Tariff Escalation: A Theoretical Foundation

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ABSTRACT

Many empirical studies have shown that most countries in the world reveal a specific form of tariff structure, referred to as tariff-escalation, which is defined as tariff rates for final products being higher than those for intermediate goods, and the latter are higher than those for raw materials. However, trade theorists have paid scant attention to the causes of tariff-escalation. To fill this gap, we set up a vertically-related-market model with \( n \) stages of successive monopolies. We find that a tariff on an imported good can be used to extract not only the profit of the foreign monopolist supplying this good, but also the rents acquired by all the foreign upstream monopolists through its effects on the prices of the upstream intermediate goods. Thus, as the number of production stages in the foreign country increases, the amount of rent captured by the foreign upstream producers rises and a higher tariff rate is therefore needed to extract the rent. This provides a theoretical explanation to the cause of tariff-escalation.
1. Introduction

It is well recognized that a tariff structure involving vertically related products is one of the most controversial issues between developed and developing countries engaging in multilateral negotiations. Many empirical studies have shown that in the tariff structure of most countries in the world, an interesting phenomenon of tariff escalation arises, which is defined in terms of tariff rates for final goods being higher than those for intermediate inputs and the latter being higher than those for raw materials. Although it is true that tariff rates fell significantly in the aftermath of several rounds of GATT trade negotiations, tariff escalation is nevertheless still prevalent. In order to examine how much tariffs have actually escalated, the escalation rates of some of the developed countries, both pre- and post-Uruguay Round, are provided in Table 1. As this table indicates, most of the tariffs involved were fairly low, even prior to the Uruguay Round, and although there is still tariff escalation, there was a significant drop following the Uruguay Round.

Table 1  Tariff escalation of developed countries: pre- and post-Uruguay Round

<table>
<thead>
<tr>
<th>Industrial products (excluding petroleum)</th>
<th>Pre-Uruguay Round tariff</th>
<th>Post-Uruguay Round tariffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials</td>
<td>2.1</td>
<td>0.8</td>
</tr>
<tr>
<td>Semi-processed</td>
<td>5.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Finished</td>
<td>9.1</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Source: Adopted from GATT (1994), Table II.5, p.15.

More recent tariff structures on selected products in USA, EU and Japan are shown in Table 2, where it is revealed that tariffs in these countries escalated in much the same way as in Table 1. Furthermore, Laird and Yeats (1987) and Safadi and Yeats (1993) both showed that in many cases, tariff escalation in the developing countries was higher.
than in the developed countries, whilst Balassa (1968: p.195) indicated that tariffs in the developed countries increased with fabrication in order to “discriminate against the processed export products of developing countries”, thereby protecting these countries’ producers from their more efficient counterparts in the developing countries.

Table 2  Selected Tariff Escalation in DC by Major Product Group. Recent years
(weighted average MFN applied tariffs, %)

<table>
<thead>
<tr>
<th>Product Group</th>
<th>USA</th>
<th>EU</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>S</td>
<td>F</td>
</tr>
<tr>
<td>Meat Products</td>
<td>0.6</td>
<td>6.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Fish Products</td>
<td>0.2</td>
<td>1.9</td>
<td>2.0</td>
</tr>
<tr>
<td>Cereal Products</td>
<td>0.9</td>
<td>4.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Coffee, tea, spices</td>
<td>0.4</td>
<td>0.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Textile</td>
<td>0.0</td>
<td>3.8</td>
<td>11.5</td>
</tr>
</tbody>
</table>

R: Raw material; S: Semi-finished products; F: Finished Products

The end result is that such escalating tariffs shift the economic activity of exporting countries away from processing, towards primary production, thus distorting the efficient distribution of primary production and processing. Much attention in the literature since then has been directed at examining the resource allocation between importing and exporting countries and their resultant welfare levels. However, the empirical results derived by Laird and Yeats (1987) call into question these traditional explanations, whilst also revealing that developing countries have found it necessary to incorporate escalation in their tariff structures; they therefore suggest that there is a need to find alternative explanations for this phenomenon. Unfortunately, to the best of our knowledge, there is a continuing absence of strong explanations for tariff escalation.

It wasn’t until recently that Greenaway and Reed (1996) and Weng and Liu (1998) began to examine the causes of the phenomenon of tariff escalation from a theoretical perspective. Greenaway and Reed (1996) assumed that markets were perfectly
competitive and defined a weighted version of the conventional net social benefit function by means of placing greater weight on consumer expenditure, tariff revenues, and the total value-added of all of the stages of production, in order to explain the phenomenon of tariff escalation. However, the mere act of placing different weights on different items in the social benefit function is still unable to provide an adequate explanation for the phenomenon of tariff escalation.

Weng and Liu (1998) assumed that there was a vertically-integrated foreign firm exporting both intermediate inputs and final goods to the domestic market, and that its final goods were competing with a domestic firm in a duopoly market for downstream final goods. The driving force for escalating tariffs was the profit-shifting motive for protection, in that tariffs could be used to shift profits from an imperfectly competitive foreign firm to a domestic firm; i.e., the profit-shifting effect a la Brander and Spencer (1985). This is because the importing country has an incentive to impose a higher tariff on final goods than on intermediate inputs in order to protect its import-competing industry and to enhance the competitiveness of the domestic downstream firm with foreign rivals. However, there are at least two shortcomings in this analysis. Firstly, they fail to explain a situation where the domestic country does not produce any final goods so that the profit-shifting effect is absent; for example, we can see (again from Table 2) that most of the Asian countries are not capable of producing high technology-intensive products (such as airplanes, automobiles and electrical appliances); nevertheless, tariff escalation still exists. Secondly, if a duopoly market structure prevails in the upstream market rather than in the downstream market, then a profit-shifting effect occurs in the upstream market resulting in a decline in tariffs; indeed, they ignore the impact of different processing stages on escalating tariffs. Both cases demonstrate that trade theorists have paid scant attention to the causes of tariff
escalation.

In order to fill this gap, this paper sets out to provide a theoretical explanation for tariff escalation. We take the simple point that a tariff can be used to extract rent from foreign firms so as to increase domestic welfare even in the case of a foreign monopoly (Brander and Spencer, 1981; 1984) and set up a vertically-related model with \( n \) processing stages of successive monopolies (Greenhut and Ohta, 1976). We find that a tariff on imported goods can be used to extract not only the profits of the foreign monopolist supplying the goods, but also the rent acquired by all the foreign upstream monopolists through its effects on the prices of the upstream intermediate goods. Therefore, as the number of processing stages in the foreign country increases, there is a rise in the amount of rent captured by the foreign upstream producers and a higher tariff rate is therefore needed to extract the rent. This, we believe, provides a reasonable explanation for the causes of tariff escalation.

The structure of this paper is as follows. Section 2 sets out a basic model that considers two particular connected stages of production: (i) the production of final goods; and (ii) the production of the raw materials used as inputs in producing the final goods. Section 3 extends the structure to an \( n \)-stage product processing chain as well as to a duopoly market for the downstream final goods. Some extensions and concluding remarks are provided in the final section.

2. The Basic Model

Tariff escalation by definition indicates tariff rates that rise with stages of processing. In order to highlight how stages of processing affect tariff rates, we shall set up a very simple model in which there is an industry undertaking \( n \) stages of processing activities, including raw material, semi-processed goods, finishing processes and the final product, and each stage of processing is conducted by a single firm. In other words, this industry is an \( n \)-stage successive monopoly industry. For simplicity, it is
further assumed that the input-output relationship in each stage of production is of one-to-one correspondence, i.e., one unit of input is required to produce one unit of output.  

We shall start by the simplest case with $n=2$ in this section and generalize it to an $n$-stage case in the next section. More specifically, the production process in this section involves: (i) a final goods to be sold to the domestic market and (ii) raw materials used as inputs in producing the final goods. The domestic country can import either the raw material with a tariff rate $\tau$, have it processed in the home country and sell the final good output to the domestic market, or the final good with a tariff rate $t$ from the world market directly. We shall then compare the two tariff rates. If the tariff rate for the final goods is higher, tariff escalation takes place. The production process flow is shown in Figure 1.

![Figure 1: The Production Process Flow](image)

According to demand pattern and pricing behavior of a successive monopoly industry, as developed by Greenhut and Ohta (1976), a sub-game perfect equilibrium model can be set up to incorporate the three decision stages. In stage 1, the domestic government determines optimal tariffs (either $t$ or $\tau$) to maximize domestic social welfare. Given tariff rates, a foreign raw materials supplier sets its price for the raw materials during stage 2. In stage 3, given tariff rates and the price of the raw materials, the domestic or foreign producer of the final goods chooses the optimal quantity of final
goods to maximize its profits. As usual, we solve the problem by backward induction.

2.1 Importation of Final Goods by the Domestic Firm

Under these circumstances, all of the production processes of the final goods are finished in the foreign country, from where they are imported by the domestic firm. Let the demand function of the final goods in the domestic market be \( p_0 = f_0(q) \) with \( f_0'(q) = \frac{df_0(q)}{dq} < 0 \) and \( f_0(0) < \infty \), where \( q \) stands for the quantity demanded at whatever price \( p_0 \) is charged in that market. The total profit of the foreign producer from the production of the final goods can be specified as:

\[
\pi_0 = [f_0(q) - t - p_1]q - F_0 \tag{1}
\]

where \( t \) is the tariff rate on the imported final goods; \( p_1 \) is the price of the raw materials; \( F_0 \) is the fixed cost of producing the final goods; subscript ‘0’ denotes the final goods and ‘1’ the raw materials. Totally differentiating Equation (1) with respect to \( q \) yields the following first- and second-order conditions for profit maximization, respectively:

\[
\frac{d\pi_0}{dq} = [f_1(q) - t] - p_1 = 0
\]

\[
\frac{d^2\pi_0}{dq^2} = f_1'(q) < 0
\]

where \( f_1(q) = f_0(q) + f_0'(q)q \) represents not only the marginal revenue of the final goods, but also the average revenue of the raw materials. Hence, Equation (2) indicates that in order to maximize its profits, the final goods producer will produce the optimal quantity \( q^* \) so that the net marginal revenue \([f_1(q) - t]\) must be equal to unit marginal cost \( p_1 \). Applying implicit function theorem, we have:
\[
\frac{\partial q^*}{\partial p_1} = \frac{\partial q^*}{\partial t} = \frac{q^*}{f_2(q^*) - f_1(q^*)} < 0
\]  

(4)

where \( f_2(q) = f_1(q) + f_1'(q)q \) is the marginal revenue of the raw materials. Equation (4) shows that an increase in either the price of raw materials or import tariff on the final goods leads to a reduction in the quantity of the final goods. This is due to the fact that a rise in the price of raw materials will raise the production costs of the final goods, while an increase in the import tariff on final goods will reduce the net marginal revenue, either of these will eventually lead to a decline in the optimal quantity of the final goods.

Turning to stage 2, we are now in a position to discuss the pricing decision by foreign raw materials supplier. The objective of a supplier is to choose the optimal price to maximize its profits, which is specified as:

\[
\pi_1 = (p_1 - c)q(p_1) - F_1
\]  

(5)

where \( c \) denotes the constant marginal cost of raw materials; and \( F_1 \) the fixed cost. Substituting Equations (2) and (4) into Equation (5) obtains the first- and second-order conditions, respectively:

\[
\frac{d\pi_1}{dp_1} = \left[f_2(q^*) - t - c\right]\frac{\partial q^*}{\partial p_1} = 0
\]  

(6)

\[
\frac{d^2\pi_1}{dp_1^2} = f_2(q^*)\left(\frac{\partial q^*}{\partial p_1}\right)^2 < 0
\]  

(7)

The imposition of an import tariff on final goods by the domestic government will reduce the demand for raw materials faced by the final goods producer, changing the derived demand to \([f_1(q) - t]\) and the corresponding marginal revenue to \([f_2(q) - t]\). Thus, Equation (6) reflects the fact that the equilibrium price of raw materials is determined by equating MR to MC of the raw materials.
Noting that the equilibrium price, $p^*_1$, of raw materials is a function of $t$, and substituting this relation into Equation (2) yields $q^* = q[p_1(t), t]$. Moreover, by use of Equations (4) and (6), we obtain the following comparative static results:

$$
\frac{dp_1}{dt} = \left[1 - \frac{f_1'(q^*)}{f_2'(q^*)}\right] = \frac{-2}{(2 + \delta_1)(2 + \delta_0)}(1 + 2\delta_0) < 0, \text{ if } (1 + 2\delta_0) > 0 \quad (8)
$$

$$
\frac{dq}{dt} = \frac{\partial q}{\partial t} + \frac{\partial q}{\partial p_1} \frac{dp_1}{dt} = \frac{1}{f'_2(q^*)} < 0 \quad (9)
$$

where $\delta_0 = \frac{f_0'(q)q}{f_0'(q)}$ measures the relative convexity of demand for the final goods and $\delta_1 = \frac{f_1'(q)q}{f_1'(q)}$, the elasticity of the slope of the inverse demand function of raw materials with the properties of $(2 + \delta_1) > 0$ and $(2 + \delta_0) > 0$. Equation (9) reveals that a rise in the import tariff on the final goods leads to a reduction in the imported quantity of the final goods. Moreover, it follows from Equation (8) that the impact of a rise in the import tariff on the price of raw materials is, in general, ambiguous, depending on the relative convexity of the demand functions.

From the above discussions, we can establish:

**Proposition 1**  Assuming that the demand function of final goods is twice-differentiable and not likely to be highly convex (i.e. $\delta_0 > -\frac{1}{2}$), a rise in import tariff on the final goods causes the price of raw materials to fall.

Proof:  See Appendix B.

The economic interpretation of this Proposition 1 is as follows. When it is unlikely that the demand will be highly convex, imposing an import tariff on the final goods will reduce the output of the final goods, via Equation (4), causing the derived demand for
upstream raw materials by final goods producer to fall and then leading to a reduction in the price of raw materials. However, when the demand for final goods is highly convex so that the marginal revenue curve is less steeply sloped than demand, the imposition of an import tariff on the final goods will reduce the net marginal post-tariff revenue of the foreign raw materials supplier, causing the supplier to raise the price of the raw materials in order to mitigate the reduced net marginal revenue.5 In what follows, we make the assumption that demand is not highly convex, because this form of demand is quite general, including the case of linear demand.

The above result is illustrated in Figure 2, where \( f_0(q) \) and \( f_1(q) \) represent the demand function for the final goods and the raw materials, respectively; \( f_2(q) \) is the marginal revenue function of the monopolistic raw materials supplier; \( c_c \) is the marginal costs of producing the raw materials, the equilibrium for the raw materials supplier is at point \( E_1 \), where \( p_{1}^{f} \) is the price of raw materials and \( q_{1}^{f} \) the quantity of raw materials supplied. However, since \( p_{1}^{f} \) represents also the marginal cost of producing the final goods, the equilibrium for the final goods is at point \( E_0 \).

Associated with this equilibrium, \( q_{f}^{o} \) and \( p_{o}^{f} \) turn out to be the respective equilibrium quantity and the price of the final goods. After imposing a tariff on the final goods, the marginal revenue function of the final goods shifts downward in parallel from \( f_{1}(q) \) to \( f_{1}^{t}(q) \), and the vertical difference between \( f_{1}(q) \) and \( f_{1}^{t}(q) \) represents the level of tariff, \( t \). Correspondingly, \( f_{1}^{t}(q) \) is also the derived demand for raw materials by the final goods producer after the imposition of the tariff, and \( f_{2}(q) \) becomes the corresponding marginal revenue of raw materials supplier, whilst the vertical difference between \( f_{2}(q) \) and \( f_{2}^{t}(q) \) represents also the level of tariff, \( t \). Hence, the imposition of a tariff on the final goods lowers the quantity of the final goods to \( q^{t} \), raising the price of the final goods to \( p_{o}^{f} \), but reducing the price of the
raw materials to $p^*_1$.

We now turn to stage 3, in which the domestic government determines the optimal tariff on the final goods, anticipating the equilibrium decisions of the raw materials and final goods producers.

\[ G(t) = s(q(p_1(t),t)) + r(q(p_1(t),t),t) \]  

(10)

where $s = \int_0^q f_0(q)dq - p^*_o q^*$ and $r = tq^*$ represent consumer surplus and tariff revenue, respectively. The domestic welfare is maximized when $G_t \left( \frac{dG}{dt} \right)$ is equal to zero.
\[ G_i = \left[ (s_q + r_q) \frac{\partial q}{\partial t} + \frac{\partial r}{\partial t} \right] + \left( s_q + r_q \right) \frac{\partial q}{\partial p_1} \frac{\partial p_1}{\partial t} = 0 \]  \hspace{1cm} (11)

where \( s_q = -f_q'(q) \cdot q \) and \( r_q = t \). As pointed out by Brander and Spencer (1981, 1984), Katrak (1977) and Svedberg (1979), when imported final goods are monopolized by a foreign firm, a tariff can be used to extract rent from the foreign monopoly so as to increase domestic welfare. This effect is termed the ‘rent-extraction effect’. As far as Equation (11) is concerned, the first term on the right hand side, \( \left[ (s_q + r_q) \frac{\partial q}{\partial t} + \frac{\partial r}{\partial t} \right] \) describes this effect. It should be noted that most of the literature on optimal tariff assumes away the existence of intermediate inputs and therefore the impact of import tariffs on intermediate goods have been largely ignored. However, it follows from Equation (11) that when an industry consists of \( n \)-stages processes including upstream and downstream activities, the effect of a tariff policy on domestic welfare includes not only the abovementioned rent-extraction effect, but also ‘the upstream rent-extraction effect’, which is indicated by the second term on the right-hand side of Equation (11):

\[ \left( s_q + r_q \right) \frac{\partial q}{\partial p_1} \frac{\partial p_1}{\partial t} \]  \hspace{1cm} (12)

Since \( (s_q + r_q) = -f_q'(q)q + t > 0 \), \( \frac{\partial q}{\partial p_1} < 0 \) by (6) and \( \frac{\partial p_1}{\partial t} < 0 \) via Proposition 1, it obviously follows that the sign of Equation (12) is positive, indicating that the upstream rent-extraction effect is beneficial to the domestic welfare. The rationale behind this effect is as follows: imposition of an import tariff on the final goods by the domestic government reduces the output of the final goods, causing the derived demand for and then the price of the upstream raw materials to fall; this, in turn, induces the
downstream final goods producer to expand its output (due to the cost reduction) and leads to an improvement in domestic welfare. It is worth pointing out that the upstream rent-extraction effect takes place only if there exists intermediate inputs (or upstream industries) in the foreign country.

If we assume the second-order condition for welfare maximization to be satisfied, the optimal tariff on the final goods is derivable from Equation (11):

\[ \tau^* = \left[ f_q'(q^*) - f_q''(q^*) \right] q^* \]  

(13)

### 2.2 Importation of Raw Materials by the Domestic Country

In this section, we instead assume that the domestic country imports raw materials from the foreign country and uses them as intermediate inputs to produce the final goods domestically. Let \( \tau \) be the import tariff rate on raw materials. Under this setting, the profit function of the domestic final goods producer is specified as \( \pi_o(q, p) = [f_o(q) - p_1]q - F_o \). The first- and second-order conditions for this profit maximization are:

\[ \frac{d\pi_o}{dq} = f_1(q) - p_1 = 0 \]  

(14)

\[ \frac{d^2\pi_o}{dq^2} = \frac{f_2(q) - f_1(q)}{q} < 0 \]  

(15)

From Equation (14), the equilibrium quantity of final goods, \( \hat{q} \), is derivable as a function of \( p_1 \) and we have:

\[ \frac{d\hat{q}}{dp_1} = \frac{\hat{q}}{f_2(\hat{q}) - f_1(\hat{q})} < 0 \]  

(16)

indicating that a rise in the price of raw materials by the foreign firm lowers the output of the domestic firm. Next, substituting \( \hat{q} \) into the profit function of the foreign firm yields \( \pi_1 = (p_1 - \tau - c)\hat{q} - F_1 \). The first- and second-order conditions for profit
maximization by the foreign firm are obtainable, respectively, by:

\[ \frac{d\pi_1}{dp_1} = \left[ f_2(\hat{q}) - \tau - c \right] \frac{d\hat{q}}{dp_1} = 0 \]  

(17)

\[ \frac{d^2\pi_1}{dp_1^2} = \frac{1}{f_2'(\hat{q})} \left( \frac{d\hat{q}}{dp_1} \right)^2 > 0 \]  

(18)

It follows from Equation (17) that the equilibrium price of raw materials is derivable as a function of import tariff \( \tau \), i.e., \( \hat{p}_1 = p_1(\tau) \) with the following properties:

\[ \frac{dp_1}{d\tau} = \frac{f_1'(\hat{q})}{f_2'(\hat{q})} > 0 \]  

(19)

\[ \frac{d\hat{q}}{d\tau} = \frac{\hat{c}\hat{q}}{\hat{c}p_1} \frac{dp_1}{d\tau} = \frac{1}{f_2'(\hat{q})} < 0 \]  

(20)

These results contrast with those obtained in the previous section. When the final goods are produced in the foreign country, imposing an import tariff on the final goods by the domestic government causes the derived demand for, and the price of, the upstream raw materials to fall. However, when the production of the final goods takes place in the domestic country, imposing a tariff on the raw materials reduces only the net marginal revenue of the foreign raw materials supplier, but leaves the derived demand for upstream raw materials by the domestic final goods producer unchanged. As a result, imposing a tariff on raw materials leads to an increase in the price of raw materials, via Equation (19), which in turn raises the import costs of the domestic final goods producer, leading to a decline in the output of the final goods, via Equation (20).

The above analysis is illustrated in Figure 3, where \( f_0(q) \) and \( f_1(q) \) represent the demand function of the final goods and the raw materials, respectively; line cc is the pre-tariff unit cost. Under free trade, the equilibrium of raw materials is at \( E_1 \) where the price of raw materials is \( p_1^f \) and the quantity supplied is \( q^f \), while the
equilibrium of the final goods is at point $E_0$ with the price of the final goods, $p_0^f$.

Figure 3  The impacts of import tariffs on raw materials

Once the domestic government imposes a tariff on raw materials, the unit cost of the raw materials becomes $c + \tau$, then the equilibrium of the raw materials shifts from $E_1$ to $E_1^\tau$ whilst that of final goods shifts from $E_0$ to $E_0^\tau$. Therefore, the price of raw materials rises from $p_1^f$ to $p_1^\tau$ and the price of final goods rises from $p_0^f$ to $p_0^\tau$.

Next, when the production of final goods occurs in the domestic country, the
domestic welfare includes the profits of the domestic final goods producer in addition to both consumer surplus and tariff revenue:

\[ G(\tau) = s(q(p_1(\tau))) + \pi_0(q(p_1(\tau)), P_1(\tau)) + r(q(p_1(\tau)), \tau) \]  \hspace{1cm} (21)

Totally differentiating Equation (21) with respect to \( \tau \), letting it be equal to zero and then substituting Equations (19) and (20) into the resulting equation, we obtain the first-order condition for welfare maximization as follows:

\[ \frac{dG}{d\tau} = \left[ f_z'(\hat{q}) - f_0'(\hat{q}) - f_1'(\hat{q}) \right] \hat{q} + \tau \cdot \frac{d\hat{q}}{d\tau} = 0 \] \hspace{1cm} (22)

Under the satisfaction of the second-order condition, it follows from Equation (22) that the optimal tariff on raw materials is derivable as

\[ \hat{\tau} = \left[ f_0'(\hat{q}) + f_1'(\hat{q}) - f_z'(\hat{q}) \right] \hat{q} \] \hspace{1cm} (23)

### 2.3 The Taxation Principle for Vertically Related Industries: Import Tariffs or Import Subsidy?

Brander and Spencer (1984) considered a case where the domestic market is monopolized by a foreign firm (i.e., a vertically integrated firm), showing that whether the domestic government imposes an import tariff or subsidy on the foreign monopolist depends on the nature of the demand function of the final goods. In general, the domestic government should impose an import tariff; however, an import subsidy is the optimal policy if the demand for the final goods is highly convex. This is because when the demand function is highly convex, the demand function of the final goods might be more steeply sloped than the marginal revenue function so that a resulting rise in the price of the final goods outweighs the level of tariff, causing domestic welfare to fall.

So far, we have extended the analysis of Brander and Spencer (1984) to the case of upstream-downstream vertically related industries. In this section, we compare our
above results with those obtained by Brander and Spencer (1984).

First of all, Equation (13) tells us that the sign of the optimal import tariff on the final goods depends on the slope of the demand function for the final goods as well as the slope of the marginal revenue function for the raw materials. Alternatively, Equation (23) indicates that the sign of the optimal tariff on raw materials is dependent upon the slope of the demand function of the raw materials in addition to the aforementioned two slopes. These results seem to contrast sharply with those of Brander and Spencer (1984). We first establish the following propositions and then provide some economic interpretations by use of Figures 2 and 3.

**Proposition 2**  
The domestic government has an incentive to impose import tariff on final goods under the following situations:

(i) If upstream industries do not exist or importing industries are vertically integrated, then the domestic demand function for final goods is flatter than its marginal revenue function (i.e., Brander and Spencer’s result).

(ii) If there exists upstream industries, then the domestic demand function for final goods is flatter than the marginal revenue function of the foreign raw material supplier.

**Proposition 3**  
When there exists a vertically related industry with the domestic production of final goods, the domestic government has an incentive to impose an import tariff on the raw materials, if the sum of absolute values of the slopes of the demand function of the domestic final good and the demand function of the foreign raw materials is less than that of the marginal revenue function of the foreign raw materials.
From a perspective of social welfare, the imposition of an import tariff on upstream and/or downstream products by the domestic government yields tariff revenue which is, on the one hand, a welfare gain, but it causes prices of imported products to rise leading, on the other hand, to a welfare loss. If the resulting gain more than offsets the loss, an import tariff will raise domestic welfare; otherwise, an import subsidy could be the optimal policy. We can use Figure 2 to prove Proposition 2(ii). When imposing a tariff on final goods, the unit tariff revenue received by the domestic government is measured by \( t = (q' - q^*) \cdot |f''_2(q)| \), that is, AB in Figure 2; while an increase in the price of the final goods after imposing the tariff is indicated by \( (p_0' - p_0^*) = (q' - q^*) \cdot |f'_0(q)| \), namely \( CE_1 \). Whenever \( |f''_2(q)| > |f'_0(q)| \), this shows that the unit tariff revenue is greater than the increase in the price of the final goods, that is, \( t > (p_0' - p_0^*) \). This simply shows that the tariff revenue gain outweighs the consumer loss; therefore, the optimal tariff is positive. Next, Proposition 3 can be interpreted by the use of Figure 3. When imposing a tariff on raw materials, unit revenue is represented by \( \tau = (q' - \hat{q}) \cdot |f'_0(q)| \), but the extent of the rise in the prices of the final goods and the raw materials are measured by \( (p_0^* - p_0^*) = (q' - \hat{q}) \cdot |f'_0(q)| \) and \( (p_i^* - p_i^*) = (q' - \hat{q}) \cdot |f'_i(q)| \), respectively. If \( |f''_2(q)| > \left( |f'_0(q)| + |f'_0(q)| \right) \), indicating that unit revenue is greater than the sum of the increase in the prices of the final goods and the raw materials, so that the revenue gain from imposing a tariff on raw materials more than offsets the losses of consumer surplus and the final goods producer’s profit. In this case, the domestic government should levy a positive import tariff on the raw materials.

2.4 The Cause of Tariff Escalation
We are now in a position to compare the relative magnitude of a tariff on the final goods, \( t \), and on the raw material \( \tau \), and to examine whether there is an escalation in the tariff structure of the domestic country.

For the purpose of comparison, we first substitute the value of \( t^* \) in Equation (13) into Equation (22) to check its sign:

\[
\left. \frac{dG}{d\tau} \right|_{\tau = t^*} = \left\{ \left[ f''_2(\hat{q}) - f''_1(\hat{q}) - f'_1(\hat{q}) \right] \hat{q} + t^* \right\} \frac{d\hat{q}}{d\tau} \tag{24}
\]

In addition, we know from Equations (6) and (17) that as long as \( \tau = \hat{\tau} \), the solutions of these two equations should be equal; therefore \( q^* = \hat{q} \). Hence, using the definitions of \( f_1(q) \) and \( f_2(q) \), Equation (24) can be rewritten as:

\[
\left. \frac{dG}{d\tau} \right|_{\tau = t^*} = \left[ f'_1(\hat{q}) - f'_2(\hat{q}) \right] \frac{d\hat{q}}{d\tau} < 0 \tag{25}
\]

Assuming the second-order condition for welfare maximization is satisfied (i.e., \( G_{\tau\tau} < 0 \)), Equation (25) gives rise to \( t^* > \hat{\tau} \), that is, the optimal import tariff on the final goods must be larger than that on the raw materials. Therefore, the optimal tariff structure should fit the principle of tariff escalation. Accordingly, we can establish:

**Proposition 4** The optimal import tariff rates set forth by the domestic government rise with the level of processing of the goods. That is, tariff escalation is a characteristic of national tariff structure.

The economic reasoning behind Proposition 4 is provided as follows. Assume that an industry undertakes two stages of processing activities with upstream and downstream firms. The imposition of an import tariff on the final goods by the
domestic government extracts not only rent from the foreign final goods producer directly (i.e., the rent-extraction effect), but also rent from the foreign raw materials supplier indirectly (i.e., the upstream rent-extraction effect) by means of reducing the price of the raw materials through a decline in the derived demand for these inputs. Nevertheless, when the domestic government imposes an import tariff on raw materials, this policy can capture only rent from the foreign raw materials supplier with the absence of the upstream rent-extraction effect. Accordingly, the domestic government should impose a higher tariff rate on final goods than on raw materials in order to maximize its social welfare.

3. A Generalization

So far, we have assumed that a successive monopoly industry is characterized by two stages of processing including final goods and raw materials. In other words, the results derived in Section 2 apply to the situation where the markets for the final goods and the raw materials are monopolized. However, what about tariff escalation if the final good market is not perfectly monopolized? Moreover, in reality, the production or manufacturing process within an industry usually involves multi-stage processing. In this section, we extend our analysis to two interesting directions. Firstly, we examine whether tariff escalation is applied to an industry with \( n \)-stage processing. Secondly, we consider the final goods market to be duopolistic and see whether tariff escalation holds true for this market structure.

3.1 Tariff Structure with \( n \)-Stage Processing

Let us assume that the flow of the international division of labor is as shown in Figure 4. In this figure, let ‘0’ denote the last stage of processing in the industry, that is final goods, and 1, 2, \( \cdots \), \( n \) denote the upstream stages. Hence, the \( i^{th} \) intermediate input indicates that the distance from the final goods in the production process is \( i \) stages satisfying \( 0 \leq i \leq n \).
In addition, let $r$ be the processing stage whose product is imported by the domestic country, so products of the processing stages that are lower than $r$ are produced within the domestic country, while products whose stages are greater than $r$ are produced in the foreign country.\(^6\)

Let $H = \{0,1,\ldots,r-1\}$ be a set of domestic producers, $F = \{r,r+1,\ldots,n\}$ be a set of foreign producers, and define $t_r$ as the import tariff rate on the $i^{th}$ product by the domestic government. Then in this $n$-stage successive monopoly industry, the profit functions of domestic and foreign producers in different stages of processing are specified, respectively:

$$\pi_i = (p_i - p_{r+1})q - F_i, \quad i \in \{0,1,\ldots,r-1,r+1,\ldots,n-1\} \quad (26-1)$$

$$\pi_r = (p_r - p_{r+1} - t_r)q - F_r \quad (26-2)$$

$$\pi_n = (p_n - c)q - F_n \quad (26-3)$$

Applying similar procedures to those developed in the previous section, we can establish the following proposition.

**Proposition 5**  
With a successive monopoly industry including $n$-stage processing, the tariff structure set by the domestic government is characterized by the principle of tariff escalation.

Proof: see Appendix C.
3.2 Tariff Structure with a Duopolistic Final Goods Market

We have thus far considered a successive monopoly industry; however, an interesting question arises: does tariff escalation exist in other market structures? To answer this question, we will confine our analysis to the two stages of processing with a duopolistic final goods market. Assume further that a foreign raw materials producer supplies raw materials to both domestic and foreign firms to produce the final goods to be sold in the domestic market. Let $p_1^D$ and $p_1^F$ be the raw material prices charged to the domestic and foreign firms respectively; $q_D$ and $q_F$ the quantities of final goods sold by the domestic and foreign firms, respectively; $t$ and $\tau$ are again defined as import tariffs on the final goods and on the raw materials, respectively, by the domestic government.

For simplicity, we also assume the demand for the final goods in the domestic market to be linear: $p_o = a - (q_D + q_F)$.

Given these assumptions, the profits of the domestic and foreign firms producing final goods are specified, respectively, as:

$$\pi_o^D = (a - q_D - q_F - p_1^D)p_1^D - F_0^D$$ (27-1)

$$\pi_o^F = (a - q_D - q_F - p_1^F - t)p_1^F - F_0^F$$ (27-2)

where $F_0^D$ and $F_0^F$ are fixed costs of the domestic and foreign firms for the production of final goods, respectively.

Totally differentiating Equations (27-1) and (27-2) with respect to $q_D$ and $q_F$ and setting the resulting equations to zero, we can derive two reaction functions for these two final goods producers. Then solving these two reaction functions simultaneously yields the equilibrium outputs for both firms:

$$q_D = \left( a - 2p_1^D + p_1^F + t \right) / 3$$ (28-1)
Next, the foreign raw materials supplier has the following profit function:

$$\pi_i = (p_i^D - \tau)q_D + p_i^F q_F - c \cdot (q_D + q_F) - F_i$$

(29)

The first term on the right-hand side of Equation (29) captures total revenue accruing from the domestic final goods producer; the second term reflects total revenue accruing from the foreign final goods producer; the third and fourth terms represent variable and fixed costs, respectively.

Based on the concept of sub-game perfect equilibrium, we first of all solve the stage 2 equilibrium. Substituting Equation (28) into Equation (29) and then differentiating the resulting equation with respect to $p_i^D$ and $p_i^F$, respectively, we obtain:

$$p_i^D = \frac{(a+c)+\tau}{2}$$

(30-1)

$$p_i^F = \frac{(a+c)-t}{2}$$

(30-2)

Equation (30-1) demonstrates that imposing a tariff on raw materials increases the cost of raw materials and hence the price charged to the domestic final goods producer; Equation (30-2) indicates that the imposition of a tariff on the final goods reduces the derived demand for the raw materials, thereby lowering the raw material price charged to the foreign final goods producer.

In addition, substituting Equation (30) into Equation (28) yields:

$$q_D^* = \frac{(a-c)+t-2\tau}{6}$$

(31-1)

$$q_F^* = \frac{(a-c)-2t-\tau}{6}$$

(31-2)
It immediately follows from Equation (31) that the imposition of an import tariff on the final goods increases the output of the domestic final goods producer but reduces that of a foreign producer. The converse holds true for the imposition of an import tariff on the raw materials.

We now turn to the solution of the first stage in which the domestic government chooses the optimal tariffs on final goods and also on raw materials. Domestic welfare is defined as:

$$G = \left( p_0^0 \int_0^Q Q dQ - p_0(Q^*)Q^* \right) + \pi^D_0 + (tq^*_D + \pi^D_0)$$

(32)

where $Q^* = q^*_D + q^*_F$. Maximizing $G$ with respect to $t$ and $\tau$ yields the optimal tariffs, respectively, as follows:

$$t^* = \frac{5(a - c)}{13}$$

(33-1)

$$\tau^* = \frac{3(a - c)}{13}$$

(33-2)

It clearly follows from Equation (33) that $t^* > \tau^*$. 

**Proposition 6** When the domestic country imports both raw materials and final goods and when the domestic final goods market is duopolistic, the optimal tariff on final goods is higher than that on raw materials. Thus, tariff escalation occurs regardless of the market structure.

Proposition 6 implies that tariff escalation appears even if the final goods market is duopolistic. This result is no surprise! With both domestic and foreign firms in the final goods market, the optimal tariff on final goods is related to the effect of a tariff on the domestic firm in addition to its effect on the foreign firm. The nature of the interaction between the two firms becomes important. Most reasonable representations of this interaction are given by Equation (31). More specifically, when imposing a tariff on the
final goods, in addition to capturing the upstream rent-extraction effect, it now has the added feature that the profits of the foreign firm are shifted to the domestic firm (i.e., the profit-shifting effect). Nevertheless, a tariff on raw materials raises the production cost of the domestic firm and weakens its competitiveness with the foreign rival. Therefore, the domestic government should impose a higher tariff rate on the final goods than on the raw materials in order to maximize its welfare.

4. Extensions and Concluding Remarks

Many empirical studies indicate that the tariff structure of most countries (including both developed and developing countries) is characterized by the phenomenon of tariff escalation, which is referred to as a pattern of import tariffs that rise with the level of processing of the commodities imported. This characteristic has induced curiosity about its underlying theoretical foundation.

In this paper, an imperfectly competitive model of world trade is set up to provide a theoretical foundation to explain the causes of tariff escalation. Some striking results may be summarized as follows:

(i) The imposition of an import tariff on downstream goods by the domestic government can extract not only rent directly from foreign downstream goods producers, but also rent indirectly from foreign upstream producers through reducing the derived demand for intermediate inputs or raw materials thereby lowering the prices of the upstream intermediate products or raw materials. This may be termed the ‘upstream rent extraction effect’, which demonstrates that as the number of processing stages in the foreign country increases, the amount of rent captured by the foreign upstream producers rises and therefore a higher tariff rate is needed by the domestic government to extract the rent for domestic welfare maximization.
(ii) When the final good market is characterized as a Cournot duopoly, there is still tariff escalation. The reason is that imposing a tariff on final goods induces not only an upstream rent-extraction effect, but also the so-called profit-shifting effect. Alternatively, imposing tariffs on upstream intermediate inputs not only weakens the upstream rent-extraction effect, but also reduces the competitiveness of the domestic downstream firms. Hence, an importing country should impose a lower tariff rate on the intermediate inputs than on the final goods.

Based on these fundamental results, we can conclude that the upstream rent extraction effect generated by the imposition of an import tariff on downstream products is a key cause of tariff escalation.

To simplify our analysis, we have so far assumed that the production functions in question are fixed-coefficient technology. An interesting question naturally arises: if we allow the production functions to exhibit variable-coefficient technology or to be substitutable amongst factors of production, is this conducive to the existence of tariff escalation? Taking these two assumptions into consideration would complicate our analysis and therefore obscures the main focus of this paper; nevertheless, we can focus on the effects of upstream rent extraction. Firstly, if the production function is increasing (decreasing) returns to scale, the production cost of the downstream goods producer becomes lower (higher), thereby increasing (decreasing) its derived demand for upstream intermediate inputs. In this case, the extent of the reduction in the upstream intermediate input price is lower (higher). As a result, the upstream rent-extraction effect becomes weaker (stronger) and it is less (more) likely that tariff escalation will exist. On the other hand, if the production of final goods requires not only intermediate inputs but also, say, labor, then imposing a tariff on final goods leads its producer to use more labor relative to intermediate inputs through a substitution
effect so that the prices of intermediate inputs are reduced accordingly. This implies that the upstream rent extraction effect becomes more significant if the substitutability between factors of production is stronger. Hence, escalating tariffs are more likely to occur.

Next, this paper has set up a vertically related model of successive monopoly to explain why tariff escalation takes place. An interesting question naturally arises: What if the market structure is reversed to successive monopsony with the final goods producer takes a leadership position while the foreign raw material supplier is a follower? If this is the case, tariff escalation becomes even easily to occur. There will be more rent going to the final goods producer and it gives the domestic country an incentive to levy a higher tariff on the imports of the final goods so as to extract more rent from the final good producer.

As a final remark, empirical studies have indicated that developing countries’ tariffs are generally set at higher levels and incorporate a greater degree of escalation than tariffs in developed countries. This issue is interesting, but its theoretical intuition is still yet to be uncovered. In future work, it would be desirable to provide a reasonable explanation.
NOTES

1 Golub and Finger (1979) investigated the impacts of escalating tariffs on the industrial structure of exporting and importing countries. They pointed out that it should be possible to simultaneously reduce developing countries’ export taxes on primary goods and developed countries’ import tariffs on processed goods in such a way that processing will expand in the developing countries but not contract in the developed countries. As a result, liberalizing tariff escalation leads to an improvement in world welfare. Yeats (1984) showed that escalating tariffs may distort resource allocation. In order to evaluate this, one must check not only the effective protection rate but also the import demand elasticities of goods. Laird and Yeats (1987) examined the structure of developing country tariffs on key primary and processed commodities and showed that these nations’ tariffs are generally set at higher levels and incorporate a greater degree of escalation than import tariffs in developed countries. On the other hand, since primary products are much bulkier and heavier than processed ones per unit of value and since transportation is a source of substantial harm to the environment, Madeley (1992) and Hecht (1997) considered the relationship between escalating tariffs and the environment.

2 The assumption of fixed-proportion technology is employed quite popularly in analyzing vertically integrated industries, such as the semiconductor chip and the natural resource (For example, see Spencer and Jones (1991,1992)).

3 The characteristics of a successive monopoly industry will be sketched in Appendix A.

4 In this subsection, it is assumed that domestic firms do not produce the final goods. Thus, the purpose of imposing tariffs is to increase the production costs of foreign firms in order to extract some profits from them. This is what we refer to as the rent-extraction effect in the trade literature (see Brander and Spencer, 1981; 1984).

5 This result is quite similar to those of Brander and Spencer (1984) and Yang et al (2002), in which they found that when demand is highly convex, optimal policies pursued by governments may be reversed.

6 Based on this commodity ordering, we see that in a vertically related industry with an n-stage processing chain, the smaller the ordering number of products, the higher the level of processing.
REFERENCES


Appendix A

Characteristics of a Successive Monopoly Industry

Consider a final good market demand function $f$ of the form:

$$p_0 = f_0(q), \quad f_0' = \frac{df_0(q)}{dq} < 0, \quad f_0(0) < \infty$$

(A1)

where $q$ stands for the quantity demanded; and $p_0$ is the market price of the final good. Then the marginal revenue function of the monopolistic final good producer can be defined as:

$$f_1(q) = \frac{d[f_0(q) \cdot q]}{dq} = f_0(q) + f_0'(q)q$$

(A2)

Since the upstream raw material market is also monopolistic, the marginal revenue of the monopolistic final good producer, in turn, constitutes the derived demand for the upstream raw material. Hence, the marginal revenue function of the raw material supplier is derivable as:

$$f_2(q) = \frac{d[f_1(q) \cdot q]}{dq} = f_1(q) + f_1'(q)q$$

(A3)

For the purpose of illustration, if we assume that $f_0(q)$ is a linear demand, the slope of $f_1(q)$ is twice that of $f_0(q)$, whilst the slope of $f_2(q)$ is twice that of $f_1(q)$, as shown in Figure A-(1). In addition, Figure A-(2) reflects the pricing behavior of each producer in the industry. Let $c$ be the constant average unit cost of the raw material supplier, this supplier determines its price of raw materials, $p_1$, to maximize its profit, and $p_1$, in turn, constitutes the average cost of the final good. Consequently, the final good producer determines the equilibrium price and output at $p_0$ and $q^*$, respectively. It should be noted that our basic results established in this Appendix can be carried over to more general forms of demand function, as illustrated in Section 3 of the text.
Figure A-(1)  Linear Demand in a Successive Monopoly Industry

Figure A-(2)  Pricing Decisions of A Successive Monopoly Industry
Appendix B

Proof of Proposition 1

Using Equations (2) and (3) as specified in the text, we have \( \frac{f_2'(q)}{f_1'(q)} = 2 + \delta_1 \), where

\[
\delta_1 = \frac{f_2'(q)q}{f_1'(q)}
\]
is the elasticity of the slope of the inverse demand function of raw materials. In fact, \( \delta_1 \) measures the curvature of the raw material demand function: the demand for raw materials is concave if \( \delta_1 > 0 \); linear if \( \delta_1 = 0 \); and convex if \( \delta_1 < 0 \).

Thus, Equation (8) can be rearranged as follows:

\[
\frac{\partial p_1}{\partial t} = -\left[ 1 - \frac{f_1'(q)}{f_2'(q)} \right] = -\frac{(1 + \delta_1)}{(2 + \delta_1)}
\]

(B1)

The second-order condition for profit maximization by the raw materials producer requires \( f_2'(q) = 2f_1'(q) + f_1'(q)q = f_1'(q)(2 + \delta_1) < 0 \), implying that \( (2 + \delta_1) > 0 \). Thus, the sufficient condition for \( \frac{\partial p_1}{\partial t} < 0 \) requires \( (1 + \delta_1) > 0 \) or \( \delta_1 > -1 \).

Moreover, if the demand function of the final goods is assumed to be twice differentiable, \( \delta_1 \) can be rewritten as:

\[
\delta_1 = \frac{f_2'(q)q}{f_1'(q)} = \frac{3f_0'(q)q}{2f_0'(q) + f_0'(q)q} = \frac{3\delta_0}{2 + \delta_0}
\]

(B2)

where \( \delta_0 = \frac{f_0'(q)q}{f_0'(q)} \) is the elasticity of slope of the demand for the final good. In addition, the second-order condition for profit maximization by the final goods producer requires:

\[
\frac{d^2\pi_0}{dq^2} = f_1'(q) = 2f_0'(q) + f_0'(q)q = f_0'(q)(2 + \delta_0) < 0.
\]

This simply implies that the denominator of Equation (B2) is positive, \textit{i.e.}, \( (2 + \delta_0) > 0 \).
Next, substituting Equation (B2) into Equation (B1) yields:

$$\frac{\partial p_l}{\partial t} = \frac{-2}{(2 + \delta_1)(2 + \delta_o)}(1 + 2\delta_o) \quad \text{(B3)}$$

Since \((2 + \delta_1) > 0\) and \((2 + \delta_o) > 0\), it follows that \(\frac{\partial p_l}{\partial t} < 0\) if \((1 + 2\delta_o) > 0\) or \(\delta_o > -\frac{1}{2}\).
Appendix C

Proof of Proposition 4

Rewrite the profit functions of the domestic and foreign firms producing the $i^{th}$-stage good ($i.e., \text{good } i$), respectively, as follows:

\[ \pi_i = (p_i - p_{i+1})q - F_i, \quad i \in \{0,1,\ldots,r-1,r+1,\ldots,n-1\} \]  \hspace{1cm} (C-1)

\[ \pi_r = (p_r - p_{r+1} - t_r)q - F_r \]  \hspace{1cm} (C-2)

\[ \pi_n = (p_n - c)q - F_n \]  \hspace{1cm} (C-3)

Assume once again that one unit of input is required to produce one unit of output. The relationship between market demand and marginal revenue functions facing the $i^{th}$ good producer can be defined as:

\[ f_{i+1}(q) = \frac{\partial(f_i(q)\cdot q)}{\partial q} = f_i(q) + f_i'(q)q, \quad i \in (H \text{ and } F) \]  \hspace{1cm} (C-4)

where $f_{i+1}(q)$ is the marginal revenue of the $i^{th}$ good producer; $f_i(q)$ is the market price of the $i^{th}$ good. Because the industry structure is successive monopoly, the monopolistic upstream supplier of the $i^{th}$ good (that is, the $(i+1)^{th}$ good producer) regards $f_{i+1}(q)$ as its average revenue function. In other words, $f_{i+1}(q)$ represents market demand for the $(i+1)^{th}$ good. According to the above definition, the first-order conditions for profit-maximization of the domestic and the foreign firms are given, respectively, by:

\[ \left[ f_{i+1}(q^*) - p_{i+1} \right] \frac{\partial q}{\partial p_i} = 0, \quad i \in H \]  \hspace{1cm} (C-5)

\[ \left[ f_{i+1}(q^*) - p_{i+1} - t_i \right] \frac{\partial q}{\partial p_i} = 0, \quad i \in \{r,r+1,\ldots,n-1\} \]  \hspace{1cm} (C-6)

\[ \left[ f_{i+1}(q^*) - c - t_r \right] \frac{\partial q}{\partial p_i} = 0, \quad i = n \]  \hspace{1cm} (C-7)
Assume the second-order conditions for profit maximization to be met, that is,
\[ f'_{i+1}(q^*) \left( \frac{\partial q}{\partial p_i} \right)^2 < 0, \quad i \in H \text{ and } F. \]
Following the concept of sub-game perfect equilibrium, we can derive the equilibrium product price at each stage and the equilibrium output of the final goods in the implicit form as:
\[ p_i^* = p_i(p_{i+1}), \quad i \in H \quad (C-8) \]
\[ p_i^* = p_i(p_{i+1}, t_r), \quad i \in F \quad (C-9) \]
\[ q^* = q(p_1(p_2(\ldots (p_r(p_{r+1}(p_{r+2}(\cdots p_{n-1}(p_n(t_r), \ldots, t_r), t_r), t_r), \ldots)))) \quad (C-10) \]
Moreover, some comparative static results are derivable as:
\[ \frac{dq^*}{dt_r} = \frac{-q^*}{[f_{n+1}(q^*) - f_{n+2}(q^*)]} \quad (C-11) \]
\[ \frac{dp_r^*}{dt_r} = \frac{f_r(q^*) - f_{r+1}(q^*)}{[f_{r+1}(q^*) - f_{r+2}(q^*)]} \quad (C-12) \]
\[ \frac{dp_i^*}{dp_{i+1}} = \frac{f_i(q^*) - f_{i+1}(q^*)}{[f_{i+1}(q^*) - f_{i+2}(q^*)]}, \quad i \in (H \text{ and } F) \quad (C-13) \]
\[ \frac{dp_i^*}{dt_r} = -1 + \frac{f_i(q^*) - f_{i+1}(q^*)}{[f_{i+1}(q^*) - f_{i+2}(q^*)]}, \quad i \in \{ r+1, r+2, \ldots, n \} \quad (C-14) \]
Now, the domestic welfare function includes consumer surplus, the profits of domestic producers at each stage and the tariff revenue of the \( r^{th} \) imported good. Thus, we have:
\[ G(t_r) = u(q^*) - \pi_0 q^* + \sum_{i=0}^{r-1} \pi_i + t_r q^* \quad (C-15) \]
Maximizing \( G \) with respect to \( t_r \) yields the first-order condition:
\[ \frac{dG}{dt_r} = \left( f_0(q^*) - f_{r+1}(q^*) \right) - \left( f_{n+1}(q^*) - f_{n+2}(q^*) \right) + t_r \frac{dq^*}{dt_r} = 0 \quad (C-16) \]
Assuming the second-order condition to be satisfied, and solving from Equation (C-16) for the optimal tariff, we obtain:

\[ t_r^* = \left[ f_{n+1}(q^*) - f_{n+2}(q^*) \right] - \left[ f_0(q^*) - f_{r+1}(q^*) \right] \]  \hspace{1cm} (C-17)

To prove the existence of tariff escalation, we shift inward the production of the \( r^{th} \) product from the foreign country to the domestic country. Under these circumstances, the product imported by the domestic country becomes the \((r+1)^{th}\) good. Following the similar procedures as above, we can solve for the optimal tariff on the \((r+1)^{th}\) product as:

\[ t_{r+1}^* = \left[ f_{n+1}(\hat{q}) - f_{n+2}(\hat{q}) \right] - \left[ f_0(\hat{q}) - f_{r+1}(\hat{q}) \right] \]  \hspace{1cm} (C-18)

where \( \hat{q} \) is the equilibrium output of the domestic final good after the production of the \( r^{th} \) good is shifted inward. To compare \( t_r^* \) with \( t_{r+1}^* \), we set the value of \( t_r \) in Equation (C-16) as \( t_{r+1}^* \) and then evaluate its sign as follows:

\[ \left. \frac{dG}{dt_r} \right|_{t_r = t_{r+1}^*} > 0 \]  \hspace{1cm} (C-19)

Given the satisfaction of the second-order condition, i.e., \( \frac{d^2G}{dt_r^2} < 0 \), Equation (C-19) simply implies that \( t_{r+1}^* < t_r^* \).

In other words, the optimal tariff on the \( r+1 \) imported good is less than that on the \( r^{th} \) imported good. It warrants note that to prove \( t_{r+1}^* < t_r^* \), we let the value of \( r \) fall within the range of 0 and \( n \) (i.e., \( 0 \leq r \leq n \)) without any other constraints on \( r \). So we can derive the following result by the induction:

\[ t_0^* > t_1^* > \cdots > t_{n-1}^* > t_n^* \]  \hspace{1cm} (C-20)