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by
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ABSTRACT

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Master of Philosophy

The internationalization of production requires each multinational firm to determine the local content rate for his product that is made and sold in a foreign country. In this thesis, we investigate the local content rate and pricing decisions for a multinational firm who competes with a local firm in a market without and with a local content requirement (LCR). We develop and solve a two-stage decision problem in which the multinational firm determines his optimal local content rate and the two firms then make their pricing decisions. Our analytical results show that the multinational firm sets a lower local content rate, when the competition between the product of the multinational firm and that of the local firm intensifies, consumers' valuation is more strongly affected by the quality of the product of the multinational firm, and the reduction in consumers' marginal utility is smaller. We also show that an LCR may induce the multinational firm to increase local content rate and transfer benefits from the multinational firm to the local firm. However, a very high LCR threshold will cause the multinational firm to adopt a low local content rate, resulting in a low demand and profit for both the multinational firm and the local firm.

Key words: Local content rate; local content requirement; quality; competition; duopoly market.

DECLARATION

I declare that this is an original work based primarily on my own research, and I warrant that all citations of previous research, published or unpublished, have been duly acknowledged.

SIGNED

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1 Introduction

With the rapid globalization and development of the world economy, nowadays there are a large number of multinational firms making direct investment in foreign countries. A vital decision for each multinational firm is to determine the local content rate for its product that are made and sold in a foreign country. Actually, most multinational firms in practice have paid increasing attention to the decision problem for the local content rate. In March 2012, Volkswagen (India) [30] released its plan for increasing its local content rate from 75% to 90%, in order to reduce its operating cost. In 2012, Toyota Kirloskar Motor (India) [19] planed to increase its local content rate for the Etios brand from 70% to 90%, and other components are imported from Japan. In December 2011, Guangzhou Fiat (China) [6] announced that the firm would raise the local content rate for C-medium automobiles to 90%, in order to greatly reduce production costs and succeed in mass production.

The local-content decision is important mainly because the acquisition cost of an imported component usually differs from that of a locally purchased one, and such a decision significantly influences the multinational firm's profit. A multinational firm has to pay the purchasing cost, the transportation cost, and the tariff for an imported component, whereas the firm mainly pays purchasing cost for a local component. Note that although the acquisition cost of an imported component includes an additional transportation cost and a tariff, it may be larger than or may be smaller than the acquisition cost of a local component. This largely depends on the difference between the technological contents in the imported and the local components. In a developing country, local components at a high technological level might be expensive due to the inferior technological capability of local components producers; however, local components at a low technological level could be very cheap. According to Veloso [33], in an OEM car assembly plant located in a developing region, most components—such as powertrain and chassis—sourced from a foreign market (e.g., the France-Benelux Scenario) with a high production volume are cheaper than the components that are locally produced, while the body subsystem is the only locally sourced component that is cheaper than an imported one. Veloso ascribed the result to the fact that the production of different subsystems relies on different proportions of manufacturing efficiency, labor, and capital. Thus, for some components, the reduction in the wage and that in the transportation cost are not enough to offset the increase in the unit production cost.

In addition to the cost, the quality is also important to the local-content decision. The technology owned by a developing country is usually less advanced than that owned by a developed country. For a specific industry, among developed countries there are also differences in the level of sophistication. Multinational firms originating in countries with advanced and mature technology in a specific industry often make foreign direct investment in countries that are less sophisticated in the industry. For example, a number of giant multinational firms with advanced and mature technologies—e.g. BMW (Germany), Volvo (Switzerland), GM (U.S.), Toyota (Japan), and Nissan (Japan)—have made FDIs in China. Chinese automakers, however, seldom invest in these developed countries. They made FDIs in other countries that are less sophisticated in auto industry. For instance, Chery invests in Egypt, Iran, Russia, Malaysia, Uruguay, Thailand, Vietnam, Ukraine and Brazil.

Thus, in line with the practice, we mainly consider the situation that a multinational firm's parent country possesses more advanced technology than the host country does. And thus components imported by a multinational firm often contain a higher technology and can be thus used to make products of a higher quality. A multinational firm usually sets specific positioning for its product. Because local technology may not satisfy the firm's requirement and the firm does not intend to reveal cutting-edge technology to the host country, the firm should import some key components. Actually, multinational firms' local content rates seldom reach 100%, a phenomenon that is especially true for the production of high-tech products such as sedans and computers. Furthermore, the local content rate may directly affect a product's quality or influence consumers' belief on the product's quality. In 2004, BMW Brilliance (China) found that customers were afraid that the enhanced local content rate may harm the quality of BMW cars, especially for high-end cars, and it seems that such concern could not be alleviated easily [13].

In this thesis, we focus on the local content rate decision for multinational firms. Motivated by the fact that the competition between two firms widely exists in practice, we consider a duopoly setting in which a multinational firm and a local firm compete in a market, and determine the impact of the competition and some other key factors on the multinational firm's local content decision. When the multinational firm's local content rate varies, the quality of his product may also change, which may induce the firm to change the price for his product. As a response, the local firm may also change the price of her product. Therefore, the prices for both firms' products should be considered as two decision variables. For the duopoly analysis, we analyze a two-stage decision problem, in which the multinational firm first makes his optimal decision on the local content rate, and the multinational and the local firms then make their pricing decisions with no communication ("simultaneously").

Since in reality, most of developed countries (e.g., Japan, Germany, the United States) do not impose any local content requirements on the products that are made by multinational firms, we first analyze the competition assuming that there is no local content requirements in the local market. For this case, we find the two firms' price in Nash equilibrium and the optimal local content rate for the multinational firm. Our analysis shows that, to determine the optimal local content rate, the multinational firm should trade off the cost and the quality of his product, and consider the product substitutability between the product of the multinational firm and that of the local firm, the sensitivity of consumers' valuation to product M's quality, and the slope of reduction in marginal utility of two firms' products.

We find that the multinational firm sets a lower local content rate when the competition between the products of the multinational and the local firms is higher, consumers' valuation is more strongly affected by the quality of the multinational firm's product, and the reduction in consumers' marginal utility is smaller. Moreover, the demand for the multinational firm's product and profit decrease if consumers are more sensitive to the quality of the multinational firm's product or the tariff rate is increased. In addition to our analytical results, we also perform numerical experiments and find a number of managerial insights regarding the impact of the product substitutability the two firms' decisions and profits.

In practice, many developing countries impose the local content requirements (LCRs) to "force" multinational firms in their countries to improve the firms' local content rates and thus increase the profitability of local suppliers. Under an LCR, a multinational firm absorbs a penalty tariff if the local content rate of the firm's product is smaller than the required minimum local content rate—which can be simply regarded as the LCR threshold. For the automobile industry many governments have implemented the LCRs. In December 2010, Russia raised the LCR threshold from 30 to 60 percent for foreign automakers to enjoy duty-free import of components [32]. In September 2011, the Brazilian government announced an up to 30% increase in the industrial products tax on cars with less than 65% locally-manufactured or other Mercosur states sourced components [12]. Other examples include South Africa (55% for all vehicles), Argentina (70% for all vehicles), Colombia (33% for some categories of vehicles), Chile (13% for vehicles assembled from completely knocked-down kits and 3% for those assembled from semi-knocked down kits), and Pakistani (the LCR threshold varies for different types of vehicles), etc. [32] In a survey conducted by the United States Commerce Department, 83 percent of private sector respondents believed that their industries are more or less affected by the LCRs [26].

According to the above, in this thesis we also examine the duopoly problem under a local content requirement with a threshold and a penalty tariff rate. For such a problem, we also compute the Nash equilibrium-characterized prices for two firms, and obtain the optimal local content rate for the multinational firm. From our analytical and numerical discussions, we learn that an LCR policy may induce the multinational firm to increase his local content rate and move benefits from the multinational firm to the local firm. However, a very high threshold for the LCR policy may cause the multinational firm to adopt a low local content rate, resulting in a low demand and profit for both the multinational firm and the local firm.

The remainder of the thesis is organized as follows: In Section 2, we review major publications that are closely related to this thesis to show the originality of our problem. In Section 3, we consider a two-stage game problem in which there is no LCR on the multinational firm. We compute the optimal local content rate decision and two firms' pricing decisions in Nash equilibrium. In Section 4 we investigate the impact of important parameters on the multinational firm's optimal local content rate, the demands for two products and two firms' profits. In Section 5, we investigate our two-stage duopoly problem under an LCR with a threshold and a penalty tariff rate, determine the two firms' decisions under the setting and perform sensitivity analysis to examine the impact of the LCR threshold and the penalty tariff rate on the two firms. The thesis ends with a summary of major findings in Section 6.

2 Literature Review

A number of papers have investigated the price and quality competition between two firms. Wauthy [34] considered a two-stage game where multiple firms first decide the quality level of their products simultaneously and then compete in price simultaneously. The author found that the decisive factor for the extent of product differentiation is the distribution of consumers' taste. Banker et. al. [3] examined the impact of competition on Nash equilibrium-based quality levels when the competition intensity is interpreted as the number of firms in the market, the extent of cooperation among firms in setting quality levels, or the amount of intrinsic demand. They found that the equilibrium quality level is affected by many factors. For instance, if price responsiveness is relatively low, then the equilibrium strategy for a weaker firm—who faces a relatively small intrinsic demand but has a relative cost advantage in quality improvement—is to select a higher quality level than the dominant firm. Brekke et. al. [4] showed that the income effects on the demand side and the cost dependence between output and quality on the supply side mainly determine the impact of competition on quality. In this thesis, assuming the quality level of the local firm's product as a constant, we focus on the multinational firm's decision on his local content rate, which can affect the firm's product quality.

The local content-related studies mostly appear in the economics literature, and they mainly concern (i) the impact of the LCRs on the macroeconomic production and welfare, and (ii) the optimal LCR threshold for policy makers. Some publications are concerned with the competition between multinational firms and local firms, which produce substitutable products in a competing market involving two or more firms. Davidson et al. [8] analyzed the competition in a duopoly market, and concluded that both the LCRs and the export requirements can reduce the world-wide output, the world-wide welfare, and the source country's welfare. Lopez-de-Silanes et al. [9] focused on the impact of the LCRs on the condition under which a multinational firm depends more on the imported components than on the local components, whereas the local firm is more dependent on the local components. Lahiri and Ono [23] considered the scenario that a government uses both a profit tax and an LCR as two policy instruments to affect the FDI under the assumption that the number of domestic firms is constant. Lahiri and Ono [24] investigated a competitive case in which multinational firms located in a country and export all of their products to another country where the multinational firms compete with a domestic firm. Lahiri and Mesa [22] examined the volatility of the exchange rate in both multinational firms' parent countries and an host country where those firms operate, and analyzed a problem in which the multinational firms and the firms in the host country compete in a third country where no firm makes the products.

From our literature review we learn that, regarding the competition between multinational firms and local firms—which produce substitutable products in a competing market involving two or more firms, most extant publications in the economics field assumed that a multinational firm's local content rate is always equal to the required local content rate, which represents the minimum proportion of the components that must be purchased from local suppliers. Accordingly, it has been commonly assumed that the total acquisition cost of components produced in the local market with the LCRs is always higher than the total cost of imported components; see, e.g., Davidson et al. [8], Lahiri and Ono [23] and [24], and Lahiri and Mesa [22]. However, in practice, some imported components may be cheaper than the locally sourced ones. Thus, in this thesis, for generality, we do not assume that all imported components are cheaper than local ones.

The publications reviewed above also assumed that multinational firms compete with the producers of substitutable products in the Cournot setting. However, except for raw materials, two or more products made by different firms are seldom homogeneous. For example, BMW has never set the same price as Xiali's, which is an old Chinese automobile brand. In the thesis, we also consider the price competition rather than the quantity competition.

Some OM literatures investigate the impact of the tax on a firm's sourcing decision. Horst [16] examined the effects of the tariff and the profit tax on a monopolistic firm's production and exporting decisions. Hsu et al. [17] found the optimal production and distribution decisions for a multinational firm under a set of China's export-oriented policies; under the policies, an exported product and its imported materials and components are exempted from tariffs and value-added taxes. Avittathur et al. [2] investigated the decision of distribution centers under the differential sales tax structure in the Indian central tax system.

To the best of our knowledge, there are only a few OM publications concerning the effect of the LCRs on the manufacturing system. Munson and Rosenblatt [29] developed a single plant model to analyze the purchasing allocation problem under the LCRs, and examined the impact of different LCR-related schemes and obtained the following findings. First, under a value-based LCR scheme, firms should purchase local components with a low relative cost penalty (i.e., local cost/foreign cost), no matter whether the calculation of the local content is based on the value of the final product or on the sum of all components' acquisition values. Secondly, under a physical content protection scheme, firms should buy local components with a low absolute cost penalty (i.e., local cost−foreign cost). Li et al. [25] solved material sourcing problems under an ROO ("Rules of Origin") value-added rule, and extended Munson and Rosenblatt's model [29] by allowing some products to be dissatisfied with the LCRs and incorporating the influences of transportation costs that differ in different countries. To analyze multinational firms' sourcing pattern, Li et al. [25] assumed that a multinational firm always keeps its profit element unchanged when the firm chooses a local content rate.

Kouvelis et al. [20] focused on a multinational firm's international location decisions rather than local content rate decision, even though the impact of the LCRs was considered. Moreover, the authors incorporated subsidies, trade tariffs, and taxation issues to investigate the trade-offs in the design of global facility networks. Guo et al. [15] analyzed a multi-stage production sourcing problem, considering production costs and tariff concessions arising from a value-added local content scheme.

There are three main differences between this thesis and extant OM publications. First, extant OM publications did not consider the competition between a multinational firm and a local firm, which will be investigated in the thesis. Secondly, extant OM publications did not incorporate the impact of a firm's local content rate on its product's quality and the demand for the product; but, we will investigate such an impact in the thesis. Thirdly, extant OM publications built mixed integer programming models, whereas we will consider a two-stage decision problem involving a "simultaneous-move" game and an optimal decision problem.

Different from the aforementioned papers, this thesis will study local content rate from the point of view of a multinational firm rather than a host country, and consider the competition between the multinational firm and a local firm. We analyze a two-stage game to derive the optimal local-content decision for the multinational firm and pricing decisions for both the multinational firm and the local firm. Since LCR is applied for some countries but not for others, we consider the game in both situations. In addition, the thesis incorporates the impact of local content rate on the quality of the product of the multinational firm. This significantly distinguishes the thesis from the existing literature.

3 The Two-Stage Model and Analysis with No Local Content Requirement

In this section the multinational firm and the local firm compete in a country where there is no requirement on a minimum local content of the multinational firm's product. Note that, in reality, most of developed countries (e.g., Japan, Germany, the United States) do not impose any local content requirements on the products that are made by multinational firms. In such a competitive setting, the multinational firm makes decisions on the sale price p and the local content rate of his product α—which is the percentage of the value of local components in the product, and the local firm determines the sale price of her product $\hat{p}$. We learn from the practice that most multinational firms' local-content rate decisions are unlikely to change as frequently as their pricing decisions, which may be attributed to the operational cost arising from component changes. Accordingly, for such a competition we investigate the following two-stage decision problem: In the first stage, the multinational firm maximizes his profit to determine an optimal local content rate (i.e., the optimal percentage of the value of the local components in the firm's product). In the second stage, the multinational and the local firms make their pricing decisions "simultaneously" (with no communication).

Remark 1 We use the backward induction approach to solve our two-stage problem. That is, we adopt the following three steps:

1. In the first step, given the value of the local content rate α, we solve a "simultaneous-move" game where the multinational firm and the local firm maximize their profits to determine the Nash equilibrium-characterized prices $p^N(\alpha)$ and $\hat{p}^N(\alpha)$, respectively.

2. In the second step, we substitute $p^N(\alpha)$ and $\hat{p}^N(\alpha)$ into the multinational firm's profit function and maximize it to find the optimal local content rate α^*.

3. In the third step, we compute the two firms' pricing decisions $p^N(\alpha^*)$ and $\hat{p}^N(\alpha^*)$ in Nash equilibrium. ■

3.1 Demand Functions

Prior to solving our two-stage problem, we develop the demand functions for the products of the multinational and the local firms, which are simply called "M" and "L," respectively. Since in practice each consumer can buy one or more of product M, product L, or both, we need to analyze a consumer's purchasing decision problem and derive the demand function for each product. In this paper, the two firms are assumed to serve a market involving a finite number of consumers whose utilities are quasilinear and concave. As Engl and Scotchmer [11] showed, under the above assumption, there must be a "representative consumer," whose utility function can be viewed as an aggregate utility function and then used to derive the aggregate demand. Note that the representative consumer's utility function may or may not be quasilinear; see, e.g., Singh and Vives [31]. The analysis of a representative consumer's utility for the aggregate demand has been widely used in the operations management field; see, e.g., Arya, Frimor, and Mittendorf [1], Chen, Vakharia, and Alptekinoğlu [5], Christen [7], Goyal and Netessine [14], Kurtuluş and Toktay [21], Lus and Muriel [27], etc.

Next, we construct a representative consumer's net utility function and maximize it to find the aggregate demand function for each product. In practice, consumers usually take the quality into account when they make purchasing decisions, which reflects the fact that multinational firms' decisions on local content rates are related to the desired quality levels of their products. Therefore, we should consider how the local content rate of M influences consumers' utility by affecting the product M's quality in the representative consumer's utility function. As discussed in Section 1, we focus on the practice that a multinational firm's parent country possesses more advanced technology than the host country does. Accordingly, we assume that components imported by the multinational firm contain a higher technology and thus can be used to manufacture a product of a higher quality. In equation 1, $g(\alpha)$ reflects the reduction in M's quality. Specifically, when the multinational firm's local content rate is increased from zero (i.e., all components are imported) to α, the quality level of product M is reduced by $g(\alpha)$ and the representative consumer's utility from each unit of product M is decreased by $\theta g(\alpha)$, where $\theta \geq 0$ denotes the degree to which the customer concerns the quality level of a product. Consumers may under- or over- react to the change of the product's quality. Therefore, the value of θ could be very small. For instance, if the consumer's preference on a product is its brand, then his or her valuation on the product may not be sensitive to the quality. The value of θ may be larger than 1. For example, if the consumer cares a lot about the local content rate of product M, then his or her belief in the quality may be greatly affected by the local content rate; as a result, his or her valuation on the product may dramatically decrease even though the quality of the product M just slightly reduces when the local content rate increases. When the product M is fully made of imported components, there is no quality decrease in the product M, and thus $g(0) = 0$.

In our paper the quality level of product L is constant because the product is independent of the local content rate. Jerath and Zhang [18] stated that consumer's utility drawn from a service is affected by the quality of another service. Similarly, we assume that a higher quality level of M can result in a decrease in the consumer's utility drawn from consuming product L. The assumption can be shown through the fact that when laptops with higher-end CPU are introduced into market, existing laptops depreciate. Such an impact is reflected by the *substitutability* index $\mu \in (0, 1)$ between products M and L. For simplicity, we call μ the M-L substitutability index. It then follows that, when the local content rate for product M is increased from zero to α, the representative consumer's utility from a unit of product L is increased by $\mu\theta g(\alpha)$. Denoting the aggregate demands of products M and L by D and $\hat{D}$, we can compute the representative consumer's quality-related utility as,

$$U_1(D, \hat{D}) \equiv -\theta g(\alpha)D + \theta\mu g(\alpha)\hat{D}. \tag{1}$$

Remark 2 We learn from practice that multinational firms' foreign direct investments (FDI) mainly stem from the important fact that the firms desire to expand their global market shares using advanced and mature technologies. This means that, in general, the imported components that are produced with advanced technologies have a higher quality level than the local components. Thus, as the quality level of a final product is largely dependent on the quality levels of its components, increasing the value of the local content rate α will result in the replacement of more imported components with local ones and hence the reduction in the quality level of the final product. In addition, we recall from Section 1 that, before buying a product, a consumer may have a perceived evaluation on the quality of the product. That is, as α increases, even if the product's real quality does not change, the consumer may still reduce the quality level of the product.

From the above argument, we conclude that as a result of increasing the local content rate α, the reduction in the quality level $g(\alpha)$ increases, i.e., $\partial g(\alpha)/\partial\alpha > 0$, which means that the representative consumer's valuation on product M decreases. Moreover, $\partial^2 g(\alpha)/\partial\alpha^2 > 0$ for $\alpha \in (0, 1)$, which indicates that the marginal reduction in the quality level of product M is an increasing function of α. ■

Similar to Dixit [10] and Singh and Vives [31], we write the representative consumer's quality-independent utility function in a quadratic and strictly concave form, i.e., $U_2(D, \hat{D}) = \delta D + \hat{\delta}\hat{D} - (\kappa D^2 + \hat{\kappa}\hat{D}^2 + 2\mu D\hat{D})/2$, where δ, $\hat{\delta}$, κ, and $\hat{\kappa}$ are positive parameters. Using the above, we can calculate the consumer's net utility function as the total utility [i.e., $U_1(D, \hat{D}) + U_2(D, \hat{D})$] minus the consumer's purchase cost $pD + \hat{p}\hat{D}$, where p and $\hat{p}$ denote the unit price of product M and that of product L, respectively.

That is,

$$
\begin{aligned}
U(D,\hat{D}) &= U_1(D,\hat{D}) + U_2(D,\hat{D}) - pD - \hat{p}\hat{D} \\
&= (\delta - \theta g(\alpha))D + (\hat{\delta} + \theta\mu g(\alpha))\hat{D} - \frac{1}{2}(\kappa D^2 + \hat{\kappa}\hat{D}^2 + 2\mu D\hat{D}) \\
&\quad -pD - \hat{p}\hat{D}, \qquad (2)
\end{aligned}
$$

which is strictly concave when the following three inequalities are satisfied.

$$
\frac{\partial^2 U(D,\hat{D})}{\partial D^2} = -\kappa < 0, \quad \frac{\partial^2 U(D,\hat{D})}{\partial \hat{D}^2} = -\hat{\kappa} < 0,
$$
$$
\frac{\partial^2 U(D,\hat{D})}{\partial D^2} \times \frac{\partial^2 U(D,\hat{D})}{\partial \hat{D}^2} - \left[\frac{\partial^2 U(D,\hat{D})}{\partial D \partial \hat{D}}\right]^2 = \kappa\hat{\kappa} - \mu^2 > 0.
$$

Note that Equation (2) is similar to the utility function developed by Jerath and Zhang [18]; and, the local content rate influences the intrinsic demand of a product but does not affect the slope of consumers' utility. By analyzing important parameters in the model, we can obtain some managerial insights. For instance, the substitutability index μ can be used to reflect the intensity of competition. As μ increases, the two firms' products become more similar, and the competition between the two firms thus is fiercer. Parameters κ and $\hat{\kappa}$ represents the slopes of reduction in consumers' utility for product M and L, respectively.

Assuming that $\kappa > 0$, $\hat{\kappa} > 0$, and $\kappa\hat{\kappa} - \mu^2 > 0$, we can solve the first order conditions (i.e., $\partial U(D,\hat{D})/\partial D = 0$ and $\partial U(D,\hat{D})/\partial \hat{D} = 0$) to obtain the optimal demands maximizing $U(D,\hat{D})$ in (2) as,

$$
\begin{aligned}
D^* &= \frac{\hat{\kappa}\delta - \mu\hat{\delta}}{\kappa\hat{\kappa} - \mu^2} - \frac{\hat{\kappa}}{\kappa\hat{\kappa} - \mu^2}p + \frac{\mu}{\kappa\hat{\kappa} - \mu^2}\hat{p} - \frac{\hat{\kappa} + \mu^2}{\kappa\hat{\kappa} - \mu^2}\theta g(\alpha), \qquad (3) \\
\hat{D}^* &= \frac{\kappa\hat{\delta} - \mu\delta}{\kappa\hat{\kappa} - \mu^2} - \frac{\kappa}{\kappa\hat{\kappa} - \mu^2}\hat{p} + \frac{\mu}{\kappa\hat{\kappa} - \mu^2}p + \frac{\mu(1+\kappa)}{\kappa\hat{\kappa} - \mu^2}\theta g(\alpha). \qquad (4)
\end{aligned}
$$

In practice, the price of a product usually has a higher impact on the demand for the product than the price of the other product. This implies that, in (3) and (4), $\kappa > \mu$ and $\hat{\kappa} > \mu$, which assure that $U(D,\hat{D})$ in (2) must be strictly concave. However, when $\kappa > \mu$ and $\hat{\kappa} > \mu$, both D^* and $\hat{D}^*$ could be negative. Observing (3) and (4) we find a necessary condition assuring that $D^* \geq 0$ and $\hat{D}^* \geq 0$ as $\delta\hat{\kappa} - \hat{\delta}\mu > 0$ and $\hat{\delta}\kappa - \delta\mu > 0$. It thus follows from the above that the parameters δ, $\hat{\delta}$, κ, $\hat{\kappa}$, and μ in (2) should be given such that $\kappa > \mu$, $\hat{\kappa} > \mu$, $\delta\hat{\kappa} - \hat{\delta}\mu > 0$, and $\hat{\delta}\kappa - \delta\mu > 0$.

As shown in (3) and (4), the demand D^* ($\hat{D}^*$) are increasing in δ ($\hat{\delta}$) but decreasing in $\hat{\delta}$ (δ). Specifically, a larger value of δ results in a higher demand for the multinational firm, whereas a larger value of $\hat{\delta}$ makes the multinational firm worse. In addition, D^* is decreasing in $g(\alpha)$ but $\hat{D}^*$ is increasing in $g(\alpha)$, which is in agreement with the fact that the demand for a product is dependent on the quality level of the product.

3.2 Model and Analysis of the Pricing Game

In this section, we consider the first step in which, given the local content rate α, the multinational and the local firms determine their prices with no communication. Next, we start by constructing the profit functions for the two firms, which is then used to obtain the two firms' prices in Nash equilibrium.

3.2.1 Profit Functions

We first develop the multinational firm's profit function Π. As indicated in Section 3.1, the multinational firm sells D^* units of product M, where D^* is given in (3). Since the unit price of product M is p, the multinational firm achieves the sale revenue pD^*. For each unit of product M, the multinational firm incurs the cost $M(\alpha)$, which includes the unit ($\alpha-$dependent) acquisition cost of all components $C(\alpha)$, the unit assembly cost C_A, and the tariff generated from the imported components. Denoting the unit tariff-exclusive cost of all imported components by C_I, we can calculate the tariff absorbed by the multinational firm as tC_I, where t is the tariff rate. Thus, the firm's total unit cost is $M(\alpha) = C(\alpha) + C_A + tC_I$.

From the above, we find that the total unit cost of all local components is $C(\alpha) - C_I$, which is dependent on the percentage of local contents in product M (i.e., the local content rate α). Such a dependence can be described by two common schemes, according to Munson and Rosenblatt [29]. The first scheme is "physical content protection scheme" under which α is the ratio of the total number of local components to that of imported components. Since the scheme is usually used for homogeneous intermediate products, it does not apply to our problem. The second scheme is "value-based content protection scheme" under which α is the ratio of the unit cost of all local components to either the unit cost of all components (i.e., $C(\alpha)$) or the value of the final product.

In this thesis, the multinational firm's profit function involves the total cost of all components rather than the number of each component. Hence, we assume that the firm applies the value-based content protection scheme, under which the local content rate α is the ratio of the total cost of all local components to the total tariff-exclusive cost of all components for one unit of the final product, i.e.,

$$\alpha = \frac{C(\alpha) - C_I}{C(\alpha)} = 1 - \frac{C_I}{C(\alpha)}. \tag{5}$$

Since the local content rate is the multinational firm's decision, we use (5) to write C_I as a function of α, i.e., $C_I = (1-\alpha)C(\alpha)$.

Using the above, we re-write the multinational firm's total unit cost function $M(\alpha)$ as,

$$M(\alpha) = C(\alpha)[1 + t(1-\alpha)] + C_A. \tag{6}$$

Given a specific local content rate, a rational firm needs to locally source the components that minimize the total acquisition cost. As Munson [29] discussed, under a value-based content protection scheme, a multinational firm should first purchase the local components with low relative cost penalties. Note that the relative cost penalty for a component is defined as the ratio of the unit cost of a local one to that of an imported one. Therefore, as α increases, more local components with higher relative cost penalties are purchased; that is, the cost (benefit) of replacing one more imported component with a local one becomes larger (smaller) when the local content rate α is greater. This implies that $C(\alpha)$ should be a convex function of α, i.e. $\partial^2 C(\alpha)/\partial\alpha^2 \geq 0$ for $\alpha \in (0,1)$, which means that the marginal cost is increasing in α. Since there is similar logic for $M(\alpha)$, it follows that $\partial^2 M(\alpha)/\partial\alpha^2 \geq 0$, for $\alpha \in (0,1)$.

Remark 3 Although $C(\alpha)$ is convex, we cannot assume the sign of the first-order derivative $\partial C(\alpha)/\partial\alpha$. For our subsequent analysis, we consider three possible scenarios: (i)

Scenario I: $C(\alpha)$ is increasing in α, i.e., $C'(\alpha) > 0$, for $\alpha \in (0,1)$; (ii) Scenario D: $C(\alpha)$ is decreasing in α, i.e., $C'(\alpha) < 0$, for $\alpha \in (0,1)$; (iii) Scenario C: $C(\alpha)$ is a unimodal, convex function of α, i.e., $C'(0) < 0$, and $C'(1) > 0$. ■

Then, we can construct the multinational firm's profit function as,

$$\Pi = pD^* - M(\alpha)D^* = V(\alpha)D^*, \quad \text{where } V(\alpha) \equiv p - M(\alpha), \tag{7}$$

where D^* and $M(\alpha)$ are given as in (3) and (6), respectively, and $V(\alpha)$ represents the multinational firm's unit profit. Similar to the above, we can compute the local firm's profit as the total sale revenue $\hat{p}\hat{D}^*$ minus the total acquisition cost $(\hat{C}_A + C_l)\hat{D}^*$, where $\hat{C}_A$ and C_l denote the local firm's unit assembly cost and unit acquisition cost of all components, respectively. That is,

$$\hat{\Pi} = \hat{p}\hat{D}^* - (\hat{C}_A + C_l)\hat{D}^* = \hat{V}(\alpha)\hat{D}^*, \quad \text{where } \hat{V}(\alpha) \equiv \hat{p} - \hat{C}_A - C_l, \tag{8}$$

where $\hat{D}^*$ is given as in (4) and $\hat{V}(\alpha)$ means the local firm's unit profit.

3.2.2 Prices in Nash Equilibrium

Given the value of the local content rate α, we solve a "simultaneous-move" game where the multinational and the local firms maximize their profits Π and $\hat{\Pi}$, respectively, and find two firms' α–dependent prices in Nash equilibrium $(p^N(\alpha), \hat{p}^N(\alpha))$.

Proposition 1 Given the multinational firm's local-content rate α, the multinational firm's and the local firm's α-dependent prices in Nash equilibrium can be uniquely obtained as,

$$\begin{aligned} p^N(\alpha) &= \frac{1}{4\kappa\hat{\kappa} - \mu^2}\Big[2\kappa\hat{\kappa}M(\alpha) - \left(2\kappa\hat{\kappa} + \kappa\mu^2 - \mu^2\right)\theta g(\alpha) + \kappa\mu\left(\hat{C}_A + C_l\right) \\ &\quad +2\kappa\hat{\kappa}\delta - \mu\kappa\hat{\delta} - \mu^2\delta\Big], \quad (9) \\ \hat{p}^N(\alpha) &= \frac{1}{4\kappa\hat{\kappa} - \mu^2}\Big[\hat{\kappa}\mu M(\alpha) + \left(\hat{\kappa} + 2\kappa\hat{\kappa} - \mu^2\right)\mu\theta g(\alpha) + 2\kappa\hat{\kappa}\left(\hat{C}_A + C_l\right) \\ &\quad +2\kappa\hat{\kappa}\hat{\delta} - \mu\hat{\kappa}\delta - \mu^2\hat{\delta}\Big]. \quad (10) \end{aligned}$$

Proof. We calculate the first- and the second-order derivatives of Π in (7) w.r.t. p as follows:

$$\frac{\partial \Pi}{\partial p} = D^* - \frac{\hat{\kappa}}{\kappa\hat{\kappa} - \mu^2} V(\alpha) \quad \text{and} \quad \frac{\partial^2 \Pi}{\partial p^2} = -\frac{2\hat{\kappa}}{\kappa\hat{\kappa} - \mu^2} < 0,$$

which implies that Π is a strictly concave function of the price p. Next, we differentiate the local firm's profit function $\hat{\Pi}$ in (8) once and twice w.r.t. $\hat{p}$, and find,

$$\frac{\partial \hat{\Pi}}{\partial \hat{p}} = \hat{D}^* - \frac{\kappa}{\kappa\hat{\kappa} - \mu^2} \hat{V}(\alpha) \quad \text{and} \quad \frac{\partial^2 \hat{\Pi}}{\partial \hat{p}^2} = -\frac{2\kappa}{\kappa\hat{\kappa} - \mu^2} < 0,$$

which means that $\hat{\Pi}$ is also strictly concave in $\hat{p}$.

Solving $\partial \Pi / \partial p = 0$ and $\partial \hat{\Pi} / \partial \hat{p} = 0$, we can attain the Nash equilibrium-characterized prices for two firms as in (9) and (10).

The Nash equilibrium is unique if $|\partial^2 \Pi / \partial p^2| > |\partial^2 \Pi / \partial p \partial \hat{p}| + |\partial^2 \hat{\Pi} / \partial p \partial \hat{p}|$ and $|\partial^2 \hat{\Pi} / \partial \hat{p}^2| > |\partial^2 \Pi / \partial p \partial \hat{p}| + |\partial^2 \hat{\Pi} / \partial p \partial \hat{p}|$, a condition identified by Milgrom and Roberts [28]. Since $\partial^2 \Pi / \partial p \partial \hat{p} = \partial^2 \hat{\Pi} / \partial p \partial \hat{p} = \mu / (\kappa\hat{\kappa} - \mu^2)$, $\kappa > \mu$, and $\hat{\kappa} > \mu$, the equilibrium is unique. ■

We note from Proposition 1 that, given the value of α, the multinational firm's unit cost $M(\alpha)$ and the reduction in the quality level of product M $g(\alpha)$ affect the $\alpha-$dependent Nash-equilibrium prices. Next, we discuss the impact of the two terms on the prices. Since $\kappa > \mu$, $\hat{\kappa} > \mu$, and all of other parameters are positive, we find from (9) and (10) that, when $M(\alpha)$ increases, both firms should respond by raising their prices. Recalling from (6) that $M(\alpha) = [C(\alpha) + C_A + tC_I]$, we conclude that both firms will increase their prices if the multinational firm incurs a higher tariff-exclusive acquisition cost or assembly cost or faces a larger tariff rate. In addition, the coefficient of $M(\alpha)$ in $p^N(\alpha)$ and that in $\hat{p}^N(\alpha)$ are $2\kappa\hat{\kappa}/(4\kappa\hat{\kappa} - \mu^2)$ and $\hat{\kappa}\mu/(4\kappa\hat{\kappa} - \mu^2)$, respectively. As $\kappa > \mu$, any change in $M(\alpha)$ results in more than twice the impact on $p^N(\alpha)$ than on $\hat{p}^N(\alpha)$.

Next, we utilize Proposition 1 to analyze the impact of the $\alpha-$dependent quality level of product M on the prices in Nash equilibrium. Since $\kappa > \mu$ and $\hat{\kappa} > \mu$, we find that $2\kappa\hat{\kappa} + \kappa\mu^2 - \mu^2 > 0$. Hence, given the value of α, the multinational firm should determine a higher price if the reduction in the quality level of product M $g(\alpha)$ is smaller. This happens because of the following two reasons: First, for a given value of α, a smaller $g(\alpha)$ implies that the quality of the local components used by the multinational firm are improved by their producers, and the multinational firm can thus produce high-quality products. Second, although the local content rate is not changed, a reduction in the value of $g(\alpha)$ reflects the improvement of consumers' confidence in the quality of product M, which also results from the rise in the quality level of local components. We learn from (10) that, because of $\hat{\kappa} + 2\kappa\hat{\kappa} - \mu^2 > 0$, $\hat{p}^N(\alpha)$ decreases if $g(\alpha)$ is reduced. That is, the local firm's price $\hat{p}^N(\alpha)$ is decreasing in the quality level of product M, which differs from the impact of $g(\alpha)$ on $p^N(\alpha)$. Our above discussion indicates that, as a consequence of improving the quality level of local components, the multinational firm will increase his sale price $p^N(\alpha)$ whereas the local firm decreases her sale price $\hat{p}^N(\alpha)$.

3.2.3 Demands and Profits in Nash Equilibrium-Characterized Prices

We now discuss demands and the two firms' profits in terms of Nash equilibrium-characterized prices.

Corollary 1 Given the multinational firm's local-content rate α, when the multinational and the local firms adopt their Nash equilibrium-based prices as in Proposition 1, the multinational firm's unit profit $V^N(\alpha)$, the demand for product M $D^N(\alpha)$, and the multinational firm's total profit $\Pi^N(\alpha)$ are computed as,

$$\begin{cases} V^N(\alpha) = & \frac{1}{4\kappa\hat{\kappa} - \mu^2} \left[-\left(2\kappa\hat{\kappa} - \mu^2\right) M(\alpha) - \left(2\kappa\hat{\kappa} + \kappa\mu^2 - \mu^2\right) \theta g(\alpha) \right. \\ & \left. + \kappa\mu \left(\hat{C}_A + C_l\right) + 2\kappa\hat{\kappa}\delta - \kappa\mu\hat{\delta} - \mu^2\delta \right], \\ D^N(\alpha) = & \hat{\kappa} V^N(\alpha) / (\kappa\hat{\kappa} - \mu^2), \\ \Pi^N(\alpha) = & \hat{\kappa} \left[V^N(\alpha)\right]^2 / (\kappa\hat{\kappa} - \mu^2). \end{cases} \tag{11}$$

Proof. This corollary follows from substituting $p^N(\alpha)$ and $\hat{p}^N(\alpha)$ into the demand function in (3) and the profit function in (7). ■

We learn from (11) that the multinational firm's local content rate α impacts $V^N(\alpha)$, $D^N(\alpha)$, and $\Pi^N(\alpha)$ in a similar manner. As discussed in Section 3.2.2, given the value of α, the multinational firm should choose a higher price when his product's quality increases and the firm's cost $M(\alpha)$ rises. Using Proposition 1 and Corollary 1, we can draw some insights as follows:

1. A higher value of $M(\alpha)$ increases $p^N(\alpha)$ but reduces $V^N(\alpha)$, $D^N(\alpha)$, and $\Pi^N(\alpha)$.

This implies that, as a result of raising $M(\alpha)$, the increase in the multinational firm's sale revenue is smaller than the increase in the firm's cost, thus not only discouraging consumers from buying the product but also decreasing the firm's unit profit. Such a result can be demonstrated by the fact that the coefficient of $M(\alpha)$ in (9)—i.e., $2\kappa\hat{\kappa}/(4\kappa\hat{\kappa}-\mu^2)$—is positive and less than 1.

2. When the local firm incurs a higher total unit cost (i.e., $\hat{C}_A + C_l$ is larger), the multinational firm should increase his price $p^N(\alpha)$ and achieves a higher unit profit $V^N(\alpha)$, a larger demand $D^N(\alpha)$, and a greater total profit $\Pi^N(\alpha)$. The impact of the local firm's cost on $V^N(\alpha)$ is mainly attributed to the fact that increasing the value of $\hat{C}_A + C_l$ does not affect the multinational firm's cost even though it raises the price $p^N(\alpha)$. Recall from (3) that, in the multinational firm's demand function, the coefficient of p is negative but that of $\hat{p}$ is positive, and the absolute value of the coefficient of p is larger than that of $\hat{p}$. Since both $D^N(\alpha)$ and $p^N(\alpha)$ increase as a result of increasing the value of $\hat{C}_A + C_l$, we can conclude that an increase in the local firm's cost causes much smaller increase in $p^N(\alpha)$ than in $\hat{p}^N(\alpha)$.

3. When the reduction in the quality level of product M $g(\alpha)$ is reduced, we find that $p^N(\alpha)$, $V^N(\alpha)$, $D^N(\alpha)$, and $\Pi^N(\alpha)$ are all increased. This means that if product M is of higher quality or consumers have a greater confidence in the quality of product M, then the multinational firm can not only enjoy a higher price but also attract more consumers.

Similar to the above, we can calculate the local firm's unit profit, demand, and total profit when two firms choose their prices in Nash equilibrium, as shown in the following corollary.

Corollary 2 Given the multinational firm's local-content rate α, when the multinational firm and the local firm adopt their prices as in Proposition 1, the local firm's

α-dependent unit profit $\hat{V}^N(\alpha)$, demand $\hat{D}(\alpha)$, and total profit $\hat{\Pi}^N(\alpha)$ are computed as,

$$
\begin{aligned}
\hat{V}^N(\alpha) &= \frac{1}{4\kappa\hat{\kappa}-\mu^2}\Big[\hat{\kappa}\mu M(\alpha) + \left(\hat{\kappa}+2\kappa\hat{\kappa}-\mu^2\right)\mu\theta g(\alpha) - \left(2\kappa\hat{\kappa}-\mu^2\right)\left(\hat{C}_A + C_l\right) \\
&\quad +2\hat{\kappa}\kappa\hat{\delta} - \mu^2\hat{\delta} - \mu\hat{\kappa}\delta\Big], \\
\hat{D}(\alpha) &= \kappa\hat{V}^N(\alpha)/(\kappa\hat{\kappa}-\mu^2), && (12)\\
\hat{\Pi}^N(\alpha) &= \kappa\left[\hat{V}^N(\alpha)\right]^2/(\kappa\hat{\kappa}-\mu^2). && (13)
\end{aligned}
$$

Proof. Substituting $p^N(\alpha)$ and $\hat{p}^N(\alpha)$ into the demand function in (4) and the profit function in (8) yields the results in this corollary. ■

The above corollary indicates that, as the value of α changes, $\hat{V}^N(\alpha)$, $\hat{D}^N(\alpha)$, and $\hat{\Pi}^N(\alpha)$ vary in a similar manner. Given the value of α, we learn from Section 3.2.2 that the local firm raises her price when the firm and the multinational firm incur higher costs, or the multinational firm reduces his product's quality level. Using Proposition 1 and Corollary 2, we find that an increase in the local firm's cost $\hat{C}_A + C_l$ leads the firm to increase her sale price $\hat{p}^N(\alpha)$ but achieves a lower unit profit $\hat{V}^N(\alpha)$, a smaller demand $\hat{D}^N(\alpha)$, and a smaller total profit $\hat{\Pi}^N(\alpha)$. Moreover, an increase in the multinational firm's cost $M(\alpha)$ raises $\hat{p}^N(\alpha)$, $\hat{V}^N(\alpha)$, $\hat{D}^N(\alpha)$, and $\hat{\Pi}^N(\alpha)$; and $\hat{p}^N(\alpha)$, $\hat{V}^N(\alpha)$, $\hat{D}^N(\alpha)$, and $\hat{\Pi}^N(\alpha)$ rise as a result of increasing $g(\alpha)$.

3.3 Optimal Local Content Rate

Using the prices in Nash equilibrium as in Proposition 1, we now determine the multinational firm's optimal local content rate α^* that maximizes the firm's profit $\Pi^N(\alpha) = \hat{\kappa}\left[V^N(\alpha)\right]^2/(\kappa\hat{\kappa}-\mu^2)$, which is given as in (11). Since κ, $\hat{\kappa}$, and μ are exogenous parameters, the optimal rate maximizing $\Pi^N(\alpha)$ is identical to that maximizing the multinational firm's α-dependent unit profit $V^N(\alpha)$ in (11). Specifically, when $\partial V^N(\alpha)/\partial\alpha = 0$, $\partial\Pi^N(\alpha)/\partial\alpha = 0$.

Differentiating $V^N(\alpha)$ once and twice with respect to α yields,

$$
\begin{aligned}
\frac{\partial V^N(\alpha)}{\partial\alpha} &= -\frac{1}{4\kappa\hat{\kappa}-\mu^2}\left[\left(2\kappa\hat{\kappa}-\mu^2\right)M'(\alpha) + \left(2\kappa\hat{\kappa}+\kappa\mu^2-\mu^2\right)\theta g'(\alpha)\right], && (14)\\
\frac{\partial^2 V^N(\alpha)}{\partial\alpha^2} &= -\frac{1}{4\kappa\hat{\kappa}-\mu^2}\left[\left(2\kappa\hat{\kappa}-\mu^2\right)M''(\alpha) + \left(2\kappa\hat{\kappa}+\kappa\mu^2-\mu^2\right)\theta g''(\alpha)\right].
\end{aligned}
$$

In the above equations, $M'(\alpha)$ and $M''(\alpha)$ [i.e., the first- and second- order derivatives of $M(\alpha)$] are,

$$
\begin{aligned}
M'(\alpha) &= [1+t(1-\alpha)]\, C'(\alpha) - tC(\alpha), \\
M''(\alpha) &= [1+t(1-\alpha)]\, C''(\alpha) - 2tC'(\alpha),
\end{aligned}
\tag{15}
$$

which are obtained by differentiating $M(\alpha) = C(\alpha)[1+t(1-\alpha)] + C_A$ once and twice w.r.t. α.

As discussed in Section 3.1, $g''(\alpha) > 0$ and $M''(\alpha) \geq 0$. Thus, $\partial^2 V^N(\alpha)/\partial\alpha^2 < 0$ for $\alpha \in [0,1]$, which means that $V^N(\alpha)$ is a strictly concave function of α. We learn from Remark 3 that $C(\alpha)$ is a convex function but it may be increasing in α (i.e., $C'(\alpha) > 0$), may be decreasing in α (i.e., $C'(\alpha) < 0$), or may be unimodal in α (i.e., $C'(0) < 0$ and $C'(1) > 0$). Therefore, $\partial V^N(\alpha)/\partial\alpha$ (for $\alpha \in [0,1]$) could be positive or negative, which means that the optimal local content rate α^* in the range $[0,1]$ may be equal to zero when $\partial V^N(\alpha)/\partial\alpha < 0$, may be equal to 1 when $\partial V^N(\alpha)/\partial\alpha > 0$, or may be a unique solution in the range $(0,1)$.

Proposition 2 The optimal local content rate α^*—which maximizes the multinational firm's profit $\Pi^N(\alpha)$ in (11)—can be uniquely attained as,

$$
\alpha^* = \begin{cases} 0, & \text{if } Sg'(0) + M'(0) \geq 0, \\ \tilde{\alpha}, & \text{if } Sg'(0) + M'(0) < 0 < Sg'(1) + M'(1), \\ 1, & \text{if } Sg'(1) + M'(1) \leq 0. \end{cases}
$$

where $S \equiv (2\kappa\hat{\kappa} + \kappa\mu^2 - \mu^2)\,\theta / (2\kappa\hat{\kappa} - \mu^2) > 0$, and $\tilde{\alpha}$ denotes a unique solution satisfying the following equation:

$$
Sg'(\tilde{\alpha}) + M'(\tilde{\alpha}) = 0. \tag{16}
$$

Proof. We learn from our argument prior to this proposition that $\partial^2 V^N(\alpha)/\partial\alpha^2 < 0$ for $\alpha \in [0,1]$. Thus, one of the following three cases must happen.

Case 1: $V^N(\alpha)$ is strictly increasing in α for $\alpha \in (0,1)$. For this case, we have $\partial V^N(\alpha)/\partial\alpha > 0$. Since $V^N(\alpha)$ is a strictly concave function, we find that, for $\alpha \in (0,1)$,

$\partial V^N(\alpha)/\partial\alpha$ must be greater than zero if and only if $\partial V^N(\alpha)/\partial\alpha|_{\alpha=1} \geq 0$, or, $Sg'(1) + M'(1) \leq 0$ where $S \equiv (2\kappa\hat{\kappa} + \kappa\mu^2 - \mu^2)\theta/(2\kappa\hat{\kappa} - \mu^2) > 0$. Hence, for Case 1, $\alpha^* = 1$.

Case 2: $V^N(\alpha)$ is strictly decreasing in α for $\alpha \in (0,1)$. For this case, we have $\partial V^N(\alpha)/\partial\alpha < 0$. Similar to our analysis of Case 1, for $\alpha \in (0,1)$, $\partial V^N(\alpha)/\partial\alpha$ must be smaller than zero if and only if $\partial V^N(\alpha)/\partial\alpha|_{\alpha=0} \leq 0$, or, $Sg'(0) + M'(0) \geq 0$. Therefore, for Case 2, $\alpha^* = 0$.

Case 3: $V^N(\alpha)$ is a unimodal, concave function of α for $\alpha \in (0,1)$. For this case, $\partial V^N(\alpha)/\partial\alpha|_{\alpha=0} > 0$ and $\partial V^N(\alpha)/\partial\alpha|_{\alpha=1} < 0$. There is a unique solution maximizing $V^N(\alpha)$, which can be obtained as $\alpha^* = \tilde{\alpha}$, where $\tilde{\alpha}$ satisfies the equation in (16).

This proposition is thus proved. ■

We note from (16) that $M'(\tilde{\alpha})+Sg'(\tilde{\alpha}) = 0$, which implies that $M'(\tilde{\alpha}) < 0$, since $g'(\alpha)$ is positive. Thus, at the optimal local content rate α^* (except boundary solutions), the multinational firm does not enjoy the lowest cost—that satisfies the equation $M'(\alpha) = 0$, and raising the value of α can reduce $M(\alpha)$ but also result in a decrease in the demand and the firm's unit profit. This implies that the multinational firm should consider the trade-off between cost and product quality, in order to maximize his total profit.

Proposition 2 indicates that the optimal local content rate α^* depends on the sign of $Sg'(0) + M'(0)$ and that of $Sg'(1) + M'(1)$. Let

$$\gamma(\alpha) \equiv \frac{d[-M(\alpha)]}{dg(\alpha)},$$

which can be regarded as the increase in the multinational firm's cost when the quality level of product M is increased by one unit, for a given value of the local content rate α. For simplicity, $\gamma(\alpha)$ reflects the marginal cost of product M's quality. Recalling that $g'(\alpha) > 0$ but $M'(\alpha)$ may be positive or negative, we cannot determine the sign of $\gamma(\alpha)$. The positive (negative) value of $\gamma(\alpha)$ means the multinational firm's cost increase (reduction) resulting from the decrease in the quality level. We note from the above proposition that when $\alpha = \tilde{\alpha}$, the marginal profit of the multinational firm is zero, i.e.,

$\partial V^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}} = 0$. It then follows that S reflects the marginal cost of product M's quality when marginal profit of product M's local content rate is 0, i.e., $\gamma(\tilde{\alpha}) = S$.

Remark 4 We learn from Proposition 2 that the multinational firm should not buy any component from the local market but import all components if the corresponding quality marginal cost $\gamma(0)$ is sufficiently small such that $\gamma(0) \leq S$, i.e., $Sg'(0) + M'(0) \geq 0$. All components for product M should be bought from the local market if the corresponding quality marginal cost $\gamma(1)$ is sufficiently large such that $\gamma(1) \geq S$, i.e., $Sg'(1) + M'(1) \leq 0$. In conclusion, the multinational firm's optimal decision on the local content rate is dependent on the impact of the quality level of product M on the firm's cost. ■

Although the above remark indicates two possible results regarding the optimal local content rate, the inequality $\gamma(1) \geq S$ (i.e., $Sg'(1) + M'(1) \leq 0$) is still unlikely to hold, because of the following two reasons. First, as usual, $g'(1)$ is significantly large since the quality of product M would be greatly decreased when the key components are localized. Secondly, $M'(1)$ should not be very small since $M''(\alpha) \geq 0$ for $\alpha \in [0, 1]$. It thus follows that the multinational firm is unlikely to buy all components from local suppliers. This is consistent with the fact that in practice very few high-technology multinational firms adopt the localization rate of 100% and multinational firms are unwilling to localize the components of high technology.

As Remark 1 indicates, to find the prices in Nash equilibrium for our two-stage problem, we should replace α in the prices $p^N(\alpha)$ in (9) and $\hat{p}^N(\alpha)$ in (10) with the optimal local content rate α^* in Proposition 2. To illustrate the above game analysis, we provide the following numerical example, in which the multinational firm's tariff-exclusive cost $C(\alpha)$ is assumed to be a convex function.

Example 1 A multinational firm makes FDI in a country to make use of the firm's advanced technology, and make and sell product M to satisfy the demand D^* in (3), where $\delta = 400$, $\hat{\delta} = 300$, $\theta = 0.7$, which reflects the degree to which customers are sensitive to product M's quality. The multinational firm competes with a local firm in the market, and the substitution index of two firms' products is $\mu = 0.6$. Moreover, in the representative consumer's utility function (2), $\kappa = 1.5$ and $\hat{\kappa} = 1.5$.

We assume the quality-related function $g(\alpha)$ as,

$$g(\alpha) = m\left[\frac{1}{(1-\alpha)^n} - 1\right],$$

where m and n are both positive. For this numerical example, we set $m = 100$ and $n = 0.4$. The function $g(\alpha)$ satisfies the properties that $g'(\alpha) > 0$ and $g''(\alpha) > 0$. Observing the fact that product M's quality significantly decreases when the multinational firm localize his key components (e.g., the engine for sedan), we assume that $g'(1)$ is sufficiently large such that the inequality $\gamma(1) \geq S$ (i.e., $Sg'(1) + M'(1) \leq 0$) does not hold. Note that $g(0) = 0$, since there is no quality decrease when all components for product M are imported (i.e., $\alpha = 0$).

As discussed in Section 3.2.1, $C(\alpha)$ possesses the property that $C''(\alpha) \geq 0$. For our numerical study in this paper, we specify the cost function as,

$$C(\alpha) = \lambda_1(1-\alpha)^{\nu_1} + \frac{\lambda_2}{(1-\alpha)^{\nu_2}} + \lambda_3,$$

where λ_1, ν_1, λ_2, ν_2,and λ_3 are all positive. For this numerical example, we set $\lambda_1 = 70$, $\nu_1 = 3$, $\lambda_2 = 50$, $\nu_2 = 0.5$ and $\lambda_3 = 80$; under such a setting, $C(\alpha)$ is a convex function of α. In addition, the multinational firm's unit cost for each imported component includes the tariff. We assume the tariff rate as 0.15, i.e., $t = 0.15$. The local firm's unit cost for all components C_l is assumed to be 150. We also assume that both firms' unit assembly costs are 5, i.e. $C_A = \hat{C}_A = 5$. Recall from Proposition 2 that $\alpha^* = \tilde{\alpha} \in (0, 1)$ when $-M'(0) > Sg'(0)$ and $-M'(1) < Sg'(1)$, which are satisfied in this example.

Next, solving the equation that $\partial\Pi^N(\alpha)/\partial\alpha = 0$, we calculate the multinational firm's optimal local content rate α^* as $\alpha^* = \tilde{\alpha} = 0.370$. We then solve (9) and (10) to find two firms' prices in Nash equilibrium as $p^N(\alpha^*) = \$262.947$ and $\hat{p}^N(\alpha^*) = \$207.201$. The resulting demands for products M and L are $D^* = 65.315$ and $\hat{D}^* = 41.429$. The two firms achieve their profits as $\Pi^N(\alpha^*) = \$5375.271$ and $\hat{\Pi}^N(\alpha^*) = \$2162.636$. ■

4 Sensitivity Analysis and Managerial Implications

In this section, we perform the sensitivity analysis to explore the impact of some important parameters (in two firms' profit functions) on the multinational firm's optimal local content rate, demand, and profit. The parameters include the tariff rate t, the M-L substitutability index μ, and others such as θ—the degree to which customers concern the product quality—and the customers' utility parameter κ in (2). From our sensitivity analysis we draw both the analytic and the numerical managerial insights.

4.1 The Impact of the Tariff Rate t

We start with the impact of the tariff rate t on the multinational firm's optimal local-content decision α^*, which may be zero, one, or $\tilde{\alpha} \in (0,1)$, as indicated by Proposition 2.

Proposition 3 By increasing the tariff rate t from t_1 to t_2, we obtain the following results regarding the impact of the tariff rate on the multinational firm's optimal local content rate decision α^*.

1. If two tariff rates t_1 and t_2 are given such that $t_1 \leq t_2 \leq \tilde{t}$, where $\tilde{t} \equiv [Sg'(0) + C'(0)]/[C(0) - C'(0)]$, then the multinational firm's optimal local content rate decision for each rate is zero, i.e., $\alpha^*|_{t=t_1} = \alpha^*|_{t=t_2} = 0$.

2. If two tariff rates t_1 and t_2 are given such that $t_1 \leq \tilde{t} < t_2$, then $0 = \alpha^*|_{t=t_1} < \alpha^*|_{t=t_2}$ when $C'(0) < C(0)$, but $\alpha^*|_{t=t_1} = \alpha^*|_{t=t_2} = 0$ when $C'(0) \geq C(0)$.

3. If two tariff rates t_1 and t_2 are given such that $\tilde{t} < t_1 < t_2$ and $t_1 < \bar{t}$, where $\bar{t} = [Sg'(1) + C'(1)]/C(1)$, then $0 < \alpha^*|_{t=t_1} < \alpha^*|_{t=t_2}$. In addition, $\alpha^*|_{t=t_2} = 1$, if $t_2 \geq \bar{t}$.

Proof. We learn from Proposition 2 that whether or not the multinational firm's optimal local content rate α^* is zero is dependent on the sign of $Sg'(0) + M'(0)$. According to (15), we find that

$$M'(0) = M'(\alpha)|_{\alpha=0} = (1+t)C'(0) - tC(0) = t[C'(0) - C(0)] + C'(0);$$

and therefore, $Sg'(0) + M'(0) = Sg'(0) + t[C'(0) - C(0)] + C'(0)$. If $C'(0) \geq C(0)$, then, for any tariff rate $t > 0$, $Sg'(0) + t[C'(0) - C(0)] + C'(0) \geq 0$, which means that $Sg'(0) + M'(0)$ must be non-negative. Otherwise, if $C'(0) < C(0)$, then

$$\begin{cases} Sg'(0) + M'(0) \geq 0, & \text{if } t \leq \tilde{t} \equiv \dfrac{Sg'(0) + C'(0)}{C(0) - C'(0)}, \\ Sg'(0) + M'(0) < 0, & \text{if } t > \tilde{t}. \end{cases}$$

Using the above, we have the following results:

1. If two tariff rates t_1 and t_2 are given such as $t_1 \leq t_2 \leq \tilde{t}$, then for each tariff rate t_i $(i = 1, 2)$, $Sg'(0) + M'(0)$ is non-negative; and as Proposition 2 indicates, the multinational firm's optimal decision on the local content rate is zero. That is, if $t_1 \leq t_2 \leq \tilde{t}$, then $\alpha^*|_{t=t_1} = \alpha^*|_{t=t_2} = 0$.

2. If two tariff rates t_1 and t_2 are given such that $t_1 \leq \tilde{t} < t_2$, then the multinational firm's optimal local content rate decision when $t = t_1$ must be zero, i.e., $\alpha^*|_{t=t_1} = 0$, but his optimal local content rare decision when $t = t_2 > \tilde{t}$ may be $\tilde{\alpha} > 0$ or may be zero, which depends on the comparison between $C'(0)$ and $C(0)$. Specifically, if $C'(0) < C(0)$, then $Sg'(0) + M'(0) < 0$ and $\alpha^*|_{t=t_2} = \tilde{\alpha} > 0$, as suggested by Proposition 2. Otherwise, if $C'(0) \geq C(0)$, then $Sg'(0) + M'(0) \geq 0$ and $\alpha^*|_{t=t_2} = \alpha^*|_{t=t_1} = 0$.

3. If two tariff rates t_1 and t_2 are given such that $\tilde{t} < t_1 < t_2$, then for each tariff rate, the sign of $Sg'(0) + M'(0)$ is negative. When $t_2 \geq \bar{t}$, $Sg'(1) + M'(1) \leq 0$. It thus follows from Proposition 2 that when the tariff rate t_1 or t_2 applies, the multinational firm determines his optimal local content rate decision as $\alpha^*|_{t=t_1} = \tilde{\alpha}$ and $\alpha^*|_{t=t_2} = 1$, respectively. That is, if $\tilde{t} < t_1 < t_2$, then $0 < \alpha^*|_{t=t_1} < \alpha^*|_{t=t_2} = 1$.

   When $\tilde{t} < t_1 < t_2 < \bar{t}$, then when the tariff rate t_1 or t_2 applies, the multinational firm always determines his optimal local content rate decision as $\tilde{\alpha}$. But, $\tilde{\alpha}_1 \equiv \tilde{\alpha}|_{t=t_1}$ is not equal to $\tilde{\alpha}_2 \equiv \tilde{\alpha}|_{t=t_2}$. Next we compare $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$.

   We note from the proof of Proposition 2 that for $t > \tilde{t}$, $V^N(\alpha)$ in (11) must be a concave function with a unique optimal solution $\tilde{\alpha}$ maximizing $V^N(\alpha)$; that is, $\tilde{\alpha}$ uniquely satisfies the first-order condition $\partial V^N(\alpha)/\partial\alpha = 0$, which can be simplified to (16). Letting $V_i^N(\alpha)$ denote the multinational firm's profit function when the tariff rate t is t_i, for $i = 1, 2$, we find from the concavity of $V^N(\alpha)$ that $\tilde{\alpha}_1 < \tilde{\alpha}_2$ if $\partial V_2^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1} > \partial V_2^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_2} = 0$. Therefore, to compare $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$, we should determine the sign of $\partial V_2^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1}$.

We calculate $\partial V_2^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1}$ and $\partial V_1^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1}$ as,

$$\begin{aligned}
\left.\frac{\partial V_2^N(\alpha)}{\partial\alpha}\right|_{\alpha=\tilde{\alpha}_1} &= -\frac{2\kappa\hat{\kappa}-\mu^2}{4\kappa\hat{\kappa}-\mu^2}\left\{Sg'(\tilde{\alpha}_1)+C'(\tilde{\alpha}_1)[1+(1-\tilde{\alpha}_1)t_2]-C(\tilde{\alpha}_1)t_2\right\}, \\
\left.\frac{\partial V_1^N(\alpha)}{\partial\alpha}\right|_{\alpha=\tilde{\alpha}_1} &= -\frac{2\kappa\hat{\kappa}-\mu^2}{4\kappa\hat{\kappa}-\mu^2}\left\{Sg'(\tilde{\alpha}_1)+C'(\tilde{\alpha}_1)[1+(1-\tilde{\alpha}_1)t_1]-C(\tilde{\alpha}_1)t_1\right\}.
\end{aligned}$$

Using $\partial V_1^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1} = 0$, we re-write $\partial V_2^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1}$ as,

$$\left.\frac{\partial V_2^N(\alpha)}{\partial\alpha}\right|_{\alpha=\tilde{\alpha}_1} = \frac{(2\kappa\hat{\kappa}-\mu^2)(t_2-t_1)}{4\kappa\hat{\kappa}-\mu^2}\left[C(\tilde{\alpha}_1)-C'(\tilde{\alpha}_1)(1-\tilde{\alpha}_1)\right],$$

which must be positive if $C'(\tilde{\alpha}_1) \le 0$. In addition, the first-order condition $\partial V_1^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1} = 0$ can be re-written as,

$$C(\tilde{\alpha}_1)t_1 - C'(\tilde{\alpha}_1)[1+(1-\tilde{\alpha}_1)t_1] = Sg'(\tilde{\alpha}_1) > 0,$$

or,

$$C(\tilde{\alpha}_1) - C'(\tilde{\alpha}_1)(1-\tilde{\alpha}_1) > C'(\tilde{\alpha}_1)/t_1.$$

This means that, if $C'(\tilde{\alpha}_1) > 0$, then $C(\tilde{\alpha}_1) - C'(\tilde{\alpha}_1)(1-\tilde{\alpha}_1) > 0$ and thus $\partial V_2^N(\alpha)/\partial\alpha|_{\alpha=\tilde{\alpha}_1} > 0$.

It follows from the above that, if two tariff rates t_1 and t_2 are given such that $\tilde{t} < t_1 < t_2$, then $\tilde{\alpha}_1 < \tilde{\alpha}_2$.

We thus prove this proposition. ■

We learn from the above proposition that a change in the tariff rate t may *not* lead the multinational firm to adjust his optimal decision on the local content rate. Specifically, when $\alpha^* = 0$, we find that if $C'(0) < C(0)$ and the tariff rate t is increased such that $t \ge \tilde{t}$, then the multinational firm should raise his optimal local content rate from zero to $\tilde{\alpha} > 0$ or 100%. Otherwise, the multinational firm should still fully use local components to make product M, i.e., $\alpha^* = 0$. Moreover, when $\alpha^* = \tilde{\alpha} \in (0,1)$, the multinational firm's optimal local content rate is increasing in the tariff rate t; and the multinational firm will use only local components to manufacture product M if the tariff rate t is increased such that $t \geq \bar{t}$.

Remark 5 We derive from the above proposition that when the tariff rate t takes different values, the multinational firm's optimal local content rate can be uniquely determined as follows:

1. When $C'(0) \geq C(0)$, $\alpha^* = 0$.
2. When $C'(0) < C(0)$,

$$\alpha^* = \begin{cases} 0, & \text{if } t \leq \tilde{t}, \\ \tilde{\alpha}, & \text{if } \tilde{t} < t < \bar{t}, \\ 1, & \text{if } t \geq \bar{t}. \end{cases}$$

This clearly shows that a tariff policy may not be useful in increasing a multinational firm's local content rate, but the firm does not decrease his local content rate as the tariff rate is increased. We find that $C'(0) < C(0)$ is a necessary criteria for the multinational firm to use some local components. In other words, if the marginal tariff-exclusive acquisition cost is greater than or equal to the tariff-exclusive acquisition cost when all components are imported, i.e., $C'(0) \geq C(0)$, then the multinational firm's optimal local content rate is always zero, and any change in the tariff rate cannot induce the multinational firm to replace some imported components with the local ones. Recall that $C'''(\alpha) \geq 0$; in this situation the tariff-exclusive cost $C(\alpha)$ is extremely tremendously increasing in α, and the increase in $C(\alpha)$ always exceeds the saving in the tariff when α increases.

If $C'(0) < C(0)$, then a tariff policy with a sufficiently high tariff rate ($t > \tilde{t}$ as is defined in Proposition 3) can lead the multinational firm to use some local components, and the increase in tariff rate can induce the firm to raise his local content rate.

Next, we discuss the impact of the tariff rate t on the demand for product M [i.e., $D^N(\alpha^*)$] and the multinational firm's profit [i.e., $\Pi^N(\alpha^*)$].

Corollary 3 Both $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ are decreasing in the tariff rate t.

Proof. We learn from (11) that

$$D(\alpha^*) = \frac{\hat{\kappa} V^N(\alpha^*)}{\kappa\hat{\kappa} - \mu^2} \quad \text{and} \quad \Pi^N(\alpha^*) = \frac{\hat{\kappa}[V^N(\alpha^*)]^2}{\kappa\hat{\kappa} - \mu^2},$$

which indicates that the impact of t on $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ is dependent on only the impact of t on $V^N(\alpha^*)$. For our proof, we consider two tariff rates t_1 and t_2, and we, without loss of generality, assume that $t_1 < t_2$. The multinational firm's optimal local content rate decisions corresponding to t_1 and t_2 are denoted by α_1^* and α_2^*, respectively. As Proposition 3 indicates, the multinational firm's optimal local content rate decision α^* is a non-decreasing function of t. Therefore, $\alpha_1^* \leq \alpha_2^*$. We also denote the multinational firm's unit profit when $t = t_i$ by $V_i^N(\alpha_i^*) \equiv V^N(\alpha^*)|_{t=t_i}$, for $i = 1, 2$.

We also learn from Proposition 3 that there are three possible cases for the values of α_1^* and α_2^* as follows: (i) both α_1^* and α_2^* are equal to zero; (ii) α_1^* is zero and $\alpha_2^* > 0$; and (iii) $\alpha_2^* > \alpha_1^* > 0$. Next, we investigate these three cases:

Case 1: $\alpha_1^* = \alpha_2^* = 0$. For this case, the multinational firm's optimal local content rate decision when $t = t_1$ is the same as that when $t = t_2$. We use (11) to find

$$V_1^N(\alpha_1^*) - V_2^N(\alpha_2^*) = V_1^N(0) - V_2^N(0) = \frac{(2\kappa\hat{\kappa} - \mu^2)\, C(0)(t_2 - t_1)}{4\kappa\hat{\kappa} - \mu^2},$$

which is positive. That is, when $\alpha_1^* = \alpha_2^* = 0$, $V_1^N(0) > V_2^N(0)$, which means that the demand for product M [i.e., $D^N(\alpha^*)$] and the multinational firm's profit [i.e., $\Pi^N(\alpha^*)$] are both decreasing in t.

Case 2: $\alpha_2^* > \alpha_1^* = 0$. For this case, we find that, when $t = t_1$, the multinational firm's optimal local content rate α_1^* maximizing the firm's profit $\Pi^N(\alpha)$—which is the same as that maximizing $V_1^N(\alpha)$, as discussed in Section 3.3—is zero. This means that $V_1^N(\alpha)$ reaches the maximum at the point $\alpha = \alpha_1^* = 0$. Since $V_1^N(\alpha)$ is a strictly concave function, as shown in Section 3.3, we have, $V_1^N(\alpha_1^*) = V_1^N(0) > V_1^N(\alpha_2^*)$. Next, we compare $V_1^N(\alpha_2^*)$ and $V_2^N(\alpha_2^*)$. Similar to our above discussion for Case 1, we use (11) to calculate

$$V_1^N(\alpha_2^*) - V_2^N(\alpha_2^*) = \frac{2\kappa\hat{\kappa} - \mu^2}{4\kappa\hat{\kappa} - \mu^2}(t_2 - t_1)(1 - \alpha_2^*)C(\alpha_2^*),$$

which is positive. Therefore, $V_1^N(\alpha_1^*) = V_1^N(0) > V_1^N(\alpha_2^*) > V_2^N(\alpha_2^*)$, which suggests that both $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ are both decreasing in t for Case 2.

Case 3: $\alpha_2^* > \alpha_1^* > 0$. Similar to our argument in Case 2, we can show that $V_1^N(\alpha_1^*) > V_1^N(\alpha_2^*) > V_2^N(\alpha_2^*)$, which implies that both $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ are both decreasing in t for Case 3.

According to the above, we prove this corollary. ■

The above corollary implies that, even though an increase in the tariff rate t may induce the multinational firm to raise his local content rate, the demand faced by the firm and the firm's profit are both decreased. This may reduce the firm's incentive to invest in the local market. Actually, before making investment, the multinational firm needs to pay attention to the local tariff policy. If the tariff rate is so high that the firm can earn only a little no matter how to change his local content rate, then the firm probably should not invest in the market.

4.2 The Impact of the M-L Substitutability Index μ

We then examine the effect of μ on the multinational firm's optimal local content rate decision α^*. Noting from Proposition 2 that α^* is 0, $\tilde{\alpha}$, or 1, we consider the impact of μ on the interior solution $\tilde{\alpha}$, as shown in the following proposition.

Proposition 4 As the substitutability index μ between products M and L increases, i.e., the competition between the multinational and the local firms intensifies, the multinational firm should reduce his optimal local content rate $\tilde{\alpha}$, i.e., $\partial\tilde{\alpha}/\partial\mu < 0$.

Proof. Differentiating the two sides of (16) once w.r.t. μ yields,

$$\frac{\partial\tilde{\alpha}}{\partial\mu} = -\frac{4\kappa^2\hat{\kappa}\mu\theta}{(2\kappa\hat{\kappa} - \mu^2)^2} \times \frac{g'(\tilde{\alpha})}{M''(\tilde{\alpha}) + Sg''(\tilde{\alpha})},$$

which is negative, because $\hat{\kappa}$, μ, θ, $g'(\tilde{\alpha}) > 0$, $g''(\alpha^*) > 0$, and $M''(\alpha^*) \geq 0$. ■

The above proposition implies that, when products M and L become similar and the resulting competition between two firms is higher, the multinational firm should reduce the local content rate to use more imported components, which can improve the quality of product M. However, such a strategy results in an increase in the multinational firm's acquisition cost, because $M'(\tilde{\alpha}) < 0$. Therefore, Proposition 4 shows that the multinational firm's best response to a rise in the product substitutability is to spend more to enhance the quality of product M rather than to save cost in the production of product M.

We cannot analytically examine the impact of the product substitutability index μ on the demand for product M and the multinational firm's profit because it is intractable to determine the sign of the first-order derivative $\partial V^N(\tilde{\alpha})/\partial\mu$, which is computed as,

$$\begin{aligned}\frac{\partial V^N(\tilde{\alpha})}{\partial\mu} &= \frac{1}{(4\kappa\hat{\kappa}-\mu^2)^2}\left[4\mu\left(\mu^2-3\kappa\hat{\kappa}\right)M(\tilde{\alpha})+(1-2\kappa)\,4\kappa\hat{\kappa}\mu\theta g(\tilde{\alpha})\right. \\ &\left. +\kappa\left(4\hat{\kappa}\kappa+\mu^2\right)\left(\hat{C}_A+C_l\right)-\left(4\kappa\hat{\kappa}\hat{\delta}+4\hat{\kappa}\mu\delta+\mu^2\delta\right)\kappa\right]. \qquad (17)\end{aligned}$$

Thus, we perform a numerical sensitivity analysis to investigate the impacts of μ on the price and the demand for product M, and the multinational firm's and the local firm's profits.

Next, for the numerical study, we consider all Scenario I, Scenario D, and Scenario C, which are defined according to the property of the total tariff-exclusive acquisition cost of all components [i.e., $C(\alpha)$]. In order to make three scenarios comparable to each other and examine the impact of three patterns of $C(\alpha)$, we specify $C(\alpha)$ in the following form for all scenarios:

$$C(\alpha) = \lambda_1(1-\alpha)^{\nu_1} + \frac{\lambda_2}{(1-\alpha)^{\nu_2}} + \lambda_3, \qquad (18)$$

where the values of parameters λ_i $(i = 1, 2, 3)$ and ν_j $(j = 1, 2)$ vary in three scenarios, as given as follows.

	λ_1	ν_1	λ_2	ν_2	λ_3
Scenario I $[C'(\alpha) > 0]$	0	3	50	0.5	150
Scenario D $[C'(\alpha) < 0]$	70	3	0	0.5	130
Scenario C $[C''(\alpha) \geq 0]$	70	3	50	0.5	80

Table 1: Values of parameters in three scenarios of tariff-exclusive unit cost

Note from the above parameter values that $C(0)$—i.e., the multinational firm's acquisition cost when his local content rate is zero—is 200 for all three scenarios. This is assumed to reflect the fact that $C(0)$ is independent of the technology level in the local market. We plot Figure 1 to illustrate the cost function $C(\alpha)$ for three scenarios.

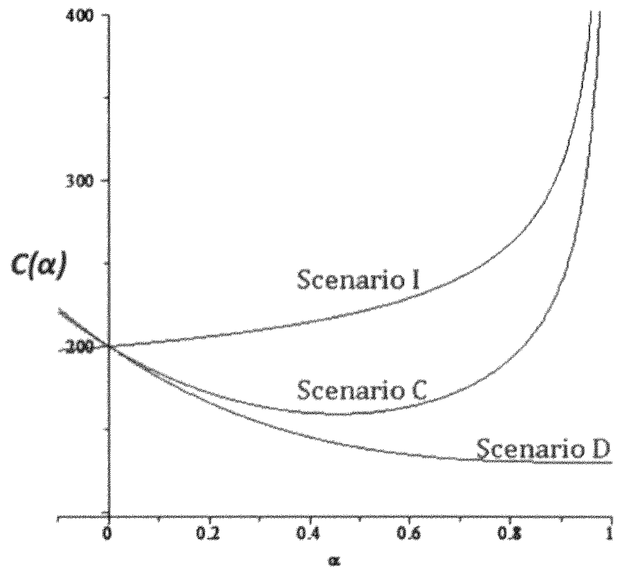

Figure 1: The cost function $C(\alpha)$ for Scenario I [$C'(\alpha) > 0$], Scenario D [$C'(\alpha) < 0$], and Scenario C [$C''(\alpha) > 0$].

In addition, for three scenarios, the function $g(\alpha)$ and all parameter values are specified as in Example 1, see a summary given as follows:

δ	$\hat{\delta}$	κ	$\hat{\kappa}$	θ	μ	C_A	$\hat{C}_A$	C_l	t
400	300	1.5	1.5	0.7	0.6	5	5	150	0.15

Table 2: Values of parameters in sensitivity analysis

Since the multinational firm owns more advanced technology than the local firm does, if product M is fully made of imported components, then the quality level of product M is much higher than that of product L. Thus we set δ to be higher than $\hat{\delta}$. Consumers may over- or under- react to the change of quality of a product; correspondingly, θ might be larger than or less than 1. Thus θ is set to be 0.7, which is larger than 0.5. From Table 3 we find that, average tariff rates for electrical machinery and transportation equipment range from 1.1% to 20.7%, and the maximum tariff rates may be as high as 139%. Therefore, we set the base value for t as 15%, which belongs to the range of average tariff rates set by the nine countries and is higher than the mean of these average tariff rates.

MFN applied duties (%)	Electrical machinery AVE	Transport equipment AVE	Electrical machinery MAX	Transport equipment MAX
China	8.3	11.5	35	45
Brazil	14.1	18.1	20	35
Russia	7.4	11.1	29	139
South Africa	4.6	5.9	25	30
India	7.2	20.7	10	100
Egypt	8	12.4	30	135
Canada	1.1	5.8	9	25
EU	2.8	4.3	14	22
U.S.	1.7	3	15	25

Table 3: Tariff rates set by different countries. Note that AVG denotes average tariff rate within the product group, MAX denotes the highest ad valorem duty within the product group, and all the rates stated in the form are for MFN (Most favourated nation).

For our sensitivity analysis regarding the impact of μ, we use the value of μ in Example 1 (i.e., $\mu = 0.6$, as presented above) as the *base* value, and increase the value of μ from 0.1 to 0.9 in steps of 0.1 but keep other parameter values unchanged. For each value of μ, we calculate α^*, $p^N(\alpha^*)$, $\hat{p}^N(\alpha^*)$, $D^N(\alpha^*)$, $\hat{D}^N(\alpha^*)$, $\Pi^N(\alpha^*)$, and $\hat{\Pi}^N(\alpha^*)$. To facilitate our discussion, we plot Figures 2, 3, and 4—where the subscript i represents Scenario i, for $i = I, D, C$—to show the impact of μ on two firms' decisions, the demands for two products, and two firms' profits, respectively.

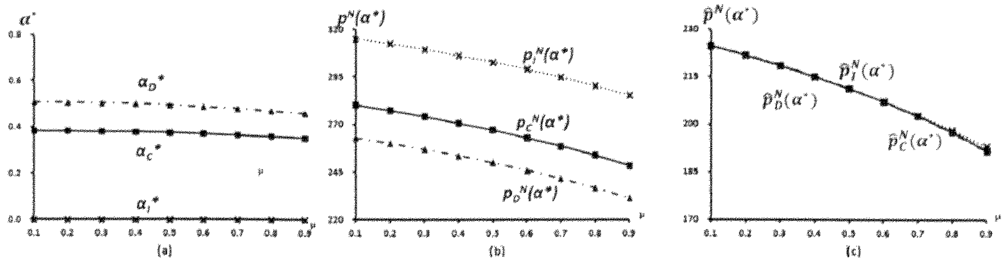

Figure 2: The Impact of the M-L substitutability index μ on the optimal local content rate α^*, and the Nash equilibrium-characterized prices $p^N(\alpha^*)$ and $\hat{p}^N(\alpha^*)$.

We learn from Figure 2(a) that the substitutability index μ does not generate any significant impact on the multinational firm's optimal local content rate decision, and the impact of μ on α^* shows almost the same pattern in three scenarios; that is, α^* keeps the same or just slightly decreases as μ increases. As Figure 2(b) and (c) indicates, as the two firms' products (namely, Products M and L) become similar (i.e., the substitutability index μ is greater), both $p^N(\alpha^*)$ and $\hat{p}^N(\alpha^*)$—two firms' pricing decisions in Nash equilibrium—are reduced in all scenarios. According to Figure 3(a) and (b), we find that, as μ increases, the demands $D^N(\alpha^*)$ and $\hat{D}^N(\alpha^*)$ vary in a different manner. Specifically, Figure 3(a) indicates that, when μ rises, $D^N(\alpha^*)$ first slightly decrease and then slightly increase. Figure 3(b) shows that $\hat{D}^N(\alpha^*)$ is significantly decreasing in μ in three scenarios.

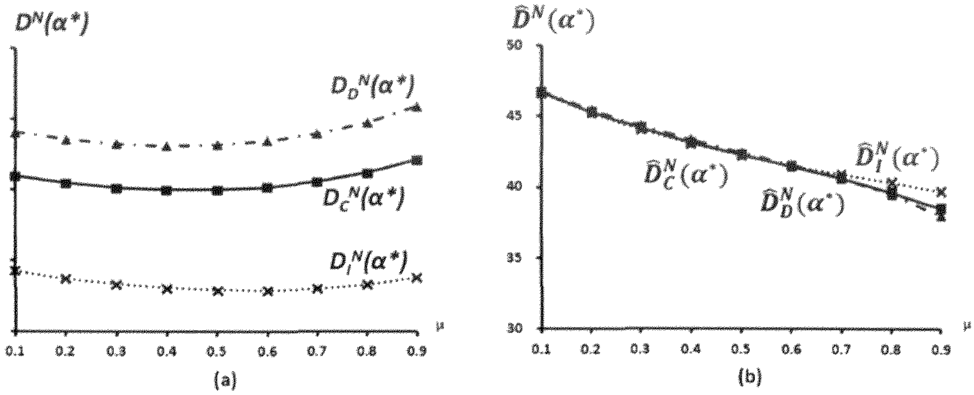

Figure 3: The Impact of the M-L substitutability index μ on the demand for product M $D^N(\alpha^*)$ and the demand for product L $\hat{D}^N(\alpha^*)$.

We also learn from Figure 4 that, as a result of increasing the value of μ, both $\Pi^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*)$ significantly decrease. According to our previous analytical results, the multinational firm should enhance the quality of product M as a response to the increase in the M-L substitutability index μ. The decrease in the multinational firm's profit when μ increases is mainly ascribed to the facts that the increase of quality is accompanied by the increase in cost, and that the price for product M decreases when competition intensifies.

From Figures 2, 3, and 4 we learn that for three scenarios, each of $p^N(\alpha^*)$, $D^N(\alpha^*)$, and $\Pi^N(\alpha^*)$ changes in a similar manner, but its values significantly vary in different scenarios. The difference is mainly ascribed to the disparity of the cost $C(\alpha^*)$ among the three scenarios. However, each of $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\alpha^*)$, and $\hat{\Pi}^N(\alpha^*)$ has almost the

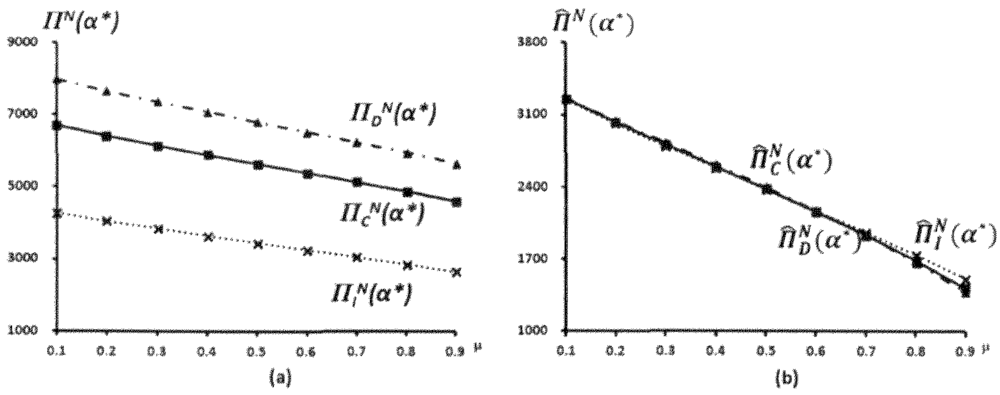

Figure 4: The impact of the M-L substitutability index μ on the multinational firm's profit $\Pi^N(\alpha^*)$ and the local firm's profit $\hat{\Pi}^N(\alpha^*)$.

same value in three scenarios; that is, $C(\alpha^*)$ imposes a negligibly small impact on the local firm. This implies that the multinational firm should consider a trade-off between his cost and his profit; as a result, the effect of $C(\alpha^*)$ could be absorbed only by the multinational firm.

4.3 The Impact of the Parameter θ

We now investigate the effects of θ on the multinational firm's optimal local content rate decision, as shown in the following proposition.

Proposition 5 If consumers are more sensitive to the quality of product M, i.e., the value of θ increases, then the multinational firm should reduce his local content rate, i.e., $\partial\tilde{\alpha}/\partial\theta < 0$.

Proof. Differentiating (16) once w.r.t. θ and κ yields,

$$\frac{\partial\tilde{\alpha}}{\partial\theta} = -\frac{(2\kappa\hat{\kappa} + \kappa\mu^2 - \mu^2)}{(2\kappa\hat{\kappa} - \mu^2)} \times \frac{g'(\tilde{\alpha})}{M''(\tilde{\alpha}) + Sg''(\tilde{\alpha})} < 0,$$

because all parameters are positive; and $g'(\tilde{\alpha}) > 0$, $g''(\alpha^*) > 0$, and $M''(\alpha^*) \geq 0$. ■

Using the above proposition, we can find the impact of the parameters θ on the demand for product M and the multinational firm's profit, as presented in the following corollary.

Corollary 4 Both the demand for product M and the multinational firm's profit become smaller, if consumers are more sensitive to the quality of product M, i.e., $\partial D^N(\tilde{\alpha})/\partial\theta < 0$ and $\partial\Pi^N(\tilde{\alpha})/\partial\theta < 0$.

Proof. We compute the first-order derivative of $D^N(\tilde{\alpha})$ w.r.t. θ as,

$$\begin{aligned}\frac{\partial D^N(\tilde{\alpha})}{\partial\theta} &= -\frac{\hat{\kappa}\,(2\kappa\hat{\kappa}-\mu^2)}{(\kappa\hat{\kappa}-\mu^2)\,(4\kappa\hat{\kappa}-\mu^2)}\left\{\left[M'(\tilde{\alpha})+\frac{(2\kappa\hat{\kappa}+\kappa\mu^2-\mu^2)\,\theta g'(\tilde{\alpha})}{2\kappa\hat{\kappa}-\mu^2}\right]\right.\\ &\left.\quad\times\frac{\partial\tilde{\alpha}}{\partial\theta}+\frac{(2\kappa\hat{\kappa}+\kappa\mu^2-\mu^2)g(\tilde{\alpha})}{2\kappa\hat{\kappa}-\mu^2}\right\}.\end{aligned}$$

According to (16), we find that

$$M'(\tilde{\alpha})+\frac{(2\kappa\hat{\kappa}+\kappa\mu^2-\mu^2)\,\theta}{2\kappa\hat{\kappa}-\mu^2}g'(\tilde{\alpha})=0,$$

which can be used to simplify $\partial D^N(\tilde{\alpha})/\partial\theta$ to

$$\frac{\partial D^N(\tilde{\alpha})}{\partial\theta}=-\frac{\hat{\kappa}\,(2\kappa\hat{\kappa}+\kappa\mu^2-\mu^2)}{(\kappa\hat{\kappa}-\mu^2)\,(4\kappa\hat{\kappa}-\mu^2)}g(\tilde{\alpha})<0.$$

We then calculate the first-order derivative of $\Pi^N(\tilde{\alpha})$ w.r.t. θ, and find

$$\frac{\partial\Pi^N(\tilde{\alpha})}{\partial\theta}=\frac{2\,(\kappa\hat{\kappa}-\mu^2)\,D^N(\alpha)}{\hat{\kappa}}\frac{\partial D^N(\tilde{\alpha})}{\partial\theta}=-\frac{2\,(2\kappa\hat{\kappa}+\kappa\mu^2-\mu^2)\,D^N(\alpha)}{(4\kappa\hat{\kappa}-\mu^2)}g(\tilde{\alpha})<0.$$

The corollary is thus proved. ■

The effects of θ on the demand for product M and the multinational firm's local content rate decision and profit are consistent with the fact that the multinational firm is willing to spend more efforts to improve the quality of product M and thereby reduce the local content rate, when consumers are more sensitive to the quality rather than other factors.

4.4 The Impact of the Parameters κ and $\hat{\kappa}$

We now investigate the effects of κ and $\hat{\kappa}$ on the multinational firm's optimal local content rate decision, as shown in the following proposition.

Proposition 6 If the reduction in consumers' marginal utility of either product M or product L becomes larger, i.e., the value of κ or $\hat{\kappa}$ increases, then the multinational firm should raise his local content rate, i.e., $\partial\tilde{\alpha}/\partial\kappa > 0$ and $\partial\tilde{\alpha}/\partial\hat{\kappa} > 0$. In addition, the impact of κ on the value of $\tilde{\alpha}$ is less significant than that of $\hat{\kappa}$, and the impact of $\hat{\kappa}$ on the value of $\tilde{\alpha}$ is less significant than that of $\hat{\kappa}$; that is, $|\partial\tilde{\alpha}/\partial\mu| > |\partial\tilde{\alpha}/\partial\hat{\kappa}| > |\partial\tilde{\alpha}/\partial\kappa|$.

Proof. Differentiating (16) once w.r.t. κ and $\hat{\kappa}$ yields,

$$\begin{aligned}
\frac{\partial\tilde{\alpha}}{\partial\kappa} &= \frac{\mu^4\theta}{(2\kappa\hat{\kappa}-\mu^2)^2} \times \frac{g'(\tilde{\alpha})}{M''(\tilde{\alpha})+Sg''(\tilde{\alpha})} > 0, \\
\frac{\partial\alpha}{\partial\hat{\kappa}} &= \frac{2\kappa^2\theta\mu^2}{(2\kappa\hat{\kappa}-\mu^2)^2} \times \frac{g'(\tilde{\alpha})}{M''(\tilde{\alpha})+Sg''(\tilde{\alpha})} > 0,
\end{aligned}$$

because all parameters are positive; and $g'(\tilde{\alpha}) > 0$, $g''(\alpha^*) > 0$, and $M''(\alpha^*) \geq 0$.

The differences among $|\partial\tilde{\alpha}/\partial\mu|$, $|\partial\tilde{\alpha}/\partial\kappa|$ and $|\partial\tilde{\alpha}/\partial\hat{\kappa}|$ are calculated as,

$$\begin{aligned}
\left|\frac{\partial\tilde{\alpha}}{\partial\mu}\right| - \left|\frac{\partial\tilde{\alpha}}{\partial\kappa}\right| &= \frac{(4\kappa^2\hat{\kappa}-\mu^3)\,\mu\theta}{(2\kappa\hat{\kappa}-\mu^2)^2} \times \frac{g'(\tilde{\alpha})}{M''(\tilde{\alpha})+Sg''(\tilde{\alpha})}, \\
\left|\frac{\partial\tilde{\alpha}}{\partial\mu}\right| - \left|\frac{\partial\alpha}{\partial\hat{\kappa}}\right| &= \frac{2\kappa^2\theta\mu\,(2\hat{\kappa}-\mu)}{(2\kappa\hat{\kappa}-\mu^2)^2} \times \frac{g'(\tilde{\alpha})}{M''(\tilde{\alpha})+Sg''(\tilde{\alpha})}, \\
\left|\frac{\partial\alpha}{\partial\hat{\kappa}}\right| - \left|\frac{\partial\tilde{\alpha}}{\partial\kappa}\right| &= \frac{(2\kappa^2-\mu^2)\,\mu^2\theta}{(2\kappa\hat{\kappa}-\mu^2)^2} \times \frac{g'(\tilde{\alpha})}{M''(\tilde{\alpha})+Sg''(\tilde{\alpha})},
\end{aligned}$$

which are positive because $\kappa > \mu$ and $\hat{\kappa} > \mu$.

According to (2), κ ($\hat{\kappa}$) reflects the degree to which the marginal utility of quantity for product M (L) is reduced. When consumers' marginal utility decreases dramatically, the quality of product M imposes a relatively small impact on total demand. The above proposition shows that the multinational firm should pay more attention to the substitutability between product M and product L when making local-content decision.

■

In addition to our above sensitivity analysis, we also find that the multinational firm's optimal local content rate α^* is not affected by (i) the parameters δ and $\hat{\delta}$—which are regarded as the multinational and the local firms' absolute advantages in the market, (ii) the local firm's unit acquisition cost C_l and unit assembly cost $\hat{C}_A$, and (iii) the multinational firm's unit assembly cost C_A. Such a result shows that when making local-content decision, the multinational firm should focus two factors related to the local firm—the product substitutability index (i.e., μ) and the degree to which the marginal utility of quantity for product L is reduced (i.e., $\hat{\kappa}$), and does not need to pay much attention to other factors about the local firm.

5 The Two-Stage Analysis under Local Content Requirements

We recall from Section 1 that some governments (especially, those in developing countries) implement the Local Content Requirements (LCRs) to impose the penalty tariff on the multinational firms that do not meet the LCRs. Let β denote the minimum local content rate required in the local market and t_p denote the additional (penalty) tariff rate when the multinational firm does not meet the LCR (i.e., $\alpha < \beta$). The multinational firm's unit cost $A(\alpha)$ under the LCR is calculated as,

$$A(\alpha) = \begin{cases} M_1(\alpha) = M(\alpha), & \text{if } \alpha \geq \beta, \\ M_2(\alpha) = M(\alpha) + t_p C(\alpha)(1-\alpha), & \text{if } \alpha < \beta. \end{cases} \tag{19}$$

Note that $M_2(\alpha)$ can be regarded as a $M(\alpha)$ with the "tariff rate $(t + t_p)$," and $M_2(\alpha)$ is also assumed to be a convex function of α, i.e., $M_2''(\alpha) \geq 0$.

5.1 Optimal Local Content Rate under the LCR

The LCR changes the multinational firm's unit acquisition cost, thereby influencing the firm's local content rate decision. This requires that, in order to find the multinational firm's optimal decision on the local content rate, we need to compare the multinational firm's maximum profit when the firm meets the minimum local content rate and that when the firm does not. Denoting by $V_1(\alpha)$ and $V_2(\alpha)$ the multinational firm's α-dependent unit profits without and with the penalty tariff, respectively, we have,

$$\begin{aligned} V_i(\alpha) \;=\; & \frac{1}{4\kappa\hat{\kappa} - \mu^2}\Big[-\left(2\kappa\hat{\kappa} - \mu^2\right) M_i(\alpha) - \left(2\kappa\hat{\kappa} + \kappa\mu^2 - \mu^2\right)\theta g(\alpha) + \kappa\mu\left(\hat{C}_A + C_l\right) \\ & +2\kappa\hat{\kappa}\delta - \kappa\mu\hat{\delta} - \mu^2\delta\Big], \quad \text{for } i = 1, 2. \end{aligned} \tag{20}$$

Therefore, the multinational firm's profit can be written as,

$$V(\alpha) = \begin{cases} V_1(\alpha), & \text{if } \alpha \geq \beta; \\ V_2(\alpha), & \text{if } \alpha < \beta. \end{cases}$$

The first- and second-order derivatives of $V_i(\alpha)$ $(i = 1, 2)$ w.r.t. α are calculated as,

$$\begin{aligned} V_i'(\alpha) &= -\frac{2\kappa\hat{\kappa} - \mu^2}{4\kappa\hat{\kappa} - \mu^2}\left[M_i'(\alpha) + Sg'(\alpha)\right], \\ V_i''(\alpha) &= -\frac{2\kappa\hat{\kappa} - \mu^2}{4\kappa\hat{\kappa} - \mu^2}\left[M_i''(\alpha) + Sg''(\alpha)\right] < 0, \end{aligned} \tag{21}$$

which follows from the facts that $g''(\alpha) > 0$, $M_1''(\alpha) \geq 0$, and $M_2''(\alpha) \geq 0$. That is, $V_i(\alpha)$ is a strictly concave function of α. Because the multinational firm absorbs the penalty tariff if and only if his local content rate is less than β, the domains for $V_1(\alpha)$ and $V_2(\alpha)$ are $[\beta, 1]$ and $[0, \beta)$, respectively.

Similar to Proposition 2, we can find the optimal local content rate α_1^* maximizing $V_1(\alpha)$ and the optimal rate α_2^* maximizing $V_2(\alpha)$ as follows:

$$\alpha_1^* = \begin{cases} \beta, & \text{if } Sg'(\beta) + M_1'(\beta) > 0, \\ \tilde{\alpha}_1, & \text{if } Sg'(\beta) + M_1'(\beta) \leq 0 < Sg'(1) + M_1'(1), \\ 1, & \text{if } Sg'(1) + M_1'(1) \leq 0; \end{cases} \tag{22}$$

and

$$\alpha_2^* = \begin{cases} 0, & \text{if } Sg'(0) + M_2'(0) \geq 0, \\ \tilde{\alpha}_2, & \text{if } Sg'(0) + M_2'(0) < 0 < Sg'(\beta) + M_2'(\beta), \\ \beta - \varepsilon, & \text{if } Sg'(\beta) + M_2'(\beta) \leq 0, \end{cases} \tag{23}$$

where $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$ represent the unique solution of $V_1'(\alpha) = 0$ [or, $Sg'(\alpha) + M_1'(\alpha) = 0$] and that of $V_2'(\alpha) = 0$ [or, $Sg'(\alpha) + M_2'(\alpha) = 0$], respectively; and ε is an infinitesimally small and positive number.

Comparing the multinational firm's maximum profit when the firm meets the minimum local content rate [i.e., $V_1(\alpha_1^*)$] and that when it does not [i.e., $V_2(\alpha_2^*)$], we can attain the multinational firm's optimal decision on the local content rate, as given in the following proposition.

Proposition 7 Under the LCR with the minimum local content rate β, the multinational firm's optimal local content rate α^*—which maximizes the firm's profit $V(\alpha)$—is uniquely obtained as,

$$\alpha^* = \begin{cases} 1, & \text{if } f_1'(1) \leq 0; \\ \tilde{\alpha}_1, & \text{if } f_1'(\beta) \leq 0 < f_1'(1); \\ \beta, & \text{if } f_1'(\beta) > 0 \text{ and } f_2'(\beta) \leq 0, \\ & \text{or, if } f_2'(0) < 0 < f_2'(\beta), \text{ and } f_1(\beta) \leq f_2(\tilde{\alpha}_2), \\ & \text{or, if } f_2'(0) \geq 0, \text{ and } f_1(\beta) \leq f_2(0); \\ \tilde{\alpha}_2, & \text{if } f_2'(0) < 0 < f_2'(\beta), \text{ and } f_1(\beta) > f_2(\tilde{\alpha}_2); \\ 0, & \text{if } f_2'(0) \geq 0, \text{ and } f_1(\beta) > f_2(0); \end{cases} \tag{24}$$

where $f_i(\alpha) \equiv Sg(\alpha) + M_i(\alpha)$ [and thus, $f_i'(\alpha) = Sg'(\alpha) + M_i'(\alpha)$]; and, $0 < \tilde{\alpha}_1 < \tilde{\alpha}_2 < 1$ if both $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$ belong to the range $(0, 1)$.

Proof. If the multinational firm's optimal local content rate α_1^* is equal to 1 or $\tilde{\alpha}_1$, then $\alpha_1^* > \beta$ and the LCR has no impact on the multinational firm's decisions. Thus, $\alpha^* = \alpha_1^*$, if $\alpha_1^* = 1$ or $\alpha_1^* = \tilde{\alpha}_1$. When $\alpha_1^* = \beta$, we cannot assure that β must be the optimal local content rate when the LCR does not apply. Thus, although the firm is responsible to the penalty tariff if his local content rate is α_2^*, he can still attain a higher profit by adopting α_2^*. It thus follows that we should compare $V_1(\beta)$ and $V_2(\alpha_2^*)$ to decide on the optimal local content rate for the multinational firm.

1. If $\alpha_1^* = \beta$ and $\alpha_2^* = \beta - \varepsilon$, then $V_2(\alpha_2^*) = V_2(\beta - \varepsilon)$. Since the firm absorbs the penalty tariff if he adopts the local content rate α_2^*, we find that $V_1(\beta) > V_2(\beta - \varepsilon)$, which means that $\alpha^* = \beta$.

2. If $\alpha_1^* = \beta$ and $\alpha_2^* = \tilde{\alpha}_2$, then $\alpha^* = \beta$ if $V_2(\tilde{\alpha}_2) \leq V_1(\beta)$, and $\alpha^* = \tilde{\alpha}_2$ if $V_2(\tilde{\alpha}_2) > V_1(\beta)$.

3. If $\alpha_1^* = \beta$ and $\alpha_2^* = 0$, then $\alpha^* = \beta$ if $V_2(0) \leq V_1(\beta)$, and $\alpha^* = 0$ if $V_2(0) > V_1(\beta)$.

We thus write α^* as,

$$\alpha^* = \begin{cases} 1, & \text{if } \alpha_1^* = 1; \\ \tilde{\alpha}_1, & \text{if } \alpha_1^* = \tilde{\alpha}_1; \\ \beta, & \text{if } \alpha_1^* = \beta \text{ and } \alpha_2^* = \beta - \varepsilon, \\ & \text{or, if } \alpha_1^* = \beta,\ \alpha_2^* = \tilde{\alpha}_2 \text{ and } V_2(\tilde{\alpha}_2) \leq V_1(\beta), \\ & \text{or, if } \alpha_1^* = \beta,\ \alpha_2^* = 0 \text{ and } V_2(0) \leq V_1(\beta); \\ \tilde{\alpha}_2, & \text{if } \alpha_1^* = \beta,\ \alpha_2^* = \tilde{\alpha}_2 \text{ and } V_2(\tilde{\alpha}_2) > V_1(\beta); \\ 0, & \text{if } \alpha_1^* = \beta,\ \alpha_2^* = 0 \text{ and } V_2(0) > V_1(\beta), \end{cases}$$

where $\tilde{\alpha}_i$ is the unique solution of the equation that $Sg'(\alpha_i) + M_i'(\alpha_i) = 0$, for $i = 1, 2$.

As Proposition 3 indicates, $\tilde{\alpha}_2 > \tilde{\alpha}_1$ since $V_2(\alpha)$ can be regarded as a $V_1(\alpha)$ with the "tariff rate $(t + t_p)$". When $\alpha_2^* = \tilde{\alpha}_2$, we find that $\tilde{\alpha}_1 < \tilde{\alpha}_2 < \beta$, and thus $\alpha_1^* = \beta$. Therefore, $\alpha_2^* = \tilde{\alpha}_2$ is a sufficient condition for $\alpha_1^* = \beta$. Similarly, when $\alpha_2^* = 0$, we have $\tilde{\alpha}_1 < \tilde{\alpha}_2 < 0$, and thus $\alpha_1^* = \beta$. It then follows that $\alpha_2^* = 0$ is also a sufficient condition for $\alpha_1^* = \beta$. Therefore, the expression of α^* can be simplified as

$$\alpha^* = \begin{cases} 1, & \text{if } \alpha_1^* = 1; \\ \tilde{\alpha}_1, & \text{if } \alpha_1^* = \tilde{\alpha}_1; \\ \beta, & \text{if } \alpha_1^* = \beta \text{ and } \alpha_2^* = \beta - \varepsilon, \\ & \text{or, if } \alpha_2^* = \tilde{\alpha}_2 \text{ and } V_2(\tilde{\alpha}_2) \leq V_1(\beta), \\ & \text{or, if } \alpha_2^* = 0 \text{ and } V_2(0) \leq V_1(\beta); \\ \tilde{\alpha}_2, & \text{if } \alpha_2^* = \tilde{\alpha}_2 \text{ and } V_2(\tilde{\alpha}_2) > V_1(\beta); \\ 0, & \text{if } \alpha_2^* = 0 \text{ and } V_2(0) > V_1(\beta), \end{cases}$$

Furthermore, the region in which the optimal local content rate α^* falls satisfies the following criteria: (i) $\alpha^* = 1$, if $V_1'(1) \geq 0$; (ii) $\alpha^* = \alpha_1$, if $V_1'(\beta) > 0 > V_1'(1)$; (iii) $\alpha^* = \beta$, if $V_1'(\beta) \leq 0 \leq V_2'(\beta)$, or if $V_1'(\beta) \leq 0$, $V_2'(0) > 0 > V_2'(\beta)$, and $V_2(\alpha_2) \leq V_1(\beta)$, or if $V_1'(\beta) \leq 0$, $V_2'(0) \leq 0$ and $V_2(0) \leq V_1(\beta)$; (iv) $\alpha^* = \alpha_2$, if $V_1'(\beta) \leq 0$, $V_2'(0) > 0 > V_2'(\beta)$ and $V_2(\alpha_2) > V_1(\beta)$; and (v) $\alpha^* = 0$, if $V_1'(\beta) \leq 0$, $V_2'(0) \leq 0$ and $V_2(0) > V_1(\beta)$.

Using equations (20) and (21), we can re-write α^* as in (24). This proposition is thus proved. ■

Noting that in equation (20) the sign of $Sg'(\alpha) + M_i'(\alpha)$ is negative, we find that the value of $V_i(\alpha)$ is decreasing in $f_i(\alpha)$. That is, in the above proposition, $[-f_i(\alpha)]$ reflects the impact of local content rate α on the multinational firm's unit profit $V_i(\alpha)$, since the value of α influences both the cost and the quality of the product M. It also follows that the first-order derivative $[-f_i'(\alpha)]$ reflects the marginal profit of local content rate. Let

$$\gamma_i(\alpha) \equiv \frac{d[-M_i(\alpha)]}{dg(\alpha)},$$

which can be regarded as the increase in the multinational firm's cost when the quality level of product M is increased by one unit, for a given value of the local content rate α. Then $f_i'(\alpha) > 0$ is equivalent to $\gamma_i(\alpha) < S$, and means that the marginal cost of product M's quality is smaller than S.

The above proposition indicates that, when calculating the optimal local content rate α^*, we should first look at the multinational firm's profit when the firm satisfies LCR. A sufficient condition for the multinational firm to meet the LCR is that the marginal cost of product M's quality when the firm adopts the LCR threshold β is sufficiently large such that $\gamma_1(\beta) \geq S$ [or, $f_1'(\beta) \leq 0$]. This indicates that if the cost for increasing product's quality is very high, then the multinational firm should adopt a high local content rate to keep the cost for product M in an acceptable level. When $\gamma_1(\beta) < S$, the optimal local content rate is β, $\tilde{\alpha}_2$, or 0, which depends on the values of $\gamma_2(0)$ and $\gamma_2(\beta)$, and 0, and also the comparison among the impact of local content rate α on the multinational firm's unit profit when the firm adopts local content rates β, $\tilde{\alpha}_2$ and 0, i.e., $f_1(\beta)$, $f_2(\tilde{\alpha}_2)$, and $f_2(0)$.

Under the LCR, two firms' prices in Nash equilibrium, unit profits, and total profits, and the resulting demands for two products can be obtained by simply replacing $M(\alpha)$ in Section 3 with $A(\alpha)$. To illustrate the multinational firm's optimal local content rate, two firms' pricing decisions, and the resulting demands for two products, and two firms' profits, we provide the following numerical example.

Example 2 We re-consider Example 1 but assume that the policy maker in the local market requires the LCR with $\beta = 60\%$ for the product of the multinational firm, and the penalty tariff rate is $t_p = 30\%$. That is, the multinational firm absorbs an additional

30% penalty tariff if the local content rate in his product is smaller than 60%.

We attain the multinational firm's optimal local content rate when he meets the LCR (i.e., α_1^*) and that when the firm does not (i.e., α_2^*). Under the constraint that $\alpha \leq \beta$, we find that $\alpha_1^* = \beta = 0.60$ because $V_1'(\beta) = -76.075 < 0$. Under the constraint that $\alpha > \beta$, $\tilde{\alpha}_2 = 0.452 \in (0, 0.60)$. It thus follows that $\alpha_2^* = \tilde{\alpha}_2 = 0.452$. Next, we compare $\Pi_2^N(\tilde{\alpha}_2)$ and $\Pi_1^N(\beta)$, which are calculated as $\Pi_2^N(\tilde{\alpha}_2) = \$3,761.128$ and $\Pi_1^N(\beta) = \$4,383.444$. Since $\Pi_1^N(\beta) > \Pi_2^N(\tilde{\alpha}_2)$, the multinational firm's optimal local content rate α^* is determined as $\alpha^* = \beta = 0.60$.

Then, we solve (9) and (10) to find two firms' prices in Nash equilibrium as $p^N =$ \$252.667 and $\hat{p}^N =$ \$213.528. The resulting demands are $D^N(\alpha^*) = 58.982$ and $\hat{D}^N(\alpha^*) = 46.451$. The two firms achieve their profits as $\Pi^N(\alpha^*) = \$4,383.444$ and $\hat{\Pi}^N(\alpha^*) = \$2,718.662$, which demonstrates that the multinational firm's profit is higher than the local firm's.

When we compare the above results with those in Example 1 (in which the LCR does not apply), we find the following insight regarding the impact of the LCR. First, the LCR significantly raises the optimal local content rate of the multinational firm from 0.370 to 0.60. Secondly, the implementation of the LCR reduces the multinational firm's profit from $\$5,375.271$ to $\$4,383.444$ by 18.452%, whereas it increases the local firm's profit from $\$2,162.636$ to $\$2,718.662$ by 25.711%. Thirdly, under the LCR, for the multinational firm's product, the demand $D^N(\alpha^*)$ is reduced from 65.315 to 58.982 and the price p^N is decreased from \$262.947 to \$252.667; but, both the demand $\hat{D}^N(\alpha^*)$ and the price $\hat{p}^N$ for the local firm's product are increased. Actually, the decrease in the price p^N partly results from the reduction in the quality of the multinational firm's product, which happens as a consequence of increasing the local content rate. The above results show that the LCR, as a "regionalism policy," transfers the demand and the profit from the multinational firm to the local firm but may not benefit local consumers, which is shown by our numerical result that, in the example, consumers' net utility is decreased from $6,110.425$ to $5,871.308$, when the LCR applies. ■

5.2 Impact of the Penalty Tariff Rate t_p under the LCR

When the multinational firm's optimal local content rate is equal to or larger than β if LCR is not implemented, i.e., $f_1'(\beta) \leq 0$, the firm satisfies the LCR, thus, any change in the value of t_p does not influence the firm's profit and his local content rate decision. Therefore, in the following proposition we investigate the impact of t_p on α^* when $f_1'(\beta) > 0$.

Proposition 8 When the multinational firm's optimal local content rate is not smaller than β if LCR is not applicable, i.e., $f_1'(\beta) > 0$, we obtain the following results regarding the impact of the penalty tariff rate t_p on the multinational firm's optimal local content rate decision α^*.

1. When $C'(0) \geq C(0)$, the multinational firm's optimal local content rate is uniquely found as,

$$\alpha^* = \begin{cases} \beta, & \text{if } t_p^1 < t_p < t_p^0; \\ 0, & \text{if } t_p < \min\{t_p^1, t_p^0\}; \end{cases}$$

   where t_p^0 and t_p^1 are the respective unique solutions of the equations $f_2'(0) = 0$ and $f_2(0) = f_1(\beta)$, and can be expressed as,

$$\begin{aligned} t_p^0 &= \frac{Sg'(0) + C'(0)}{C(0) - C'(0)} - t, \\ t_p^1 &= \frac{Sg(\beta) + C(\beta)\left[1 + t(1-\beta)\right]}{C(0)} - t - 1. \end{aligned}$$

2. When $C'(0) < C(0)$, the multinational firm's optimal local content rate is uniquely found as,

$$\alpha^* = \begin{cases} \beta, & \text{if } t_p > \tilde{t}_p, \\ & \text{or, if } t_p^0 < t_p < \tilde{t}_p, \text{ and } t_p > \bar{t}_p, \\ & \text{or, if } t_p^1 < t_p < t_p^0; \\ \tilde{\alpha}_2, & \text{if } t_p^0 < t_p < \tilde{t}_p, \text{ and } t_p < \bar{t}_p; \\ 0, & \text{if } t_p < \min\{t_p^1, t_p^0\}; \end{cases} \tag{25}$$

   where $\tilde{t}_p$ and $\bar{t}_p$ are the respective unique solutions of the equations $f_2'(\beta) = 0$ and

$f_2(\tilde{\alpha}_2) = f_1(\beta)$, and can be expressed as,

$$
\begin{aligned}
\tilde{t}_p &= \frac{Sg'(\beta) + C'(\beta)}{C(\beta) - (1-\beta)\,C'(\beta)} - t, \\
\bar{t}_p &= \frac{S\,[g(\beta) - g(\tilde{\alpha}_2)] + C(\beta)\,[1 + t(1-\beta)]}{C(\tilde{\alpha}_2)(1-\tilde{\alpha}_2)} - t - \frac{1}{1-\tilde{\alpha}_2}.
\end{aligned}
$$

Proof. As indicated by Proposition 7, when $f_1'(\beta) > 0$, the multinational firm's optimal local content rate is uniquely found as,

$$
\alpha^* = \begin{cases}
\beta, & \text{if } f_2'(\beta) \le 0, \\
 & \text{or, if } f_2'(0) < 0 < f_2'(\beta), \text{ and } f_1(\beta) \le f_2(\tilde{\alpha}_2), \\
 & \text{or, if } f_2'(0) \ge 0, \text{ and } f_1(\beta) \le f_2(0); \\
\tilde{\alpha}_2, & \text{if } f_2'(0) < 0 < f_2'(\beta), \text{ and } f_1(\beta) > f_2(\tilde{\alpha}_2); \\
0, & \text{if } f_2'(0) \ge 0, \text{ and } f_1(\beta) > f_2(0).
\end{cases}
$$

1. We firstly discuss the situation when $C'(0) \ge C(0)$. Since $f_2'(0) = Sg'(0) + C'(0) + (t + t_p)\,[C'(0) - C(0)]$, if $C'(0) \ge C(0)$, then $f_2'(0) > 0$. Since $V_2(\alpha)$ can be regarded as a $V_1(\alpha)$ with the "tariff rate $(t+t_p)$", the firm's profit is decreasing in penalty tariff rate t_p according to Corollary 3. In this case, the multinational firm adopts the optimal local content rate of β if t_p is large enough to assure that $V_2(0) \le V_1(\beta)$, i.e., $f_1(\beta) \le f_2(0)$. Otherwise, the firm uses only imported components to make product M; that is, $\alpha^* = 0$, if $V_2(0) > V_1(\beta)$.

2. When $C'(0) \ge C(0)$, we easily rewrite $f_2'(0) < 0$ as $t_p > t_p^0 = [Sg'(0) + C'(0)]/[C(0) - C'(0)] - t$, and $f_2'(0) \ge 0$ as $t_p \le t_p^0$.

Using $f_i(\alpha) \equiv Sg(\alpha) + M_i(\alpha)$, equation 19 and $g(0) = 0$, we can easily rewrite α^* as stated in equation 25. This proposition is thus proved. ■

We learn from above proposition that if the penalty tariff rate t_p is sufficiently high, then it can induce the multinational firm to adopt the LCR threshold β. While both the increase of tariff rate t and that of penalty tariff rate t_p can lead the firm to increase his local content rate in most cases, t does not work when $C'(0) \ge C(0)$. This distinguishes penalty tariff rate t_p from tariff rate t in the ability to change the multinational firm's local content rate since if t_p is large enough that $t_p > t_p^1$, then the multinational firm should satisfy the LCR, i.e., $\alpha^* = \beta$.

Remark 6 A penalty tariff policy is very useful in inducing a multinational firm to enhance his local content rate. If the firm's local content rate is zero and $C'(0) \geq C(0)$, then the firm has only two choices concerning his local content rate: either zero or β, the choice of which depends on the comparison between $V_2(0)$ and $V_1(\beta)$. If the firm's local content rate is zero but $C'(0) < C(0)$, or if the firm's optimal local content rate is not zero, then the firm's optimal local content rate might be any value between $[0, \beta]$, and he should enhance his local content rate when t_p increases; but the firm should adopt the LCR threshold β only when t_p is sufficiently high to assure that $V_2(\tilde{\alpha}_2) \leq V_1(\beta)$ or $\tilde{\alpha}_2 \geq \beta$, i.e., when $t_p > \bar{t}_p$ or $t_p > \tilde{t}_p$.

Using the above proposition, we attain the results regarding the impact of t_p on the demands for products M and L, and the multinational and the local firms' profits, as shown in the following corollary.

Corollary 5 When product M is not fully made of local components (i.e., $\alpha^* = \tilde{\alpha}_2$ or $\alpha^* = 0$), then both the demand for product M and the multinational firm's profit are decreasing in t_p but both the demand for product L and the local firm's profit are increasing in t_p. Otherwise, neither the demand nor the profit for two firms change as t_p is increased.

Proof. If an increase in the penalty tariff rate t_p does not induce the multinational firm to meet the local content requirement, then the firm always pays the penalty tariff. We can regard the sum of t and t_p as the total tariff rate applicable to the firm. According to Corollary 3, increasing the penalty tariff rate can result in an decrease in the demand for product M and the multinational firm's profit.

If, after t_{p2} is increased, the multinational firm's local content rate is β, then we compare the firm's unit profit before and after the increase of t_p—which are $V_2(\alpha^*)$ and $V_1(\beta)$, respectively—to find the impact of t_p. Prior to the increase of t_p, the optimal local content rate α^* is not β; this means that $V_2(\alpha^*) > V_1(\beta)$. However, subsequent to the increase of t_p, the optimal local content rate α^* is turned into β; this means that

$V_2(\alpha^*) < V_1(\beta)$ under the new penalty tariff policy. Since $V_1(\beta)$ keeps the same before and after the change of t_p, this indicates that the increase of t_p causes the decrease in $V_2(\alpha^*)$ from the value that is larger than $V_1(\beta)$ to the value that is smaller than $V_1(\beta)$. That is, the multinational firm's profit decreases after the increase of t_p. We thus prove the impact of t_p on the demand for product M and the multinational firm's profit.

Next, we show the impact of t_p on the local firm. If an increase of the penalty tariff rate t_p makes the multinational firm to increase his local content rate but does not induce the firm to adopt the LCR threshold β, then we can calculate $\partial\hat{V}^N(\tilde{\alpha})/\partial t_p$ to examine the impact of t_p on $\hat{V}^N(\tilde{\alpha})$. Differentiating the local firm's unit profit function in (13) once with respect to α, we have,

$$\begin{aligned}\frac{\partial\hat{V}^N(\alpha)}{\partial\alpha} &= \frac{1}{4\kappa\hat{\kappa}-\mu^2}\left\{\hat{\kappa}\mu\left[C'(\alpha)+tC'(\alpha)-t\alpha C'(\alpha)-tC(\alpha)\right]\right.\\ &\quad \left.+\left(\hat{\kappa}+2\kappa\hat{\kappa}-\mu^2\right)\mu\theta g(\alpha)\right\}.\end{aligned}$$

Using (16), we find the first-order derivative $\partial\hat{V}^N(\tilde{\alpha})/\partial t_p$ at the point $\tilde{\alpha}$ as,

$$\left.\frac{\partial\hat{V}^N(\alpha)}{\partial\alpha}\right|_{\alpha=\tilde{\alpha}} = \mu\theta(\kappa\hat{\kappa}-\mu^2)g'(\tilde{\alpha})/\left(2\kappa\hat{\kappa}-\mu^2\right) > 0.$$

Differentiate $\hat{V}^N(\alpha)$ once w.r.t t_p yields,

$$\frac{\partial\hat{V}^N(\tilde{\alpha})}{\partial t_p} = \frac{1}{4\kappa\hat{\kappa}-\mu^2}\times\left.\frac{\partial\hat{V}^N(\alpha)}{\partial\alpha}\right|_{\alpha=\tilde{\alpha}}\times\frac{\partial\tilde{\alpha}}{\partial t_p}+\frac{\hat{\kappa}\mu}{4\kappa\hat{\kappa}-\mu^2}\left(1-\tilde{\alpha}\right)C(\tilde{\alpha}).$$

According to Proposition 8, $\tilde{\alpha}$ is increasing with t_p, i.e., $\partial\tilde{\alpha}/\partial t_p > 0$. It thus follows that $\partial\hat{V}^N(\tilde{\alpha})/\partial t_p > 0$.

If, after t_{p2} is increased, the multinational firm's local content rate is still 0, then we compare the local firm's unit profit $\hat{V}^N(0)$ for different values of t_p. From Corollary 2 and (19), we learn that, when $\alpha = 0$, increasing the value of t_p raises $M_2(0)$ but increase $\hat{V}^N(0)$.

The above analysis indicates that as t_p increases, if α is increased within $(0,1)$, then the local firm's unit profit $\hat{V}^N(\tilde{\alpha})$ increases. Noting from Corollary 2 that, when $\alpha = \beta$, $\hat{V}^N(\beta)$ when the penalty tariff is not applicable is lower than that when the penalty tariff is applicable. Therefore, if an increase in the penalty tariff rate t_p makes the multinational firm to adopt the LCR threshold β, the local firm's demand and profit increase. The corollary is thus proved. ■

To illustrate the above analysis, we perform a sensitivity analysis to examine the impact of the penalty tariff rate t_p. All parameter values are specified as in Example 2, see a summary given as follows:

δ	$\hat{\delta}$	κ	$\hat{\kappa}$	θ	μ	C_A	$\hat{C}_A$	C_l	t	t_p	β
400	300	1.5	1.5	0.7	0.6	5	5	150	0.15	0.3	0.60

Table 4: Values of parameters in sensitivity analysis when the LCR is implemented

Similar to Section 4.2, we consider three scenarios including Scenario I [$C'(\alpha) > 0$ for $\alpha \in (0,1)$], Scenario D [$C'(\alpha) < 0$ for $\alpha \in (0,1)$], and Scenario C [$C''(\alpha) \geq 0$ for $\alpha \in (0,1)$], and for each scenario we increase the value of t_p from 0 to 0.9 in increments of 0.1. For each value of t_p, we calculate α^*, $p^N(\alpha^*)$, $\hat{p}^N(\alpha^*)$, $D^N(\alpha^*)$, $\hat{D}^N(\alpha^*)$, $\Pi^N(\alpha^*)$, and $\hat{\Pi}^N(\alpha^*)$.

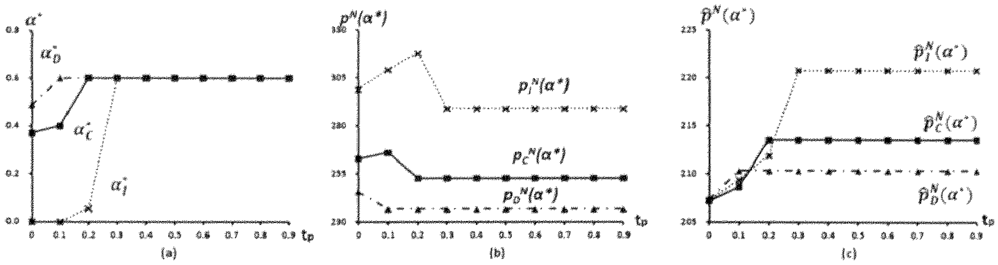

Figure 5: The impact of the penalty tariff rate t_p on the optimal local content rate α^*, and the Nash equilibrium-characterized prices $p^N(\alpha^*)$ and $\hat{p}^N(\alpha^*)$.

As Figure 5(a) indicates, the curve for α_I^* depicts three possibilities for Case 3 in Proposition 8. Specifically, if we increase t_p from 0 to 0.1, then the optimal local content rate for the multinational firm is 0; if we increase t_p to 0.2, then the firm should increase his local content rate to 0.055 which is smaller than the LCR threshold $\beta = 0.6$; and, if we increase t_p to 0.3, then the firm has to adopt the LCR threshold $\beta = 0.6$. The curve of α_C^* depicts two possibilities for Case 2 in Proposition 8. That is, if t_p is increased from 0 to 0.1, then the firm increases his local content rate which is smaller than the

LCR threshold β; if t_p is increased to 0.2, the firm adopts the LCR cutoff level $\beta = 0.6$. We can learn from all three curves for α_I^*, α_C^*, and α_D^* that, after the firm adopts the rate $\beta = 0.6$, i.e., $\alpha^* \geq \beta$, the firm will not change his local content rate as t_p increases. Figure 5(b) and 5(c) reflects that, as t_p increases, two firms' prices first both increase; but, when t_p is sufficiently large such that the multinational firm adopts the LCR threshold β (i.e., $\alpha^* = \beta$), $p^N(\beta)$ is always smaller than $p^N(\alpha^*)|_{\alpha^*<\beta}$ before the firm adopts the rate β, whereas $\hat{p}^N(\beta)$ is always higher than $\hat{p}^N(\alpha^*)|_{\alpha^*<\beta}$ before the firm adopts the rate β.

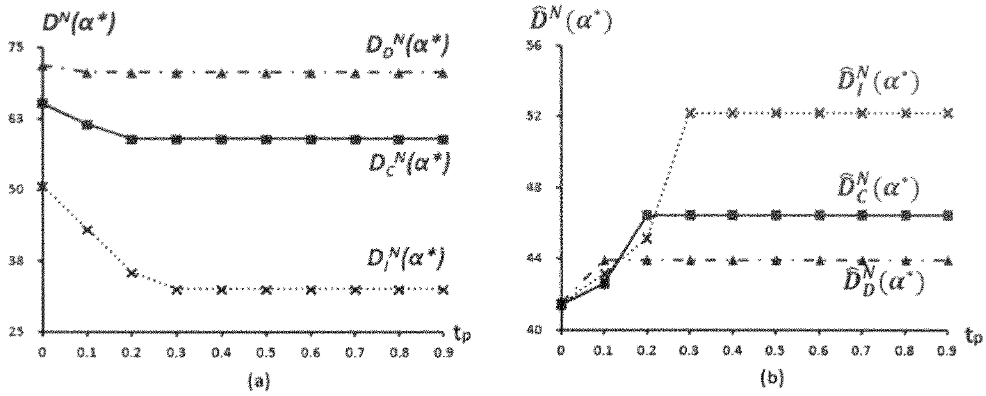

Figure 6: The impact of t_p on the demand for product M $D^N(\alpha^*)$ and the demand for product L $\hat{D}^N(\alpha^*)$.

We note from Figures 6 and 7 that, as t_p is increased, the demand for product M $D^N(\alpha^*)$ and the multinational firm's profit $\Pi^N(\alpha^*)$ change in a similar manner, and the demand for product L $\hat{D}^N(\alpha^*)$ and the local firm's profit $\hat{\Pi}^N(\alpha^*)$ also change similarly. This happens mainly because each firm's profit is proportional to the square of the firm's own demand in terms of the Nash equilibrium-based prices and the optimal local content rates, as shown by Corollaries 1 and 2. Before the value of t_p is increased such that the multinational firm adopts the LCR threshold β, $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ for the multinational firm are both decreasing in t_p, whereas $\hat{D}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*)$ are both increasing in t_p.

We learn from Section 4.2 that the differences among the values of $\hat{\Pi}^N(\alpha^*)$ in three scenarios are negligible when LCR is not applied. Specifically, $\hat{\Pi}_I^N(\alpha^*)$, $\hat{\Pi}_C^N(\alpha^*)$, and $\hat{\Pi}_D^N(\alpha^*)$ are equal to 2170.173, 2162.636, and 2175.966, respectively. However, Figure 7

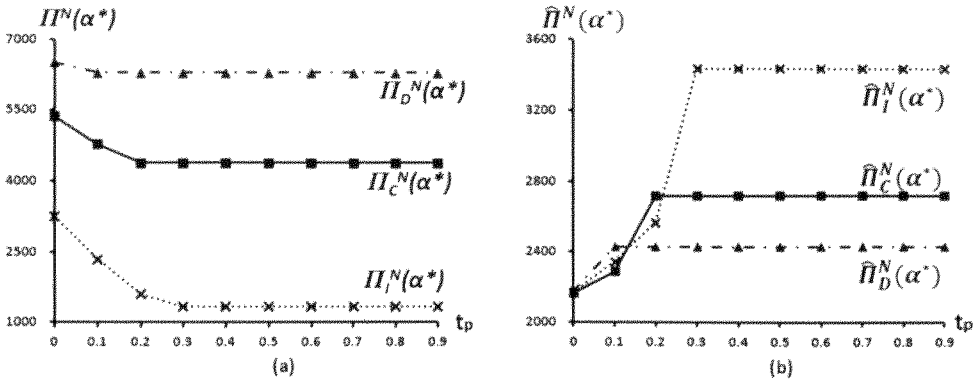

Figure 7: The impact of t_p on the multinational firm's profit $\Pi^N(\alpha^*)$ and the local firm's profit $\hat{\Pi}^N(\alpha^*)$.

shows that when the government imposes LCR on the multinational firm, the value of $\hat{\Pi}^N(\alpha^*)$ differs greatly among three scenarios. Furthermore, at situations in which the multinational firm satisfies LCR, $\hat{\Pi}_I^N(\alpha^*) > \hat{\Pi}_C^N(\alpha^*) > \hat{\Pi}_D^N(\alpha^*)$. The results imply that when LCR is implemented, the multinational firm cannot totally absorb the impact of $C(\alpha^*)$ by choosing his local content rate "freely". Rather, the firm has to compare the penalty tariff and the additional cost resulting from increasing his local content rate. LCR transfers the most benefit from the multinational firm to the local firm when $C(\alpha)$ is increasing in α, because in Scenario I for any kind of component, an imported one is always cheaper than a local one.

5.3 The Impact of the LCR Threshold β

We analyze the impact of the LCR threshold β on the multinational firm's optimal local content rate decision α^* and the demands for two products and two firms' profits.

Proposition 9 When increasing the LCR cutoff level β in the local market from 0, we have the following results regarding the impact of β on the multinational firm's optimal local content rate α^*.

1. If $f_2'(0) \geq 0$, then α^* is determined as,

$$\alpha^* = \begin{cases} \beta, & \text{when } \beta \leq \beta^o, \\ 0, & \text{when } \beta > \beta^o, \end{cases}$$

where β^o is the unique solution satisfying $V_2(0) = V_1(\beta^o)$ [or, $f_2(0) = f_1(\beta^o)$]. That is, α^* is increasing in β when $\beta \le \beta^o$ and it is independent of β when $\beta > \beta^o$.

2. If $f_1'(0) \ge 0$ and $f_2'(0) < 0 < f_2'(1)$, then α^* is determined as,

$$\alpha^* = \begin{cases} \beta, & \text{when } \beta \le \bar{\beta}, \\ \tilde{\alpha}_2, & \text{when } \beta > \bar{\beta}, \end{cases}$$

   where $\bar{\beta}$ is the unique solution satisfying $V_2(\tilde{\alpha}_2) = V_1(\bar{\beta})$ [or, $f_2(\tilde{\alpha}_2) = f_1(\bar{\beta})$] and $\tilde{\alpha}_1 < \tilde{\alpha}_2 < \bar{\beta}$. That is, α^* is increasing in β when $\beta \le \bar{\beta}$ but it is independent of β when $\beta > \bar{\beta}$.

3. If $f_1'(0) \ge 0$ and $f_2'(1) \le 0$, then $\alpha^* = \beta$ for all $\beta \in [0, 1]$, which means that α^* is increasing in β.

4. If $f_1'(0) < 0 < f_1'(1)$ and $f_2'(1) \le 0$, then α^* is determined as,

$$\alpha^* = \begin{cases} \alpha_1, & \text{when } \beta < \tilde{\alpha}_1, \\ \beta, & \text{when } \beta \ge \tilde{\alpha}_1. \end{cases}$$

   That is, α^* is independent of β when $\beta < \alpha_1$ and α^* is increasing in β when $\beta \ge \alpha_1$.

5. If $f_1'(0) < 0 < f_1'(1)$ and $f_2'(0) < 0 < f_2'(1)$, then α^* is determined as,

$$\alpha^* = \begin{cases} \tilde{\alpha}_1, & \text{when } \beta < \tilde{\alpha}_1, \\ \beta, & \text{when } \tilde{\alpha}_1 \le \beta \le \bar{\beta}, \\ \tilde{\alpha}_2, & \text{when } \beta > \bar{\beta}. \end{cases}$$

   That is, α^* is independent of β when $\beta < \tilde{\alpha}_1$, α^* is increasing in β when $\alpha_1 \le \beta \le \bar{\beta}$, and α^* is also independent of β when $\beta > \bar{\beta}$.

6. If $f_1'(1) \le 0$, then $\alpha^* = 1$ for any value of $\beta \in [0, 1]$. That is, α^* is always independent of β.

Proof. According to (22), (23) and Proposition 7, we consider the following six possibilities.

1. If $f_2'(0) \geq 0$, then $\tilde{\alpha}_2 \leq 0$. According to Proposition 3, $\tilde{\alpha}_1 < \tilde{\alpha}_2 \leq 0$. Therefore, $\alpha_1^* = \beta$, $\alpha_2^* = 0$, and $V_1'(\alpha) < 0$. When $\beta = 0$, we find that $\alpha_1^* = 0$. Since $V_1(\alpha)$ is decreasing in α and $\alpha_1^* = \beta$, $V_1(\alpha_1^*) \geq V_2(0)$ for $\beta \leq \beta^o$ and $V_1(\alpha_1^*) < V_2(0)$ for $\beta > \beta^o$. Therefore, $\alpha^* = \alpha_1^* = \beta$ for $\beta > \beta^o$ and $\alpha^* = \alpha_2^* = 0$ for $\beta < \beta^o$.

2. If $f_1'(0) \geq 0$ and $f_2'(0) < 0 < f_2'(1)$, then $\alpha_1^* = \beta$, $\alpha_2^* = \min\{\tilde{\alpha}_2, \beta - \varepsilon\}$, and $V_1'(\alpha) < 0$. When $\beta = 0$, $\alpha_1^* = 0$. Thus, $\alpha^* = \beta$ when $\beta \leq \tilde{\alpha}_2$; and, the value of α^* depends on the value of $V_1(\beta)$ and $V_2(\tilde{\alpha}_2)$, when $\beta > \tilde{\alpha}_2$. For the case that $\beta > \tilde{\alpha}_2$, we find that, because $V_1(\alpha)$ is decreasing in α, $V_1(\beta) \geq V_2(\tilde{\alpha}_2)$ if $\tilde{\alpha}_2 < \beta \leq \bar{\beta}$, and $V_1(\beta) < V_2(\tilde{\alpha}_2)$ if $\beta > \bar{\beta}$. It thus follows that $\alpha^* = \beta$ when $\beta \leq \bar{\beta}$ and $\alpha^* = \tilde{\alpha}_2$ when $\beta > \bar{\beta}$.

3. If $f_1'(0) \geq 0$ and $f_2'(1) \leq 0$, then $\alpha_1^* = \beta$ and $\alpha_2^* = \beta - \varepsilon$. Thus, $\alpha^* = \beta$.

4. If $f_1'(0) < 0 < f_1'(1)$ and $f_2'(1) \leq 0$, then $\alpha_1^* = \max\{\tilde{\alpha}_1, \beta\}$, $\alpha_2^* = \beta - \varepsilon$, and $V_1'(\alpha) < 0$ for $\alpha \in [\tilde{\alpha}_1, \beta]$. When $\beta < \tilde{\alpha}_1$, the LCR does not have any impact on the multinational firm and thus, $\alpha^* = \tilde{\alpha}_1$. When $\beta \geq \alpha_1$, $\alpha_1^* = \beta$, and thus $\alpha^* = \beta$.

5. If $f_1'(0) < 0 < f_1'(1)$ and $f_2'(0) < 0 < f_2'(1)$, then $\alpha_1^* = \max\{\tilde{\alpha}_1, \beta\}$ and $\alpha_2^* = \min\{\tilde{\alpha}_2, \beta - \varepsilon\}$. When $\beta < \tilde{\alpha}_1$, the LCR does not impact the multinational firm and thus $\alpha^* = \tilde{\alpha}_1$. When $\tilde{\alpha}_1 \leq \beta \leq \tilde{\alpha}_2$, we find that $\alpha_1^* = \beta$ and $\alpha_2^* = \beta - \varepsilon$, and thus $\alpha^* = \beta$. When $\beta > \tilde{\alpha}_2$, $V_1(\beta) \geq V_2(\tilde{\alpha}_2)$ for $\tilde{\alpha}_2 < \beta \leq \bar{\beta}$, and $V_1(\beta) < V_2(\tilde{\alpha}_2)$ for $\beta > \bar{\beta}$. Hence, $\alpha^* = \tilde{\alpha}_1$ if $\beta < \tilde{\alpha}_1$; $\alpha^* = \beta$ if $\tilde{\alpha}_1 \leq \beta \leq \bar{\beta}$; and $\alpha^* = \tilde{\alpha}_2$ if $\beta > \bar{\beta}$.

6. If $f_1'(1) \leq 0$, then $\tilde{\alpha}_1 \geq 1$. According to Proposition 3, $0 \leq \tilde{\alpha}_1 < \tilde{\alpha}_2$. Therefore, $\alpha_1^* = 1$ and $\alpha_2^* = \beta - \varepsilon$. Since $\beta \leq 1 = \alpha_1^*$, $\alpha^* = 1$.

This proposition is thus proved. ∎

We learn from the above proposition that a multinational firm should satisfy the LCR when threshold β belongs to a certain range, i.e., $\beta \in \max\{0, \tilde{\alpha}_1\} \leq \beta \leq \min\{\bar{\beta}, 1\}$ when $f_2'(0) < 0$ and $\beta \in (0, \beta^o]$ when $f_2'(0) \geq 0$. Within the range, the increase of β leads the firm to increase his local content rate. However, when β is largely increased such that $\beta > \bar{\beta}$ [when $f_2'(0) < 0$] or $\beta > \beta^o$ [when $f_2'(0) \geq 0$], then the firm will adopt a lower local content rate $\tilde{\alpha}_2$ or zero.

We next conduct a numerical sensitivity analysis to illustrate the above analysis and show how the multinational firm's and the local firm's Nash equilibrium-characterized pricing decisions and the resulting demands and profits vary when the value of β changes. Similar to our previous numerical studies, we consider Scenario I [$C'(\alpha) > 0$ for $\alpha \in (0,1)$], Scenario D [$C'(\alpha) < 0$ for $\alpha \in (0,1)$], and Scenario C [$C''(\alpha) \geq 0$ for $\alpha \in (0,1)$]. We increase the value of β from 0 to 0.9 in steps of 0.1; for each value of β, we calculate the multinational firm's optimal local content rate α^*, and two firms' prices in Nash equilibrium, the demands for two products, and two firms' profits.

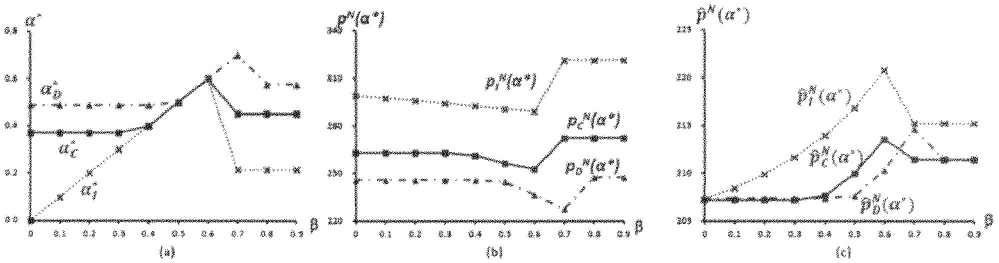

Figure 8: The impact of β on the optimal local content rate α^*, and the Nash equilibrium-characterized prices $p^N(\alpha^*)$ and $\hat{p}^N(\alpha^*)$.

We learn from Figure 8(a) that the curves for both α_D^* and α_C^* correspond to Case 5 in Proposition 9. For example, from the curve of α_D^*, we find that α^* is the constant 0.487 when $\beta < 0.487$; α^* is increasing in β when $\tilde{\alpha}_1 \leq \beta \leq \bar{\beta}_D = 0.660$; and, α^* is the constant 0.452 when $\beta > \bar{\beta}_D$. The curve for α_I^* corresponds to Case 2 in Proposition 9; that is, α^* is increasing in β when $\beta \leq \bar{\beta}_I = 0.646$, and is then the constant $\tilde{\alpha}_2 = 0.214$ when $\beta > \bar{\beta}_I$.

We can also note from Figures 8(b), 9(a), and 10(a) that, as the value of β is increased, the multinational firm's Nash equilibrium-based price $p^N(\alpha^*)$ decreases when $\beta \leq \bar{\beta}$; and the firm's price when $\beta > \bar{\beta}$ is much higher than that when $\beta \leq \bar{\beta}$. However, $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ are non-increasing in β; specifically, both $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ is decreasing in β when $\beta \leq \bar{\beta}$, and they are both reduced to lower values when $\beta \leq \bar{\beta}$.

As Figures 8(c), 9(b), and 10(b) indicate, the curves for $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\alpha^*)$, and $\hat{\Pi}^N(\alpha^*)$ show a similar pattern. That is, when $\beta \leq \bar{\beta}$, they are increasing in β; and when $\beta > \bar{\beta}$, they are constant. The value of $\hat{p}^N(\alpha^*)$ increases very significantly for Scenario I, which happens mainly because $C(\alpha)$ increases dramatically in this scenario and, as

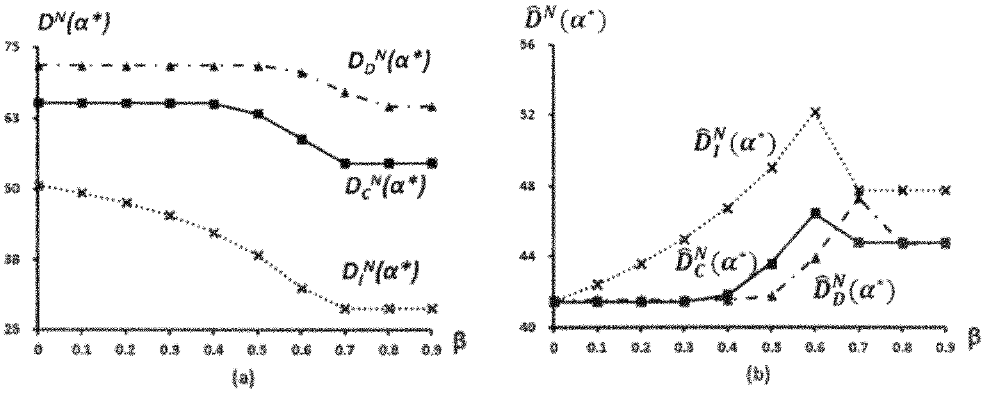

Figure 9: The impact of β on the demand for product M $D^N(\alpha^*)$ and the demand for product L $\hat{D}^N(\alpha^*)$.

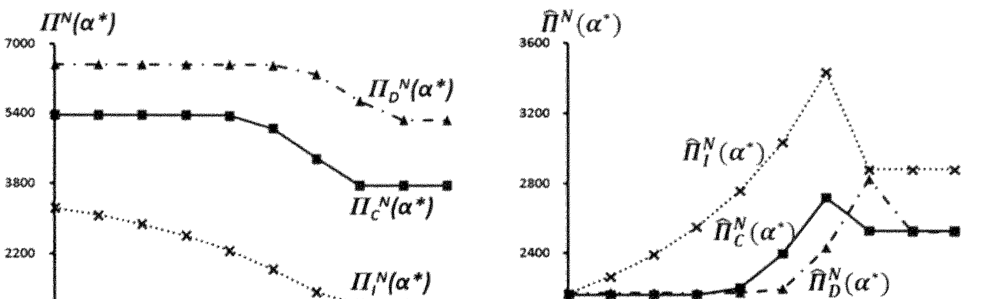

Figure 10: The impact of β on the multinational firm's profit $\Pi^N(\alpha^*)$ and the local firm's profit $\hat{\Pi}^N(\alpha^*)$.

we discussed previously, $\hat{p}^N(\alpha^*)$ is increasing in $C(\alpha)$.

Our above numerical results imply some insights for the policy maker in the local market.

Remark 7 A proper increase in the value of β, i.e., increasing β is within $[\max\{0, \tilde{\alpha}_1\}, \min\{\bar{\beta}, 1\}]$ when $f_2'(0) < 0$ or within $\beta \in (0, \beta^o]$ when $f_2'(0) \geq 0$, can induce the multinational firm to increase his local content rate, help the local firm achieve a higher price, demand, and profit, and enables consumers to purchase product M at a lower price. However, if the LCR is largely increased, then the multinational firm may disagree to raise his local content rate as his profit would be reduced to a very low level. At the time, the multinational firm chooses the local content rate $\tilde{\alpha}_2$, which is even lower than β, and thus the price, demand, and profit for the local firm are all decreased to a low level whereas the price for product M is increased to a high level. In addition, a very low LCR threshold β, i.e., $\beta < \tilde{\alpha}_1$, imposes no impact on the multinational firm, and the firm should adopt the local content rate $\tilde{\alpha}_1$ under such LCR threshold. ■

6 Summary and Concluding Remarks

In this thesis, we consider a duopoly market involving a multinational firm and a local firm. The two firms produce two competitive products (i.e., products M and L are made by the multinational and local firms, respectively), and the quality of the multinational firm's product is affected by his local content rate. We first analyze the competition between the multinational firm and the local firm when the LCR is not implemented in the local country, and then investigate the impact of the LCR by investigate the competition between the two firms under the LCR with a minimum local content rate and a penalty tariff rate. Under such an LCR, the multinational firm absorbs a penalty tariff if the local content rate for his product made in the local market is smaller than the minimum required local content rate.

We develop and analyze a two-stage decision problem for the two firms, in which the multinational firm first determines his local content rate and announces it to the local firm, and two firms then decide on their prices for their products "simultaneously" (with no communication). Given the value of the local content rate α, we solve the "simultaneous-move" game and find two firms' $\alpha-$dependent prices in Nash equilibrium and the corresponding demands and profits of the two firms. For a given value of α, when $g(\alpha)$ is reduced, we find that the multinational firm achieves a higher price, demand, and profit, whereas the price and demand for product L and the local firm's profit all decrease. Here, a reduction in the value of $g(\alpha)$ implies that (i) the quality of the local components used by the multinational firm are improved by their producers, and the multinational firm can thus produce high-quality products, or (ii) consumers' confidence in the quality of product M is improved. We also find that, an increase in the multinational firm's cost leads to an increase in the price for product M but a decrease in the profit of the multinational firm.

Solving the two-stage problem, we find that, if the LCR does not apply, then the multinational firm's optimal local content rate is a trade-off between the cost and the quality of product M, depending on the product substitutability between products M and L, the sensitivity of consumers' valuation to product M's quality, and the slope of reduction in marginal utility of two firms' products.

Our analytical results show that the multinational firm should set a lower local content rate when the competition between products M and L intensifies, consumers' valuation is more strongly affected by product M's quality, and the reduction in consumers' marginal utility is smaller. We also show that, when making local-content decision, the firm needs to pay more attention to the substitutability of the two products than to the slop of reduction in consumers' marginal utility, because the former impacts his optimal local content rate more significantly. In addition, the demand for product M and the multinational firm's profit decrease if consumers are more sensitive to the quality of product M. Using our numerical analysis, we also find that when two firms' products become more similar, the demand for product M may decrease or may first decrease and then increase, but the demand for product L, the prices for product M and product L, and both firms' profits certainly decrease.

Our analytical results also indicate that the tariff rate impacts the multinational firm's local content rate by influencing the firm's cost. However, when the tariff-exclusive cost increases too dramatically as the local content rate increases such that $C'(0) > C(0)$, any change in the tariff rate cannot induce the multinational firm to replace some imported components with the local ones. Otherwise, the firm needs to choose a positive local content rate if the tariff rate is sufficiently high. Moreover, if the multinational firm adopts a local content rate larger than 0, then the firm should raise his local content rate as the tariff rate increases. Nevertheless, no matter how the multinational firm adjusts his local content rate, the demand for product M and the firm's profit are both decreasing in the tariff rate.

In Section 5, we analyze the impact of the LCR on the multinational firm's optimal local content rate and two firms' prices in Nash equilibrium, and the resulting demands and profits. We find that a sufficient condition for the multinational firm to satisfy the LCR is that the marginal cost of product M's quality is sufficiently large when the firm adopts the LCR threshold β. Note that the LCR contains the minimum required local content rate β and the penalty tariff rate t_p. Our numerical experiment shows the possible great impact of the LCR on the multinational firm. We derive the conditions under which the multinational firm needs to increase his local content rate. In the presence of the LCR, the multinational firm's optimal local content rate is not only the trade-off between the quality and cost of product M but also a comparison between the possible maximum profit when the firm meets the LCR and that when the firm does not. The multinational firm should satisfy the LCR when the value of β belongs to a certain range; and within the range, the multinational firm should increase his local content rate, set a lower price, and obtain a smaller profit, while the local firm achieves a higher price, demand, and profit. However, a very high threshold that is out of the range will induce the multinational firm to adopt a low local content rate that is much lower than β and set a higher price for product M, causing the local firm to decide on a lower price for product L, and resulting in a low demand and profit for both the multinational firm and the local firm. In addition, if the value of β is lower than the multinational firm's optimal local content rate made when the LCR is not implemented, then the LCR has no impact on the multinational firm.

Our sensitivity analysis for the penalty tariff rate t_p shows that a penalty tariff policy is very useful in inducing a multinational firm to enhance his local content rate: (i) as long as the firm is still profitable, he should adopt the LCR threshold when t_p is sufficiently high, and (ii) if the firm does not satisfy the LCR and does not fully use imported components to make product M, then he should increase his local content rate as the value of t_p rises, resulting in a decrease in the demand for product M and the multinational firm's profit but an increase in the demand for product L and the local firm's profit.

In conclusion, we identify a number of factors that influence the multinational firm's local content rate decision, and find that the LCR largely affect both the multinational firm and the local firm. We derive the condition under which the multinational firm should satisfy the LCR, and present a number of other managerial insights that are expected to help practitioners to make a judicious decision on the local content rate.

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