price $\left[p_2 \cdot (1+t)^{\lambda-1}\right] \cdot (1+t) = p_2 \cdot (1+t)^{\lambda}$. Hence, when $\lambda = 1$, the tariff is fully passed through to consumers, while $\lambda = 0$ indicates a situation of no pass-through. The price of the domestically produced and exported product remains constant at p_1.[11] This pass-through parameter, which theoretically ranges between zero and one, plays an essential role in the analysis. Empirical evidence indicates that the pass-through of tariffs to consumer prices tends to be high, implying a parameter λ close to or equal to one.[12]

3.3 Tariff revenues

Tariff revenues are given by the world price (after the introduction of the tariff) multiplied by import demand and the tariff rate. The tariff revenue function is then given by

$$r = \frac{\alpha_2 \cdot y \cdot t}{[1 + (1-\alpha_2) \cdot t]} \qquad \text{with } \frac{dr}{dt} > 0 \text{ and } \frac{d^2 r}{dt^2} < 0$$

First, the higher the tariff rate is, the larger the tariff revenues are, as indicated by the first derivative, which is positive. The second derivative is negative, which implies that it has a concave shape (i.e. the higher the tariff rate is, the lower the additional revenues become). For $t \to \infty$, tariff revenues converge to $\frac{\alpha_2}{\alpha_1} \cdot y$. Second, the higher the expenditure share of the imported product α_2 is, the larger the tariff revenues are.[13] Third, and interestingly, the revenues do not depend on the pass-through with constant expenditure shares.

One can further assume that only a fraction $0 \leq \beta \leq 1$ of the tariff revenues is spent on consumption,[14] in which case the tariff revenues are given by

$$r = \frac{\alpha_2 \cdot y \cdot t}{[1 + (1-\beta \cdot \alpha_2) \cdot t]} \qquad \text{with } \frac{dr}{dt} > 0 \text{ and } \frac{d^2 r}{dt^2} < 0 \tag{3.1}$$

Note that tariff income is lower with $\beta < 1$, as imports are lower as well. Tariff revenues have an upper bound at $\frac{\alpha_2 \cdot y}{1-\beta \cdot (1-\alpha_2)}$ for $t \to \infty$. As a limiting case, one can assume $\beta = 0$ (i.e. that tariff income is not spent at all), resulting in a tariff income of $r = \frac{\alpha_2 \cdot y \cdot t}{1+t}$, with the upper bound given by $\alpha_2 \cdot y$ for $t \to \infty$. Figure 3.1 visualises the revenues in percent of income y. For $\alpha_2 = 0.10$, a tariff rate of $t = 0.2$ would imply tariff revenues of about 1.7% of income y, whereas for $\alpha_2 = 0.25$ revenues would be about 4.3%. The smaller β is, the smaller the tariff revenues are, though the impact of this is rather small.

[11] The terms of trade are therefore given by

$$\text{Terms of trade} = \frac{p_1}{p_2 \cdot (1+t)^{\lambda-1}} = \frac{p_1}{p_2} \cdot (1+t)^{1-\lambda},$$

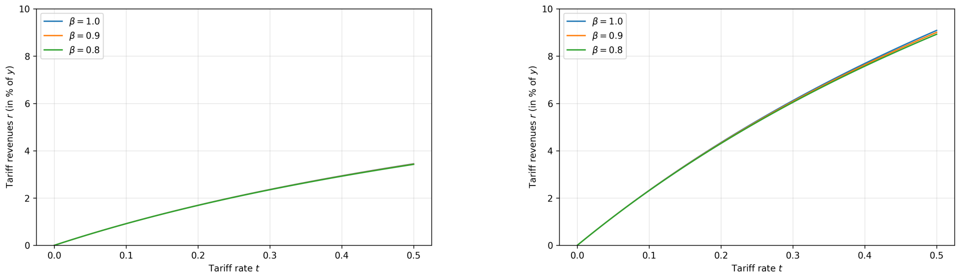
which implies that these remain constant for $\lambda = 1$ (full pass-through) and increase for $\lambda < 1$, as the relative price of the exported product rises.

[12] For example, Cavallo et al. (2021) conclude that the tariff pass-through to US border prices was nearly 100%, meaning the cost of tariffs was almost entirely passed on to US importers. The study thus finds that, for products subject to US tariffs (specifically on Chinese goods), the cost was almost fully passed through to the total prices paid by importers. Compared to exchange rate movements, the pass-through rate of tariffs was found to be much higher than the exchange rate pass-through. While a 20% dollar appreciation may only decrease import prices by 4.4%, a similarly sized tariff resulted in nearly 100% pass-through, indicating that foreign exporters did not significantly lower their dollar prices. As the US recently hiked tariffs and experienced a devaluation of the US dollar, it is even more likely that prices for US consumers will strongly increase, implying an even lower pass-through of rising tariffs. More recent evidence on the US tariffs is provided in Cavallo et al. (2025).

[13] When applying a CES demand function with an elasticity of substitution larger than one, the imported product would become more expensive (for $\lambda \neq 1$) and the expenditure share would decline, implying lower tariff revenues; see Section 6 for further discussions.

[14] The part not spent could, for example, be used for lowering government debt.

Figure 3.1: Tariff revenues as a percentage of income



$\alpha_2 = 0.10$ $\alpha_2 = 0.25$

Source: Own elaboration.

3.3.1 Nominal income and expenditures

Using the full-employment assumption, nominal income would not change under a tariff and, thus, is still given by $y = w \cdot h$, with $w = p_1 \cdot \varphi_1$. Total nominal expenditures (i.e. wage income $y = w \cdot h$ plus tariff income r, of which the share β is spent) is thus given by

$$e = y + \beta \cdot r = y + \beta \cdot \frac{\alpha_2 \cdot y \cdot t}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]}$$

Simplifying this expression yields

$$e = \frac{y \cdot (1 + t)}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]} \qquad \text{with } \frac{de}{dt} > 0 \text{ and } \frac{d^2e}{dt^2} < 0 \tag{3.2}$$

Driven by the tariff revenues, the nominal expenditure function also has a concave shape with respect to an increases in t (as the first derivative is positive and the second negative). In line with the tariff revenues, the larger expenditures are, the larger the share of the imported product α_2 is and the larger β is in the case of positive tariffs. Special cases are $e = \frac{y(\cdot(1+t)}{1+\alpha_1 \cdot t}$ for $\beta = 1$ and $e = y$ for $\beta = 0$. In the latter case, tariff revenues are not spent and therefore nominal expenditures equal nominal income. The expenditure function is also bounded above and converges to $\lim_{t \to \infty} e = \frac{y}{1 - \beta \cdot \alpha_2}$ (with the respective special cases $y/(1 - \alpha_2)$ for $\beta = 1$ and y for $\beta = 0$).

3.3.2 Final demand

Given total expenditures e and the price of the domestically produced and exported good p_1, demand is given by

$$f_1 = \alpha_1 \cdot \frac{e}{p_1} = \alpha_1 \cdot \frac{y}{p_1} \cdot \frac{1 + t}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]}$$

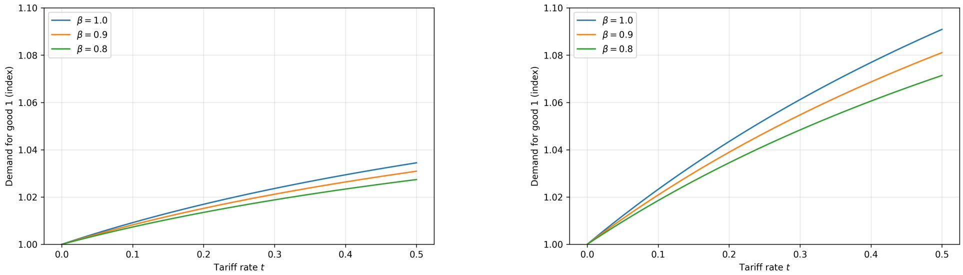
with $\frac{df_1}{dt} > 0$ and $\frac{d^2 f_1}{dt^2} < 0$. The derivatives follow from the concavity of the tariff revenue and expenditure function. Thus, demand for good 1 always increases (though at a declining rate) with tariffs due to the additional tariff income for $\beta > 0$ and converges to $\alpha_1 \cdot \frac{y}{p_1} \cdot \frac{1}{1 - \beta \cdot \alpha_2}$ for $t \to \infty$. For $\beta = 0$, final demand for this good remains constant at $f_1 = \alpha_1 \cdot \frac{y}{p_1}$. Figure 3.2 shows the effects of tariffs on demand for this good. Not surprisingly – as domestic income y and the price of this good does not change by assumption – the changes are proportional to those of the tariff revenues.

Analogously, demand for the imported product can be written as

$$f_2 = \alpha_2 \cdot \frac{e}{p_2 \cdot (1 + t)^{\lambda}} = \alpha_2 \cdot \frac{y \cdot (1 + t)}{p_2 \cdot (1 + t)^{\lambda} \cdot [1 + (1 - \alpha_2 \cdot \beta) \cdot t]} = \alpha_2 \cdot \frac{y \cdot (1 + t)^{1 - \lambda}}{p_2 \cdot [1 + (1 - \alpha_2 \cdot \beta) \cdot t]}$$

First, it is clear that f_2 is increasing with β as more tariff revenues (which are also increasing with β) are used for consumption. Second, the lower the pass-through on consumer prices is (i.e. the lower λ is), the

Figure 3.2: Demand for good 1

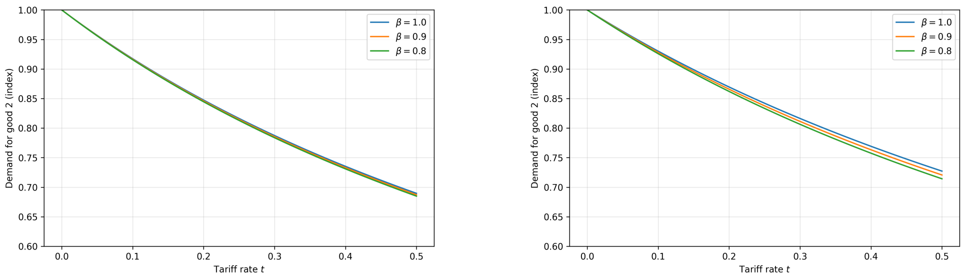


$\alpha_2 = 0.10$ $\alpha_2 = 0.25$

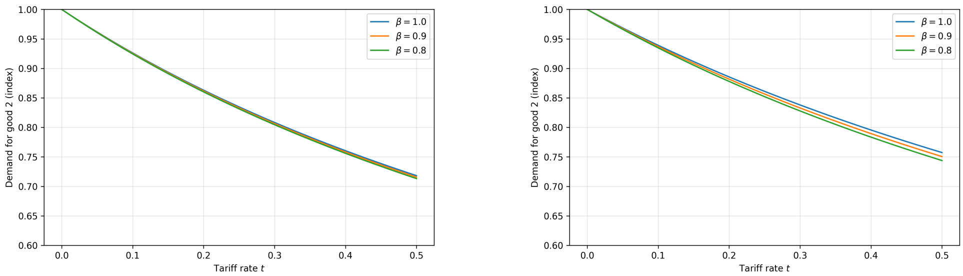
Note: Normalised to $f_1 = 1$.
Source: Own elaboration.

larger consumption of the imported product is, as the price for consumers is increasing less with the tariff. In Appendix Section B.3, we prove that demand for the imported product is increasing with the tariff rate (i.e. the first derivative is positive) if $\beta \cdot \alpha_2 > \lambda$. The pass-through of a tariff on consumer prices must be sufficiently small such that demand for the imported product increases due to the increasing tariff revenues. For example, if $\beta = 1$, the pass-through parameter would need to satisfy $\lambda < \alpha_2$ for f_2 to increase. Figure 3.3 indicates changes in demand for the imported product for reasonable parameter ranges. If $\alpha_2 = 0.1$, a tariff of $t = 0.2$ would decrease demand by about 15% in the case of a full pass-through (upper left panel); if $\lambda = 0.9$, the decline would be slightly smaller, at 13% (lower left panel). For a larger share of expenditures, the decline would be somewhat smaller due to higher tariff revenues, but it would nonetheless be about 12% even in the case of a limited pass-through (lower right panel).

Figure 3.3: Demand for f_2



$\alpha_2 = 0.10$ and $\lambda = 1.00$ $\alpha_2 = 0.25$ and $\lambda = 1.00$



$\alpha_2 = 0.10$ and $\lambda = 0.90$ $\alpha_2 = 0.25$ and $\lambda = 0.90$

Note: Normalised to $f_2 = 1$.
Source: Own elaboration.

3.4 Welfare

These changes in final demand for both products lead to changes in real income (i.e. welfare).[15] Intuitively, it is clear from the results above that welfare will only decrease if demand for the second product declines strongly enough to counteract the increase in demand for the first product, which will increase in any case due to tariff revenues. The effects on welfare are a weighted average of the changes in consumption of both products. Welfare effects differ depending on the parameters, which will be discussed in detail below.

3.4.1 Price index

For studying these welfare effects, the price index can be written as

$$p = p_1^{\alpha_1} \cdot \left(p_2 \cdot (1+t)^{\lambda}\right)^{\alpha_2} = p_0 \cdot (1+t)^{\lambda \cdot \alpha_2} \qquad \text{with } p_0 = p_1^{\alpha_1} \cdot p_1^{\alpha_2}$$

The larger the pass-through is, the higher the price index is in the case of a tariff. Further, the larger the expenditure share on the imported product is, the stronger the price index increasing with the tariff is. The price index would go to infinity if tariffs go to infinity.

3.4.2 Real income and tariffs

Real income is nominal expenditures divided by the price index, which is also equal to maximum utility. Alternatively, one can plug the final demand levels into the utility function, which results in the same expression (known as the 'indirect' utility function). Formally, welfare can therefore be expressed as

$$\begin{aligned} u &= \frac{e}{p} = \frac{y \cdot (1+t)}{[1 + (1 - \alpha_2 \cdot \beta) \cdot t] \cdot p_0 \cdot (1+t)^{\lambda \cdot \alpha_2}} \\ &= u_0 \cdot \frac{(1+t)^{1 - \lambda \cdot \alpha_2}}{[1 + (1 - \alpha_2 \cdot \beta) \cdot t]} \qquad \text{with } u_0 = y/p_0 \end{aligned}$$

The welfare effects of a tariff can thus be easily proxied by the share of expenditures on imports α_2, an estimate or assumption of the pass-through λ, and the share of tariff revenues used for additional expenditures β.[16] Though derived from a rather rigid framework, this equation allows the impacts of a tariff shock to be assessed, as it is only based on a few easily observable variables, such as the expenditures share of the imported product α_2, the pass-through parameter λ (which can be estimated or taken from the literature, as discussed above), and the applied tariff rate. Figure 3.4 indicates the magnitudes of welfare changes. In the case of a full pass-through (i.e. $\lambda = 1.0$), a tariff always has a larger negative impact the larger the expenditure share on the imported product is (upper-left and -right panel). However, the negative impact is relatively small: a tariff of $t = 0.2$ results in a decline in welfare of about 0.1% for $\alpha_2 = 0.1$ and about 0.3% for $\alpha_2 = 0.25$ (in both cases under the assumption that $\beta = 1.0$). If not all tariff revenues are spent, the negative impact of a tariff is correspondingly larger. If there is only an incomplete pass-through (see lower panels, where $\lambda = 0.9$), the impact of the tariff is less pronounced. Tariffs up to a certain range may even result in an increase in welfare. For example, for $\alpha_2 = 0.25$ and $\lambda = 0.9$ (see lower-right panel), welfare would increase by 0.2% for a tariff of about $t = 0.18$. For even higher tariffs, however, welfare would become lower. This indicates that, in the case of an incomplete pass-through, there exists an optimal tariff rate, which is studied in more detail in the next section. Again, for lower levels of β, the effects of tariffs on welfare are lower.

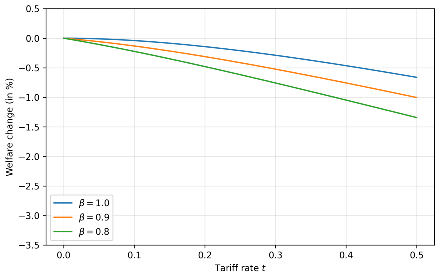
[15] In this framework, maximum utility equals maximum real income, which we will refer to as welfare.

[16] Using $\alpha_1 + \alpha_2 = 1$, this can be rewritten as

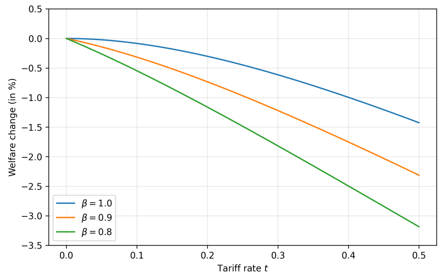
$$u = u_0 \cdot \frac{(1+t)^{\alpha_1 + \alpha_2 - \lambda \cdot \alpha_2}}{[1 + (1 - \alpha_2 \cdot \beta) \cdot t]} = u_0 \cdot \frac{(1+t)^{\alpha_1} \cdot (1+t)^{\alpha_2 \cdot (1 - \lambda)}}{[1 + (1 - \alpha_2 \cdot \beta) \cdot t]}$$

This indicates that the impact of the tariff is a weighted average of the changes in demand for both goods.

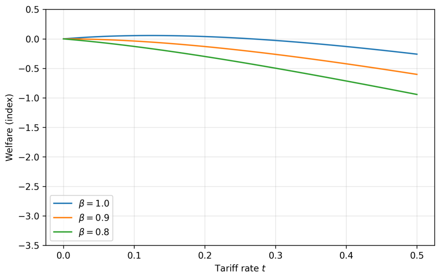
Figure 3.4: Tariff impact on real income



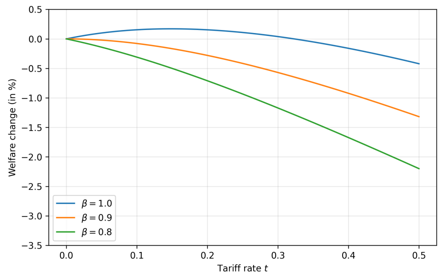
$\alpha_2 = 0.10$ and $\lambda = 1.00$



$\alpha_2 = 0.25$ and $\lambda = 1.00$



$\alpha_2 = 0.10$ and $\lambda = 0.90$



$\alpha_2 = 0.25$ and $\lambda = 0.90$

Source: Own elaboration.

4 Optimal and threshold tariff rates

4.1 Optimal tariffs and welfare

In the previous section, it was shown that an optimal (i.e. welfare-maximising) tariff rate exists for an incomplete pass-through ($\lambda < 1$). In Appendix Section B.4, it is shown that the optimal tariff rate can be calculated by setting the first derivative of the welfare function to zero and simplify, resulting in

$$t^* = \frac{\beta - \lambda}{(1 - \beta \cdot \alpha_2) \cdot \lambda} \qquad \text{for } 0 < \lambda \leq 1 \tag{4.3}$$

For $\lambda = 0$, the first derivative is always positive, as a tariff leads to revenues and thus additional spending with no pass-through, whereas the prices consumers face remain constant.[17] From the formula above, one can also see that the condition $\beta > \lambda$ has to hold such that $t^* > 0$. The lower the share of tariff revenues actually spent is, the lower the pass-through of tariffs on consumer prices has to be to guarantee a positive effect on welfare.[18] Considering the case $\beta = 1.0$, the optimal tariff rate is given by

$$t^* = \frac{1 - \lambda}{(1 - \alpha_2) \cdot \lambda} = \frac{1}{\alpha_1} \cdot \frac{1 - \lambda}{\lambda} \qquad \text{for } 0 < \lambda \leq 1$$

As can be easily be seen, the optimal tariff rate is increasing in α_2 (i.e. the higher the share of expenditures on imports, the higher the optimal tariff rate). The optimal tariff rate is decreasing in λ (i.e. with a stronger pass-through to consumer prices) and would be zero for $\lambda = 1$.

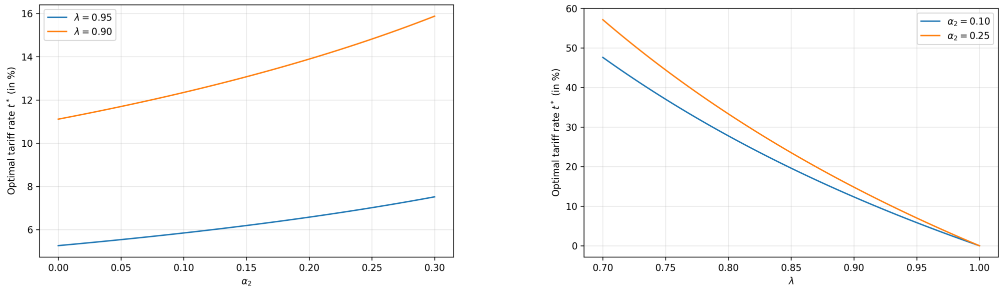
Figure 4.1 presents the size of the optimal tariff rate as a function of α_2 and λ, respectively. For $\alpha_2 = 0.10$ and $\lambda = 0.95$, the optimal tariff rate would be about 5.8%, and it would increase to 12.3% for $\lambda = 0.90$. For $\alpha_2 = 0.25$, the optimal tariff rate would be higher, at 7.0% and 14.8%, respectively. Analogous magnitudes can be seen in the right panel of Figure 4.1, which shows the optimal tariff rate as a function of λ. For even

[17] The optimal tariff rate therefore goes to infinity. However, welfare is bounded above with $\lim_{t \to \infty} u = u_0 \cdot \frac{1}{1 - \beta \cdot \alpha_2}$.

[18] Technically, the first derivative is positive for $0 < t < t^*$ and zero for $t = t^*$, whereas for $t > t^*$ the first derivative becomes negative.

lower levels of λ (i.e. less pass-through of tariffs to consumer prices), the optimal tariff rates go up rapidly.

Figure 4.1: Optimal tariff rates t^* ($\beta = 1.0$)

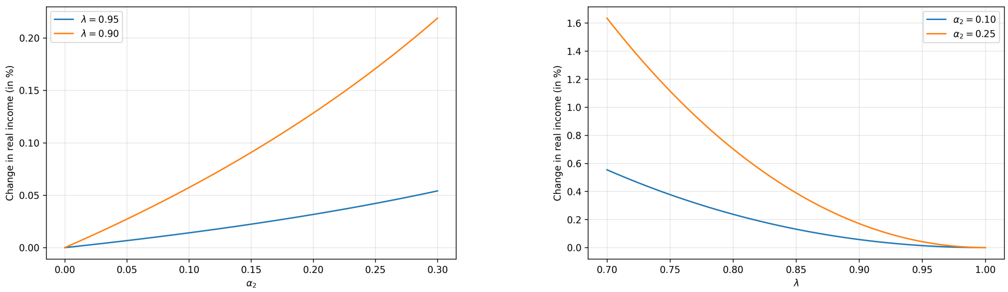


... as a function of α_2 ... as a function of λ

Source: Own elaboration.

Figure 4.2 shows the welfare effects evaluated at the optimal tariff rates. Continuing with the examples above, with $\alpha_2 = 0.10$ and $\lambda = 0.95$, welfare would only increase by 0.01%; with a lower pass-through of 0.9, the welfare increase would amount to 0.06%. For the higher expenditure share on imported goods $\alpha_2 = 0.25$, the gains would be 0.04% and 0.17%, respectively.

Figure 4.2: Welfare at optimal tariff rates t^* ($\beta = 1.0$)



... as a function of α_2 ... as a function of λ

Source: Own elaboration.

4.2 Interpretation

When interpreting the pass-through effect as a function of the foreign supply elasticity $\lambda = \frac{\sigma-1}{\sigma}$ for $\sigma > 1$ (as discussed above) this formula becomes

$$t^* = \frac{1}{(1-\alpha_2)\cdot(\sigma-1)}$$

This equation corresponds to the one provided in Gros (1987) in a homogenous firm model à la Krugman (1980)[19] and reflects the standard result that the optimal tariff rate equals the inverse of the foreign supply elasticity (the higher the supply elasticity the smaller is the pass-through and the smaller is the optimal tariff). Further, the larger is the import share α_2, the larger is the optimal tariff. Importantly, the optimal tariff for countries with a small share of imported products is comparatively low.[20]

[19] For generalisations of this formula see Ara (2024).

[20] In this equation the effects of the fundamental trade elasticity and the import share as in Gros (1987) and heterogenous firm models as discussed in Ara (2024).

4.3 Threshold tariffs

The discussion in the previous section also suggests that welfare becomes lower if tariffs are hiked too strongly compared to the situation with no tariffs. Setting $u = u_0$, the welfare equation can be rearranged to

$$1 + (1 - \beta \cdot \alpha_2) \cdot t = (1 + t)^{1 - \lambda \cdot \alpha_2}$$

which therefore becomes a non-linear relation. Solving this equation with respect to λ

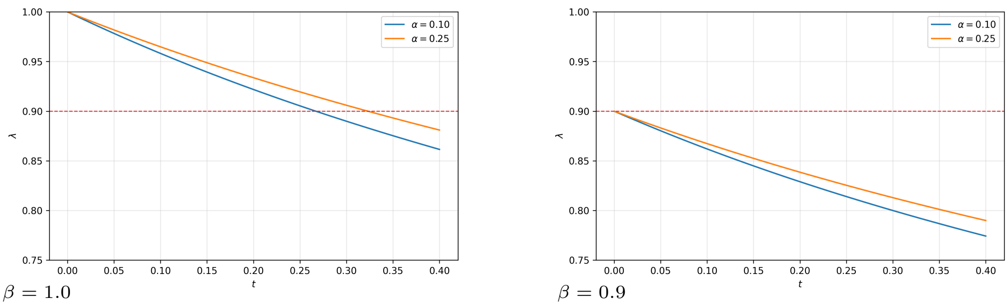
$$\begin{aligned} \ln(1 + (1 - \beta \cdot \alpha_2) \cdot t) &= (1 - \lambda \cdot \alpha_2) \cdot \ln(1 + t) \\ -\frac{1}{\alpha_2} \cdot \left(\frac{\ln(1 + (1 - \beta \cdot \alpha_2) \cdot t)}{\ln(1 + t)} - 1 \right) &= \lambda \end{aligned}$$

results in an expression where λ is a function of the tariff rate t (for given α_2 and β):

$$\lambda = \frac{1}{\alpha_2} \cdot \left(\frac{\ln(1 + t) - \ln(1 + (1 - \beta \cdot \alpha_2) \cdot t)}{\ln(1 + t)} \right)$$

Figure 4.3 visualises this relation.[21] For example, for $\alpha_2 = 0.10$ and $\beta = 1.0$, the threshold tariff is $t \approx 0.27$ and, for $\alpha_2 = 0.25$, it is $t \approx 0.33$. These threshold tariffs are lower for lower β and would already be $t = 0$ for $\beta = 0.9$ (see right panel).

Figure 4.3: Threshold tariffs



$\beta = 1.0$ $\qquad$ $\beta = 0.9$

Source: Own elaboration.

5 Trade balance and welfare

Finally, one can assess the effects of a tariff on the country's trade balance. If tariff revenues are fully spent (i.e. $\beta = 1$), trade remains balanced, which follows from the definition of trade balance, as this implies that total income (including tariffs) equals total spending.[22] If, however, tariff revenues are not fully spent (e.g. if a portion of them is used to lower the government's budget deficit), the nominal income spent on consumption becomes smaller and the trade balance turns positive, according to national accounting identities. Formally, the trade balance is given by

$$tb = y \cdot \frac{\alpha_2 \cdot (1 - \beta) \cdot t}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]} \qquad \text{with } \frac{d\,tb}{dt} > 0 \text{ and } \frac{d^2 tb}{dt} < 0$$

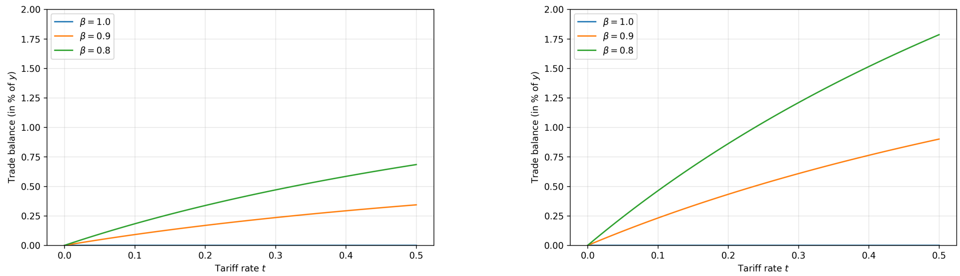
If $\beta = 0$ (i.e. tariff revenues are fully spent), the expression is $tb = \alpha_2 \cdot y \cdot \frac{t}{1+t}$. Clearly, if $t = 0$, trade is balanced. The trade balance is increasing with the tariff rate, though at a declining rate. Thus, the trade balance function is concave (see Figure 5.1). For the tariff rate going to infinity, the trade balance becomes

[21] Conversely, one could interpret this as an inverse function of λ determining t.

[22] This assumes that the government spends the tariff revenues in the same way as final consumers. See the derivation in Appendix Section B.5.

$\lim_{t\to\infty} = \alpha_2 \cdot y \cdot \frac{1-\beta}{(1-\beta\cdot\alpha_2)}$ (or $\lim_{t\to\infty} = \alpha_2 \cdot y$ for $\beta = 0$). Figure 5.1 shows the resulting trade surplus in percent of income y. This indicates that not spending tariff revenues could substantially improve the trade balance. For example, for $\alpha_2 = 0.25$ and $\beta = 0.5$, the trade surplus would amount to 2.56% of income. Of course, these numbers are larger the higher the tariffs are and the lower is β is.

Figure 5.1: Trade balance

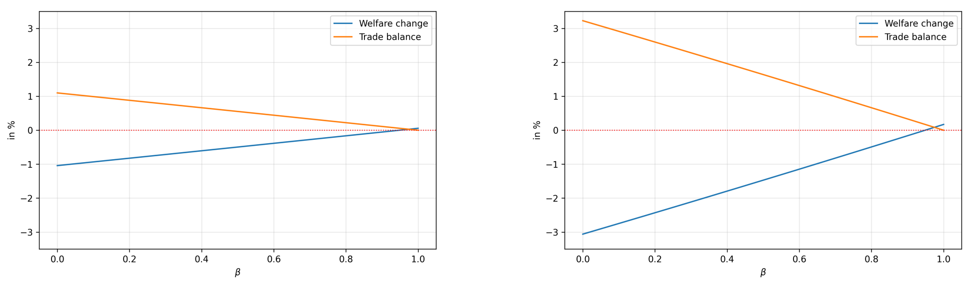


$\alpha_2 = 0.10$ $\alpha_2 = 0.25$

Source: Own elaboration.

However, there is a trade-off between welfare and trade surplus, as indicated in Figure 5.2, which shows the trade balance as a percentage of income y and the welfare change as a function of β (for given α_2 and λ). The lower β is, the larger the trade surplus is and the lower welfare is. Importantly, as one can easily see, welfare is declining from relatively high levels of β onwards.

Figure 5.2: Welfare and trade balance trade-off



$\alpha_2 = 0.10$, $\lambda = 0.9$ and $t = t^*$ at $\beta = 0$ $\alpha_2 = 0.25$, $\lambda = 0.9$ and $t = t^*$ at $\beta = 0$

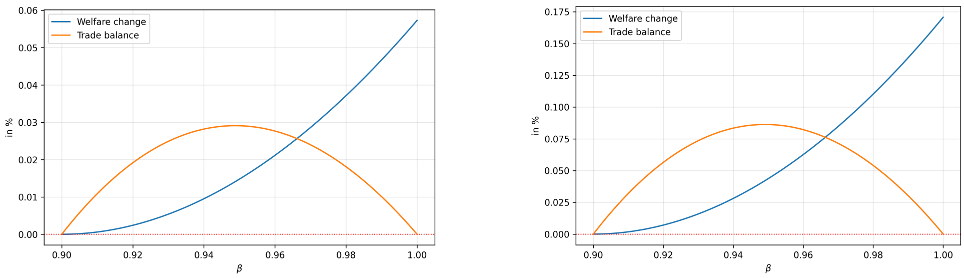
Source: Own elaboration.

In Figure 5.2, the applied tariff rate was set to the optimal tariff at $\beta = 1.0$ and held constant. One can also evaluate the trade balance at the optimal tariff rate (therefore changing with β):

$$\begin{aligned}
tb &= y \cdot \frac{\alpha_2 \cdot (1-\beta) \cdot \frac{\beta-\lambda}{(1-\beta\cdot\alpha_2)\cdot\lambda}}{[1+(1-\beta\cdot\alpha_2)\cdot\frac{\beta-\lambda}{(1-\beta\cdot\alpha_2)\cdot\lambda}]} \\
&= y \cdot \frac{\alpha_2 \cdot (1-\beta) \cdot \frac{(\beta-\lambda)}{(1-\beta\cdot\alpha_2)\cdot\lambda}}{[1+\frac{(1-\beta\cdot\alpha_2)\cdot(\beta-\lambda)}{(1-\beta\cdot\alpha_2)\cdot\lambda}]} \\
&= y \cdot \frac{\alpha_2 \cdot (1-\beta) \cdot \frac{(\beta-\lambda)}{(1-\beta\cdot\alpha_2)\cdot\lambda}}{\frac{(1-\beta\cdot\alpha_2)\cdot\lambda+(1-\beta\cdot\alpha_2)\cdot(\beta-\lambda)}{(1-\beta\cdot\alpha_2)\cdot\lambda}]} \\
&= y \cdot \frac{\alpha_2 \cdot (1-\beta)\cdot(\beta-\lambda)}{(1-\beta\cdot\alpha_2)\cdot\lambda+(1-\beta\cdot\alpha_2)\cdot(\beta-\lambda)]} \\
&= y \cdot \frac{\alpha_2 \cdot (1-\beta)\cdot(\beta-\lambda)}{(1-\beta\cdot\alpha_2)\cdot\beta}
\end{aligned}$$

This relationship is presented in Figure 5.3. Welfare declines when β becomes lower. The trade surplus would be zero for $\beta = 1.0$, would increase for lower levels of β, and would reach a maximum for a certain level of this parameter from which point on the trade surplus would become lower again and even become zero. Thus, the maximum trade surplus that could be achieved (for $\alpha_2 = 0.1$ and $\lambda = 0.9$) would be at a level of $\beta \approx 0.95$; the trade surplus would be about 0.9% of income, with a welfare gain of 0.05%. Results for a higher expenditure share α_2 are only slightly higher (with the 'optimal' β being slightly smaller).[23]

Figure 5.3: Welfare and trade balance at the optimal tariff rate



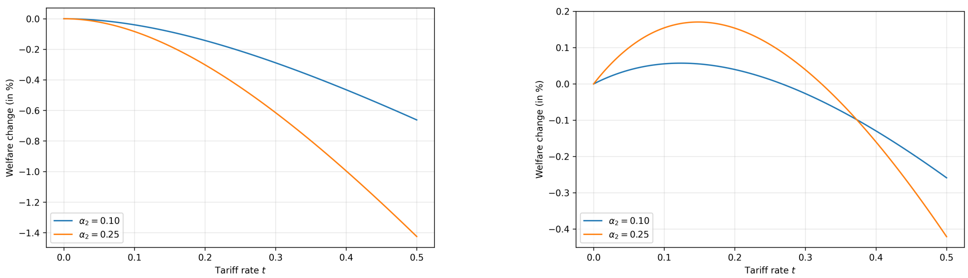
$\alpha_2 = 0.10, \lambda = 0.9$ $\alpha_2 = 0.25, \lambda = 0.9$

Source: Own elaboration.

6 CES demand

In the considerations above, we already pointed towards the role of the expenditure share of imports on welfare and the optimal tariff rate. We highlight this relation again in Figure 6.1. The larger α_2 is, the more pronounced the welfare effects are and the larger the optimal tariff rates are.

Figure 6.1: Welfare and optimal tariffs with CES demand



$\lambda = 1.00$ and $\beta = 1.00$ $\lambda = 0.90$ and $\beta = 1.00$

Source: Own elaboration.

An analogous conclusion can be made when assuming a CES demand specification with expenditure shares depending on relative prices and thus changing with the introduction of tariffs (as compared to constant shares assumed so far following a Cobb-Douglas demand system). The resulting expenditure share of the imported product is then given by

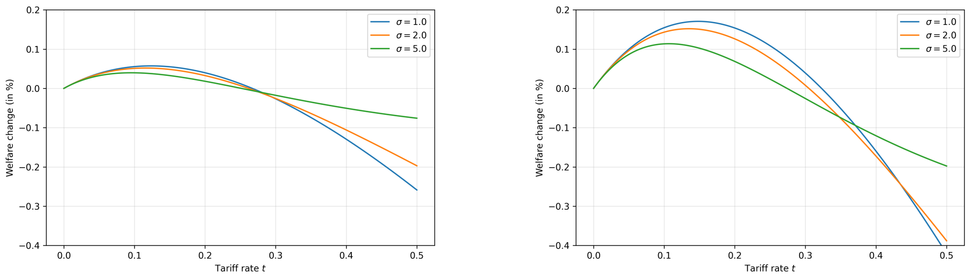
$$\tilde{\alpha}_2 = \frac{\alpha_2 \cdot \left(p_2 \cdot (1+t)^\lambda\right)^{1-\sigma}}{\alpha_2 \cdot p_1^{1-\sigma} + \alpha_2 \cdot \left(p_2 \cdot (1+t)^\lambda\right)^{1-\sigma}}$$

which becomes a function of the applied tariff rate and the pass-through parameter λ. Importantly, for $\sigma > 1$, the expenditure share for the imported product becomes smaller, as the imported product becomes more expensive (for $\lambda > 0$). Using these expenditure shares, tariff income r, total income $z = y + r$, and

[23] At lower levels of β, the welfare effect of optimal tariffs would again become positive, although they would go hand in hand with a trade deficit.

demand for both goods can be derived as before. For $\beta = 1$, trade remains balanced, and the price index is given by $p = \left[\beta_1 \cdot p_1^{1-\sigma} + \beta_2 \cdot \left(p_2 \cdot (1+t)^{\lambda}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$ (for $\sigma \neq 1$). For a given tariff rate t, welfare u and both the optimal and threshold tariffs can be calculated as before. Simulations for the Cobb-Douglas case ($\sigma = 1.0$) and $\sigma = 5.0$ are presented in Figure 6.2. These results show that a higher elasticity of

Figure 6.2: Welfare and optimal tariffs with CES demand



$\alpha_2 = 0.10$, $\lambda = 0.90$, and $\beta = 1.00$ | $\alpha_2 = 0.25$, $\lambda = 0.90$, and $\beta = 1.00$

Source: Own elaboration.

substitution implies a relatively lower welfare effect. The reason is that a higher elasticity of substitution shifts expenditures relatively more to the domestically produced good (as the imported good becomes relatively more expensive), which reduces tariff revenues. Correspondingly, the optimal and threshold tariffs are smaller the larger the elasticity of substitution σ is, which also implies lower welfare effects. Thus, the more sensitively consumers react to price changes of the imported product, the lower the welfare effects of a tariff are.

7 Application

In this section, we provide some empirical evidence of the effects of (potential) tariff hikes based on the considerations above. We calculate the share of imports in total expenditures α_2 from multi-country input-output tables (MC IOTs). Specifically, we calculate expenditures on final goods differentiated for domestic and import demand, which allow us to calculate this share.[24] From the literature, we infer that the pass-through of tariffs on consumers is large and therefore show the results for $\lambda \geq 0.8$.

7.1 Welfare effects of tariff hikes

In a first exercise, we calculate the welfare effects of a tariff hike to 10% and 25%, respectively, based on equation (3.3). The results are presented in Table 7.1. The first column shows the share of imported final goods in total expenditures of final goods, which range from 3.6% in the US to more than 30% in Switzerland. If these countries were to impose a tariff of 10%, the welfare loss in the case of a complete pass-through would amount to 0.02% in the US and Brazil to 0.10% in Switzerland. For a tariff hike to 25%, the loss would range between 0.08% in the US to 0.54% in Switzerland. Assuming a slightly lower pass-through ($\lambda = 0.9$), there would hardly be any welfare effect for a tariff of 10%; similarly, for $\lambda = 0.9$, the welfare effect of a 25% tariff would be very small (an exception might be Switzerland due to the high share of imports). The lower the pass-through is, the higher the welfare gains are, as can be seen from this table. However, even for a relatively weak pass-through of $\lambda = 0.8$, a 25% tariff of the US would lead to a

[24] In Appendix Section C, we provide the results when using total imports as a share in total gross output. These results are similar in magnitude.

welfare gain of only 0.08%. Generally, as seen above, the welfare effects are more positive the lower λ is and stronger the higher the expenditure share of imports is.

Table 7.1: Welfare effects of tariffs (final demand-based), in %

				λ					λ		
Importer	α_2	0.80	0.85	0.90	0.95	1.00	0.80	0.85	0.90	0.95	1.00
				$t = 0.10$					$t = 0.25$		
US	3.6	0.05	0.04	0.02	0.00	-0.02	0.08	0.04	-0.00	-0.04	-0.08
BR	5.0	0.07	0.05	0.03	0.00	-0.02	0.11	0.06	0.00	-0.06	-0.11
AU	7.1	0.11	0.07	0.04	0.00	-0.03	0.16	0.08	0.00	-0.07	-0.15
RU	7.2	0.11	0.07	0.04	0.00	-0.03	0.16	0.08	0.00	-0.08	-0.16
AR	8.4	0.13	0.09	0.05	0.01	-0.03	0.20	0.10	0.01	-0.09	-0.18
ID	8.8	0.13	0.09	0.05	0.01	-0.04	0.20	0.11	0.01	-0.09	-0.19
SA	8.8	0.13	0.09	0.05	0.01	-0.04	0.21	0.11	0.01	-0.09	-0.19
JP	9.0	0.14	0.09	0.05	0.01	-0.04	0.21	0.11	0.01	-0.09	-0.19
EU	9.3	0.14	0.10	0.05	0.01	-0.04	0.22	0.11	0.01	-0.09	-0.20
UK	9.4	0.14	0.10	0.05	0.01	-0.04	0.22	0.11	0.01	-0.09	-0.20
IN	10.2	0.15	0.11	0.06	0.01	-0.04	0.24	0.13	0.01	-0.10	-0.22
CA	10.4	0.16	0.11	0.06	0.01	-0.04	0.25	0.13	0.01	-0.10	-0.22
CN	10.8	0.16	0.11	0.06	0.01	-0.04	0.26	0.14	0.01	-0.11	-0.23
ZA	11.2	0.17	0.12	0.06	0.01	-0.04	0.27	0.14	0.02	-0.11	-0.23
NO	12.9	0.20	0.14	0.07	0.01	-0.05	0.31	0.17	0.02	-0.12	-0.27
ZR	13.3	0.20	0.14	0.08	0.01	-0.05	0.32	0.17	0.02	-0.12	-0.27
TR	13.9	0.21	0.15	0.08	0.01	-0.05	0.34	0.18	0.03	-0.13	-0.28
KR	16.2	0.25	0.17	0.09	0.02	-0.06	0.40	0.22	0.04	-0.14	-0.32
MX	19.2	0.30	0.21	0.11	0.02	-0.07	0.49	0.27	0.06	-0.15	-0.37
CH	33.8	0.55	0.38	0.22	0.06	-0.10	0.97	0.59	0.21	-0.17	-0.54

Source: FIGARO MC IOTs, own calculations.

7.2 Optimal and threshold tariffs

Table 7.2 shows the share of imports in total final goods expenditures (i.e. corresponding to parameter α_2). For these expenditure shares, we calculate the optimal tariff rates according to equation (4.3) for various levels of the pass-through parameter λ. The last two columns show the most-favoured-nation (MFN) tariffs in force in 2022 (according to the WTO tariff profiles) for all goods except agricultural products. Clearly,

Table 7.2: Optimal and applied tariffs: final demand-based

					λ				MFN applied*	
Importer	α_2	0.70	0.75	0.80	0.85	0.90	0.95	1.00	Total	Non-Ag.
US	3.6	44.5	34.6	25.9	18.3	11.5	5.5	0.0	3.3	3.1
BR	5.0	45.1	35.1	26.3	18.6	11.7	5.5	0.0	11.2	11.7
AU	7.1	46.1	35.9	26.9	19.0	12.0	5.7	0.0	2.4	2.6
RU	7.2	46.2	35.9	26.9	19.0	12.0	5.7	0.0	6.6	6.1
AR	8.4	46.8	36.4	27.3	19.3	12.1	5.7	0.0	13.4	13.9
ID	8.8	47.0	36.5	27.4	19.3	12.2	5.8	0.0	8.0	7.9
SA	8.8	47.0	36.6	27.4	19.4	12.2	5.8	0.0	6.2	5.7
JP	9.0	47.1	36.6	27.5	19.4	12.2	5.8	0.0	3.7	2.4
EU	9.3	47.3	36.8	27.6	19.5	12.3	5.8	0.0	5.0	4.1
UK	9.4	47.3	36.8	27.6	19.5	12.3	5.8	0.0	3.8	2.9
IN	10.2	47.7	37.1	27.8	19.7	12.4	5.9	0.0	17.0	13.5
CA	10.4	47.8	37.2	27.9	19.7	12.4	5.9	0.0	3.8	2.0
CN	10.8	48.1	37.4	28.0	19.8	12.5	5.9	0.0	7.5	6.4
ZA	11.2	48.3	37.5	28.2	19.9	12.5	5.9	0.0	7.6	7.4
NO	12.9	49.2	38.3	28.7	20.3	12.8	6.0	0.0	4.6	0.4
ZR	13.3	49.4	38.4	28.8	20.3	12.8	6.1	0.0		
TR	13.9	49.8	38.7	29.1	20.5	12.9	6.1	0.0	15.2	12.5
KR	16.2	51.2	39.8	29.8	21.1	13.3	6.3	0.0		
MX	19.2	53.0	41.3	30.9	21.8	13.8	6.5	0.0	6.8	6.0
CH	33.8	64.8	50.4	37.8	26.7	16.8	8.0	0.0	5.2	1.3

*Note: Simple average. Data for 2023.

Source: FIGARO MC IOTs, own calculations; WTO tariff profiles.

for a complete pass-through ($\lambda = 1$), the optimal tariff would be zero. For $\lambda = 0.95$, the optimal tariff rate ranges from 5.5% in the US to 8% in Switzerland. For an even lower pass-through of $\lambda = 0.90$, this range would be between 11.5% and 16.8%. Generally, the lower the pass-through is and the larger the expenditure share on imports is, the higher the potential optimal tariff rates are. For most countries, the average MFN tariffs are below the optimal tariffs for $\lambda = 0.95$ (or, conversely, would correspond to higher levels of λ). Exceptions to this are Brazil, Argentina, India, and Turkey, which charge much higher tariffs on average.

Table 7.3 shows the threshold tariffs (i.e. the tariff rate from which the welfare effect is negative). For $\lambda = 0.95$, this ranges from 10.9% in the US to 16.3% in Switzerland. Even with a pass-through of $\lambda = 0.90$, the threshold tariff would be nearly 25% for the US. For comparison,the actually applied tariff in the US is about 16% and therefore likely beyond these thresholds.

Table 7.3: Threshold tariffs: final demand-based

		λ							MFN applied*	
Importer	α_2	0.80	0.75	0.80	0.85	0.90	0.95	1.00	Total	Non-Ag.
US	3.6	121.1	81.1	66.3	44.4	24.3	10.9	0.0	3.3	3.1
BR	5.0	121.1	81.1	66.3	44.4	24.3	10.9	0.0	11.2	11.7
AU	7.1	121.1	99.1	66.3	44.4	24.3	10.9	0.0	2.4	2.6
RU	7.2	121.1	99.1	66.3	44.4	24.3	10.9	0.0	6.6	6.1
AR	8.4	121.1	99.1	66.3	44.4	24.3	10.9	0.0	13.4	13.9
ID	8.8	121.1	99.1	66.3	44.4	24.3	10.9	0.0	8.0	7.9
SA	8.8	121.1	99.1	66.3	44.4	24.3	10.9	0.0	6.2	5.7
JP	9.0	121.1	99.1	66.3	44.4	24.3	10.9	0.0	3.7	2.4
EU	9.3	121.1	99.1	66.3	44.4	24.3	10.9	0.0	5.0	4.1
GB	9.4	121.1	99.1	66.3	44.4	24.3	10.9	0.0	3.8	2.9
IN	10.2	121.1	99.1	66.3	44.4	24.3	13.3	0.0	17.0	13.5
CA	10.4	121.1	99.1	66.3	44.4	24.3	13.3	0.0	3.8	2.0
CN	10.8	121.1	99.1	66.3	44.4	24.3	13.3	0.0	7.5	6.4
ZA	11.2	121.1	99.1	66.3	44.4	29.7	13.3	0.0	7.6	7.4
NO	12.9	121.1	99.1	66.3	44.4	29.7	13.3	0.0	4.6	0.4
ZR	13.3	121.1	99.1	66.3	44.4	29.7	13.3	0.0		
TR	13.9	148.0	99.1	66.3	44.4	29.7	13.3	0.0	15.2	12.5
KR	16.2	148.0	99.1	66.3	44.4	29.7	13.3	0.0		
MX	19.2	148.0	99.1	81.1	54.3	29.7	13.3	0.0	6.8	6.0
CH	33.8	180.9	121.1	99.1	66.3	36.3	16.3	0.0	5.2	1.3

*Note: Simple average. Data for 2023.
Source: FIGARO MC IOTs, own calculations; WTO tariff profiles.

8 Conclusions

This paper has examined the welfare and trade-balance effects of tariff policy within a stylised but analytically transparent Ricardian model for a small open economy. By focusing on three core structural determinants (i.e. the expenditure share on imported goods, the degree of tariff pass-through to consumer prices, and the share of tariff revenues injected back into domestic demand), the model provides a unified explanation for several empirical patterns commonly observed in more complex quantitative trade environments. Despite its simplicity, the framework succeeds in illuminating why tariff hikes often yield diminishing marginal effects as well as why welfare and real wage responses diverge from changes in overall income.

The closed-form expressions for welfare, optimal tariff rates, and threshold tariff levels are in line with existing literature and make explicit the conditions under which tariffs can raise welfare and, conversely, when they unambiguously reduce it. In particular, the results underscore the central role of pass-through: when pass-through is high, as documented in the empirical literature, tariff-induced price increases substantially erode potential gains from tariff revenues. This, in turn, leads to welfare effects that are either negligible or negative, even when the optimal tariff rate is chosen. Moreover, the model clarifies why real wage income invariably falls when tariff revenues are not recycled through additional domestic spending as well as why the trade balance may improve in such scenarios through adjustments in domestic versus foreign savings. The results also highlight a fundamental trade-off between welfare and external balances. Tariffs may improve the trade balance when tariff revenues are saved rather than spent, but this improvement typically comes at the cost of reduced real wages and lower welfare. Conversely, using tariff revenues to support domestic demand can mitigate welfare losses but reduces the associated trade-balance gains.

These mechanisms help to rationalise the observed range of outcomes in applied general equilibrium models and provide a coherent lens through which to interpret the small welfare effects of recent tariff episodes. While the model abstracts from important real-world features (e.g. retaliation, global value chains, sectoral and firm heterogeneity, or employment dynamics), the underlying mechanisms are likely to carry over to richer settings as examined in recent literature. In this sense, this paper's simple structure is a strength, as it makes transparent the channels through which tariffs affect real income, welfare, and trade balances, and it clarifies the narrow set of conditions under which tariff policy may offer marginal welfare improvements. Overall, the findings suggest that, for economies facing high pass-through, the scope for welfare-enhancing tariff policy is extremely limited, and that optimal tariff rates, when they exist at all, only yield negligible benefits.

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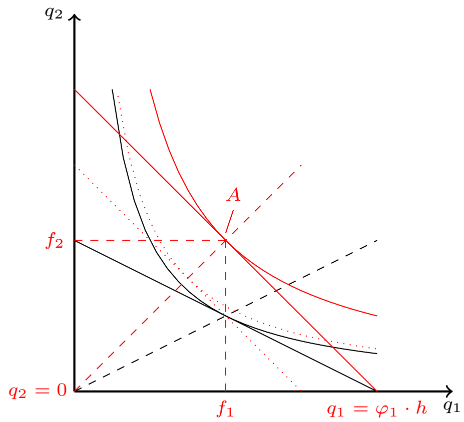
A Graphical presentation of the impact of tariffs

The free trade situation, together with the transition from autarky to free trade, is illustrated in Figure A.1. The black lines indicate the autarky situation, while the red dotted lines depict the 'gains from exchange'. The free trade equilibrium itself is shown in red. The slope of the budget constraint reflects the relative price of good 1. Point A characterises this free trade equilibrium.

Figure A.1: Ricardian free trade equilibrium



A.1 Graphical presentation of the impact of tariff

The impacts of tariff hikes can be studied using this graphical framework in the following way. We distinguish two special cases: a full pass-through of the tariff and a case of no pass-through. Finally, we discuss an example of partial pass-through, which illustrates the possibility of an optimal tariff and a threshold tariff rate.

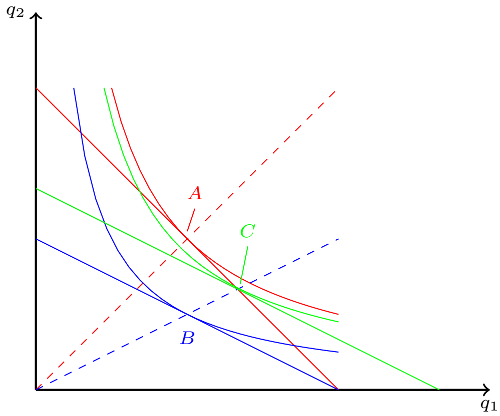
A.1.1 Full pass-through

First, we assume a full pass-through, such that consumers face the price $p_2 \cdot (1 + t)$ after the tariff hike. Graphically, an increase in the price of the imported good due to the tariff hike rotates the budget constraint counterclockwise (see blue lines in Figure A.2), as the imported goods become relatively more expensive. If the resulting tariff revenues are not spent, the new equilibrium would be at point B. As shown later, in this case, the trade balance would become positive, as not all income (including tariff income) is spent on consumption and, thus, total income (including the tariff income) is higher than expenditures. As shown analytically in the next section, even if tariff revenues are fully spent, this is not sufficient to compensate for income losses due to higher import prices. Therefore, real total income or welfare is lower under a positive tariff. This situation is indicated as point C. We further show below that, in this situation, trade would again be balanced.

A.1.2 No pass-through

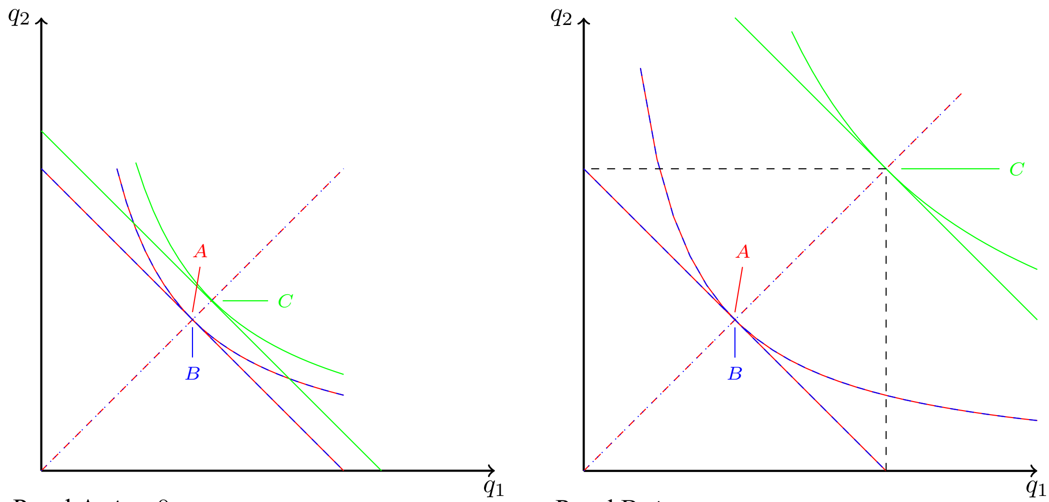
First, we assume full pass-through, such that consumers face the price $p_2 \cdot (1 + t)$ after the tariff hike. Graphically, an increase in the price of the imported good rotates the budget constraint counterclockwise (see the blue lines in Figure A.2), as the imported good becomes relatively more expensive. If the resulting tariff revenues are not spent, the new equilibrium is located at point B. As shown later, in this case, the trade

Figure A.2: Tariff impact: full pass-through



balance becomes positive because not all income (including tariff revenues) is spent on consumption; hence, total income (including tariff income) exceeds total expenditures. As demonstrated analytically in the next section, even if tariff revenues are fully spent, this is not sufficient to offset the income losses arising from higher import prices. Consequently, real income or welfare is lower under a positive tariff. This outcome is represented by point C. We also show below that, in this case, trade is again balanced.

Figure A.3: Tariff impact: no pass-through



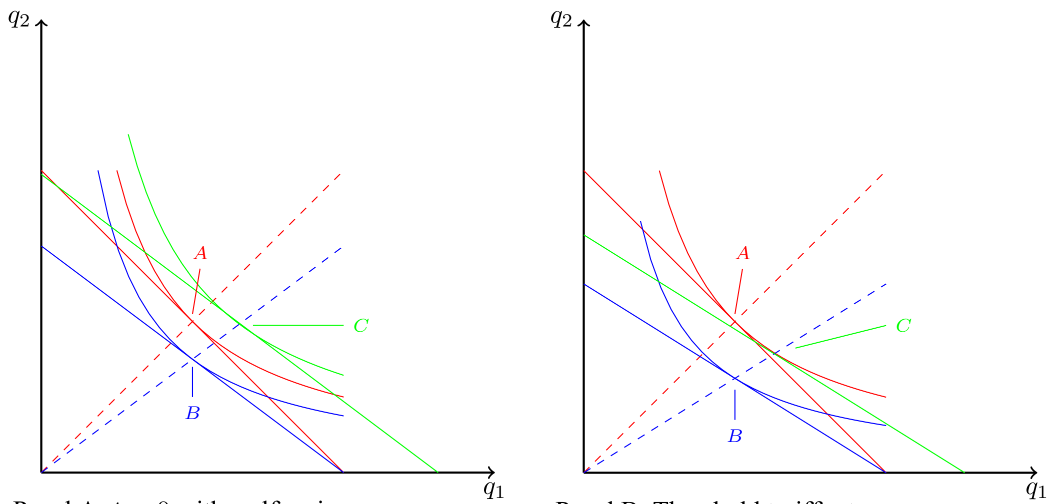
Panel A: $t > 0$ Panel B: $t \rightarrow \infty$

A.1.3 Partial pass-through

In the case of partial pass-through of the tariff hike to consumer prices, we show below that welfare gains arise up to a certain tariff level, referred to as the optimal tariff rate. If tariffs are increased beyond this point, welfare begins to decline and may eventually fall below the free trade level. The tariff rate at which welfare becomes lower than under free trade is referred to as the threshold tariff. The first situation is illustrated in Figure A.4. The increase in the tariff rotates the budget constraint counterclockwise, though by less than in the case of full pass-through (shown in Figure A.2) and, of course, by more than in the case of no pass-through (Figure A.3). If tariff revenues are not spent, the new equilibrium is at point B. When tariff revenues are spent, the new equilibrium is eventually at point C, indicating a welfare increase. This may correspond to the optimal tariff rate.

However, if the tariff rate is increased further, real income begins to decline and may fall back to the level observed before the tariff was introduced. This situation is depicted in the right panel of Figure A.4, where the new equilibrium point C lies on the original indifference curve. Beyond this point, any further increase in the tariff rate results in welfare losses.

Figure A.4: Tariff impact with a partial pass-through and welfare gains



Panel A: $t > 0$ with welfare increases

Panel B: Threshold tariff rate

A.2 Summary

In this section, we introduced the Ricardian trade model in a graphical way and discussed how the effects of tariffs can be shown and analysed graphically. These graphical outlines illustrate the effects of tariff hikes that can arise in such a general equilibrium framework. The impact of a tariff depends on the expenditure share of the imported product, the degree of pass-through to consumer prices, and the share of tariff revenues that is actually spent rather than saved. Under partial pass-through, both an optimal (i.e. welfare-maximising) tariff rate and a threshold tariff rate (i.e. the tariff level at which welfare turns from positive to negative) can be derived. These outlines also highlight that if not all tariff revenues are spent, the welfare effects are lower. However, we will see that these can nonetheless be positive in some cases. These mechanisms motivate a more detailed analytical investigation, which we turn to in the next section.

B Technical details

B.1 Tariff revenue function

Tariff revenues are given by the price at border times the imported quantity times the tariff rate. Total expenditures are equal to income y and the tariff revenues of which a share of $0 \leq \beta \leq 1$ is spent on final demand:

$$r = \left(p_2 \cdot (1+t)^{\lambda-1}\right) \cdot \alpha_2 \cdot \frac{y + \beta \cdot r}{p_2 \cdot (1+t)^{\lambda}} \cdot t$$

Simplifying and solving for r

$$\begin{aligned} r &= \alpha_2 \cdot \frac{y + \beta \cdot r}{(1+t)} \cdot t \\ (1+t) \cdot r &= \alpha_2 \cdot y \cdot t + \alpha_2 \cdot \beta \cdot r \cdot t \\ (1 + t - \alpha_2 \cdot \beta \cdot t) \cdot r &= \alpha_2 \cdot y \cdot t \end{aligned}$$

results in[25]

$$r = \frac{\alpha_2 \cdot y \cdot t}{[1 + (1 - \alpha_2 \cdot \beta) \cdot t]}$$

The larger β is and the larger the share of the imported products α_2 is, the larger tariff revenues are. If the tariff revenues are fully spent (i.e. $\beta = 1$), this expressions becomes $r = \frac{\alpha_2 \cdot y \cdot t}{1 + (1-\alpha_2) \cdot t}$. If $\beta = 0$, tariff revenues are given by $r = \frac{\alpha_2 \cdot y \cdot t}{1+t}$. Tariff revenues are increasing with the tariff rate as

$$\begin{aligned} \frac{dr}{dt} &= \alpha_2 \cdot y \cdot \frac{[1 + (1 - \beta \cdot \alpha_2) \cdot t] - (1 - \beta \cdot \alpha_2) \cdot t}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]^2} \\ &= \frac{\alpha_2 \cdot y}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]^2} > 0 \end{aligned}$$

The second derivative is

$$\frac{d^2 r}{dt^2} = \frac{-2 \cdot \alpha_2 \cdot y \cdot (1 - \beta \cdot \alpha_2)}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]^3} < 0$$

and, thus, the tariff revenue function has a concave shape. Tariff revenues have an upper bound, as – according to the rule of de l'Hospital[26] – it holds that

$$\lim_{t \to \infty} r = \frac{\alpha_2 \cdot y}{1 - \beta \cdot \alpha_2}$$

For $\beta = 0$, the upper bound is thus given by $\lim_{t\to\infty} r = \alpha_2 \cdot y$; for $\beta = 1$, it is $\lim_{t\to\infty} r = \frac{\alpha_2}{\alpha_1} \cdot y$.

B.2 Nominal income and expenditures

Nominal total income z is equal to total wage income y plus tariff revenues r. We assume that wage income is spent (i.e. no savings) whereas only a part of tariff revenues $0 \leq \beta \leq 1$ is spent. Therefore, nominal expenditures e can differ from nominal total income, as a part of tariff revenues $(1 - \beta) \cdot r$ is saved. Expenditures are thus given by $e = y + \beta \cdot r$. Inserting for r, these can be written as

$$\begin{aligned} e &= y + \beta \cdot \frac{\alpha_2 \cdot y \cdot t}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]} \\ &= \frac{y \cdot [1 + (1 - \beta \cdot \alpha_2) \cdot t] + \beta \cdot \alpha_2 \cdot y \cdot t}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]} \\ &= \frac{y \cdot (1+t)}{[1 + (1 - \beta \cdot \alpha_2) \cdot t]} \end{aligned}$$

[25] The denominator would be zero if $t = \frac{-1}{(1-\beta \cdot \alpha_2)}$, which we rule out as we only consider $t \geq 0$.

[26] This rule says that $\lim_{x\to\infty} \frac{f(x)}{g(x)} = \lim_{x\to\infty} \frac{f'(x)}{g'(x)}$ if $\lim_{x\to\infty} f(x) = \lim_{x\to\infty} g(x) = \pm\infty$ or $\lim_{x\to\infty} f(x) = \lim_{x\to\infty} g(x) = 0$.

In the two polar cases, this expression becomes $e = \frac{y\cdot(1+t)}{1+(1-\alpha_2)\cdot t} = \frac{y\cdot(1+t)}{1+\alpha_1\cdot t}$ for $\beta = 1$ and $e = y$ for $\beta = 0$. Similarly to the revenue function, one can show that the expenditure function is concave when $de/dt > 0$ and $d^2e/dt^2 < 0$, which can be shown analogously to the revenue function. Further, $\lim_{t\to\infty} e = \frac{y}{1-\beta\cdot\alpha_2}$ with $\lim_{t\to\infty} e = \frac{1}{\alpha_1}\cdot y$ for $\beta = 1$, and $\lim_{t\to\infty} e = y$ for $\beta = 0$. Expenditures increase with higher shares β and α_2, as one can easily see.

B.3 Final demand

Final demand for good 1 is $f_1 = \alpha_1 \cdot \frac{e}{p_1}$. Inserting for nominal expenditures e results in

$$f_1 = \alpha_1 \cdot \frac{y}{p_1} \cdot \frac{1+t}{[1+(1-\beta\cdot\alpha_2)\cdot t]}$$

with polar cases $f_1 = \alpha_1 \cdot \frac{y}{p_1}$ for $\beta = 0$ and $f_1 = \alpha_1 \cdot \frac{y}{p_1} \cdot \frac{1+t}{1+\alpha_1\cdot t}$ for $\beta = 1$. As for the revenue function, one can easily derive $df_1/dt > 0$ and $d^2f_1/dt^2 < 0$. Further, $\lim_{t\to\infty} = \frac{\alpha_1\cdot y}{p_1\cdot(1-\beta\cdot\alpha_2)}$ becomes $\alpha_1 \cdot \frac{y}{p_1}$ for $\beta = 0$ and $\frac{y}{p_1}$ for $\beta = 1$ (as, in this case, $\lim_{t\to\infty} e = y/\alpha_1$, as shown above).

Analogously, demand for the imported product can be derived as

$$f_2 = \alpha_2 \cdot \frac{e}{p_2\cdot(1+t)^\lambda} = \alpha_2 \cdot \frac{y\cdot(1+t)}{p_2\cdot(1+t)^\lambda\cdot[1+(1-\alpha_2\cdot\beta)\cdot t]} = \alpha_2 \cdot \frac{y\cdot(1+t)^{1-\lambda}}{p_2\cdot[1+(1-\alpha_2\cdot\beta)\cdot t]}$$

Demand for the imported product therefore depends on parameters α_2, β, and λ. It is increasing in α_2 and β and decreasing in λ (as the pass-through of the tariff to consumer prices is larger). The first derivative is given by

$$\begin{aligned}\frac{df_2}{dt} &= \frac{\alpha_2\cdot y}{p_2} \cdot \frac{(1-\lambda)\cdot(1+t)^{-\lambda}\cdot[1+(1-\alpha_2\cdot\beta)\cdot t] - (1+t)^{1-\lambda}\cdot(1-\alpha_2\cdot\beta)}{[1+(1-\alpha_2\cdot\beta)\cdot t]^2}\\ &= \frac{\alpha_2\cdot y}{p_2}\cdot(1+t)^{-\lambda}\cdot\frac{(1-\lambda)\cdot[1+(1-\alpha_2\cdot\beta)\cdot t] - (1+t)\cdot(1-\alpha_2\cdot\beta)}{[1+(1-\alpha_2\cdot\beta)\cdot t]^2}\end{aligned}$$

Demand for good 2 is increasing with the tariff if

$$(1-\lambda)\cdot[1+(1-\alpha_2\cdot\beta)\cdot t] \quad > \quad (1+t)\cdot(1-\alpha_2\cdot\beta)$$

resulting in the condition $t < \frac{\alpha_2\cdot\beta-\lambda}{\lambda\cdot(1-\alpha_2\cdot\beta)}$ for $\alpha_2\cdot\beta > \lambda$; for a larger t, demand for the imported product would decline. In other words, demand for good 2 reaches a maximum at the tariff rate

$$t = \frac{\alpha_2\cdot\beta-\lambda}{\lambda\cdot(1-\alpha_2\cdot\beta)} \qquad \text{for } \alpha_2\cdot\beta > \lambda$$

This shows that the pass-through λ has to be sufficiently low such that demand for the imported product would increase. For example. assuming that $\beta = 1$, the condition would become $\lambda < \alpha_2$, which –- given empirical evidence –- is hardly the case. With $\beta < 1$, this is even less likely to be satisfied. Finally, for the tariff rate going to infinity, demand for the imported product would go to zero for $\lambda > 0$. For $\lambda = 0$ (no pass-through), the limit is $\frac{\alpha_2\cdot y}{p_2}\frac{1}{1-\alpha_2\cdot\beta}$.

B.4 Price index and welfare

B.4.1 Price index

The price index can be written as

$$p = p_1^{\alpha_1}\cdot\left(p_2\cdot(1+t)^\lambda\right)^{\alpha_2} = p_0\cdot(1+t)^{\lambda\cdot\alpha_2} \qquad \text{with } p_0 = p_1^{\alpha_1}\cdot p_1^{\alpha_2}$$

The larger the pass-through is, the higher the price index is in the case of a tariff. Further, the larger the expenditure share on the imported product is, the stronger the price index increasing with the tariff is. The price index would go to infinity if tariffs go to infinity.

B.4.2 Welfare function

Maximum real income is given by[27]

$$\begin{aligned} u &= \frac{e}{p} = \frac{y \cdot (1+t)}{[1 + (1-\alpha_2 \cdot \beta) \cdot t] \cdot p_0 \cdot (1+t)^{\lambda \cdot \alpha_2}} \\ &= u_0 \cdot \frac{(1+t)^{1-\lambda \cdot \alpha_2}}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]} \qquad \text{with } u_0 = y/p_0 \end{aligned}$$

If the tariff rate goes to infinity, welfare becomes

$$\lim_{t\to\infty} u = u_0 \cdot \lim_{t\to\infty} \frac{(1-\lambda \cdot \alpha_2) \cdot (1+t)^{-\lambda \cdot \alpha_2}}{1 - \beta \cdot \alpha_2} = u_0 \cdot \frac{(1-\lambda \cdot \alpha_2)}{1-\beta \cdot \alpha_2} \cdot \lim_{t\to\infty} (1+t)^{-\lambda \cdot \alpha_2}$$

It goes to zero if $\lambda > 0$. For $\lambda = 0$ (no pass-through), welfare is bounded above at $\lim_{t\to\infty} u = u_0 \cdot \frac{1}{1-\beta \cdot \alpha_2}$.

B.4.3 Optimal tariffs

The first derivative is given by

$$\begin{aligned} \frac{du}{dt} &= u_0 \cdot \frac{(1-\lambda \cdot \alpha_2) \cdot (1+t)^{-\lambda \cdot \alpha_2} \cdot [1 + (1-\alpha_2 \cdot \beta) \cdot t] - (1+t)^{1-\lambda \cdot \alpha_2} \cdot (1-\alpha_2 \cdot \beta)}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]^2} \\ &= u_0 \cdot (1+t)^{-\lambda \cdot \alpha_2} \cdot \frac{(1-\lambda \cdot \alpha_2) \cdot [1 + (1-\alpha_2 \cdot \beta) \cdot t] - (1+t) \cdot (1-\alpha_2 \cdot \beta)}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]^2} \end{aligned}$$

For $\lambda = 0$ (no spill-over of tariffs on consumer prices), this expression simplifies to

$$\begin{aligned} \frac{du}{dt} &= u_0 \cdot \frac{[1 + (1-\alpha_2 \cdot \beta) \cdot t] - (1+t) \cdot (1-\alpha_2 \cdot \beta)}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]^2} \\ &= u_0 \cdot \frac{1 + (1-\alpha_2 \cdot \beta) \cdot t - (1-\alpha_2 \cdot \beta) - t \cdot (1-\alpha_2 \cdot \beta)}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]^2} \\ &= u_0 \cdot \frac{\alpha_2 \cdot \beta}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]^2} > 0 \end{aligned}$$

Thus, in this case, the first derivative is always positive and a tariff increase will lead to welfare gains. This implies that the optimal tariff rate goes to infinity with $\lim_{t\to\infty} = u_0 \cdot \frac{1}{1-\alpha_2 \cdot \beta}$, as discussed above.

In the opposite case – that is, of full pass-through of tariffs to consumer prices ($\lambda = 1$) – the first derivative is negative

$$\frac{du}{dt} = u_0 \cdot (1+t)^{-1} \cdot \frac{(1-\alpha_2) \cdot [1 + (1-\alpha_2 \cdot \beta) \cdot t] - (1+t) \cdot (1-\alpha_2 \cdot \beta)}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]^2} < 0$$

as, for $t > 0$, it holds that

$$\begin{aligned} (1-\alpha_2) \cdot [1 + (1-\alpha_2 \cdot \beta) \cdot t] &< (1+t) \cdot (1-\alpha_2 \cdot \beta) \\ 1 - \alpha_2 \cdot [1 + (1-\alpha_2 \cdot \beta) \cdot t] &< (1-\alpha_2 \cdot \beta) \\ \alpha_2 \cdot [1 + (1-\alpha_2 \cdot \beta) \cdot t] &> \alpha_2 \cdot \beta \\ (1-\alpha_2 \cdot \beta) \cdot t &> \beta - 1 \end{aligned}$$

[27] Alternatively, one can derive this term as

$$u = \left(\frac{f_1}{\alpha_1}\right)^{\alpha_1} \cdot \left(\frac{f_1}{\alpha_2}\right)^{\alpha_2} = \frac{y^{\alpha_1}}{p_1^{\alpha_1}} \cdot \frac{(1+t)^{\alpha_1}}{[1 + (1-\beta \cdot \alpha_2) \cdot t]^{\alpha_1}} \cdot \frac{y^{\alpha_2}}{p_2^{\alpha_2}} \cdot \frac{(1+t)^{\alpha_2 - \lambda \cdot \alpha_2}}{p_2^{\alpha_1} \cdot [1 + (1-\alpha_2 \cdot \beta) \cdot t]^{\alpha_1}}$$

which simplifies to the expression in the text as $\alpha_1 + \alpha_2 = 1$. Using $\alpha_1 + \alpha_2 = 1$, this can be rewritten as

$$= u_0 \cdot \frac{(1+t)^{\alpha_1} \cdot (1+t)^{\alpha_2 \cdot (1-\lambda)}}{[1 + (1-\alpha_2 \cdot \beta) \cdot t]}$$

A tariff in this case would always lead to a decline in welfare and, thus, the optimal tariff rate is zero.

For $\lambda > 0$, the optimal tariff rate can be calculated as

$$\begin{aligned}
(1-\lambda\cdot\alpha_2)\cdot[1+(1-\alpha_2\cdot\beta)\cdot t] &= (1+t)\cdot(1-\alpha_2\cdot\beta)\\
1+(1-\alpha_2\cdot\beta)\cdot t &= (1+t)\cdot\frac{(1-\alpha_2\cdot\beta)}{(1-\lambda\cdot\alpha_2)}\\
1+(1-\alpha_2\cdot\beta)\cdot t &= \frac{(1-\alpha_2\cdot\beta)}{(1-\lambda\cdot\alpha_2)}+\frac{(1-\alpha_2\cdot\beta)}{(1-\lambda\cdot\alpha_2)}\cdot t\\
(1-\alpha_2\cdot\beta)\cdot t-\frac{(1-\alpha_2\cdot\beta)}{(1-\lambda\cdot\alpha_2)}\cdot t &= \frac{(1-\alpha_2\cdot\beta)}{(1-\lambda\cdot\alpha_2)}-1\\
\Big[\frac{(1-\alpha_2\cdot\beta)\cdot(1-\lambda\cdot\alpha_2)-(1-\alpha_2\cdot\beta)}{(1-\lambda\cdot\alpha_2)}\Big]\cdot t &= \frac{(1-\alpha_2\cdot\beta)-(1-\lambda\cdot\alpha_2)}{(1-\lambda\cdot\alpha_2)}\\
\Big[(1-\alpha_2\cdot\beta)\cdot(1-\lambda\cdot\alpha_2)-(1-\alpha_2\cdot\beta)\Big]\cdot t &= (1-\alpha_2\cdot\beta)-(1-\lambda\cdot\alpha_2)\\
(1-\alpha_2\cdot\beta)\cdot\Big[(1-\lambda\cdot\alpha_2)-1\Big]\cdot t &= \alpha_2\cdot(\lambda-\beta)\\
(1-\alpha_2\cdot\beta)\cdot\Big[-\lambda\cdot\alpha_2\Big]\cdot t &= \alpha_2\cdot(\lambda-\beta)\\
(1-\alpha_2\cdot\beta)\cdot\lambda\cdot\alpha_2\cdot t &= \alpha_2\cdot(\beta-\lambda)
\end{aligned}$$

resulting in

$$t^* = \frac{(\beta-\lambda)}{(1-\alpha_2\cdot\beta)\cdot\lambda}$$

For the special case $\beta = 1$, this expression becomes[28]

$$t^* = \frac{(1-\lambda)}{(1-\alpha_2)\cdot\lambda}$$

Generally, the pass-through of tariffs to consumer prices λ has to be lower the lower β is to assure that $\beta-\lambda > 0$.

The optimal tariff rate is increasing in α_2 (as can easily be seen) and decreasing in λ:

$$\begin{aligned}
\frac{dt^*}{d\lambda} &= \frac{-(1-\beta\cdot\alpha_2)\cdot\lambda-(1-\lambda)\cdot(1-\beta\cdot\alpha_2)}{[(1-\beta\cdot\alpha_2)\cdot\lambda]^2}\\
&= \frac{-\lambda+\beta\cdot\alpha_2\cdot\lambda-[1-\lambda-\beta\cdot\alpha_2+\lambda\cdot\beta\cdot\alpha_2]}{[(1-\beta\cdot\alpha_2)\cdot\lambda]^2}\\
&= \frac{-\lambda+\beta\cdot\alpha_2\cdot\lambda-1+\lambda+\beta\cdot\alpha_2-\lambda\cdot\beta\cdot\alpha_2}{[(1-\beta\cdot\alpha_2)\cdot\lambda]^2}\\
&= -\frac{1-\beta\cdot\alpha_2}{[(1-\beta\cdot\alpha_2)\cdot\lambda]^2}\\
&= -\frac{1}{(1-\beta\cdot\alpha_2)\cdot\lambda^2} < 0
\end{aligned}$$

B.4.4 Threshold tariffs

Assuming $\lambda < 1$ and $t > 0$, one can derive a threshold tariff from which point on the welfare effect is negative by setting $u = u_0$, resulting in $[1+(1-\alpha_2\cdot\beta)\cdot t] = (1+t)^{1-\lambda\cdot\alpha_2}$. This then results in the non-linear condition

$$(1+t)-\alpha_2\cdot\beta\cdot t = (1+t)^{1-\lambda\cdot\alpha_2}$$

[28] For the case $\lambda = 1$ (full pass-through), the optimal tariff is $t^* = 0$, as discussed earlier.

B.5 Trade balance

The trade balance is the value of exports minus the value of imports evaluated at world prices given by p_1 and $p_2 \cdot (1+t)^{1-\lambda}$. Thus,

$$tb = (q_1 - f_1) \cdot p_1 - f_2 \cdot p_2 \cdot (1+t)^{\lambda-1}$$

Inserting for final demand and rearranging leads to

$$\begin{aligned}
tb &= (q_1 - f_1) \cdot p_1 - f_2 \cdot p_2 \cdot (1+t)^{\lambda-1} \\
&= y - \alpha_1 \cdot \frac{y}{p_1} \cdot \frac{1+t}{[1+(1-\beta\cdot\alpha_2)\cdot t]} \cdot p_1 - \alpha_2 \cdot \frac{y\cdot(1+t)^{1-\lambda}}{p_2\cdot[1+(1-\alpha_2\cdot\beta)\cdot t]} \cdot p_2 \cdot (1+t)^{\lambda-1} \\
&= y - \frac{\alpha_1\cdot y\cdot(1+t)}{[1+(1-\beta\cdot\alpha_2)\cdot t]} - \frac{\alpha_2\cdot y}{[1+(1-\alpha_2\cdot\beta)\cdot t]} \\
&= \frac{y\cdot[1+(1-\beta\cdot\alpha_2)\cdot t] - \alpha_1\cdot y\cdot(1+t) - \alpha_2\cdot y}{[1+(1-\beta\cdot\alpha_2)\cdot t]} \\
&= y \cdot \frac{[1+(1-\beta\cdot\alpha_2)\cdot t] - \alpha_1\cdot(1+t) - \alpha_2}{[1+(1-\beta\cdot\alpha_2)\cdot t]} \\
&= y \cdot \frac{1+(1-\beta\cdot\alpha_2)\cdot t - \alpha_1 - \alpha_1\cdot t - \alpha_2}{[1+(1-\beta\cdot\alpha_2)\cdot t]} \\
&= y \cdot \frac{(1-\beta\cdot\alpha_2)\cdot t - (1-\alpha_2)\cdot t}{[1+(1-\beta\cdot\alpha_2)\cdot t]} \\
&= y \cdot \frac{t - \beta\cdot\alpha_2\cdot t - t + \alpha_2\cdot t}{[1+(1-\beta\cdot\alpha_2)\cdot t]} \\
&= y \cdot \frac{-\beta\cdot\alpha_2\cdot t + \alpha_2\cdot t}{[1+(1-\beta\cdot\alpha_2)\cdot t]}
\end{aligned}$$

resulting in

$$tb = \frac{y\cdot(1-\beta)\cdot\alpha_2\cdot t}{[1+(1-\beta\cdot\alpha_2)\cdot t]}$$

For $\beta = 1$, trade remains balanced at $tb = 0$, whereas for $\beta = 0$ the trade surplus is given by $tb = \frac{y\cdot\alpha_2\cdot t}{1+t}$. The trade balance is positive and increasing with the tariff rate as the first derivative is positive

$$\begin{aligned}
\frac{d\,tb}{dt} &= y \cdot \frac{\alpha_2\cdot(1-\beta)\cdot[1+(1-\beta\cdot\alpha_2)\cdot t] - \alpha_2\cdot(1-\beta)\cdot t\cdot(1-\beta\cdot\alpha_2)}{[1+(1-\beta\cdot\alpha_2)\cdot t]^2} \\
&= y\cdot\alpha_2\cdot(1-\beta)\cdot\frac{[1+(1-\beta\cdot\alpha_2)\cdot t] - t\cdot(1-\beta\cdot\alpha_2)}{[1+(1-\beta\cdot\alpha_2)\cdot t]^2} \\
&= y\cdot\frac{\alpha_2\cdot(1-\beta)}{[1+(1-\beta\cdot\alpha_2)\cdot t]^2} > 0 \qquad \text{for } 0 \le \beta < 1
\end{aligned}$$

and zero for $\beta = 1$. The second derivative is

$$\frac{d^2\,tb}{dt^2} = -2\cdot y\cdot\alpha_2\cdot(1-\beta)\cdot[1+(1-\beta\cdot\alpha_2)\cdot t]^{-3}\cdot(1-\beta\cdot\alpha_2) < 0 \qquad \text{for } 0 \le \beta < 1$$

and zero for $\beta = 1$. Thus, the trade balance function has a concave shape. If the tariff rate approaches infinity, the trade balance (for $0 \le \beta < 1$) is – applying the rule of de l'Hospital – given by

$$\lim_{t\to\infty} tb = y \cdot \lim_{t\to\infty} \frac{\alpha_2\cdot(1-\beta)\cdot t}{[1+(1-\beta\cdot\alpha_2)\cdot t]} = y\cdot\frac{\alpha_2\cdot(1-\beta)}{(1-\beta\cdot\alpha_2)}$$

which for $\beta = 0$ reduces to $\lim_{t\to\infty} tb = \alpha_2 \cdot y$; for $\beta = 1$ the trade balance is zero in any case. The trade balance is increasing with α_2, as tariff revenues are higher. Further, the trade balance is larger the lower β is.

C Additional results

Table C.1: Welfare effects of tariffs: gross output-based

		$t = 0.10$					$t = 0.25$				
Importer	α_2	0.80	0.85	0.90	0.95	1.00	0.80	0.85	0.90	0.95	1.00
US	5.7	0.09	0.06	0.03	0.00	-0.02	0.13	0.07	0.00	-0.06	-0.13
CN	8.4	0.13	0.09	0.05	0.01	-0.03	0.19	0.10	0.01	-0.09	-0.18
AR	9.5	0.14	0.10	0.05	0.01	-0.04	0.22	0.12	0.01	-0.10	-0.20
BR	9.6	0.14	0.10	0.05	0.01	-0.04	0.23	0.12	0.01	-0.10	-0.20
EU	10.4	0.16	0.11	0.06	0.01	-0.04	0.25	0.13	0.01	-0.10	-0.22
JP	11.7	0.18	0.12	0.07	0.01	-0.05	0.28	0.15	0.02	-0.11	-0.24
ID	12.2	0.19	0.13	0.07	0.01	-0.05	0.29	0.16	0.02	-0.12	-0.25
IN	12.5	0.19	0.13	0.07	0.01	-0.05	0.30	0.16	0.02	-0.12	-0.26
AU	13.4	0.20	0.14	0.08	0.01	-0.05	0.33	0.18	0.03	-0.12	-0.27
RU	15.1	0.23	0.16	0.09	0.02	-0.06	0.37	0.20	0.03	-0.13	-0.30
TR	15.3	0.23	0.16	0.09	0.02	-0.06	0.38	0.21	0.03	-0.14	-0.31
UK	15.3	0.23	0.16	0.09	0.02	-0.06	0.38	0.21	0.03	-0.14	-0.31
ZA	17.2	0.27	0.18	0.10	0.02	-0.06	0.43	0.24	0.05	-0.15	-0.34
CA	18.6	0.29	0.20	0.11	0.02	-0.07	0.47	0.26	0.06	-0.15	-0.36
KR	21.6	0.34	0.23	0.13	0.03	-0.08	0.56	0.32	0.08	-0.16	-0.40
MX	23.0	0.36	0.25	0.14	0.03	-0.08	0.61	0.35	0.09	-0.17	-0.42
SA	27.0	0.43	0.30	0.17	0.04	-0.09	0.73	0.43	0.13	-0.17	-0.47
CH	33.2	0.53	0.38	0.22	0.06	-0.10	0.95	0.57	0.20	-0.17	-0.54
NO	34.4	0.56	0.39	0.23	0.06	-0.10	0.99	0.60	0.22	-0.16	-0.55

Source: FIGARO MC IOTs, own calculations.

Table C.2: Optimal and applied tariffs: gross output-based

					λ				MFN applied*	
Importer	α_2	0.70	0.75	0.80	0.85	0.90	0.95	1.00	Total	Non-Ag.
US	5.7	45.4	35.3	26.5	18.7	11.8	5.6	0.0	3.3	3.1
CN	8.4	46.8	36.4	27.3	19.3	12.1	5.7	0.0	7.5	6.4
AR	9.5	47.4	36.8	27.6	19.5	12.3	5.8	0.0	13.4	13.9
BR	9.6	47.4	36.9	27.7	19.5	12.3	5.8	0.0	11.2	11.7
EU	10.4	47.8	37.2	27.9	19.7	12.4	5.9	0.0	5.0	4.1
JP	11.7	48.5	37.8	28.3	20.0	12.6	6.0	0.0	3.7	2.4
ID	12.2	48.8	38.0	28.5	20.1	12.7	6.0	0.0	8.0	7.9
IN	12.5	49.0	38.1	28.6	20.2	12.7	6.0	0.0	17.0	13.5
AU	13.4	49.5	38.5	28.9	20.4	12.8	6.1	0.0	2.4	2.6
RU	15.1	50.5	39.3	29.5	20.8	13.1	6.2	0.0	6.6	6.1
TR	15.3	50.6	39.3	29.5	20.8	13.1	6.2	0.0	15.2	12.5
UK	15.3	50.6	39.3	29.5	20.8	13.1	6.2	0.0	3.8	2.9
ZA	17.2	51.8	40.3	30.2	21.3	13.4	6.4	0.0	7.6	7.4
CA	18.6	52.7	41.0	30.7	21.7	13.7	6.5	0.0	3.8	2.0
KR	21.6	54.7	42.5	31.9	22.5	14.2	6.7	0.0		
MX	23.0	55.7	43.3	32.5	22.9	14.4	6.8	0.0	6.8	6.0
SA	27.0	58.7	45.6	34.2	24.2	15.2	7.2	0.0	6.2	5.7
CH	33.2	64.1	49.9	37.4	26.4	16.6	7.9	0.0	5.2	1.3
NO	34.4	65.3	50.8	38.1	26.9	16.9	8.0	0.0	4.6	0.4

*Note: Simple average. Data for 2023.

Source: FIGARO MC IOTs, own calculations; WTO tariff profiles.

Table C.3: Threshold tariffs: gross output-based

					λ				MFN applied*	
Importer	α_2	0.80	0.75	0.80	0.85	0.90	0.95	1.00	Total	Non-Ag.
US	5.7	121.1	81.1	66.3	44.4	24.3	10.9	0.0	3.3	3.1
CN	8.4	121.1	99.1	66.3	44.4	24.3	10.9	0.0	7.5	6.4
AR	9.5	121.1	99.1	66.3	44.4	24.3	10.9	0.0	13.4	13.9
BR	9.6	121.1	99.1	66.3	44.4	24.3	10.9	0.0	11.2	11.7
EU	10.4	121.1	99.1	66.3	44.4	24.3	13.3	0.0	5.0	4.1
JP	11.7	121.1	99.1	66.3	44.4	29.7	13.3	0.0	3.7	2.4
ID	12.2	121.1	99.1	66.3	44.4	29.7	13.3	0.0	8.0	7.9
IN	12.5	121.1	99.1	66.3	44.4	29.7	13.3	0.0	17.0	13.5
AU	13.4	148.0	99.1	66.3	44.4	29.7	13.3	0.0	2.4	2.6
RU	15.1	148.0	99.1	66.3	44.4	29.7	13.3	0.0	6.6	6.1
TR	15.3	148.0	99.1	66.3	44.4	29.7	13.3	0.0	15.2	12.5
UK	15.3	148.0	99.1	66.3	44.4	29.7	13.3	0.0	3.8	2.9
ZA	17.2	148.0	99.1	66.3	44.4	29.7	13.3	0.0	7.6	7.4
CA	18.6	148.0	99.1	81.1	54.3	29.7	13.3	0.0	3.8	2.0
KR	21.6	148.0	99.1	81.1	54.3	29.7	13.3	0.0		
MX	23.0	148.0	121.1	81.1	54.3	29.7	13.3	0.0	6.8	6.0
SA	27.0	148.0	121.1	81.1	54.3	36.3	16.3	0.0	6.2	5.7
CH	33.2	180.9	121.1	99.1	66.3	36.3	16.3	0.0	5.2	1.3
NO	34.4	180.9	121.1	99.1	66.3	36.3	16.3	0.0	4.6	0.4

*Note: Simple average. Data for 2023.

Source: FIGARO MC IOTs, own calculations; WTO tariff profiles.

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