Penetrating a Market with Local-Content and Pricing Decisions: Implications for a Multinational Firm in the Competition with a Local Firm[a]

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Submitted February 2023; Revised September 2023; Accepted October 2023

To appear in *Naval Research Logistics*

[a]The authors are grateful to the Department Editor (Professor Ying-Ju Chen), the Associate Editor, and two anonymous reviewers for their insightful comments that helped improve this paper.

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Abstract

The internationalization of production requires multinational firms to determine a local content rate for their products made and sold in a foreign country. In this paper, we investigate the impact of a government's local content requirement (LCR) on the local content rate and pricing decisions of a multinational firm who competes with a local firm in a market. In an emerging market, the multinational firm increases his local content rate to comply with an LCR if the LCR involves a moderate threshold and a sufficiently large penalty tariff rate. Although a small penalty tariff rate cannot induce the multinational firm's compliance, a larger penalty tariff leads the firm to adopt a higher local content rate. When the multinational firm complies with the LCR, a higher LCR threshold or penalty tariff rate shifts away the multinational firm's demand and profit but may not benefit the local firm if the two firms' price competition is fiercer than their quality competition. In addition, if the two firms' quality competition is fiercer than their price competition, a large LCR threshold may still not benefit the local firm. In contrast, in a developed market, the multinational firm should increase his local content rate as the quality-cost tradeoff ratio increases. The LCR plays the same effect on the multinational firm as that in an emerging market, whereas its effect on the local firm still depends on the relative intensity of the two firms' price competition versus quality competition, but under reverse conditions.

Key words: Duopoly game; local content; price competition; quality competition.

1 Introduction

With the globalization and development of the world economy, many multinational firms have made direct investments in foreign countries. Despite the severe impact of COVID-19 pandemic on the global economy, the foreign direct investment (FDI) attracted by the Asia region increased by 19% to a record high of $619 billion in 2021, which marks the third consecutive year of growth. In particular, the FDI in West Asia and that in Southeast Asia increased by 59% and 44%, respectively (UNCTAD 2022).

Multinational firms need to determine a local content rate for their products that are made and sold in a foreign market. The value-based local content rate of a product is calculated as the percentage of the value of its components purchased locally among the total value of all components purchased locally and imported (Munson and Rosenblatt 1997). The local content rate decision is of strategic importance to multinational firms. For example, in July 2014, Volkswagen India released its plan to increase its localization of components from 65% to 90% so as to reduce its cost (Reuters 2014). In 2018, Toyota India planned to increase the local content rate for Suzuki products to reduce prices and sell the products competitively in the Indian market (Carandbike.com 2018).[a] It is common practice that when multinational manufacturers (in, e.g., the automobile sector) enter emerging markets, they usually localize their production to lower cost at the expense of technological content and quality (Pardi 2019).

In this paper, we study the local content rate decision of a multinational firm who produces and sells a product in a foreign market. This decision is important because the acquisition cost of a locally purchased component usually differs from that of an imported one. The difference is partly due to the fact that the former mainly contains a purchase cost, whereas the latter includes not only a purchase cost but also a transportation cost and sometimes a tariff. The difference can also be attributed to the gap in technological levels between the imported and local components. In an emerging market, local components at a high-technology level might be more expensive than imported components due to the inferior technological capability of local producers. As our literature review in Section 2 indicates, the extant publications commonly assumed that local components are more costly than imported ones. Nonetheless, in reality, local components at a low-technology level could be much cheaper, partially due to lower labor costs. This can be evidenced by the practice of multinational firms (e.g., Volkswagen [Reuters 2014], Toyota [Carandbike.com 2018], and Ford [Euronews 2019]) in increasing local sourcing in India to reduce cost. Therefore, the acquisition cost of a local component may be higher or lower than that of an imported one. Accordingly, in our paper we consider a general situation in which local components may or may not be more expensive than imported components.

Apart from the acquisition cost, product quality is another key factor in the local content rate decision. Multinational firms originating from countries with advanced and mature technology in a specific industry often make FDI in countries with less sophisticated technology in that industry. Taking the automobile industry as an example, giant multinational firms with advanced technologies (e.g., BMW, Volvo, and Toyota) have made FDI in emerging markets. Accordingly,

[a] In the Indian automobile market, Tata Motors and Mahindra & Mahindra are the major local manufacturers that compete with a number of multinational auto makers such as Hyundai and BMW. For details, see `https://parkplus.io/blog/cars/top-automobile-companies-with-manufacturing-units-in-india` (URL last accessed on October 8, 2023).

we consider the situation where the multinational firm possesses more advanced technology than the local firm, and the imported components contain a higher technology than the local ones. In fact, the Japan International Cooperation Agency (2022) has shown that in the African automotive industry, local components have limited quality due to local suppliers' low skill levels. Cui and Lu (2019) suggested that future research should investigate both price and quality competition under an LCR, assuming that local suppliers of emerging markets may provide low-cost but low-quality components.

If the local technology cannot meet the multinational firm's requirement and the firm intends not to reveal its cutting-edge technology to the emerging market, then some key components may need to be imported. In reality, a multinational firm's local content rate rarely reaches 100%; this is especially true for the production of high-tech products such as automobiles and computers. In addition to the direct impact on the quality of a product, the local content rate may also influence consumers' belief about the quality of the product. As BMW Brilliance (China) found, consumers were often concerned that a high local content rate may deteriorate the quality of a multinational firm's product, for example, high-end cars such as BMW cars (Gong 2004).

Government policies such as tariffs can influence multinational firms' local content rate decisions. Many countries have imposed local content requirements (LCRs) to compel multinational firms in their countries to increase their local content rates. The objectives of the policies vary, such as promoting the domestic industry and employment, protecting an industry from foreign competition, etc. Since 2008, over 100 new LCRs have been proposed or implemented, including 34 in advanced economies and 84 in developing and other economies; in particular, the U.S. has imposed 14 new LCRs (Hufbauer et al. 2013). Furthermore, the past decade has witnessed a growing implementation of LCRs in the green sector. For example, countries of different sizes have adopted LCRs to support domestic solar and wind equipment manufacturing (OECD 2013). Many developed and developing countries (e.g., Canada, The EU, the U.S., China, Brazil, India, and South Africa) are increasingly using LCRs in their industrial policies for the green economy (UNCTAD 2014).

Among the various forms that LCRs may take, a common one is characterized by a minimum local content rate (i.e., an LCR threshold) required on a product and a higher tariff or tax to be imposed if the product does not meet the threshold. For instance, China implemented an LCR of 70% with tariff incentives on wind energy projects in 2009 (Cui and Lu 2019). In September 2011, the Brazilian government announced an up to 30% increase in the industrial product tax on vehicles with components that were less than 65% manufactured locally or sourced from the South American Mercosur trade region or Mexico (Leahy 2011). As part of Indonesia's free trade agreement commitments, the Indonesian government has implemented over 10 LCRs in sectors such as telecommunication, energy, and automotive. Among them, an LCR for battery electric vehicles issued in 2019 specifies a target local content rate of 35% in 2019-21 (to be increased to 60% in 2024-29) together with fiscal incentives (e.g., import duty) for compliance (Fernando and Ing 2022).

We learn from the above that a multinational firm's local content rate affects both the quality and cost of a product, and thus influences the firm's pricing decision. The government policy and technological level of the market that the firm enters may also affect its local content rate and pricing decisions. As a multinational firm usually faces competition from the local firms in a foreign market, the local content rate decision can have a strategic impact on its competitive success. In practice, a multinational firm can penetrate the market in both a developing country and a developed country, where the government may or may not require multinational firms to meet a minimum local content rate requirement. Accordingly, in this paper we study the competition between the multinational and local firms in both an emerging market and a developed market. In the emerging market, local components are made with a lower technology than imported ones, whereas in the developed market, local components are made with a higher technology.

We first consider the emerging market and ask the following research questions: If the local government does not adopt an LCR but only implements a tariff on the imported components, what are the multinational firm's local content rate and pricing decisions and the local firm's pricing decision in equilibrium? What are the resulting demands and profits of the two firms? If the local government implements an LCR that includes a threshold and a penalty tariff for non-compliance, how does the LCR affect the multinational firm's decisions, and what are its impacts on the two firms' demand and profitability?

To address the above questions, we analyze a duopoly game in which a multinational firm (he) makes a product and competes with a local firm (she) in an emerging market. Market demand for each firm's product is dependent on both product price and quality. The multinational firm decides a local content rate for his product, where a higher local content rate reduces the product quality. The two firms make their pricing decisions. Both firms aim to maximize their respective profits. We first derive the firms' equilibrium decisions when the local government only implements a tariff on imported components, and then examine the problem when the government imposes an LCR with a threshold and a penalty tariff on the multinational firm's product. We also extend the study to the case of a developed market, where a higher local content rate improves the multinational firm's product quality. We examine if the answers to our research questions for the case of emerging market continue to hold.

Our results indicate that both the tariff and the LCR may induce the multinational firm to increase his local content rate, making his demand and profit decline. When the government only implements a tariff, as the quality-cost tradeoff ratio of his product increases, the multinational firm should reduce his local content rate in an emerging market but increase it in a developed market. When the government imposes an LCR, the multinational firm may be better off from not complying with the LCR if the threshold is excessively high or the penalty tariff rate is sufficiently low. Moreover, we find that increasing the tariff rate or the LCR threshold/penalty tariff rate may not always benefit the local firm, which depends on the relative intensity of the two firms' price competition vs. quality competition. In an emerging market, the local firm's demand and profit may decline when the two firms' price competition is more intense than their quality competition. However, in a developed market, the same effect may occur when the two firms' quality competition is fiercer. The findings imply that a policy maker should understand the nature of competition between the multinational firm and the local firm when implementing a tariff or an LCR to help the local firm.

Our study contributes to the literature by generalizing the extant studies on LCRs in several aspects. First, the literature focuses on the LCR implemented in an emerging market and assumes that the acquisition cost of local components is higher than that of imported ones. We model a more general situation where the acquisition cost of local components can be either higher or lower than imported ones. Second, the literature tends to overlook the impact of a multinational firm's local content rate decision on its product quality. In our model, the local content rate affects both the quality and acquisition cost of the product. The associated findings reveal the importance of relative competition intensity of price vs. quality to the firms' decisions and the effectiveness of local content-related policies. Furthermore, we study the cases where the multinational firm makes FDI in an emerging/developed market such that the technology level of an imported component is higher/lower than a local one and thus can improve/reduce the quality of the final product.

The rest of the paper is organized as follows. In Section 2, we review the publications that are related to this paper. In Section 3, we develop demand functions for the products of the multinational firm and the local firm. In Section 4, we analyze the two firms' game in an emerging market with no LCR. In Section 5, we investigate the duopoly problem in an emerging market with an LCR. In Section 6, we extend our study of the duopoly problem to the case of a developed market. Our paper ends with a summary of major findings in Section 7. We provide a list of parameters and variables in online Appendix A, and relegate the proofs of all propositions to online Appendix B, in the order that they appear in the main body of our paper. In addition, online Appendix C presents supplementary results of Sections 5 and 6.

2 Literature Review

The local content-related issues have been extensively studied in the economics literature, which mainly concern the impact of an LCR on the macroeconomic production and welfare as well as the optimal LCR threshold for policy makers (see, e.g., Davidson et al. 1985, Richardson 1991, Lopez et al. 1996, Lahiri and Ono 1998 and 2003, and Lahiri and Mesa 2006). These works usually assume that a multinational firm complies with the LCR and makes its local content rate equal to the LCR threshold, which is the minimum proportion of components that must be purchased from local suppliers. Accordingly, these works commonly assume that the total acquisition cost of components that are produced in the local market under an LCR is always higher than that of imported ones. However, in practice, some imported components can be more expensive than locally sourced ones. We relax this assumption in our paper and allow imported components to be either cheaper or more expensive than local ones.

Extant publications that study firms' competition under an LCR usually assume that multinational firms compete with each other or with local firms in a Cournot game (i.e., quantity competition). However, except for some raw materials, different firms usually make heterogeneous products and set different prices. For example, BMW has never set the same price as Toyota. In this paper, we consider price and quality competition rather than quantity competition.

Our paper is also related to the operations management literature that studies the effect of government policies on supply chains. Most of the publications in this literature concern the impact of an LCR on a single firm's decisions related to a manufacturing system or supply chain network design. For example, Munson and Rosenblatt (1997) developed a single plant model to analyze the purchasing allocation problem under an LCR, and examined the impact of different LCR-related schemes. Kouvelis et al. (2004) proposed a mathematical programming model for the design of a firm's global facility network, which incorporates government subsidies, trade tariffs and local content requirements, and taxation issues. Li et al. (2007) constructed a mathematical model for a firm's material sourcing problem under an ROO value-added rule, which differs from Munson and Rosenblatt's model (1997) in that the firm can decide the combination of components given a minimum required local content rate and a tariff if the requirement is not met. Guo et al. (2008) analyzed a multi-stage production sourcing problem, in which the production costs and tariff concessions arise from a value-added local content scheme. In addition, Mariel and Minner (2017) solved strategic network design problems to reduce overall material and production costs under the LCRs of the North American Free Trade Agreement (NAFTA).

Recently, Cui and Lu (2019) studied a government's optimal LCR decision regarding a product-level LCR and a component-level LCR, assuming that a multinational firm always complies with the LCR. They considered linear price-dependent demand and modeled the Cournot competition among multinational firms and the competition between multinational firms and local firms under an LCR. With a focus on the LCR in a developing country, Cui and Lu (2019) assumed that the sourcing cost of a local component is higher than that of an imported one due to the technology gap. Our paper has the following major differences from Cui and Lu (2019). First, our paper studies the more general situation that the acquisition cost of a local component can be either higher or lower than that of an imported one. Second, in our paper, the local content rate not only affects the total unit cost of the multinational firm's product but also its quality level, while Cui and Lu (2019) didn't consider the quality issue associated with an LCR decision. Third, we study the problem in both an emerging market and a developed market. More importantly, our paper differs from the majority of publications in that a government does not require the multinational firm's mandatory compliance with the LCR, and the multinational firm and the local firm compete on both product price and quality rather than quantity.

3 Quality and Demand Functions

A multinational firm makes and sells a product in an emerging market and competes with a local firm who makes a substitutable product. For ease of statement, we hereafter call the multinational firm's and the local firm's products by "M" and "L," respectively. Product quality is an important factor for consumers' purchase decisions, which is closely related to the quality of product components. Multinational firms' FDIs often stem from an incentive to expand their global market shares into an emerging market using advanced and mature technologies. Accordingly, the components imported by the multinational firm are by and large made with more advanced technologies compared to those locally-purchased components. This makes product M possess higher quality than product L that is made of local components only.

As the proportion of local components in a product influences the product quality, the multinational firm naturally needs to determine the percentage value of the local components in product M, which is called the "local content rate" of product M. We use $\alpha \in [0, 1]$ to denote the local content rate and a function $g(\alpha)$ to represent the α-dependent quality level of product M. In an emerging market, the quality of local components is likely to be lower than that of imported components (especially those key components). In Section 1, we have explained that, due to local suppliers' low skill levels, local components usually have limited quality (see, Japan International Cooperation Agency 2022). For key components such as vehicle engines, the quality difference between imported and local ones is remarkable. This can explain why a high local content rate could cause big problems for foreign automakers in emerging markets (China Daily 2004).

Consequently, as the local content rate increases, the quality of product M may decrease, and the marginal quality reduction becomes larger as more components are localized. That is, $g'(\alpha) < 0$ and $g''(\alpha) < 0$ for $\alpha \in [0, 1]$. For generality of analytic results, we do not consider any specific function form for $g(\alpha)$ in our subsequent discussions and analysis. As the multinational firm has a higher production capability and brand reputation than the local firm, the quality of product M is usually superior to that of product L, even if all the components of product M are purchased locally. Thus, we assume $g(\alpha) > 1$ for $\alpha \in [0, 1]$, where the quality level of product L is normalized to be a constant of 1. We set a constant quality level for product L because it is not affected by the multinational firm's local content rate decision.

Banker et al. (1998) developed linear demand functions to model price and quality competition between two firms. Similar demand functions have been used in other studies (e.g., Tsay and Agrawal 2000, Balasubramanian and Bhardwaj 2004, Bernstein and Federgruen 2004, and Bernstein and Federgruen 2007). In a similar vein, we define the demand function for product M (i.e., D) and that for product L (i.e., $\hat{D}$) below:

$$
\begin{aligned}
D &= kA - \beta_1 p + \beta_2 \hat{p} + \lambda_1 g(\alpha) - \lambda_2, && (1)\\
\hat{D} &= (1-k)A - \beta_1 \hat{p} + \beta_2 p + \lambda_1 - \lambda_2 g(\alpha). && (2)
\end{aligned}
$$

We use the hat symbol " ˆ " to present the notations for product L. In (1) and (2), kA and $(1-k)A$ ($0 < k < 1$ and $A > 0$) are potential market sizes for products M and L, respectively; and p and $\hat{p}$ denote the prices of these two products. For each product, parameters β_1 (λ_1) and β_2 (λ_2) denote the own price (quality) and cross price (quality) sensitivity of its demand, respectively.

Here, $\beta_1 \geq \beta_2 > 0$, because the price of a product usually has a higher impact on the product demand than the price of its competing product (substitute). The ratio β_2/β_1 reflects the degree of substitution (or, the intensity of price competition) between the two products. When $\beta_2/\beta_1 = 1$, the impacts of changes in the two prices on each product's demand are identical, and the price competition between the two products is the most intense. The intensity of price competition increases for a larger ratio β_2/β_1. Similarly, $\lambda_1 \geq \lambda_2 > 0$, and a larger ratio λ_2/λ_1 indicates a more intense quality competition between the two products.

4 The Two-Firm Competition under No Local Content Requirement

Some countries (e.g., Japan and Germany) do not impose any local content requirement on the products made by multinational firms. They usually charge a tariff on the imported components. For this case, the multinational firm determines his product price p and local content rate α, and the local firm decides on her product price $\hat{p}$. Both firms aim to maximize their profits, respectively. In practice, most multinational firms' local content rate decisions are unlikely to change as frequently as their pricing decisions, mainly because any change in the local content rate of a product entails the replacement of some components and alters the supply source. Accordingly, we investigate the following two-stage decision problem for the competition between the two firms. In the first stage, the multinational firm determines a local content rate for product M. In the second stage, the two firms make their pricing decisions "simultaneously" (with no communication).

We solve the two-stage problem using backward induction that involves three steps. In the first step, given a value of the local content rate α, we solve a "simultaneous-move" game to derive the Nash equilibrium-characterized prices $p^N(\alpha)$ and $\hat{p}^N(\alpha)$ for the two firms. In the second step, we substitute $p^N(\alpha)$ and $\hat{p}^N(\alpha)$ into the multinational firm's profit function and maximize the resulting profit to find the firm's optimal local content rate α^*. In the third step, we compute the two firms' prices $p^N(\alpha^*)$ and $\hat{p}^N(\alpha^*)$ in Nash equilibrium as well as the resulting demand and profit for each firm.

4.1 Nash Equilibrium Pricing Decisions Given a Local Content Rate

We begin by deriving the multinational firm's and the local firm's prices in Nash equilibrium for a given local content rate of product M.

4.1.1 Profit Functions

For one unit of product M, the multinational firm incurs an α-dependent purchase cost of all components $C(\alpha)$ and an assembly cost C_A. In addition, the firm pays a tariff for the imported components tC_I, where t is the tariff rate and C_I denotes the unit tariff-exclusive cost of those imported components. Thus, the multinational firm's total unit cost is $M(\alpha) \equiv C(\alpha) + C_A + tC_I$.

Munson and Rosenblatt (1997) discussed two schemes for the calculation of local content rate. One is the "value-based content protection scheme," under which the local content rate 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. The other is the "physical content protection scheme," under which α is the ratio of the total number of local components to that of all components. We adopt the value-based content protection scheme, as it has been widely used when the inputs for the production of a final product are heterogeneous. Under such a scheme, $\alpha = (C(\alpha) - C_I)/C(\alpha)$. Writing C_I as a function of α, we have $C_I = (1-\alpha)C(\alpha)$. Then, $M(\alpha)$ can be rewritten as

$$M(\alpha) = C(\alpha)[1 + t(1-\alpha)] + C_A. \tag{3}$$

Given a specific local content rate, a firm should decide the components to source locally to reduce the total unit cost. As Munson and Rosenblatt (1997) discussed, under a value-based content protection scheme, the multinational firm would first purchase the local component with a low ratio of the unit cost to that of an imported one. Therefore, as the local content rate α increases, more local components—that may have higher cost ratios—are bought. That is, the cost of replacing one more imported component with a local one becomes larger. This implies that $C(\alpha)$ should be a convex function of α (i.e., $C''(\alpha) > 0$ for $\alpha \in [0, 1]$). Moreover, as the local content rate increases, the multinational firm's cost resulting from the imported components should decrease. Thus, C_I is decreasing in α, or, $(1-\alpha)C'(\alpha) - C(\alpha) < 0$, which implies that $C'(0) < C(0)$.

Remark 1 Although $C(\alpha)$ is convex, the sign of the first-order derivative $C'(\alpha)$ cannot be ascertained. For our analysis, we consider three 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 unimodal, i.e., $C'(0) < 0$ and $C'(1) > 0$. ◀

We calculate the second-order derivative of $M(\alpha)$ with respect to α as $M''(\alpha) = C''(\alpha)[1 + t(1-\alpha)] - 2tC'(\alpha)$, which is positive if the tariff rate t satisfies the following condition:

$$C''(\alpha) > t[2C'(\alpha) - (1-\alpha)C''(\alpha)]. \tag{4}$$

If $2C'(\alpha) \leq (1-\alpha)C''(\alpha)$ (which holds under, e.g., Scenario D), then the condition in (4) is satisfied for any value of t. Otherwise, the condition holds if $t < C''(\alpha)/[2C'(\alpha) - (1-\alpha)C''(\alpha)]$. Therefore, a sufficiently small tariff rate t is very likely to satisfy the condition in (4). As shown by Suranovic (2010), the average tariff rates in most countries are less than 20%, and they are usually much smaller for industrial products than for agricultural products. For example, in the European Union, the average tariff rates for industrial products and those for agricultural products are 6.4% and 16.1%, respectively. Moreover, as the World Trade Organization (2015) reported in the World Tariff Profiles 2015, the average tariff rates for electrical machinery and transportation equipment vary from 1.1% to 20.7%, according to relevant statistics in major countries (e.g., Brazil, Canada, China, the EU, India, Russia, South Africa, and the United States). Accordingly, we reasonably confine the value of t to satisfy the condition in (4), which ensures the convexity of $M(\alpha)$.

The multinational firm receives sales revenue pD, where demand D is given as in (1). We then obtain the firm's profit function as

$$\Pi(\alpha) = V(\alpha)D, \text{ where } V(\alpha) \equiv p - M(\alpha). \tag{5}$$

We compute the local firm's profit as the total revenue $\hat{p}\hat{D}$ minus the total acquisition cost $\hat{C}\hat{D}$, where $\hat{C}$ denotes the local firm's unit cost of product L (including the assembly cost and the acquisition cost of all components), and demand $\hat{D}$ is given in (2). That is,

$$\hat{\Pi}(\alpha) = \hat{V}(\alpha)\hat{D}, \text{ where } \hat{V}(\alpha) \equiv \hat{p} - \hat{C}. \tag{6}$$

4.1.2 Equilibrium Prices and the Resulting Demands and Profits

Solving the simultaneous-move game between the multinational and the local firms, we obtain the following results.

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 $(p^N(\alpha), \hat{p}^N(\alpha))$ can be uniquely obtained as*

$$p^N(\alpha) = \frac{2\beta_1^2 M(\alpha) + (2\lambda_1\beta_1 - \lambda_2\beta_2)\, g(\alpha) + \beta_1\beta_2\hat{C} + A_1}{4\beta_1^2 - \beta_2^2}, \tag{7}$$

$$\hat{p}^N(\alpha) = \frac{\beta_1\beta_2 M(\alpha) + (\lambda_1\beta_2 - 2\lambda_2\beta_1) g(\alpha) + 2\beta_1^2\hat{C} + A_2}{4\beta_1^2 - \beta_2^2}, \tag{8}$$

where $A_1 \equiv 2\beta_1 (kA - \lambda_2) + \beta_2 [(1-k)A + \lambda_1]$ and $A_2 \equiv \beta_2 (kA - \lambda_2) + 2\beta_1 [(1-k)A + \lambda_1]$.

It follows from Proposition 1 that in Nash equilibrium the multinational firm's unit profit $V^N(\alpha)$, demand $D^N(\alpha)$, and total profit $\Pi^N(\alpha)$ are computed as

$$\begin{cases} V^N(\alpha) = \dfrac{\left(\beta_2^2 - 2\beta_1^2\right) M(\alpha) + (2\lambda_1\beta_1 - \lambda_2\beta_2)\, g(\alpha) + \beta_1\beta_2\hat{C} + A_1}{4\beta_1^2 - \beta_2^2}, \\ D^N(\alpha) = \beta_1 V^N(\alpha), \text{ and } \Pi^N(\alpha) = \beta_1\left(V^N(\alpha)\right)^2; \end{cases} \tag{9}$$

and the local firm's unit profit $\hat{V}^N(\alpha)$, demand $\hat{D}^N(\alpha)$, and total profit $\hat{\Pi}^N(\alpha)$ are

$$\begin{cases} \hat{V}^N(\alpha) = \dfrac{\beta_1\beta_2 M(\alpha) + (\lambda_1\beta_2 - 2\lambda_2\beta_1) g(\alpha) + \left(\beta_2^2 - 2\beta_1^2\right)\hat{C} + A_2}{4\beta_1^2 - \beta_2^2}, \\ \hat{D}^N(\alpha) = \beta_1\hat{V}^N(\alpha), \text{ and } \hat{\Pi}^N(\alpha) = \beta_1(\hat{V}^N(\alpha))^2. \end{cases} \tag{10}$$

We learn from (9) and (10) that, as the local content rate α changes, $V^N(\alpha)$, $D^N(\alpha)$, and $\Pi^N(\alpha)$ vary in the same direction (i.e., $\partial V^N(\alpha)/\partial\alpha$, $\partial D^N(\alpha)/\partial\alpha$, and $\partial\Pi^N(\alpha)/\partial\alpha$ have identical signs). Meanwhile, $\hat{V}^N(\alpha)$, $\hat{D}^N(\alpha)$, and $\hat{\Pi}^N(\alpha)$ change in the same direction (i.e., $\partial\hat{V}^N(\alpha)/\partial\alpha$, $\partial\hat{D}^N(\alpha)/\partial\alpha$, and $\partial\hat{\Pi}^N(\alpha)/\partial\alpha$ have identical signs).

Given a local content rate α, we can observe from (7) - (10) the impacts of product M's cost and quality functions (i.e., $M(\alpha)$ and $g(\alpha)$) on the two firms as follows.

1. A smaller unit cost $M(\alpha)$ of product M enables the multinational firm to set a lower price $p^N(\alpha)$ and obtain a higher unit profit $V^N(\alpha)$, demand $D^N(\alpha)$, and total profit $\Pi^N(\alpha)$. Meanwhile, the local firm has to set a lower price $\hat{p}^N(\alpha)$ for product L and receives a lower unit profit $\hat{V}^N(\alpha)$, demand $\hat{D}^N(\alpha)$, and total profit $\hat{\Pi}^N(\alpha)$. The results imply that a reduction in the multinational firm's local sourcing and assembly costs in the emerging market can benefit the multinational firm, but make the local firm worse off.

2. A higher quality level $g(\alpha)$ of product M allows the multinational firm to set a higher price and achieve a higher unit profit, demand, and total profit. However, the impact of $g(\alpha)$ on the local firm depends on the sign of $\lambda_1\beta_2 - 2\lambda_2\beta_1$. If $\beta_2/\beta_1 > 2\lambda_2/\lambda_1$ (i.e., $\lambda_1\beta_2 - 2\lambda_2\beta_1 > 0$), the two firms' price competition is sufficiently intense relative to their quality competition. In this case, the local firm can benefit from a higher quality level of product M by setting a higher price for product L and gaining a larger unit profit, demand, and total profit. However, if $\beta_2/\beta_1 < 2\lambda_2/\lambda_1$ (i.e., the two firms' quality competition is sufficiently intense relative to their price competition), then the local firm is worse off from a higher quality level of product M.

4.2 The Optimal Local Content Rate

As A, k, λ_1, λ_2, β_1, and β_2 are exogenous parameters, the optimal local content rate that maximizes the multinational firm's profit $\Pi^N(\alpha)$ in (9) is identical to the rate that maximizes his α-dependent unit profit $V^N(\alpha)$ in (9). For the multinational firm's product with a local content rate α, we define

$$\gamma(\alpha) \equiv \frac{M'(\alpha)}{g'(\alpha)},$$

which is the ratio of the marginal change in its unit cost to the marginal change in its quality level. We also define $S \equiv (2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2 - \beta_2^2)$.

Proposition 2 *The multinational firm's optimal local content rate α^* is obtained as*

$$\alpha^* = \begin{cases} 0, & \text{if } \gamma(0) \le S; \\ \alpha^0, & \text{if } \gamma(1) < S < \gamma(0); \\ 1, & \text{if } \gamma(1) \ge S, \end{cases}$$

where α^0 denotes the unique solution obtained by solving the equation $\gamma(\alpha) = S$ for α.

We find from (9) and the proof of Proposition 2 that the constant S equals a ratio of the effect of marginal change in product quality $g(\alpha)$ on the firm's unit profit to that of marginal change in product cost $M(\alpha)$. Thus, it reflects the quality-cost trade-off faced by the multinational firm when he makes the local content rate decision, and a larger value of S means that the marginal change in the quality of product M has a greater impact on the firm's unit profit than the marginal change in its cost. Hereafter, we call S the "quality-cost trade-off ratio." Although Proposition 2 indicates three possible results regarding the optimal local content rate, the inequality $\gamma(1) \ge S$ (or, $Sg'(1) - M'(1) \ge 0$) is unlikely to hold, because of the following two facts. First, in our setting, $S > 0$, $g'(\alpha) < 0$, and $g''(\alpha) < 0$ for $\alpha \in [0, 1]$; hence, $Sg'(1) < 0$ is small. Second, if $M'(\alpha)$ is negative, $M'(1)$ should not be very small because $M''(\alpha) > 0$ 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 practice that few high-tech multinational firms adopt a 100% local content rate and localize all the components of high technology. If α^* equals α^0, then we find $M'(\alpha^0) = Sg'(\alpha^0) < 0$, and $\gamma'(\alpha^0) < 0$. Therefore,

$$\partial\alpha^0/\partial S = 1/\gamma'(\alpha^0) < 0,$$

meaning that α^0 is decreasing in S. That is, as the quality-cost trade-off ratio of the multinational firm's product increases, the firm adopts a lower local content rate for the product and improves product quality. By replacing α in the expressions in (7)-(10) with the optimal local content rate α^* in Proposition 2, we obtain the two firms' prices in Nash equilibrium and the corresponding unit profits, demands, and total profits.

4.3 Impact of Key Parameters

We perform a sensitivity analysis to investigate the impacts of key parameters on the multinational firm's and the local firm's equilibrium decisions, demands, and profits.

4.3.1 Impact of Demand Parameters

We learn from Proposition 2 that the quality-cost trade-off ratio S is crucial to determining the multinational firm's optimal local content rate α^*. Noting that S is dependent on demand parameters λ_1, λ_2, β_1, and β_2, we examine how these parameters influence α^*.

Proposition 3 *When the optimal local content rate $\alpha^* = \alpha^0$ (where α^0 is defined as in Proposition 2), we find*

$$\frac{\partial\alpha^*}{\partial\lambda_1} < 0,\ \frac{\partial\alpha^*}{\partial\lambda_2} > 0,\ \frac{\partial\alpha^*}{\partial\beta_1} > 0;$$

and

$$\frac{\partial \alpha^*}{\partial \beta_2} \begin{cases} > 0, & \text{if } \kappa \equiv 2\left(\frac{\beta_1}{\beta_2}\right)^2 - 4\frac{\lambda_1}{\lambda_2}\frac{\beta_1}{\beta_2} + 1 > 0, \\ = 0, & \text{if } \kappa = 0, \\ < 0, & \text{if } \kappa < 0. \end{cases}$$

One notes that "low cost" and "product differentiation" are two important competitive strategies, which can be adopted by the multinational firm when making his local content rate decision. Proposition 3 indicates that as the demand for product M becomes more sensitive to its own quality (i.e., the value of λ_1 increases), the multinational firm should reduce the local content rate of product M to improve its quality, enhancing his competitiveness through product differentiation. As the demand for product M becomes more sensitive to the quality of product L (i.e., the value of λ_2 increases) or to its own price (i.e., the value of β_1 increases), the multinational firm should increase the local content rate. By doing this, although the quality of product M decreases, the firm can lower the acquisition cost (because $M'(\alpha^0) < 0$ as shown in Section 4.2) and become more competitive in price.

We also learn from Proposition 3 that the impact of cross price sensitivity of demand β_2 on the multinational firm's local content rate decision depends on the ratios λ_1/λ_2 and β_1/β_2. As discussed in Section 3, the ratios λ_2/λ_1 and β_2/β_1 reflect the intensity of quality competition and that of price competition, respectively. Hence, a larger value of λ_1/λ_2 or β_1/β_2 means a lower intensity of competition on quality or price, and an increase in the price sensitivity of the competing product β_2 implies that the price competition intensifies. If the two firms' quality competition is sufficiently fierce compared to their price competition such that $\kappa > 0$, then as the demand becomes more sensitive to the price of competing product, the multinational firm should increase his local content rate to reduce the product cost. This implies that the firm mainly relies on the low cost strategy to compete. Otherwise, if the two firms' price competition is sufficiently fierce compared to their quality competition, then as the demand becomes more sensitive to the price of competing product, the multinational firm should decrease his local content rate to improve product quality. That is, the firm adopts the product differentiation strategy to compete.

Next, we investigate how the own quality and cross quality sensitivity of demand parameters λ_1 and λ_2 affect the two firms' prices, demands, and profits.

Proposition 4 *For the multinational firm, $p^N(\alpha^*)$, $D^N(\alpha^*)$, and $\Pi^N(\alpha^*)$ are increasing in λ_1 but decreasing in λ_2.*

We have learned from Proposition 3 that an increase in the own quality sensitivity of demand λ_1 or a decrease in the cross quality sensitivity of demand λ_2 leads the multinational firm to reduce his local content rate, which enhances product differentiation from the local firm. This provides the multinational firm with a competitive advantage so that he can raise his product price and achieve an increase in demand and profit.

Proposition 5 *For the local firm, if $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$, then $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\alpha^*)$, and $\hat{\Pi}^N(\alpha^*)$ are increasing in λ_1 but decreasing in λ_2.*

Comparing Proposition 5 with Proposition 4, we find that the impacts of demand parameters λ_1 and λ_2 on the local firm are dependent on the intensity of the two firms' quality competition

(λ_2/λ_1) relative to the intensity of their price competition (β_2/β_1). If the firms' quality competition is less fierce than their price competition, then an increase in λ_1 or a decrease in λ_2 makes the local firm better off, similar to those impacts on the multinational firm. Otherwise, if the two firms' quality competition is fiercer than price competition, then the effect of a change in λ_1 or λ_2 on the local firm is uncertain.

4.3.2 Impact of the Tariff Rate

The tariff rate t plays an important role in the multinational firm's local content rate decision, as shown below.

Proposition 6 *Letting*

$$\bar{t}_1 \equiv \frac{C'(0) - Sg'(0)}{C(0) - C'(0)} \text{ and } \bar{t}_2 \equiv \frac{C'(1) - Sg'(1)}{C(1)},$$

where $\bar{t}_1 < \bar{t}_2$, *we have*

$$\alpha^* = \begin{cases} 0, & \text{if } t \le \bar{t}_1, \\ \alpha^0, & \text{if } \bar{t}_1 < t < \bar{t}_2, \\ 1, & \text{if } t \ge \bar{t}_2, \end{cases}$$

where $\alpha^0 \in (0,1)$, *defined in Proposition 2, is strictly increasing in* t.

Proposition 6 shows that the optimal local content rate α^* is weakly increasing in tariff rate t. More specifically, as the tariff rate increases, the multinational firm should correspondingly increase the local content of product M only if the tariff rate takes a moderate value, but should not change the local content rate if the tariff rate is sufficiently small or large. Accordingly, we focus on the scenario that the firm's optimal local content rate α^* is equal to α^0 to examine the impact of tariff rate on the firm's price, demand, and profit.

Proposition 7 *When the multinational firm's optimal local content rate* $\alpha^* = \alpha^0$, $p^N(\alpha^*)$, $D^N(\alpha^*)$, *and* $\Pi^N(\alpha^*)$ *are decreasing in* t.

As Propositions 6 and 7 expose, although an increase in a moderate-valued tariff rate can effectively induce the multinational firm to increase his local content rate, it hurts the firm by reducing his demand and profit. This occurs because the increased use of local components reduces the quality of product M and product acquisition cost, and in response, the multinational firm decreases the product price. Thus, an increase in the tariff rate may affect the multinational firm's incentive to invest in the local market. Next, we investigate the impact of the tariff rate on the local firm.

Proposition 8 *When the multinational firm's optimal local content rate* $\alpha^* = \alpha^0$, $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\alpha^*)$, *and* $\hat{\Pi}^N(\alpha^*)$ *are increasing in* t *if* $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$.

Proposition 8 indicates that if the two firms' quality competition is fiercer than their price competition, then an increase in the tariff rate makes the local firm better off. This is because, according to Proposition 6, an increase in the tariff rate can induce the multinational firm to increase his local content rate and thus reduce product M's quality. As a result, the multinational firm's competitiveness in quality decreases, and the local firm can raise her product price while achieving a higher demand and profit.

When the two firms' price competition is fiercer than their quality competition, our numerical study shows that a higher tariff rate t may hurt the local firm, as illustrated by Figure 1[b]. We find from Figure 1 that the local firm's profit decreases at the tariff rate above 0.15, and stays constant at the tariff rate higher than 0.31 (because the multinational firm fully localizes his product and pays no tariff). In addition, as (10) indicates that the local firm's demand and profit change with t along the same direction, the local firm's demand also decreases at the tariff rate above 0.15. The decline in the local firm's demand and profit may be attributed to the following fact. According to Proposition 6, an increase in the tariff rate can induce the multinational firm to increase his local content rate, which may reduce the unit cost of product M and enhance the firm's competitiveness in price competition. This puts the local firm at a weaker position when the two firms' price competition is fiercer than their quality competition. Therefore, to ensure the effectiveness of a tariff in protecting the local firm, it is important for the policy maker to understand the level of quality competition vs. that of price competition between the multinational firm and the local firm.

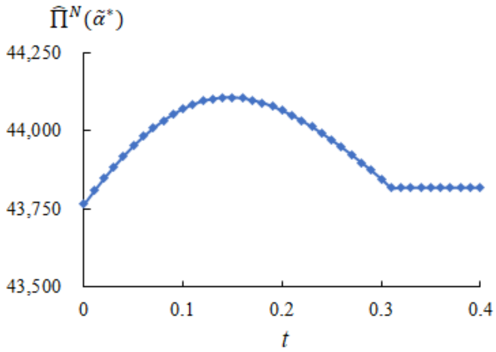

Figure 1: The impact of tariff rate t on the local firm's profit $\hat{\Pi}^N(\alpha^*)$.

5 The Two-Firm Competition under a Local Content Requirement Imposed in an Emerging Market

Some governments of emerging markets (e.g., Brazil and India) have implemented a local content policy that charges a multinational firm a higher tariff if the firm's product does not meet the LCR. We let $\theta \in (0, 1)$ denote the minimum local content rate (i.e., the LCR threshold) required by a government. We use $t \geq 0$ to represent the tariff rate applicable to the multinational firm's product if the product meets the LCR (i.e., $\alpha \geq \theta$) and use $t_p > 0$ to denote the additional (penalty) tariff rate when the product does not meet the LCR. We can calculate the multinational firm's unit cost $M_L(\alpha)$ under the LCR as

$$M_L(\alpha) = \begin{cases} M_1(\alpha) \equiv M(\alpha), & \text{if } \theta \leq \alpha \leq 1; \\ M_2(\alpha) \equiv M(\alpha) + t_p C(\alpha)(1-\alpha), & \text{if } 0 \leq \alpha < \theta. \end{cases} \tag{11}$$

[b] We use $A = 1000$, $k = 0.6$, $\lambda_1 = 500$, $\lambda_2 = 100$, $\beta_1 = 3$, $\beta_2 = 1$, $g(\alpha) = 2.5 - 0.2/(2-\alpha)$, $C(\alpha) = 5(1-\alpha)^4 + 110$, $C_A = 5$, and $\hat{C} = 105$, and change t from 0 to 0.4 in steps of 0.01.

In (11), the multinational firm's unit cost $M(\alpha)$ is given in (3), and $M_2(\alpha)$ equals $M(\alpha)$ plus a penalty tariff $t_p C(\alpha)(1-\alpha)$. We can rewrite $M_2(\alpha)$ as $M_2(\alpha) = C(\alpha)[1 + (t + t_p)(1 - \alpha)] + C_A$. Thus, $M_2(\alpha)$ can be seen as replacing t in $M_1(\alpha)$ with $t + t_p$. Note that $M_2(\alpha)$ is the multinational firm's unit cost function only when α is small such that $\alpha < \theta < 1$, and $t + t_p$ is usually less than 1 in practice. Using a similar argument as in Section 4.1.1, we can focus our analysis on the case when $M_2(\alpha)$ is convex (i.e., $M_2''(\alpha) > 0$).

5.1 Local Content and Pricing Decisions under the LCR

The LCR affects the multinational firm's unit acquisition cost, thereby influencing his local content rate decision. To find the firm's optimal decision on the local content rate, we need to compare the firm's maximum profit when he meets the LCR and that when he does not. Let $V_1(\alpha)$ and $V_2(\alpha)$ denote the multinational firm's α-dependent unit profit in Nash equilibrium without the penalty tariff and that with the penalty tariff, respectively. We can obtain $V_i(\alpha)$ $(i = 1, 2)$ by replacing $M(\alpha)$ in (9) with $M_i(\alpha)$. Following the argument in Section 4.2, we find that $V_i(\alpha)$ is a strictly concave function of α. Similarly, let $\hat{V}_1(\alpha)$ and $\hat{V}_2(\alpha)$ denote the local firm's corresponding α-dependent unit profit in Nash equilibrium. We can calculate $\hat{V}_i(\alpha)$ $(i = 1, 2)$ by replacing $M(\alpha)$ in (10) with $M_i(\alpha)$, and $\hat{V}_i(\alpha)$ are strictly concave function of α. Thus, the multinational firm's and the local firm's unit profits can be written as

$$[V^N(\alpha) \mid \hat{V}^N(\alpha)] = \begin{cases} [V_1(\alpha) \mid \hat{V}_1(\alpha)], & \text{if } \theta \le \alpha \le 1; \\ [V_2(\alpha) \mid \hat{V}_2(\alpha)], & \text{if } 0 \le \alpha < \theta. \end{cases} \tag{12}$$

Similar to Proposition 2, we find the local content rate $\tilde{\alpha}_i^*$ $(i = 1, 2)$ that maximizes $V_i(\alpha)$ as follows:

$$\tilde{\alpha}_i^* = \begin{cases} 0, & \text{if } \gamma_i(0) \le S; \\ \alpha_i^0, & \text{if } \gamma_i(1) < S < \gamma_i(0); \\ 1, & \text{if } \gamma_i(1) \ge S, \end{cases} \tag{13}$$

where $\gamma_i(\alpha) \equiv M_i'(\alpha)/g'(\alpha)$, and α_i^0 satisfies the first-order condition of $V_i(\alpha)$ and thus represents the unique solution to the equation $\gamma_i(\alpha) = S$ for $i = 1, 2$. In addition, $0 < \alpha_1^0 < \alpha_2^0 < 1$ for a given value of S. It is easy to show that for $\alpha \in [0, 1)$, $M_2'(\alpha) < M_1'(\alpha)$, and thus $\gamma_2(\alpha) > \gamma_1(\alpha)$. Hereafter, we use the tilda symbol "~" to represent the case with the LCR so as to distinguish it from the case without the LCR in Section 4.

Proposition 9 *Under the LCR with the minimum local content rate θ, the multinational firm's optimal local content rate $\tilde{\alpha}^*$ can be uniquely obtained as*

$$\tilde{\alpha}^* = \begin{cases} \tilde{\alpha}_1^*, & \text{if } \theta \le \tilde{\alpha}_1^*; \\ \theta, & \text{if } \tilde{\alpha}_1^* < \theta \le \bar{\theta}; \\ \tilde{\alpha}_2^*, & \text{if } \theta \ge \bar{\theta}, \end{cases} \tag{14}$$

where $\bar{\theta} \in [\tilde{\alpha}_2^*, 1]$ satisfies the equation $V_1\left(\bar{\theta}\right) = V_2\left(\tilde{\alpha}_2^*\right)$ and $\tilde{\alpha}_1^* \le \tilde{\alpha}_2^* < \bar{\theta}$.

We note from (13) and Proposition 9 that the values of $\tilde{\alpha}_1^*$ and $\bar{\theta}$ are independent of θ but dependent on other parameters. The multinational firm's optimal local content rate under an LCR is always greater than or equal to that with no LCR. Moreover, because $\tilde{\alpha}_1^* \le \tilde{\alpha}_2^* < \bar{\theta}$, $\tilde{\alpha}^*$ is not monotonically increasing in θ. Specifically, if the LCR threshold θ is sufficiently small, then the multinational firm will adopt a local content rate $\tilde{\alpha}_1^*$ that is higher than θ. Thus, the LCR is ineffective. If θ takes a moderate value, then the multinational firm will comply with the LCR by setting his local content rate as the threshold θ. Consequently, the firm increases his local content rate as θ rises. Otherwise, if θ is sufficiently large (above $\bar{\theta}$), then the multinational firm will not comply with the LCR, and instead, reduce his local content rate to $\tilde{\alpha}_2^*$. In addition, when θ is equal to $\bar{\theta}$, the multinational firm is indifferent between complying (choosing the local content rate $\bar{\theta}$) and not complying with the LCR (choosing $\tilde{\alpha}_2^*$).

The result in (13) and Proposition 9 indicate that the optimal $\tilde{\alpha}^*$ is either equal to α_i^0 or is a constant (i.e., 0, θ, or 1). We can find that $\tilde{\alpha}^*$ is weakly decreasing in the quality-cost tradeoff ratio S (see the details in Online Appendix C). This means, under an LCR, as the quality-cost tradeoff ratio of his product increases, the multinational firm should reduce the local content rate. This finding is similar to the result in Section 4.2 for the case with no LCR. Because S is a function of demand parameters λ_1, λ_2, β_1, and β_2, we find that when $\tilde{\alpha}^* = \alpha_i^0$, the effects of these parameters on $\tilde{\alpha}^*$ are the same as those in Proposition 3 for the case with no LCR.

Under the LCR, the two firms' prices in Nash equilibrium and the resulting unit profits, demands, and total profits can be obtained by simply replacing $M(\alpha^*)$ in (7) - (10) with $M_i(\tilde{\alpha}^*)$. We provide a numerical example to illustrate the results.

Example 1 A multinational firm makes FDI in an emerging market, uses his advanced technology to produce product M, and sells it in the local market. The firm competes with a local firm who makes product L. The demand functions for products M and L are given in (1) and (2), for which we let $A = 1000$, $k = 0.6$, $\lambda_1 = 200$, $\lambda_2 = 100$, $\beta_1 = 3$, and $\beta_2 = 1$.

For the multinational firm, we consider a quality-related function that is dependent on the local content rate, $g(\alpha) = 2.5 - 1/(2 - \alpha)$, which satisfies the properties that $g'(\alpha) < 0$, $g''(\alpha) < 0$, and $g(\alpha) > 1$ for $\alpha \in [0, 1]$. The firm's unit (α-dependent) purchase cost $C(\alpha) = 5(1 - \alpha)^4 + 110$, which satisfies all the assumptions for $C(\alpha)$ specified in Section 4.1.1. The firm's unit assembly cost $C_A = 5$. The local firm's total unit cost is $\hat{C} = 105$, which includes the same unit assembly cost as that of the multinational firm. In addition, the tariff rate $t = 10\%$.

In the absence of an LCR, we find that $\gamma_1(1) < S < \gamma_1(0)$ is satisfied, and thus $\alpha^* = \alpha^0 \in (0, 1)$. Solving the equation $\partial \Pi^N(\alpha)/\partial \alpha = 0$, we obtain the multinational firm's optimal local content rate as $\alpha^* = \alpha^0 = 23.6\%$. We use (7) and (8) to compute the two firms' prices in Nash equilibrium, and then use (9) and (10) to calculate the resulting demands for products M and L and the two firms' profits. All the results are shown in Table 1.

		Price		Demand		Profit	
	Local content rate	p^N	$\hat{p}^N$	D^N	$\hat{D}^N$	Π^N	$\hat{\Pi}^N$
No LCR	$\alpha^* = 23.6\%$	237.020	159.785	335.347	164.355	$37,485.783$	$9,004.145$
LCR ($\theta = 60\%$)	$\tilde{\alpha}^* = 60\%$	229.454	160.980	329.762	167.941	$36,247.646$	$9,401.412$
% change		-3.19%	0.75%	-1.67%	2.18%	-3.30%	4.41%

Table 1: The comparision of results for the case with no LCR and the case with LCR.

Next, suppose that the policy maker in the local market imposes an LCR on the multinational firm's product. Under the LCR, the minimum local content rate is $\theta = 60\%$ and the penalty tariff rate is $t_p = 20\%$. Thus, the actual tariff rate applied to the multinational firm's product is

$t + t_p = 30\%$ if the local content rate of the product is below 60%. We compute the multinational firm's local content rate in (13) as $\tilde{\alpha}_1^* = 23.6\%$ and $\tilde{\alpha}_2^* = 62.5\%$. The value of θ above which the multinational firm decides not to comply with the LCR is $\bar{\theta} = 89.1\%$. Because $\tilde{\alpha}_1^* < \theta \le \bar{\theta}$, the firm's optimal local content rate $\tilde{\alpha}^*$ is determined as $\tilde{\alpha}^* = \theta = 60\%$. We use (7) and (8) to obtain the two firms' prices in Nash equilibrium, and then calculate the resulting demands and the two firms' profits. The results are presented in Table 1.

Comparing the results without an LCR and those with the LCR in Table 1, we reach the following findings regarding the impact of the LCR. First, the LCR significantly raises the multinational firm's optimal local content rate from 23.6% to 60%. Second, under the LCR, the multinational firm has to reduce his product price but faces a decline in demand, whereas the local firm can increase her price and achieve a higher demand. Third, the implementation of the LCR reduces the multinational firm's profit by 3.3% but increases the local firm's profit by 4.41%. The above results show that the LCR "transfers" the demand and profit from the multinational firm to the local firm. ◄

5.2 Impact of the LCR Threshold

We have shown in Proposition 9 that the LCR threshold θ may not effectively influence the multinational firm's local content rate decision. To examine the impact of θ on the demands and profits of the multinational firm and the local firm, we use (9) to calculate $D^N(\tilde{\alpha}^*)$ and $\Pi^N(\tilde{\alpha}^*)$ for the multinational firm and use (10) to calculate $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ for the local firm.

Proposition 10 *The multinational firm's demand $D^N(\tilde{\alpha}^*)$ and profit $\Pi^N(\tilde{\alpha}^*)$ are continuous and (weakly) decreasing in the LCR threshold $\theta \in [0, 1]$. Specifically, $D^N(\tilde{\alpha}^*)$ and $\Pi^N(\tilde{\alpha}^*)$ are constant for $\theta \in [0, \tilde{\alpha}_1^*]$, strictly decreasing in θ for $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$, and constant for $\theta \in [\bar{\theta}, 1]$.*

The effects of θ on the local firm's demand $\hat{D}^N(\tilde{\alpha}^*)$ and profit $\hat{\Pi}^N(\tilde{\alpha}^*)$ are specified below.

1. *For $\theta \in [0, \tilde{\alpha}_1^*]$, both $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are constant.*

2. *For $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$, (i) when $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$, both $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are strictly increasing in θ; (ii) when $\lambda_2/\lambda_1 < \beta_2/\beta_1$, both $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are strictly increasing in θ if $\gamma_1(\theta) < (2\lambda_2\beta_1 - \lambda_1\beta_2)/(\beta_1\beta_2)$ and strictly decreasing in θ if $\gamma_1(\theta) > (2\lambda_2\beta_1 - \lambda_1\beta_2)/(\beta_1\beta_2)$.*

3. *For $\theta \in [\bar{\theta}, 1]$, (i) when $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$, $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ drop at $\theta = \bar{\theta}$ to values $\hat{D}^N(\tilde{\alpha}_2^*)$ and $\hat{\Pi}^N(\tilde{\alpha}_2^*)$, respectively, and then remain constant; but, (ii) when $\lambda_2/\lambda_1 < \beta_2/\beta_1$, $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ rise at $\theta = \bar{\theta}$ to values $\hat{D}^N(\tilde{\alpha}_2^*)$ and $\hat{\Pi}^N(\tilde{\alpha}_2^*)$, respectively, and then stay constant.*

From Propositions 9 and 10, we find that only a moderate value of LCR threshold θ can effectively influence the multinational firm's local content rate decision as well as the two firms' demands and profits. Specifically, any increase in a low threshold $\theta \in [0, \tilde{\alpha}_1^*]$ cannot affect the multinational firm's local content rate decision and hence the two firms' demands and profits. This is because, if the threshold is low, the multinational firm will automatically meet the LCR.

In contrast, an increase in a moderate-valued $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$ can induce the multinational firm to raise his local content rate to meet the LCR. As a result, the multinational firm sacrifices a loss in demand and profit. However, the local firm may not benefit from the increased LCR threshold. In particular, when the two firms' quality competition is less fierce than their price competition (i.e., $\lambda_2/\lambda_1 < \beta_2/\beta_1$), if the marginal change in the multinational firm's unit cost is sufficiently large relative to the marginal change in his product quality (i.e., $\gamma_1(\theta)$ is sufficiently large), then an increase in $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$ can reduce the local firm's demand and profit. This is attributed to the fact that an increase in the local content rate can greatly reduce the multinational firm's unit cost, giving him an advantage in the price competition with the local firm.

Moreover, if the LCR threshold takes a high value $\bar{\theta}$, the multinational firm will choose to not comply with the LCR. This is because, otherwise, the firm will suffer a drastic loss of profit. Instead, he reduces the local content rate from θ to $\tilde{\alpha}_2^*$ and becomes more competitive in product quality. The local firm may not benefit from such a high LCR threshold. In particular, when the two firms' quality competition is fiercer than their price competition (i.e., $\lambda_2/\lambda_1 \geq \beta_2/\beta_1$), the local firm experiences a drop in demand and profit at the threshold $\bar{\theta}$. Any further increase in a high threshold $\theta \in [\bar{\theta}, 1]$ cannot affect the multinational firm's local content rate decision and hence the two firms' demands and profits.

5.3 Impact of the Penalty Tariff Rate under the LCR

When the LCR threshold θ is low such that the multinational firm's optimal local content rate with no LCR already meets the LCR (i.e., $\tilde{\alpha}_1^* \geq \theta$), any change in the penalty tariff rate t_p has no effect on the firm's local content rate decision and profit. Thus, we focus on the situation when $\theta > \tilde{\alpha}_1^*$ to investigate the impact of t_p.

Proposition 11 *When $\theta > \tilde{\alpha}_1^*$, the multinational firm's optimal local content rate $\tilde{\alpha}^*$ is weakly increasing in t_p. Specifically, (i) if $t_p < \bar{t}_p \equiv \{t_p | V_1(\theta) = V_2(\tilde{\alpha}_2^*(t_p))\}$, then $\tilde{\alpha}^* = \tilde{\alpha}_2^*(t_p)$ is strictly increasing in t_p; and (ii) if $t_p \geq \bar{t}_p$, then $\tilde{\alpha}^* = \theta$, and the multinational firm satisfies the LCR.*

Moreover, the value $\bar{\theta}$ (defined by $V_1\left(\bar{\theta}\right) = V_2\left(\tilde{\alpha}_2^*\right)$) is increasing in t_p.

One can note that $\bar{\theta}$, as defined in Proposition 9, is the LCR threshold value at which the multinational firm is indifferent between choosing the local content rate as $\bar{\theta}$ (to comply with the LCR) and choosing $\tilde{\alpha}_2^*$ (not to comply with the LCR). As Proposition 11 indicates, although a small penalty tariff cannot induce the multinational firm's compliance, an increase in the penalty tariff can effectively push the firm to raise his local content rate. To render the multinational firm's compliance with the LCR, the government should not only set an LCR threshold above the firm's optimal local content rate in the absence of the LCR but also associate it with a sufficiently large penalty tariff rate. Moreover, a larger penalty tariff rate widens the range of effective LCR threshold for the multinational firm's compliance.

Proposition 12 *When $\theta > \tilde{\alpha}_1^*$, for $\tilde{\alpha}_1^* > 0$, the multinational firm's price $p^N(\alpha^*)$, demand $D^N(\tilde{\alpha}^*)$, and profit $\Pi^N(\tilde{\alpha}^*)$ are weakly decreasing in t_p. Specifically, (i) if $t_p < \bar{t}_p$, then $p^N(\alpha^*)$, $D^N(\tilde{\alpha}^*(\theta))$ and $\Pi^N(\tilde{\alpha}^*(\theta))$ are strictly decreasing in t_p; but, (ii) if $t_p \geq \bar{t}_p$, then $D^N(\tilde{\alpha}^*)$ and $\Pi^N(\tilde{\alpha}^*)$ are constant.*

When $\theta > \tilde{\alpha}_1^*$ and $\lambda_2/\lambda_1 > \beta_2/\beta_1$, the local firm's price $\hat{p}^N(\alpha^*)$, demand $\hat{D}^N(\tilde{\alpha}^*)$, and profit $\hat{\Pi}^N(\tilde{\alpha}^*)$ are strictly increasing in t_p for $t_p < \bar{t}_p$, rise at $t_p = \bar{t}_p$, and stay constant for $t_p \geq \bar{t}_p$.

Propositions 11 and 12 expose that when the government sets a sufficiently high LCR threshold, an increase in a small penalty tariff rate (below $\bar{t}_p$) can drive the multinational firm to increase his local content rate, making the firm worse off with declined demand and profit. When the two firms' quality competition is fiercer than their price competition (i.e., $\lambda_2/\lambda_1 > \beta_2/\beta_1$), an increase in a small penalty tariff rate can benefit the local firm by increasing her demand and profit. However, any increase in a large penalty tariff rate (above $\bar{t}_p$) plays no effect on the two firms. This is because, in this situation, the multinational firm sets his local content rate identical to the LCR threshold to comply with the LCR and avoid the penalty tariff.

When the two firms' price competition is fiercer than their quality competition (i.e., $\beta_2/\beta_1 > \lambda_2/\lambda_1$), our numerical study shows that a higher penalty tariff rate t_p may make the local firm worse off, as illustrated by Figure 2[c]. In Figure 2, the local firm's profit decreases at the penalty tariff rate above 0.12, and then stays constant after dropping drastically at the penalty tariff rate of 0.21 (because the multinational firm meets the LCR and pays no penalty tariff). In addition, as (10) indicates that the local firm's demand and profit change with t_p along the same direction, the penalty tariff rate has a similar effect on the local firm's demand. This happens possibly because an increase in the penalty tariff rate drives the multinational firm to increase his local content rate and thus reduces his product cost, giving the firm an advantage in the price competition.

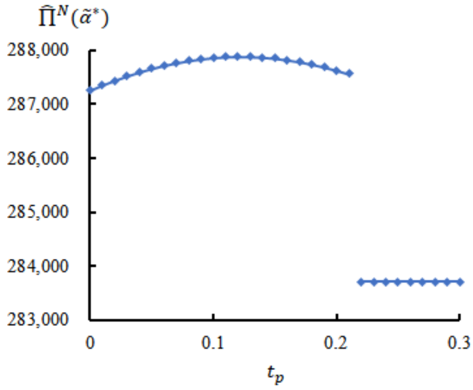

Figure 2: The impact of penalty tariff rate t_p on the local firm's total profit $\hat{\Pi}^N(\tilde{\alpha}^*)$.

Our results have the following implications to multinational firms who make FDI in an emerging market. A multinational firm may need to increase his local content rate when the local government implements an LCR on his product. In particular, if the LCR contains a moderate threshold and a sufficiently high penalty tariff rate, the firm should increase his local content rate to comply with the LCR; if the LCR involves an excessively high threshold, the firm should not alter his local content rate, but pay a penalty tariff for non-compliance. Our results also offer insights to the policy maker in an emerging market. An LCR may not always benefit the local firm, which depends on the relative intensity of quality competition vs. price competition between the multinational firm and the local firm. If the quality competition is fiercer than price competition, a moderate LCR threshold can help increase the local firm's demand and profit, whereas a high threshold can make the local firm worse off. If the price competition is fiercer than quality competition, the effect of the LCR threshold can differ greatly. A moderate LCR threshold does not necessarily benefit the local firm, but a high threshold adds a cost to the multinational firm with a penalty tariff and thus benefits the local firm. Moreover, a high penalty tariff may not benefit the local firm, which depends on which type of competition is more intense.

[c]We use $A = 1000$, $k = 0.6$, $\lambda_1 = 500$, $\lambda_2 = 100$, $\beta_1 = 1.5$, $\beta_2 = 1$, $g(\alpha) = 2.5-0.2/(2-\alpha)$, $C(\alpha) = 5(1-\alpha)^4+110$, $C_A = 5$, and $\hat{C} = 105$, $t = 0.1$, and change t_p from 0 to 0.3 in steps of 0.01.

5.4 Robustness Test

We have used linear demand functions for the analysis of the two-firm competition. In this section, we examine whether our major results hold or not if we use nonlinear demand functions. To our knowledge, attraction functions have been commonly used to model competing firms' market shares in empirical and theoretical studies; see, e.g., Huang, Leng, and Parlar (2013) and Leeflang et al. (2013)). We now consider the following attraction function form with the common multiplicative competitive interaction (MCI) structure (see, e.g., Bernstein and Federgruen 2004):

$$D = A\frac{u_1}{u_0 + u_1 + u_2}, \text{ and } \hat{D} = A\frac{u_2}{u_0 + u_1 + u_2}, \tag{15}$$

where $A > 0$ is the total market size, and $u_0 > 0$ is the value of no-purchase. In addition, $u_i = k_i y_i^{\lambda_i} p_i^{-\beta_i}$ $(i = 1, 2)$ are the values of purchasing products M and L (with price p_i and quality level y_i), respectively, where k_i, λ_i, and β_i are positive parameters. More specifically, $u_1 = k_1(g(\alpha))^{\lambda_1} p^{-\beta_1}$ and $u_2 = k_2\hat{p}^{-\beta_2}$, where the quality level of product L is normalized to be 1 as before.

As the equilibrium analysis of the two-firm competition with demand functions in (15) is intractable, we perform a numerical study for the two-firm non-cooperative game. To that end, we write the multinational firm's cost function as $C(\alpha) = 80 + (1-\alpha)^4$ and quality function as $g(\alpha) = 1.2 - 0.1/(2-\alpha)$. The demand function parameters are $A = 1,000$, $u_0 = 0.1$, $k_1 = 50,000$, $k_2 = 100,000$, $\lambda_1 = 6$, $\beta_1 = 2.1$, and $\beta_2 = 2.4$. Moreover, the two firms' cost parameter values are $C_A = 50$ and $\hat{C} = 105$.

For the impact of tariff rate t, our numerical results show that an increase in the tariff rate can induce the multinational firm to increase his local content rate, which reduces the multinational firm's demand and profit but may or may not improve the local firm's demand and profit. As shown in Figure 3(a), a larger tariff rate can increase the local firm's profit. However, if we set $\lambda_1 = 5$, $\beta_1 = 2.2$, and $\beta_2 = 2.5$, as depicted in Figure 3(b), a small to moderate tariff rate can improve the local firm's profit, while a further increase in the tariff rate above 0.61 reduces the local firm's profit. It implies that a large tariff rate may not always benefit the local firm. Therefore, the major findings about the impact of tariff rate on the two firms in Section 4.3.2 hold.

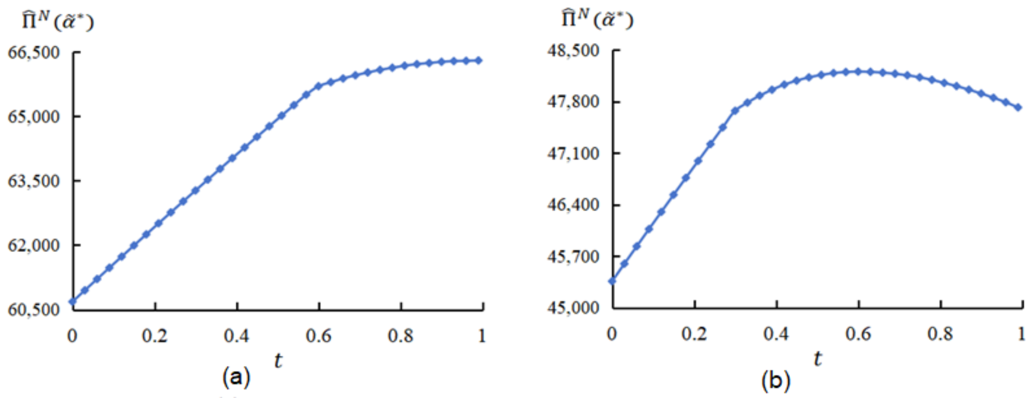

Figure 3: The impact of tariff rate t on the local firm's profit $\hat{\Pi}^N(\alpha^*)$ with attraction functions.

Next, for the impact of LCR threshold θ, our numerical analysis verifies that a low or high threshold has no impact on the two firms' demand and profit. Moreover, an increase in the moderate-valued LCR threshold always decreases the multinational firm's demand and profit but may not benefit the local firm. To illustrate the result, we set the tariff rate as $t = 0.3$, penalty tariff rate as $t_p = 0.3$, and $g(\alpha) = 1.2 - 0.2/(2 - \alpha)$. We learn from Figure 4(a) that a larger threshold can make the local firm better off. Differently, when $\lambda_1 = 5$, $\beta_1 = 2.5$, and $\beta_2 = 2.5$, Figure 4(b) indicates that an increase in the moderate-valued θ may reduce the local firm's profit. Hence, our findings about the impact of LCR threshold on the two firms in Section 5.2 are still valid.

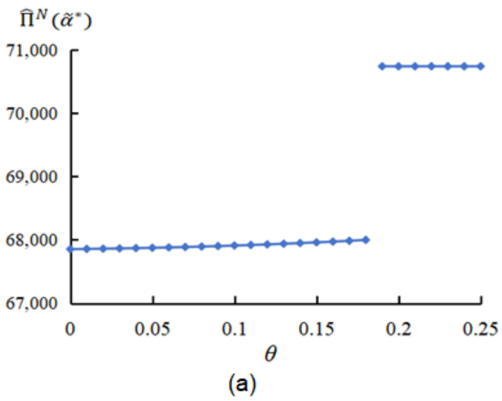

Figure 4: The impact of LCR threshold θ on the local firm's profit $\hat{\Pi}^N(\alpha^*)$ with attraction functions.

Finally, for the impact of penalty tariff rate t_p, we find from the numerical results that, under a high LCR threshold, increasing a small or moderate valued t_p can reduce the multinational firm's demand and profit, which, but, may not benefit the local firm. Moreover, a sufficiently large penalty tariff rate can induce the multinational firm to comply with the LCR and thus, any further increase in t_p has no impact on the two firms. Using $\theta = 0.8$ and the same parameter values as above for the analysis of tariff rate, we obtain results for different values of t_p as plotted in Figure 5. Figures 5(a) and (b) expose that increasing a small or moderate valued t_p may or may not raise the local firm's profit. It follows that the main findings about the impact of penalty tariff rate in Section 5.3 remain unchanged.

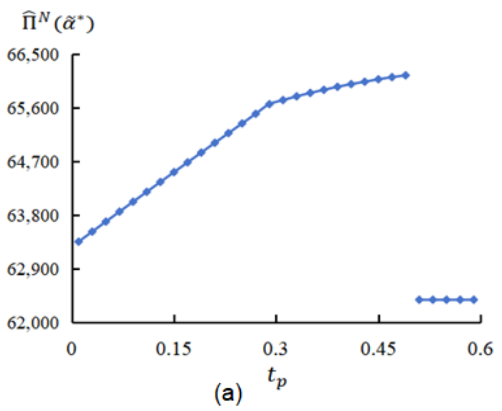

Figure 5: The impact of penalty tariff rate t_p on the local firm's profit $\hat{\Pi}^N(\alpha^*)$ with attraction functions.

According to the above, we can conclude that our major findings with the base model hold when we use the demand models in attraction function form. That is, although a higher tariff rate or a tighter LCR can potentially make a negative impact on the multinational firm, it may not make the local firm better off. Moreover, we have the following observations. Under the linear demand functions in (1) and (2), the values of price and quality sensitivity of demand parameters β_i and λ_i directly affect the demands of competing products in a linear manner. Thus, the positive/negative effects of tariff rate and LCR on the two firms are directly dependent on the relative values of the parameters (i.e., the relative intensity of price competition vs. quality competition). However, such findings may not hold when we use the attraction demand functions, because the parameters β_i and λ_i affect the market shares of competing products in a nonlinear manner, and the individual values of β_i and λ_i also determine the positive/negative effects of tariff rate and LCR on the two firms.

6 Extension: The Duopoly Analysis in a Developed Market

We have examined the multinational firm's local content and pricing decisions when the firm makes FDI in an emerging market. We have considered a common situation that the quality of local components is lower than that of imported components and the multinational firm has more advanced technology and brand reputation than the local firm. Accordingly, for the effect of local content rate α on product M's quality level $g(\alpha)$, we have assumed $g'(\alpha) < 0$ and $g''(\alpha) < 0$ for $\alpha \in [0, 1]$ with $g(1) > 1$.

It is common that multinational firms make FDI and sell products in a developed market. For instance, the report by Statista (2023) indicates that multinational firms such as Toyota and Honda have set up plants in the U.S., and they have been among the major carmakers in the country and are competing with the U.S. carmakers including General Motors, Ford, and others. Moreover, as discussed in Section 1, LCRs have also been proposed or implemented in developed economies, and many developed countries (e.g., Canada, the EU, and the U.S.) are using LCRs in their industrial policies for the green economy.

Motivated by the above practice, in this section, we extend our model to the case that the multinational firm makes FDI and sells a product in a developed market. In this case, local components are often made with a higher technology and thus have better quality than imported ones. As the multinational firm's local content rate increases, the quality of his product is improved, while the marginal quality improvement is diminishing. Correspondingly, we assume the following properties for $g(\alpha)$: $g'(\alpha) > 0$ and $g''(\alpha) < 0$ for $\alpha \in [0, 1]$. Moreover, we consider the situation that the multinational firm has a lower technology and brand reputation than the local firm. Thus, the quality of product M is inferior to that of local product L, even if product M is fully localized. That is, $g(1) < 1$, where 1 is the normalized quality level of product L, as discussed in Section 3. Apart from this new assumption on $g(\alpha)$, other setups of the base model remain unchanged.

6.1 The Two-Firm Competition under No Local Content Requirement

For the case with no LCR, we can conduct an analysis similar to that in Section 4 to obtain the equilibrium results for the game between the multinational firm and the local firm. The multinational firm's and the local firm's α-dependent prices in Nash equilibrium $(p^N(\alpha), \hat{p}^N(\alpha))$ are the same as those in Proposition 1. Then, we find the multinational firm's optimal local content rate as follows.

Proposition 13 *When there is no local content requirement, the multinational firm's optimal local content rate α^* is obtained as*

$$\alpha^* = \begin{cases} 0, & \text{if } \gamma(0) \geq S; \\ \alpha^0, & \text{if } \gamma(0) < S < \gamma(1); \\ 1, & \text{if } \gamma(1) \leq S, \end{cases}$$

where α^0 denotes the unique solution to the following equation for α: $\gamma(\alpha) = S$.

In a developed market, although product M's quality improves as the local content rate increases, the last condition in Proposition 13, $\gamma(1) \leq S$ (or, $Sg'(1) - M'(1) \geq 0$), may not hold, because of the following two facts. First, in our setting, $S > 0$, $g'(\alpha) > 0$, and $g''(\alpha) < 0$ for $\alpha \in [0, 1]$; hence, $Sg'(1) > 0$ is small. Second, $M'(1)$ can be positive and large because $M''(\alpha) > 0$ for $\alpha \in [0, 1]$. It thus follows that the multinational firm may not adopt a 100% local content rate and buy all components from local suppliers in a developed market. If α^* equals α^0, then we find $M'(\alpha^0) = Sg'(\alpha^0) > 0$, and $\gamma'(\alpha^0) > 0$. Hence,

$$\partial\alpha^0/\partial S = 1/\gamma'(\alpha^0) > 0,$$

meaning that α^0 is increasing in S. That is, for the multinational firm, as the quality-cost trade-off ratio of his product increases, the firm adopts a higher local content rate and improves product quality. This result differs from that in the case of an emerging market, because a higher degree of localization in a developed market can improve the multinational firm's product quality.

Similar to Proposition 3, we find that, when the optimal local content rate $\alpha^* = \alpha^0$ (where α^0 is defined as in Proposition 13),

$$\frac{\partial\alpha^*}{\partial\lambda_1} < 0, \ \frac{\partial\alpha^*}{\partial\lambda_2} > 0, \ \frac{\partial\alpha^*}{\partial\beta_1} > 0;$$

and

$$\frac{\partial\alpha^*}{\partial\beta_2} \begin{cases} > 0, & \text{if } \kappa \equiv 2\left(\frac{\beta_1}{\beta_2}\right)^2 - 4\frac{\lambda_1}{\lambda_2}\frac{\beta_1}{\beta_2} + 1 > 0, \\ = 0, & \text{if } \kappa = 0, \\ < 0, & \text{if } \kappa < 0. \end{cases}$$

The above indicates that the impacts of demand parameters on the multinational firm's optimal local content rate do not differ in the emerging market and the developed market.

For the multinational firm, $p^N(\alpha^*)$, $D^N(\alpha^*)$, and $\Pi^N(\alpha^*)$ are increasing in λ_1 but decreasing in λ_2, which is similar to those in Proposition 4. Hence, in the developed market, the own quality and cross quality sensitivity of demand parameters affect the two firms' prices, demands, and profits in the same way as those in the emerging market.

Proposition 14 *For the local firm, if $\lambda_2/\lambda_1 \geq \beta_2/\beta_1$, then $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\alpha^*)$, and $\hat{\Pi}^N(\alpha^*)$ are increasing in λ_1 but decreasing in λ_2.*

For the impacts of quality sensitivity of demand parameters (λ_1 and λ_2) on the local firm, Proposition 14 shows that if the two firms' quality competition is fiercer than their price competition, then an increase in λ_1 or a decrease in λ_2 makes the local firm better off, similar to those impacts on the multinational firm. This is in contrast with the case of emerging market in Proposition 5, where the same effects occur if the two firms' quality competition is less fierce than their price competition.

Letting

$$\bar{t}_1 \equiv \frac{C'(0) - Sg'(0)}{C(0) - C'(0)} < \bar{t}_2 \equiv \frac{C'(1) - Sg'(1)}{C(1)},$$

we have

$$\alpha^* = \begin{cases} 0, & \text{if } t \leq \bar{t}_1, \\ \alpha^0, & \text{if } \bar{t}_1 < t < \bar{t}_2, \\ 1, & \text{if } t \geq \bar{t}_2, \end{cases}$$

where $\alpha^0 \in (0, 1)$, as defined in Proposition 13, is strictly increasing in the tariff rate t. Comparing the results with those in Proposition 6, we find that the tariff rate plays the same effect on the multinational firm's local content rate in both the emerging market and the developed market.

Moreover, we can show that when the multinational firm's optimal local content rate $\alpha^* = \alpha^0$, his price $p^N(\alpha^*)$, demand $D^N(\alpha^*)$, and profit $\Pi^N(\alpha^*)$ are all decreasing in the tariff rate t. As the results are similar to those in Proposition 7, we conclude that the tariff rate t has the same effect on the multinational firm's demand and profit in both the emerging market and the developed market.

Proposition 15 *When the multinational firm's optimal local content rate* $\alpha^* = \alpha^0$*,* $\hat{p}^N(\alpha^*)$*,* $\hat{D}^N(\alpha^*)$*, and* $\hat{\Pi}^N(\alpha^*)$ *are increasing in* t *if* $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$*.*

Comparing Proposition 15 with Proposition 8, we learn that, if the two firms' price competition is more intense than their quality competition, a higher tariff rate t can improve the local firm's demand and profit in the developed market. In the emerging market, however, such effect occurs under a reverse condition for competition intensity. On the other hand, if the two firms' quality competition is more intense than their price competition, our numerical study indicates that a higher tariff rate may decrease the local firm's demand and profit, making the firm worse off. Such effect of the tariff rate on the local firm was found in our analysis of the emerging market, but under a reverse condition for competition intensity. The difference in the effect is due to the following fact. In the developed market, a higher tariff rate makes the multinational firm increase his local content rate and improve his product quality, giving the multinational firm an advantage in quality competition.

6.2 The Two-Firm Competition under a Local Content Requirement Imposed in a Developed Market

Using a similar method in Section 5, we can examine the two firms' game when the government in a developed market imposes an LCR on the multinational firm's product. First, following the discussion in Section 5.1, we find the local content rate $\tilde{\alpha}_i^*$ $(i = 1, 2)$ that maximizes the multinational firm's unit profit in Nash equilibrium without/with the penalty tariff (i.e., $V_i(\alpha)$) as follows:

$$\tilde{\alpha}_i^* = \begin{cases} 0, & \text{if } \gamma_i(0) \geq S; \\ \alpha_i^0, & \text{if } \gamma_i(0) < S < \gamma_i(1); \\ 1, & \text{if } \gamma_i(1) \leq S, \end{cases} \tag{16}$$

where $\gamma_i(\alpha) = M_i'(\alpha)/g'(\alpha)$, and α_i^0 is the solution to the equation $\gamma_i(\alpha) = S$ for $i = 1, 2$. Then, for the multinational firm's optimal local content rate $\tilde{\alpha}^*$ under an LCR, we can derive the same result as that in Proposition 9. That is, under the LCR with the minimum local content rate θ, the multinational firm's optimal local content rate $\tilde{\alpha}^*$ can be uniquely obtained as

$$\tilde{\alpha}^* = \begin{cases} \tilde{\alpha}_1^*, & \text{if } \theta \leq \tilde{\alpha}_1^*; \\ \theta, & \text{if } \tilde{\alpha}_1^* < \theta \leq \bar{\theta}; \\ \tilde{\alpha}_2^*, & \text{if } \theta \geq \bar{\theta}. \end{cases} \tag{17}$$

In (17), $\bar{\theta} \in [\tilde{\alpha}_2^*, 1]$ satisfies the equation $V_1\left(\bar{\theta}\right) = V_2\left(\tilde{\alpha}_2^*\right)$ and $\tilde{\alpha}_1^* \leq \tilde{\alpha}_2^* < \bar{\theta}$.

Using a similar argument as for Proposition 9, we find that in a developed market, the multinational firm's optimal local content rate $\tilde{\alpha}^*$ is increasing in the quality-cost tradeoff ratio S. This is contrary to the finding in Section 5.1 for the case of an emerging market, and is attributed to the fact that the quality of the multinational firm's product increases with the local content rate in a developed market. More specifically, if the multinational firm's total unit cost $M(\alpha)$ is decreasing in the local content rate (i.e., $M'(\alpha) < 0$), then the multinational firm always chooses a 100% local content rate. This is because a higher local content rate not only improves the quality of product M but also reduces its unit cost. If $M(\alpha)$ is an increasing function (i.e., $M'(\alpha) > 0$) or a convex function of α, we can obtain the impact of the LCR (including the threshold θ and penalty rate t_p) on the multinational firm as follows.

Proposition 16 *The multinational firm's price $p^N(\alpha^*)$, demand $D^N(\tilde{\alpha}^*)$, and profit $\Pi^N(\tilde{\alpha}^*)$ are continuous and (weakly) decreasing in the LCR threshold $\theta \in [0, 1]$. Specifically, $p^N(\alpha^*)$, $D^N(\tilde{\alpha}^*)$, and $\Pi^N(\tilde{\alpha}^*)$ are constant for $\theta \in [0, \tilde{\alpha}_1^*]$, strictly decreasing in θ for $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$, and constant for $\theta \in [\bar{\theta}, 1]$.*

The effects of θ on the local firm's price $\hat{p}^N(\alpha^*)$, demand $\hat{D}^N(\tilde{\alpha}^*)$, and profit $\hat{\Pi}^N(\tilde{\alpha}^*)$ are as follows.

1. *For $\theta \in [0, \tilde{\alpha}_1^*]$, $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\tilde{\alpha}^*)$, and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are constant.*

2. *For $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$, (i) when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$, $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\tilde{\alpha}^*)$, and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are strictly increasing in θ; (ii) when $\lambda_2/\lambda_1 > \beta_2/\beta_1$, $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\tilde{\alpha}^*)$, and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are strictly increasing in θ if $\gamma_1(\theta) > (2\lambda_2\beta_1 - \lambda_1\beta_2)/(\beta_1\beta_2)$ and strictly decreasing in θ if $\gamma_1(\theta) < (2\lambda_2\beta_1 - \lambda_1\beta_2)/(\beta_1\beta_2)$.*

3. *for $\theta \in [\bar{\theta}, 1]$, (i) when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$, $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\tilde{\alpha}^*)$, and $\hat{\Pi}^N(\tilde{\alpha}^*)$ drop at $\theta = \bar{\theta}$ to values $\hat{p}^N(\tilde{\alpha}_2^*)$, $\hat{D}^N(\tilde{\alpha}_2^*)$, and $\hat{\Pi}^N(\tilde{\alpha}_2^*)$, respectively, and then remain constant; but, (ii) when $\lambda_2/\lambda_1 > \beta_2/\beta_1$, $\hat{p}^N(\alpha^*)$, $\hat{D}^N(\tilde{\alpha}^*)$, and $\hat{\Pi}^N(\tilde{\alpha}^*)$ rise at $\theta = \bar{\theta}$ to values $\hat{p}^N(\tilde{\alpha}_2^*)$, $\hat{D}^N(\tilde{\alpha}_2^*)$, and $\hat{\Pi}^N(\tilde{\alpha}_2^*)$, respectively, and then stay constant.*

Comparing Proposition 16 with Proposition 10, we find that in a developed market, the impacts of LCR threshold θ on the multinational firm's demand and profit are similar to those in an emerging market. For the local firm, the impacts of θ are also similar to those in an emerging market, but under reverse conditions. More specifically, when the two firms' quality competition is fiercer than their price competition (i.e., $\lambda_2/\lambda_1 > \beta_2/\beta_1$), if the marginal change in the multinational firm's unit cost is sufficiently small relative to the marginal change in his product quality (i.e., $\gamma_1(\theta)$ is sufficiently small), then an increase in a moderate-valued threshold $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$ can reduce the local firm's demand and profit. Both conditions are contrary to those in the case of an emerging market. The result is attributed to the fact that an increase in the local content rate in a developed market can greatly improve the multinational firm's product quality, giving him an advantage in the quality competition with the local firm.

Moreover, if the LCR threshold takes a high value $\bar{\theta}$, the multinational firm will choose to not comply with the LCR. This is because, otherwise, the firm will suffer a drastic loss of profit. Instead, he reduces the local content rate from θ to $\tilde{\alpha}_2^*$ and becomes more competitive in product price. This is in contrast to the case of an emerging market, where the multinational firm chooses non-compliance with the LCR but adopts a lower local content rate to be more competitive in product quality. The local firm may not benefit from such a high LCR threshold. When the two firms' quality competition is less fierce than their price competition (i.e., $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$), the local firm experiences a drop in demand and profit at the threshold $\bar{\theta}$. Any further increase in a high threshold $\theta \in [\bar{\theta}, 1]$ cannot affect the multinational firm's local content rate decision and hence the two firms' demands and profits.

When $\theta > \tilde{\alpha}_1^*$, the multinational firm's optimal local content rate $\tilde{\alpha}^*$ is weakly increasing in t_p. Specifically, (i) if $t_p < \bar{t}_p \equiv \{t_p | V_1(\theta) = V_2(\tilde{\alpha}_2^*(t_p))\}$, then $\tilde{\alpha}^* = \tilde{\alpha}_2^*(t_p)$ is strictly increasing in t_p; and (ii) if $t_p \geq \bar{t}_p$, then $\tilde{\alpha}^* = \theta$, and the multinational firm satisfies the LCR. In addition, the value $\bar{\theta}$ (defined by $V_1\left(\bar{\theta}\right) = V_2\left(\tilde{\alpha}_2^*\right)$) is increasing in t_p. Because the results are similar to those in Proposition 11, we draw the conclusion that the impact of LCR penalty rate t_p on the optimal local content rate $\tilde{\alpha}^*$ in a developed market is the same as that in an emerging market. Therefore, an LCR can affect the multinational firm's local content rate decision in a similar way in both an emerging market and a developed market.

Proposition 17 *When $\theta > \tilde{\alpha}_1^*$, the multinational firm's demand $D^N(\tilde{\alpha}^*)$ and profit $\Pi^N(\tilde{\alpha}^*)$ are weakly decreasing in t_p. Specifically, (i) if $t_p < \bar{t}_p$, then $D^N(\tilde{\alpha}^*(\theta))$ and $\Pi^N(\tilde{\alpha}^*(\theta))$ are strictly decreasing in t_p; but, (ii) if $t_p \geq \bar{t}_p$, then $D^N(\tilde{\alpha}^*)$ and $\Pi^N(\tilde{\alpha}^*)$ are constant.*

When $\theta > \tilde{\alpha}_1^*$ and $\lambda_2/\lambda_1 < \beta_2/\beta_1$, the local firm's demand $\hat{D}^N(\tilde{\alpha}^*)$ and profit $\hat{\Pi}^N(\tilde{\alpha}^*)$ are strictly increasing in t_p when $t_p < \bar{t}_p$, rise at $t_p = \bar{t}_p$, and stay constant for $t_p \geq \bar{t}_p$.

Compared with the results in Sections 5.2 and 5.3 for the case of an emerging market, Propositions 16 and 17 indicate that the LCR threshold and penalty tariff rate for an LCR in a developed market have similar effects on the multinational firm, but their effects on the local firm are under reverse conditions for the relative intensity of quality vs. price competition between the two firms. For example, in a developed market, an LCR with moderate-valued LCR threshold and penalty tariff rate can effectively induce the multinational firm's compliance with the LCR and shifts away his demand and profit. Meanwhile, it benefits the local firm when the price competition is fiercer than quality competition (i.e., $\lambda_2/\lambda_1 < \beta_2/\beta_1$), whereas in an emerging market, such an LCR is effective when the quality competition is fiercer (i.e., $\lambda_2/\lambda_1 > \beta_2/\beta_1$). In addition, in a developed market, if the two firms' quality competition is fiercer than their price competition, we also find from our numerical study that a higher penalty tariff rate may decrease the local firm's demand and profit, making the firm worse off. We have shown such effect in the emerging market, but under a reverse condition for competition intensity. This is because, in a developed market, a higher degree of localization of the multinational firm's product can improve his product quality and competitiveness in quality competition, but it may increase his product cost and weaken his competitiveness in price competition.

Our results indicate that our managerial insights for multinational firms who make FDI in an emerging market generally apply to those firms who make FDI in a developed market. The only difference is that, as the quality-cost tradeoff ratio of the product becomes larger, the multinational firm should decrease the local content rate in an emerging market, but increase it in a developed market. Moreover, our results have further implications for policy makers in both an emerging market and a developed market. To determine an LCR, a policy maker needs to carefully evaluate how the local technology level in a sector is vis-à-vis that of foreign firms and how the quality and cost of a multinational firm's product is affected by its local content rate. The policy maker also needs to learn the level of quality competition vs. that of price competition in the local market, which is critical for the policy maker to assess the impact of the LCR on the local firm.

In October 2017, for the renegotiation of the North American Free Trade Agreement (NAFTA), the U.S. Trump administration proposed a new regional value content (RVC) requirement for automobiles to 85% from the original 62.5% for duty free in the NAFTA region (Bloomberg 2017). The proposal aimed to raise the purchase of vehicle parts made in North America. It has caused concerns that a "very stringent" content target could make an opposite effect on its goal; later, the proposed RVC threshold was dropped to 75% (Reuters 2018b). Given this new RVC threshold, foreign-owned automakers continued to oppose the Trump administration's proposal with concerns that it could increase the costs of cars made in the U.S., raising prices and reducing sales. In contrast, American automakers were more supportive of the proposal (Reuters 2018a). Our study could explain the above because we find that setting an extremely high LCR threshold may not effectively induce multinational firms' compliance with the LCR, and the proposed increase in RVC/LCR threshold could benefit the local automakers but hurts the multinational manufacturers.

7 Summary and Concluding Remarks

LCRs have been widely adopted by the governments of developing and developed economies to support a local industry. In this paper, we study the value-based LCR defined at the product level. In contrast to extant studies that assumed multinational firms' compliance with an LCR, we focus on another common form of LCR, which does not require mandatory compliance by a multinational firm that makes and sells a product in the domestic market of a host country. Instead, the LCR specifies a threshold for the minimum local content rate of a product and a penalty tariff rate if the product's local content rate is below the threshold.

Our results indicate that the multinational firm makes his local content rate and pricing decisions based on a tradeoff between the "low cost" and "product differentiation" strategies for competition. In an emerging market, the multinational firm should reduce his local content rate as the quality-cost tradeoff ratio of his product increases. As the demand becomes more sensitive to product quality, the multinational firm should reduce the local content rate to improve product quality while increasing the product price, thus relying more on product differentiation. However, as the demand for a product becomes more sensitive to the quality of competing product or to its own price, the multinational firm should increase the local content rate to reduce the acquisition cost while decreasing product price, thus relying more on the low cost strategy. In addition, the multinational firm should alter his local content rate with any change in the tariff rate only when the tariff rate takes a moderate value. In such a situation, if the tariff rate becomes larger, the multinational firm needs to increase his local content rate and product price, but suffers a loss of demand and profit. All the above findings and insights continue to hold in a developed market. The only exception is that in a developed market the multinational firm should increase his local content rate as the quality-cost tradeoff ratio of his product increases.

In the presence of an LCR imposed in an emerging or developed market, the multinational firm should comply with the LCR by increasing his local content rate only if both the LCR threshold takes a moderate value and the penalty tariff rate is sufficiently large. When the penalty tariff rate is small, although the multinational firm is better off from opting for non-compliance, he still needs to raise his local content rate as the penalty tariff rate increases. Under an excessively large LCR threshold, the firm should not comply with the LCR, but pay a penalty tariff instead.

Our study also offers insights to policy makers who intend to influence a multinational firm's local content decision. Using either a tariff rate or an LCR may increase the multinational firm's local content. For the use of a tariff rate, the policy maker should adopt a moderate-valued tariff rate to effectively affect the multinational firm's local content decision. For the use of an LCR, the policy maker should choose a moderate-valued LCR threshold and a sufficiently large penalty tariff rate to induce the multinational firm's compliance with the LCR. An LCR makes the multinational firm worse off by shifting his demand and profit away. However, it may not always benefit the local firm, which depends on the technology level of the local sector vs. that of the multinational firm as well as the relative intensity of quality competition vs. price competition between the local firm and the multinational firm. In an emerging market, when the two firms' price competition is more intense than their quality competition, a higher tariff rate, LCR threshold, or penalty tariff rate may make the local firm's demand and profit decline. In contrast, in a developed market, when the two firms' quality competition is more intense, a higher tariff rate, LCR threshold, or penalty tariff rate may make the local firm worse off.

As discussed in Section 1, governments implement LCRs for diverse policy objectives, such as promoting the domestic industry and employment, protecting an industry from foreign competition, etc. Accordingly, instead of finding an optimal LCR for a specific objective such as maximizing social welfare, we have attempted to examine the impact of an LCR on the multinational firm and the local firm and shed light on the key factors that influence the effectiveness of the LCR. In particular, we find that the LCR may not always benefit the local firm but can make the multinational firm worse off.

Acknowledgement 1 *The second author (Liping Liang) was supported by Direct Grant DR21A3 of Lingnan University in Hong Kong. The fourth author (Mingming Leng) was supported by the General Research Fund (GRF) of the Hong Kong Research Grants Council under Research Project No. LU13500822.* ■

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Online Appendices

Penetrating a Market with Local-Content and Pricing Decisions: Implications for a Multinational Firm in the Competition with a Local Firm

Z. Dong, L. Liang, N. Liu, M. Leng

Appendix A List of Parameters and Variables

Notation	Definition	Notation	Definition
M	Product of the multinational firm	D	Demand of product M
L	Product of the local firm	$\hat{D}$	Demand of product L
α	Local content rate	p	Multinational firm's price
$g(\alpha)$	α-dependent quality level of product M	$\hat{p}$	Local firm's price
t	Tariff rate	$p^N(\alpha)$	Multinational firm's α-dependent price in Nash equilibrium
t_p	Penalty tariff rate		
$C(\alpha)$	Unit purchase cost of all components of product M	$\hat{p}^N(\alpha)$	Local firm's α-dependent price in Nash equilibrium
C_I	Unit tariff-exclusive cost of all imported components of product M	$V(\alpha)$	Multinational firm's α-dependent unit profit
C_A	Unit assembly cost of product M	$\Pi(\alpha)$	Multinational firm's α-dependent total profit
$M(\alpha)$	Total unit cost of product M		
$\hat{C}$	Total unit cost of product L	$\hat{V}(\alpha)$	Local firm's α-dependent unit profit
$M_L(\alpha)$	Total unit cost of product M under an LCR	$\hat{\Pi}(\alpha)$	Local firm's α-dependent total profit
θ	Local content requirement threshold	$D^N(\alpha)$	Multinational firm's α-dependent total demand in Nash equilibrium
$\tilde{\alpha}^*$	The optimal local content rate under an LCR		
A	Total potential market demand	$\hat{D}^N(\alpha)$	Local firm's α-dependent total demand in Nash equilibrium
k	Potential market share of product M		
β_1	Own price sensitivity of demand for product M (L)	$V^N(\alpha)$	Multinational firm's α-dependent unit profit in Nash equilibrium
β_2	Cross price sensitivity of demand for product M (L)	$\hat{V}^N(\alpha)$	Local firm's α-dependent unit profit in Nash equilibrium
λ_1	Own quality sensitivity of demand for product M (L)	$\Pi^N(\alpha)$	Multinational firm's α-dependent total profit in Nash equilibrium
λ_2	Cross quality sensitivity of demand for product M (L)	$\hat{\Pi}^N(\alpha)$	Local firm's α-dependent total profit in Nash equilibrium

Appendix B Proofs

Proof of Proposition 1. We calculate the first- and second-order derivatives of $\Pi(\alpha)$ in (5) w.r.t. p as follows:

$$\frac{\partial \Pi}{\partial p} = D - \beta_1 V(\alpha) \quad \text{and} \quad \frac{\partial^2 \Pi}{\partial p^2} = -2\beta_1 < 0,$$

which implies that $\Pi(\alpha)$ is a strictly concave function of price p. Next, we differentiate the local firm's profit function $\hat{\Pi}(\alpha)$ in (6) once and twice w.r.t. $\hat{p}$, and find that

$$\frac{\partial \hat{\Pi}}{\partial \hat{p}} = \hat{D} - \beta_1 \hat{V}(\alpha) \quad \text{and} \quad \frac{\partial^2 \hat{\Pi}}{\partial \hat{p}^2} = -2\beta_1 < 0,$$

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

Solving $\partial \Pi / \partial p = 0$ and $\partial \hat{\Pi} / \partial \hat{p} = 0$, we obtain the unique Nash equilibrium-characterized prices for the two firms as in (7) and (8). ■

Proof of Proposition 2. Differentiating $V^N(\alpha)$ in (9) once and twice with respect to α yields

$$\begin{cases} \dfrac{\partial V^N(\alpha)}{\partial \alpha} = \dfrac{\left(\beta_2^2 - 2\beta_1^2\right) M'(\alpha) + (2\lambda_1\beta_1 - \lambda_2\beta_2)\, g'(\alpha)}{4\beta_1^2 - \beta_2^2}, \\ \dfrac{\partial^2 V^N(\alpha)}{\partial \alpha^2} = \dfrac{\left(\beta_2^2 - 2\beta_1^2\right) M''(\alpha) + (2\lambda_1\beta_1 - \lambda_2\beta_2)\, g''(\alpha)}{4\beta_1^2 - \beta_2^2}, \end{cases}$$

where we compute $M'(\alpha)$ and $M''(\alpha)$ as

$$M'(\alpha) = C'(\alpha)\,[1 + t\,(1-\alpha)] - tC(\alpha) \text{ and } M''(\alpha) = C''(\alpha)\,[1 + t\,(1-\alpha)] - 2tC'(\alpha). \tag{18}$$

As discussed in Sections 3 and 4.1.1, $g''(\alpha) < 0$ and $M''(\alpha) > 0$. Thus, $\partial^2 V^N(\alpha)/\partial\alpha^2 < 0$, which means that $V^N(\alpha)$ is a strictly concave function of α. We learn from Section 3 and Remark 1 that $g'(\alpha) < 0$, and $C(\alpha)$ is a convex function but may be increasing in α (i.e., $C'(\alpha) > 0$), decreasing in α (i.e., $C'(\alpha) < 0$), or unimodal in α (i.e., $C'(0) < 0$ and $C'(1) > 0$). Therefore, $\partial V^N(\alpha)/\partial\alpha$ (for $\alpha \in [0,1]$) can be positive or negative, and one of the following three cases must happen.

1. $V^N(\alpha)$ is strictly decreasing in α. Because $V^N(\alpha)$ is a strictly concave function, this case happens if and only if $\partial V^N(\alpha)/\partial\alpha|_{\alpha=0} \leq 0$, or, $\gamma(0) \leq S$. Therefore, the optimal $\alpha^* = 0$.

2. $V^N(\alpha)$ is a unimodal, concave function of α. That is, $\left(\partial V^N(\alpha)/\partial\alpha\right)|_{\alpha=0} > 0$ and $\left(\partial V^N(\alpha)/\partial\alpha\right)|_{\alpha=1} < 0$. It follows from the first-order condition that the optimal $\alpha^* = \alpha^0$, where α^0 satisfies $\gamma(\alpha^0) = S$.

3. $V^N(\alpha)$ is strictly increasing in α. Because $V^N(\alpha)$ is a strictly concave function, this case happens if and only if $\left(\partial V^N(\alpha)/\partial\alpha\right)|_{\alpha=1} \geq 0$, or, $\gamma(1) \geq S$. Hence, the optimal $\alpha^* = 1$.

This proposition is thus proved. ■

Proof of Proposition 3. We learn from Section 4.2 that if the multinational firm's optimal local content rate takes the interior solution ($\alpha^* = \alpha^0$), then α^0 is the unique solution satisfying $\gamma(\alpha^0) = M'(\alpha^0)/g'(\alpha^0) = S$. Thus, $\partial\alpha^0/\partial x = [1/\gamma'(\alpha^0)] \times (\partial S/\partial x)$, where x represents the parameter λ_1, λ_2, β_1, or β_2. We also learn from Section 4.2 that $\gamma'(\alpha^0) < 0$. Therefore, to determine how x influences α^0, we only need to calculate $\partial S/\partial x$, which has the opposite sign as $\partial\alpha^0/\partial x$.

Because $\lambda_1 \geq \lambda_2 > 0$ and $\beta_1 \geq \beta_2 > 0$, it is easy to obtain that

$$\frac{\partial S}{\partial \lambda_1} = \frac{2\beta_1}{2\beta_1^2 - \beta_2^2} > 0, \ \frac{\partial S}{\partial \lambda_2} = \frac{-\beta_2}{2\beta_1^2 - \beta_2^2} < 0, \ \frac{\partial S}{\partial \beta_1} = \frac{-2\lambda_1(2\beta_1^2 + \beta_2^2) + 4\lambda_2\beta_1\beta_2}{(2\beta_1^2 - \beta_2^2)^2} < 0$$

Therefore, we find

$$\frac{\partial \alpha^0}{\partial \lambda_1} < 0, \ \frac{\partial \alpha^0}{\partial \lambda_2} > 0, \text{ and } \frac{\partial \alpha^0}{\partial \beta_1} > 0.$$

We also obtain that $\partial S/\partial \beta_2 = -\left(2\lambda_2\beta_1^2 + \lambda_2\beta_2^2 - 4\lambda_1\beta_1\beta_2\right)/(2\beta_1^2 - \beta_2^2)^2$. Thus, if $2\lambda_2\beta_1^2 + \lambda_2\beta_2^2 - 4\lambda_1\beta_1\beta_2 > 0$, or, $2\left(\beta_1/\beta_2\right)^2 - 4(\lambda_1/\lambda_2)(\beta_1/\beta_2) + 1 > 0$, then $\partial\alpha^0/\partial\beta_2 > 0$; if $2\left(\beta_1/\beta_2\right)^2 - 4(\lambda_1/\lambda_2)(\beta_1/\beta_2) + 1 < 0$, then $\partial\alpha^0/\partial\beta_2 < 0$; if $2\left(\beta_1/\beta_2\right)^2 - 4(\lambda_1/\lambda_2)(\beta_1/\beta_2) + 1 = 0$, then $\partial\alpha^0/\partial\beta_2 = 0$. ■

Proof of Proposition 4. Using the results from Proposition 2, we find that

$$\alpha^* = \begin{cases} 0, & \text{if } \lambda_1 \geq \lambda_1^0, \\ \alpha^0, & \text{if } \lambda_1^1 < \lambda_1 < \lambda_1^0, \\ 1, & \text{if } \lambda_1 \leq \lambda_1^1, \end{cases} \tag{19}$$

where $\lambda_1^0 \equiv \left[(2\beta_1^2 - \beta_2^2)\gamma(0) + \lambda_2\beta_2\right]/(2\beta_1)$ and $\lambda_1^1 \equiv \left[(2\beta_1^2 - \beta_2^2)\gamma(1) + \lambda_2\beta_2\right]/(2\beta_1)$, and $\gamma(\alpha^0) = S \equiv (2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2 - \beta_2^2)$. We first investigate the impact of λ_1 on $p^N(\alpha^*)$ and $V^N(\alpha^*)$ in the following three cases.

Case 1. $\lambda_1 \geq \lambda_1^0$**.** The optimal $\alpha^* = 0$. From (7) and (9), we obtain that

$$p^N(0) = \frac{1}{4\beta_1^2 - \beta_2^2}\{2\beta_1^2 M(0) + (2\lambda_1\beta_1 - \lambda_2\beta_2)\, g(0) + \beta_1\beta_2\hat{C} + 2\beta_1\,(kA - \lambda_2) + \beta_2\,[(1-k)A + \lambda_1]\},$$

and

$$V^N(0) = \frac{1}{4\beta_1^2 - \beta_2^2}\{(2\lambda_1\beta_1 - \lambda_2\beta_2)\, g(0) - \left(2\beta_1^2 - \beta_2^2\right) M(0) + \beta_1\beta_2\hat{C} + 2\beta_1\,(kA - \lambda_2) + \beta_2\,[(1-k)A + \lambda_1]\}.$$

It follows that $\partial p^N(0)/\partial\lambda_1 = \partial V^N(0)/\partial\lambda_1 = (2\beta_1 g(0) + \beta_2)/\left(4\beta_1^2 - \beta_2^2\right)$, which is positive because $\beta_1 \geq \beta_2 > 0$ and $g(0) > 1$, as assumed in Section 3. Thus, both $p^N(\alpha^*)$ and $V^N(\alpha^*)$ are increasing in λ_1 when $\lambda_1 \geq \lambda_1^0$.

Case 2. $\lambda_1^1 < \lambda_1 < \lambda_1^0$**.** The optimal $\alpha^* = \alpha^0$. From (9), we obtain

$$\frac{\partial V^N(\alpha^0)}{\partial \lambda_1} = \frac{(2\lambda_1\beta_1 - \lambda_2\beta_2)\, g'(\alpha^0) - \left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0)}{4\beta_1^2 - \beta_2^2}\frac{\partial \alpha^0}{\partial \lambda_1} + \frac{2\beta_1 g(\alpha^0) + \beta_2}{4\beta_1^2 - \beta_2^2}.$$

Because $\gamma(\alpha^0) = S$, we find that

$$(2\lambda_1\beta_1 - \lambda_2\beta_2)\, g'(\alpha^0) - \left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0) = 0.$$

Thus, $\partial V^N(\alpha^0)/\partial\lambda_1 = (2\beta_1 g(\alpha^0) + \beta_2)/(4\beta_1^2 - \beta_2^2) > 0$, meaning that $V^N(\alpha^*)$ is increasing in λ_1 when $\lambda_1^1 < \lambda_1 < \lambda_1^0$.

Next, from (7) we obtain

$$\frac{\partial p^N(\alpha^0)}{\partial \lambda_1} = \frac{\partial V^N(\alpha^0)}{\partial \lambda_1} + M'(\alpha^0)\frac{\partial \alpha^0}{\partial \lambda_1}.$$

Because $M'(\alpha^0) < 0$ as shown in Section 4.2 and $\partial \alpha^0/\partial \lambda_1 < 0$ as shown in Proposition 3, we have $\partial p^N(\alpha^0)/\partial \lambda_1 > 0$, that is, $p^N(\alpha^*)$ is increasing in λ_1 when $\lambda_1^1 < \lambda_1 < \lambda_1^0$.

Case 3. $\lambda_1 \le \lambda_1^1$. The optimal $\alpha^* = 1$. Similar to the analysis of Case 1, we obtain that $\partial p^N(1)/\partial \lambda_1 = \partial V^N(1)/\partial \lambda_1 = (2\beta_1 g(1) + \beta_2)/\left(4\beta_1^2 - \beta_2^2\right) > 0$. Thus, both $p^N(\alpha^*)$ and $V^N(\alpha^*)$ are increasing in λ_1 when $\lambda_1 \le \lambda_1^1$.

According to (19), α^* is a continuous function of λ_1. Thus, the results in the above three cases imply that $p^N(\alpha^*)$ and $V^N(\alpha^*)$ are increasing in λ_1 for any λ_1. From (9), we learn that $D^N(\alpha^*) = \beta_1 V^N(\alpha^*)$ and $\Pi^N(\alpha^*) = \beta_1 \left(V^N(\alpha^*)\right)^2$, indicating that $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ have the same monotonicity in λ_1 as $V^N(\alpha^*)$.

The impact of λ_2 on $p^N(\alpha^*)$, $D^N(\alpha^*)$, and $\Pi^N(\alpha^*)$ can be similarly proved, and it is omitted here. ■

Proof of Proposition 5. Similar to the proof of Proposition 4, we first investigate the impact of λ_1 on $\hat{p}^N(\alpha^*)$ in the following three cases.

Case 1. $\lambda_1 \ge \lambda_1^0$. The optimal $\alpha^* = 0$. From (8) we obtain

$$\hat{p}^N(0) = \frac{1}{4\beta_1^2 - \beta_2^2}\{\beta_1\beta_2 M(0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g(0) + 2\beta_1^2\hat{C} + \beta_2(kA - \lambda_2) + 2\beta_1[(1-k)A + \lambda_1]\}.$$

It follows that

$$\frac{\partial \hat{p}^N(0)}{\partial \lambda_1} = \frac{\beta_2 g(0) + 2\beta_1}{4\beta_1^2 - \beta_2^2} > 0, \text{ and } \frac{\partial \hat{p}^N(0)}{\partial \lambda_2} = -\frac{2\beta_1 g(0) + \beta_2}{4\beta_1^2 - \beta_2^2} < 0.$$

Thus $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_1 \ge \lambda_1^0$.

Case 2. $\lambda_1^1 < \lambda_1 < \lambda_1^0$. The optimal $\alpha^* = \alpha^0$. We differentiate $\hat{p}^N(\alpha^0)$ in (8) once w.r.t. λ_1 and λ_2, respectively, and obtain

$$\frac{\partial \hat{p}^N(\alpha^0)}{\partial \lambda_1} = \frac{\beta_1\beta_2 M'(\alpha^0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha^0)}{4\beta_1^2 - \beta_2^2}\frac{\partial \alpha^0}{\partial \lambda_1} + \frac{\beta_2 g(\alpha^0) + 2\beta_1}{4\beta_1^2 - \beta_2^2}, \tag{20}$$

and

$$\frac{\partial \hat{p}^N(\alpha^0)}{\partial \lambda_2} = \frac{\beta_1\beta_2 M'(\alpha^0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha^0)}{4\beta_1^2 - \beta_2^2}\frac{\partial \alpha^0}{\partial \lambda_2} - \frac{2\beta_1 g(\alpha^0) + \beta_2}{4\beta_1^2 - \beta_2^2}. \tag{21}$$

Because $\gamma(\alpha^0) = S$, we find that

$$(2\lambda_1\beta_1 - \lambda_2\beta_2)\, g'(\alpha^0) - \left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0) = 0,$$

which gives $M'(\alpha^0) = \left[(2\lambda_1\beta_1 - \lambda_2\beta_2)\, g'(\alpha^0)\right] / \left(2\beta_1^2 - \beta_2^2\right)$. Then, we can rewrite (20) and (21) as

$$\frac{\partial \hat{p}^N(\alpha^0)}{\partial \lambda_1} = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2}g'(\alpha^0)\frac{\partial \alpha^0}{\partial \lambda_1} + \frac{\beta_2 g(\alpha^0) + 2\beta_1}{4\beta_1^2 - \beta_2^2},$$

and
$$\frac{\partial \hat{p}^N(\alpha^0)}{\partial \lambda_2} = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2} g'(\alpha^0)\frac{\partial \alpha^0}{\partial \lambda_2} - \frac{2\beta_1 g(\alpha^0) + \beta_2}{4\beta_1^2 - \beta_2^2}.$$

We learn from Proposition 3 that $\partial\alpha^0/\partial\lambda_1 < 0$ and $\partial\alpha^0/\partial\lambda_2 > 0$ and from Section 3 that $g'(\alpha^0) < 0$. Therefore, if $\lambda_1\beta_2 - \lambda_2\beta_1 \geq 0$, then $\partial\hat{p}^N(\alpha^0)/\partial\lambda_1 > 0$ and $\partial\hat{p}^N(\alpha^0)/\partial\lambda_2 < 0$. That is, if $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$, then $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_1^1 < \lambda_1 < \lambda_1^0$.

Case 3. $\lambda_1 \leq \lambda_1^1$**.** The optimal $\alpha^* = 1$. Similar to the analysis of Case 1, we obtain that

$$\frac{\partial \hat{p}^N(1)}{\partial \lambda_1} = \frac{\beta_2 g(1) + 2\beta_1}{4\beta_1^2 - \beta_2^2} > 0, \text{ and } \frac{\partial \hat{p}^N(1)}{\partial \lambda_2} = -\frac{2\beta_1 g(1) + \beta_2}{4\beta_1^2 - \beta_2^2} < 0.$$

Thus $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_1 \leq \lambda_1^1$.

According to (19), α^* is a continuous function of λ_1. Thus, the results in the above three cases imply that $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$. Because $\hat{V}^N(\alpha^*) = \hat{p}^N(\alpha^*) - \hat{C}$ (according to (6)) and the local firm's unit cost $\hat{C}$ is constant, $\hat{V}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$. We find from (10) that $\hat{D}^N(\alpha^*) = \beta_1\hat{V}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*) = \beta_1(\hat{V}^N(\alpha^*))^2$. Thus, both $\hat{D}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*)$ are increasing in λ_1 and decreasing in λ_2 when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$. ■

Proof of Proposition 6. We learn from Proposition 2 that

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

From (18), we find that

$$\begin{aligned} M'(0) &= (1+t)C'(0) - tC(0) = t[C'(0) - C(0)] + C'(0), \\ M'(1) &= C'(1) - tC(1). \end{aligned}$$

As discussed in Section 4.1.1, $(1-\alpha)C'(\alpha) - C(\alpha) < 0$ for any $\alpha \in [0,1]$, and thus $C(0) - C'(0) > 0$. It follows that $Sg'(0) - M'(0) \leq 0$ can be rewritten as $t \leq \bar{t}_1$, and $Sg'(1) - M'(1) \geq 0$ can be rewritten as $t \geq \bar{t}_2$, where $\bar{t}_1 = [C'(0) - Sg'(0)]/[C(0) - C'(0)]$ and $\bar{t}_2 = [C'(1) - Sg'(1)]/C(1)$.

Because $S > 0$, $g''(\alpha) < 0$, and $M''(\alpha) > 0$, we obtain that $Sg'(1) - M'(1) < Sg'(0) - M'(0)$, or $Sg'(1) - C'(1) + tC(1) < Sg'(0) + t[C(0) - C'(0)] - C'(0)$ for any t. We find that

$$\begin{aligned} Sg'(1) - C'(1) + \bar{t}_2 C(1) &< Sg'(0) + \bar{t}_2[C(0) - C'(0)] - C'(0) \\ &= Sg'(0) + \bar{t}_1[C(0) - C'(0)] - C'(0) + (\bar{t}_2 - \bar{t}_1)[C(0) - C'(0)] \\ &= Sg'(1) - C'(1) + \bar{t}_2 C(1) + (\bar{t}_2 - \bar{t}_1)[C(0) - C'(0)]. \end{aligned}$$

The last equality above follows from the fact that

$$Sg'(1) - C'(1) + \bar{t}_2 C(1) = 0 = Sg'(0) + \bar{t}_1[C(0) - C'(0)] - C'(0).$$

Thus, $(\bar{t}_2 - \bar{t}_1)[C(0) - C'(0)] > 0$. Because $C(0) - C'(0) > 0$, we obtain $\bar{t}_2 > \bar{t}_1$.

Using the above, we obtain results in the following three cases.

Case 1. $t \le \bar{t}_1$**.** In this case, $Sg'(0) - M'(0) \le 0$. As Proposition 2 indicates, the multinational firm's optimal local content rate is $\alpha^* = 0$ for $t \le \bar{t}_1$.

Case 2. $t \ge \bar{t}_2$**.** In this case, $Sg'(1) - M'(1) \ge 0$, and thus the multinational firm's optimal local content rate is $\alpha^* = 1$ for $t \ge \bar{t}_2$.

Case 3. $\bar{t}_1 < t < \bar{t}_2$**.** In this case, $Sg'(0) - M'(0) > 0$ and $Sg'(1) - M'(1) < 0$. It follows from Proposition 2 that the multinational firm determines his optimal local content rate as $\alpha^* = \alpha^0$ for $\bar{t}_1 < t < \bar{t}_2$. We consider two arbitrary tariff rates t_1 and t_2, and without loss of generality, assume that $\bar{t}_1 < t_1 < t_2 < \bar{t}_2$. When the tariff rate t_1 or t_2 applies, the multinational firm determines his optimal local content rate as $\alpha^0_{t1} = \alpha^0|_{t=t_1}$ and $\alpha^0_{t2} = \alpha^0|_{t=t_2}$, respectively. Next, we compare α^0_{t1} and α^0_{t2}.

We note from the proof of Proposition 2 that for $t > \bar{t}_1$, $V^N(\alpha)$ in (9) is a concave function with a unique optimal solution α^0 that maximizes $V^N(\alpha)$; that is, α^0 uniquely satisfies the first-order condition $\partial V^N(\alpha)/\partial\alpha = 0$, or $\gamma(\alpha^0) = S$. Let $V^N_{ti}(\alpha)$ 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 $\alpha^0_{t1} < \alpha^0_{t2}$ if and only if $(\partial V^N_{t2}(\alpha)/\partial\alpha)\big|_{\alpha=\alpha^0_{t1}} > (\partial V^N_{t2}(\alpha)/\partial\alpha)\big|_{\alpha=\alpha^0_{t2}} = 0$. Therefore, to compare α^0_{t1} and α^0_{t2}, we should determine the sign of $(\partial V^N_{t2}(\alpha)/\partial\alpha)\big|_{\alpha=\alpha^0_{t1}}$.

We calculate

$$\left.\frac{\partial V^N_{t1}(\alpha)}{\partial\alpha}\right|_{\alpha=\alpha^0_{t1}} = \frac{\left(\beta_2^2 - 2\beta_1^2\right)\left\{C'(\alpha^0_{t1})\left[1 + t_1\left(1 - \alpha^0_{t1}\right)\right] - t_1 C(\alpha^0_{t1})\right\} + \left(2\lambda_1\beta_1 - \lambda_2\beta_2\right)g'(\alpha^0_{t1})}{4\beta_1^2 - \beta_2^2},$$
$$\left.\frac{\partial V^N_{t2}(\alpha)}{\partial\alpha}\right|_{\alpha=\alpha^0_{t1}} = \frac{\left(\beta_2^2 - 2\beta_1^2\right)\left\{C'(\alpha^0_{t1})\left[1 + t_2\left(1 - \alpha^0_{t1}\right)\right] - t_2 C(\alpha^0_{t1})\right\} + \left(2\lambda_1\beta_1 - \lambda_2\beta_2\right)g'(\alpha^0_{t1})}{4\beta_1^2 - \beta_2^2}.$$

Then, we have

$$\left.\frac{\partial V^N_{t2}(\alpha)}{\partial\alpha}\right|_{\alpha=\alpha^0_{t1}} - \left.\frac{\partial V^N_{t1}(\alpha)}{\partial\alpha}\right|_{\alpha=\alpha^0_{t1}} = \frac{\left(\beta_2^2 - 2\beta_1^2\right)\left[\left(1 - \alpha^0_{t1}\right)C'(\alpha^0_{t1}) - C(\alpha^0_{t1})\right]}{4\beta_1^2 - \beta_2^2}(t_2 - t_1).$$

Because it is assumed in Section 3 that $\beta_1 \ge \beta_2 > 0$ and in Section 4.1.1 that $(1-\alpha)C'(\alpha) - C(\alpha) < 0$, we find $(\partial V^N_{t2}(\alpha)/\partial\alpha)\big|_{\alpha=\alpha^0_{t1}} - (\partial V^N_{t1}(\alpha)/\partial\alpha)\big|_{\alpha=\alpha^0_{t1}} > 0$, i.e., $(\partial V^N_{t2}(\alpha)/\partial\alpha)\big|_{\alpha=\alpha^0_{t1}} > (\partial V^N_{t1}(\alpha)/\partial\alpha)\big|_{\alpha=\alpha^0_{t1}} = 0$. Therefore, if two tariff rates t_1 and t_2 are given such that $\bar{t}_1 < t_1 < t_2 < \bar{t}_2$, then $\alpha^0_{t1} < \alpha^0_{t2}$. That is, α^* is increasing in t for $\bar{t}_1 < t < \bar{t}_2$.

■

Proof of Proposition 7. We learn from (9) that $D^N(\alpha^*) = \beta_1 V^N(\alpha^*)$ and $\Pi^N(\alpha^*) = \beta_1(V^N(\alpha^*))^2$, which indicates that the impacts of t on $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ are dependent on the impact of t on $V^N(\alpha^*)$. For this proof, we consider two tariff rates t_1 and t_2, and without loss of generality, we 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 $\alpha^*_{t_1}$ and $\alpha^*_{t_2}$, respectively. As Proposition 6 indicates, the multinational firm's optimal local content rate α^* is a weakly increasing function of t. Therefore, $\alpha^*_{t_1} \leq \alpha^*_{t_2}$. We denote the multinational firm's unit profit when $t = t_i$ as $V^N_{t_i}(\alpha^*) \equiv V^N(\alpha^*)|_{t=t_i}$, for $i = 1, 2$.

For $0 < \alpha^*_{t_1} < \alpha^*_{t_2} < 1$, we use (7) to find that

$$p^N_{t_1}(\alpha^*_{t_1}) - p^N_{t_2}(\alpha^*_{t_2}) = \frac{2\beta_1^2(M(\alpha^*_{t_1}) - M(\alpha^*_{t_2})) + (2\lambda_1\beta_1 - \lambda_2\beta_2)\,(g(\alpha^*_{t_1}) - g(\alpha^*_{t_2}))}{4\beta_1^2 - \beta_2^2}$$

Because $g'(\alpha) < 0$ and $M''(\alpha) > 0$ for $\alpha \in [0, 1]$, and $M'(\alpha^*_{t_2}) = Sg'(\alpha^*_{t_2}) < 0$, we obtain that $p^N_{t_1}(\alpha^*_{t_1}) - p^N_{t_2}(\alpha^*_{t_2}) > 0$.

The first-order derivative of $V^N(\alpha^0)$ w.r.t. t is computed as

$$\frac{dV^N(\alpha^0)}{dt} = \frac{-1}{4\beta_1^2 - \beta_2^2}\left\{\left(2\beta_1^2 - \beta_2^2\right) C(\alpha^0)(1-\alpha^0) + \frac{\partial\alpha^0}{\partial t}\left[\left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0) + (\lambda_2\beta_2 - 2\lambda_1\beta_1)\, g'(\alpha^0)\right]\right\}.$$

Because $\gamma(\alpha^0) = S$, we find that

$$\left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0) + (\lambda_2\beta_2 - 2\lambda_1\beta_1)\, g'(\alpha^0) = 0,$$

and

$$\frac{dV^N(\alpha^0)}{dt} = -\frac{2\beta_1^2 - \beta_2^2}{4\beta_1^2 - \beta_2^2} C(\alpha^0)(1-\alpha^0) < 0.$$

Therefore, $V^N_{t_1}(\alpha^*_{t_1}) > V^N_{t_2}(\alpha^*_{t_2})$.

In conclusion, $p^N(\alpha^*)$ and $V^N(\alpha^*)$ are decreasing in t. It follows that both $D^N(\alpha^*)$ and $\Pi^N(\alpha^*)$ are decreasing in t. ■

Proof of Proposition 8.

We learn from (10) that $\hat{D}^N(\alpha^*) = \beta_1\hat{V}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*) = \beta_1(\hat{V}^N(\alpha^*))^2$, which indicates that the impacts of t on $\hat{D}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*)$ are dependent on the impact of t on $\hat{V}^N(\alpha^*)$. Similar to the proof of Proposition 7, we consider two tariff rates t_1 and t_2, with $t_1 < t_2$. Thus, the multinational firm's corresponding optimal local content rates $\alpha^*_{t_1}$ and $\alpha^*_{t_2}$ satisfy $\alpha^*_{t_1} \leq \alpha^*_{t_2}$. Denote the local firm's unit profit when $t = t_i$ by $\hat{V}^N_{t_i}(\alpha^*) \equiv \hat{V}^N(\alpha^*)|_{t=t_i}$, for $i = 1, 2$.

The first-order derivative of $\hat{p}^N(\alpha^0)$ w.r.t. t is computed as

$$\frac{d\hat{p}^N(\alpha^0)}{dt} = \frac{1}{4\beta_1^2 - \beta_2^2}\left\{\beta_1\beta_2 C(\alpha^0)(1-\alpha^0) + \frac{\partial\alpha^0}{\partial t}\left[\beta_1\beta_2 M'(\alpha^0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha^0)\right]\right\}.$$

Because $\left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0) + (\lambda_2\beta_2 - 2\lambda_1\beta_1)\, g'(\alpha^0) = 0$ as shown in the proof of Proposition 7, we can simplify $d\hat{p}^N(\alpha^0)/dt$ to

$$\frac{d\hat{p}^N(\alpha^0)}{dt} = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2} g'(\alpha^0)\frac{\partial\alpha^0}{\partial t} + \frac{\beta_1\beta_2}{4\beta_1^2 - \beta_2^2} C(\alpha^0)(1-\alpha^0).$$

Because we have assumed $g'(\alpha^0) < 0$ in Section 3, and Proposition 6 has shown that $\partial\alpha^0/\partial t > 0$ for $\alpha^0 \in (0, 1)$, we obtain that $[(\lambda_1\beta_2 - \lambda_2\beta_1)/(2\beta_1^2 - \beta_2^2)]g'(\alpha^0)(\partial\alpha^0/\partial t) \geq 0$ when $\lambda_2/\lambda_1 \geq \beta_2/\beta_1$, and hence $d\hat{p}^N(\alpha^0)/dt > 0$, that is, $\hat{p}^N_{t_1}(\alpha^*_{t_1}) < \hat{p}^N_{t_2}(\alpha^*_{t_2})$. We also find that $d\hat{V}^N(\alpha^0)/dt = d\hat{p}^N(\alpha^0)/dt > 0$, and thus $\hat{V}^N_{t_1}(\alpha^*_{t_1}) < \hat{V}^N_{t_2}(\alpha^*_{t_2})$.

In conclusion, $\hat{p}^N(\alpha^*)$ and $\hat{V}^N(\alpha^*)$ are increasing in t when $\lambda_2/\lambda_1 \geq \beta_2/\beta_1$. Thus, the local firm's demand $\hat{D}(\alpha^*)$ and total profit $\hat{V}(\alpha^*)$ are increasing in t when $\lambda_2/\lambda_1 \geq \beta_2/\beta_1$. ■

Proof of Proposition 9. We first prove that there exists $\bar{\theta} \in [\tilde{\alpha}_2^*, 1]$ that satisfies $V_2(\tilde{\alpha}_2^*) = V_1(\bar{\theta})$. Suppose such a value of $\bar{\theta}$ does not exist. Because $V_i(\alpha)$ is a continuous function, we obtain that (i) $V_2(\tilde{\alpha}_2^*) > V_1(\alpha)$ for all $\alpha \in [\tilde{\alpha}_2^*, 1]$ or (ii) $V_2(\tilde{\alpha}_2^*) < V_1(\alpha)$ for all $\alpha \in [\tilde{\alpha}_2^*, 1]$. Result (i) leads to $V_2(\tilde{\alpha}_2^*) > V_1(\tilde{\alpha}_2^*)$, which contradicts $V_2(\alpha) \leq V_1(\alpha)$. Result (ii) leads to $V_2(\tilde{\alpha}_2^*) < V_1(1)$, which contradicts $V_2(\tilde{\alpha}_2^*) \geq V_2(1) = V_1(1)$.

As $\tilde{\alpha}_2^* > \tilde{\alpha}_1^*$ and $V_1(\alpha)$ is strictly concave in α, $V_1(\alpha)$ is strictly decreasing in α for $\alpha \in [\tilde{\alpha}_2^*, 1]$. Thus, such $\bar{\theta}$ is unique, and $\tilde{\alpha}_1^* < \bar{\theta}$. Next, we find the optimal local content rate $\tilde{\alpha}^*$ for different values of θ.

Case 1. $\theta \leq \tilde{\alpha}_1^*$**.** By definition, $\tilde{\alpha}_1^*$ maximizes $V_1(\alpha)$, and thus $V_1(\tilde{\alpha}_1^*) > V_1(\alpha)$ for $\alpha \neq \tilde{\alpha}_1^*$ and $V_1(\tilde{\alpha}_1^*) > V_2(\alpha)$. Because $\theta \leq \tilde{\alpha}_1^*$, when $\tilde{\alpha}_1^*$ is chosen, the penalty tariff is not applicable to the multinational firm. Therefore, $\tilde{\alpha}^* = \tilde{\alpha}_1^*$.

Case 2. $\tilde{\alpha}_1^* < \theta < \bar{\theta}$**.** Because $V_1(\alpha)$ is strictly concave in α and $\tilde{\alpha}_1^*$ maximizes $V_1(\alpha)$, $V_1(\alpha)$ is strictly decreasing in α for $\alpha \geq \tilde{\alpha}_1^*$. Thus, the multinational firm's maximum profit if he meets the LCR is $V_1(\theta)$, which satisfies $V_1(\theta) > V_1(\bar{\theta})$ because $\tilde{\alpha}_1^* < \theta < \bar{\theta}$. The multinational firm's maximum profit if he does not meet the LCR is $V_2(\tilde{\alpha}_2^*)$. Next, we compare the multinational firm's respective maximum profits if he meets and does not meet the LCR (i.e., $V_1(\theta)$ and $V_2(\tilde{\alpha}_2^*)$). By definition, $V_2(\tilde{\alpha}_2^*) = V_1(\bar{\theta})$, and we obtain $V_1(\theta) > V_1(\bar{\theta}) = V_2(\tilde{\alpha}_2^*)$. Therefore, $\tilde{\alpha}^* = \theta$.

Case 3. $\theta \geq \bar{\theta}$**.** As discussed in Case 2, $V_1(\alpha)$ is strictly decreasing in α for $\alpha \geq \tilde{\alpha}_1^*$. Thus, the multinational firm's maximum profit if he satisfies the LCR is $V_1(\theta)$. However, in the current case, $V_1(\theta) \leq V_1(\bar{\theta})$ because $\alpha_1^* < \bar{\theta} \leq \theta$. It then follows that $V_1(\theta) \leq V_1(\bar{\theta}) = V_2(\tilde{\alpha}_2^*)$. Thus, $\tilde{\alpha}^* = \tilde{\alpha}_2^*$ when $\theta > \bar{\theta}$, and $\tilde{\alpha}^* = \tilde{\alpha}_2^*$ or $\bar{\theta}$ when $\theta = \bar{\theta}$.

■

Proof of Proposition 10. We start with the impacts of θ on the multinational firm. We learn from (9) that the impacts of θ on $D^N(\tilde{\alpha}^*)$ and $\Pi^N(\tilde{\alpha}^*)$ are similar to that on $V^N(\tilde{\alpha}^*)$. Thus, we only need to analyze the impact of θ on $V^N(\tilde{\alpha}^*)$ in this proof. Using (14) in Proposition 9, we can express the multinational firm's maximum unit profit $V^N(\tilde{\alpha}^*)$ in (12) as

$$V^N(\tilde{\alpha}^*) = \begin{cases} V_1(\tilde{\alpha}_1^*) & \text{if } \theta \leq \tilde{\alpha}_1^*, \\ V_1(\theta), & \text{if } \tilde{\alpha}_1^* < \theta \leq \bar{\theta}, \\ V_2(\tilde{\alpha}_2^*), & \text{if } \theta \geq \bar{\theta}, \end{cases}$$

where $V_i(\tilde{\alpha}_i^*)$ $(i = 1, 2)$ are independent of θ. As the value of θ increases, $V^N(\tilde{\alpha}^*)$ takes the constant value $V_1(\tilde{\alpha}_1^*)$ for $\theta \leq \tilde{\alpha}_1^*$, and takes the constant value $V_2(\tilde{\alpha}_2^*)$ (which is equal to $V_1(\bar{\theta})$) for $\theta \geq \bar{\theta}$.

As $V_1(\alpha)$ is a strictly concave function (shown in Section 4.2) and $\tilde{\alpha}_1^*$ maximizes $V_1(\alpha)$, we find that for $\tilde{\alpha}_1^* < \theta < \bar{\theta}$, $V_1(\theta)$ is strictly decreasing in θ, $V_1(\tilde{\alpha}_1^*) > V_1(\theta) > V_1(\bar{\theta}) = V_2(\tilde{\alpha}_2^*)$, where the equality holds as defined in Proposition 9.

Next, we investigate the impacts of θ on the local firm. We learn from Section 4.1.2 that the impacts of θ on $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are similar to that on $\hat{V}^N(\tilde{\alpha}^*)$. Thus, we only need to analyze the impact of θ on $\hat{V}^N(\tilde{\alpha}^*)$ in this proof. Using (14) in Proposition 9, we can express the local firm's maximum unit profit $\hat{V}^N(\tilde{\alpha}^*)$ in (12) as

$$\hat{V}^N(\tilde{\alpha}^*) = \begin{cases} \hat{V}_1(\tilde{\alpha}_1^*) & \text{if } \theta \le \tilde{\alpha}_1^*, \\ \hat{V}_1(\theta), & \text{if } \tilde{\alpha}_1^* < \theta < \bar{\theta}, \\ \hat{V}_2(\tilde{\alpha}_2^*), & \text{if } \theta \ge \bar{\theta}, \end{cases}$$

where $\hat{V}_i(\tilde{\alpha}_i^*)$ $(i = 1, 2)$ are independent of θ. As the value of θ increases, $\hat{V}^N(\tilde{\alpha}^*)$ is the constant $\hat{V}_1(\tilde{\alpha}_1^*)$ for $\theta \le \tilde{\alpha}_1^*$ and is the constant $\hat{V}_2(\tilde{\alpha}_2^*)$ for $\theta \ge \bar{\theta}$.

Differentiating $\hat{V}_1(\alpha)$ once with respect to α yields

$$\frac{\partial \hat{V}_1(\alpha)}{\partial \alpha} = \frac{\beta_1\beta_2 M_1'(\alpha) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha)}{4\beta_1^2 - \beta_2^2}.$$

Because $V_1(\alpha)$ is a strictly concave function and $\tilde{\alpha}_1^*$ maximizes $V_1(\alpha)$, we find that for $\alpha \in (\tilde{\alpha}_1^*, \bar{\theta})$, $\partial V_1(\alpha)/\partial\alpha = \left[\left(\beta_2^2 - 2\beta_1^2\right) M_1'(\alpha) + \left(2\lambda_1\beta_1 - \lambda_2\beta_2\right) g'(\alpha)\right] / \left(4\beta_1^2 - \beta_2^2\right) < 0$, which gives $M_1'(\alpha) > \left[\left(2\lambda_1\beta_1 - \lambda_2\beta_2\right) g'(\alpha)\right] / \left(2\beta_1^2 - \beta_2^2\right)$. Thus, we obtain

$$\frac{\partial \hat{V}_1(\alpha)}{\partial \alpha} > \frac{1}{4\beta_1^2 - \beta_2^2}\left[\frac{\beta_1\beta_2\left(2\lambda_1\beta_1 - \lambda_2\beta_2\right) g'(\alpha)}{2\beta_1^2 - \beta_2^2} + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha)\right] = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2} g'(\alpha).$$

Because $g'(\alpha) < 0$ as assumed in Section 3, if $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$, we have $\partial\hat{V}_1(\alpha)/\partial\alpha > 0$. That is, if $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$, $\hat{V}_1(\theta)$ is strictly increasing in θ for $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$. Otherwise, if $\lambda_2/\lambda_1 < \beta_2/\beta_1$, because it is shown above that

$$\gamma_1(\alpha) = \frac{M_1'(\alpha)}{g'(\alpha)} < \frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2} \text{ for } \alpha \in (\tilde{\alpha}_1^*, \bar{\theta}),$$

we find that when
$$\frac{2\lambda_2\beta_1 - \lambda_1\beta_2}{\beta_1\beta_2} < \gamma_1(\theta) = \frac{M_1'(\theta)}{g'(\theta)} < \frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2},$$

$\partial\hat{V}_1(\alpha)/\partial\alpha\Big|_{\alpha=\theta} < 0$, and $\hat{V}_1(\theta)$ is decreasing in θ. The condition holds because

$$\frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2} - \frac{2\lambda_2\beta_1 - \lambda_1\beta_2}{\beta_1\beta_2} = \frac{(4\beta_1^2 - \beta_2^2)(\lambda_1\beta_2 - \lambda_2\beta_1)}{\beta_1\beta_2(2\beta_1^2 - \beta_2^2)} > 0.$$

In addition, when $\gamma_1(\theta) < (2\lambda_2\beta_1 - \lambda_1\beta_2)/(\beta_1\beta_2)$, $\partial\hat{V}_1(\alpha)/\partial\alpha\Big|_{\alpha=\theta} > 0$, and $\hat{V}_1(\theta)$ is increasing in θ.

Next, using (12), we obtain

$$\hat{V}_2(\tilde{\alpha}_2^*) - \hat{V}_1(\bar{\theta}) = \frac{1}{4\beta_1^2 - \beta_2^2}[\beta_1\beta_2\left(M_2(\tilde{\alpha}_2^*) - M_1(\bar{\theta})\right) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)\left(g(\tilde{\alpha}_2^*) - g(\bar{\theta})\right)].$$

It follows from $V_1\left(\bar{\theta}\right) = V_2\left(\tilde{\alpha}_2^*\right)$ that $M_2(\tilde{\alpha}_2^*) - M_1(\bar{\theta}) = (g(\tilde{\alpha}_2^*) - g(\bar{\theta}))(2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2 - \beta_2^2)$, and thus

$$\hat{V}_2(\tilde{\alpha}_2^*) - \hat{V}_1(\bar{\theta}) = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2}\left(g(\tilde{\alpha}_2^*) - g(\bar{\theta})\right).$$

Because $g'(\alpha) < 0$ and $\tilde{\alpha}_2^* < \bar{\theta}$ (as shown in Proposition 9), we have $g(\tilde{\alpha}_2^*) - g(\bar{\theta}) > 0$. Thus, if

$\lambda_2/\lambda_1 > \beta_2/\beta_1$, $\hat{V}_2(\tilde{\alpha}_2^*) - \hat{V}_1(\bar{\theta}) < 0$, i.e., $\hat{V}_2(\tilde{\alpha}_2^*) < \hat{V}_1(\bar{\theta})$; if $\lambda_2/\lambda_1 < \beta_2/\beta_1$, $\hat{V}_2(\tilde{\alpha}_2^*) > \hat{V}_1(\bar{\theta})$. ∎

Proof of Proposition 11. From the result in Proposition 9, when $\theta > \tilde{\alpha}_1^*$, the multinational firm's optimal local content rate is

$$\tilde{\alpha}^* = \begin{cases} \theta, & \text{if } \tilde{\alpha}_1^* < \theta < \bar{\theta}, \\ \tilde{\alpha}_2^*, & \text{if } \theta \geq \bar{\theta}, \end{cases}$$

where $\bar{\theta} \in [\tilde{\alpha}_2^*, 1]$ satisfies $V_1\left(\bar{\theta}\right) = V_2\left(\tilde{\alpha}_2^*\right)$.

As indicated by Proposition 6 and the proof of Proposition 7, when the tariff rate t increases, (i) $\tilde{\alpha}_1^*$ (weakly) increases, i.e., remains at the boundary value 0 or 1, or strictly increases, and (ii) $V_1(\tilde{\alpha}_1^*)$ decreases. Because $V_2(\alpha)$ can be regarded as $V_1(\alpha)$ with the tariff rate $(t + t_p)$, as the penalty tariff rate t_p increases, (i) $\tilde{\alpha}_2^*$ remains at the boundary value 0, strictly increases, or reaches the LCR threshold θ, and (ii) $V_2(\tilde{\alpha}_2^*)$ decreases.

Then, for any value of t_p, there are two cases:

Case 1. $t_p < \bar{t}_p \equiv \{t_p | V_1(\theta) = V_2(\tilde{\alpha}_2^*(t_p))\}$**.** We find that $\tilde{\alpha}_2^*(t_p) < \tilde{\alpha}_2^*(\bar{t}_p)$ and $V_2(\tilde{\alpha}_2^*(t_p)) > V_2(\tilde{\alpha}_2^*(\bar{t}_p)) = V_1(\theta)$. Thus, the multinational firm's optimal decision is $\tilde{\alpha}^* = \tilde{\alpha}_2^*(t_p)$, and $\tilde{\alpha}^*$ is strictly increasing in t_p.

Case 2. $t_p > \bar{t}_p$**.** We have $V_2(\tilde{\alpha}_2^*(t_p)) < V_2(\tilde{\alpha}_2^*(\bar{t}_p)) = V_1(\theta)$. Thus, $\tilde{\alpha}^* = \theta$.

Because $V_1\left(\alpha\right)$ is strictly concave in α and $\tilde{\alpha}_1^*$ maximizes $V_1\left(\alpha\right)$, $V_1\left(\alpha\right)$ is monotonically decreasing in α for $\alpha \geq \tilde{\alpha}_1^*$. Together with the fact that (i) $\tilde{\alpha}_1^* < \theta < \bar{\theta}$, (ii) $V_2\left(\tilde{\alpha}_2^*\right) = V_1\left(\bar{\theta}\right)$, and (iii) $V_2(\tilde{\alpha}_2^*)$ is decreasing in t_p, we find that $\bar{\theta}$ is increasing in t_p. ∎

Proof of Proposition 12. We start with the impacts of t_p on the multinational firm. We learn from (9) that $D^N(\tilde{\alpha}^*) = \beta_1 V^N(\tilde{\alpha}^*)$ and $\Pi^N(\tilde{\alpha}^*) = \beta_1(V^N(\tilde{\alpha}^*))^2$, which indicates that the impacts of t_p on $D^N(\tilde{\alpha}^*)$ and $\Pi^N(\tilde{\alpha}^*)$ are similar to that on $V^N(\tilde{\alpha}^*)$. Thus, we only need to analyze the impact of t_p on $V^N(\tilde{\alpha}^*)$ and $p^N(\tilde{\alpha}^*)$. Without loss of generality, we assume that t_p is increased from t_{p1} to t_{p2}, where $0 < t_{p1} < t_{p2}$. According the value of $\bar{t}_p$, there are following three cases.

Case 1. $t_{p1} < t_{p2} < \bar{t}_p$**.** According to Proposition 11, we have $\tilde{\alpha}^*(t_{p1}) = \tilde{\alpha}_2^*(t_{p1}) < \tilde{\alpha}_2^*(t_{p2}) = \tilde{\alpha}^*(t_{p2})$, and $V_2(\tilde{\alpha}_2^*)$ is decreasing in t_p. Thus, $V^N(\tilde{\alpha}^*(t_{p1})) = V_2(\tilde{\alpha}_2^*(t_{p1})) > V_2(\tilde{\alpha}_2^*(t_{p2})) = V^N(\tilde{\alpha}^*(t_{p2}))$. As the penalty tariff rate t_p can be seen as part of the tariff rate t, following the proof of Proposition 7, we can find that the price $p^N(\tilde{\alpha}_2^*(t_p))$ is decreasing in the penalty tariff t_p.

Case 2. $t_{p1} < \bar{t}_p < t_{p2}$**.** According to Proposition 11, we have $\tilde{\alpha}_1^* < \tilde{\alpha}^*(t_{p1}) = \tilde{\alpha}_2^*(t_{p1}) < \tilde{\alpha}_2^*(\bar{t}_p) = \theta$ and $\tilde{\alpha}^*(t_{p2}) = \theta$. As $V_2(\alpha)$ is a strictly concave function and $\tilde{\alpha}_2^*$ maximizes $V_2(\alpha)$, we find that $V_2(\tilde{\alpha}_2^*(t_{p1})) > V_2(\tilde{\alpha}_2^*(\bar{t}_p))$. According the definition of $\bar{t}_p$, $V_2(\tilde{\alpha}_2^*(\bar{t}_p)) = V_1(\theta) = V_1(\tilde{\alpha}^*(t_{p2}))$. Thus, we find that $V_2(\tilde{\alpha}_2^*(t_{p1})) > V_2(\tilde{\alpha}_2^*(\bar{t}_p)) = V_1(\tilde{\alpha}^*(t_{p2}))$, that is, $V^N(\tilde{\alpha}^*(t_{p1})) > V^N(\tilde{\alpha}^*(t_{p2}))$.

Because $t_{p1} < \bar{t}_p$, according to the discussion in Case 1, we have $p^N(\tilde{\alpha}_2^*(t_{p1})) > p^N(\tilde{\alpha}_2^*(\bar{t}_p))$. As $\bar{t}_p < t_{p2}$, we find that $\tilde{\alpha}_2^*(\bar{t}_p) = \tilde{\alpha}^*(t_{p2}) = \theta$, so $M(\tilde{\alpha}_2^*(\bar{t}_p)) = M(\tilde{\alpha}^*(t_{p2})) = M(\theta)$, and $g(\tilde{\alpha}_2^*(\bar{t}_p)) = g(\tilde{\alpha}^*(t_{p2})) = g(\theta)$. Thus, $p^N(\tilde{\alpha}_2^*(\bar{t}_p)) = p^N(\tilde{\alpha}_2^*(t_{p2}))$, and $p^N(\tilde{\alpha}_2^*(t_{p1})) > p^N(\tilde{\alpha}_2^*(t_{p2}))$, which means that the price $p^N(\tilde{\alpha}_2^*(t_p))$ is decreasing in the penalty tariff rate t_p.

Case 3. $\bar{t}_p < t_{p1} < t_{p2}$**.** According to Proposition 11, we have $\tilde{\alpha}^*(t_{p1}) = \tilde{\alpha}^*(t_{p2}) = \theta$, then $V^N(\tilde{\alpha}^*(t_{p1})) = V^N(\tilde{\alpha}^*(t_{p2})) = V_1(\theta)$, and the price $p^N(\theta)$ is constant.

Then, we investigate the impacts of t_p on the local firm. We learn from the discussion in Section 4.1.2 that the impacts of t_p on $\hat{p}^N(\tilde{\alpha}^*)$, $\hat{D}^N(\tilde{\alpha}^*)$, and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are similar to that on $\hat{V}^N(\tilde{\alpha}^*)$. Thus, we only need to analyze the impact of t_p on $\hat{V}^N(\tilde{\alpha}^*)$.

When $\theta > \tilde{\alpha}_1^*$, using the result in Proposition 11, we obtain that

$$\tilde{\alpha}^* = \begin{cases} \theta, & \text{if } t_p \geq \bar{t}_p, \\ \tilde{\alpha}_2^*, & \text{if } t_p < \bar{t}_p, \end{cases}$$

and

$$\hat{V}^N(\tilde{\alpha}^*) = \begin{cases} \hat{V}_1(\theta), & \text{if } t_p \geq \bar{t}_p, \\ \hat{V}_2(\tilde{\alpha}_2^*), & \text{if } t_p < \bar{t}_p. \end{cases}$$

Thus, $\hat{V}^N(\tilde{\alpha}^*)$ is a constant $\hat{V}_1(\theta)$ for $t_p \geq \bar{t}_p$.

Next, we show that $\hat{V}^N(\tilde{\alpha}^*)$ is strictly increasing in t_p for $t_p < \bar{t}_p$. Differentiating $\hat{V}_2(\alpha)$ once with respect to α yields

$$\frac{\partial \hat{V}_2(\alpha)}{\partial \alpha} = \frac{\beta_1\beta_2 M_2'(\alpha) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g_2'(\alpha)}{4\beta_1^2 - \beta_2^2}.$$

Because $(\partial V_2(\alpha)/\partial\alpha)|_{\alpha=\tilde{\alpha}_2^*} = 0$, we obtain

$$M_2'(\tilde{\alpha}_2^*) - \frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2} g'(\tilde{\alpha}_2^*) = 0,$$

and

$$\left.\frac{\partial \hat{V}_2(\alpha)}{\partial \alpha}\right|_{\alpha=\tilde{\alpha}_2^*} = \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right) \frac{\lambda_2\beta_2}{2\beta_1^2 - \beta_2^2} g'(\tilde{\alpha}_2^*).$$

Then, we obtain the first-order derivative of $\hat{V}_2(\tilde{\alpha}_2^*)$ with respect to t_p as

$$\begin{aligned} \frac{d\hat{V}_2(\tilde{\alpha}_2^*)}{dt_p} &= \left.\frac{\partial \hat{V}_2(\alpha)}{\partial \alpha}\right|_{\alpha=\tilde{\alpha}_2^*} \times \frac{d\tilde{\alpha}_2^*}{dt_p} + \frac{\partial \hat{V}_2(\tilde{\alpha}_2^*)}{\partial t_p} \\ &= \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right) \frac{\lambda_2\beta_2}{2\beta_1^2 - \beta_2^2} g'(\tilde{\alpha}_2^*) \frac{d\tilde{\alpha}_2^*}{dt_p} + \frac{\beta_1\beta_2 C(\tilde{\alpha}_2^*)(1-\tilde{\alpha}_2^*)}{4\beta_1^2 - \beta_2^2} \\ &> \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right) \frac{\lambda_2\beta_2}{2\beta_1^2 - \beta_2^2} g'(\tilde{\alpha}_2^*) \frac{d\tilde{\alpha}_2^*}{dt_p}. \end{aligned}$$

Because $d\tilde{\alpha}_2^*/dt_p > 0$ for $t_p < \bar{t}_p$ as shown in Proposition 11 and it is assumed that $g'(\tilde{\alpha}_2^*) < 0$, we find that when $\lambda_2/\lambda_1 > \beta_2/\beta_1$, $d\hat{V}_2(\tilde{\alpha}_2^*)/dt_p > 0$, i.e., $\hat{V}_2(\tilde{\alpha}_2^*)$ is strictly increasing in t_p.

Furthermore, we show that $\hat{V}_2^N(\tilde{\alpha}_2^*(\bar{t}_p)) < \hat{V}_1^N(\theta)$. Using (12), the difference between $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p))$ and $\hat{V}_1^N(\theta)$ is calculated as

$$\hat{V}_2^N(\tilde{\alpha}_2^*(\bar{t}_p)) - \hat{V}_1^N(\theta) = \frac{1}{4\beta_1^2 - \beta_2^2}[\beta_1\beta_2 (M_2(\tilde{\alpha}_2^*(\bar{t}_p)) - M_1(\theta)) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)(g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta))].$$

Because $V_1(\theta) = V_2(\tilde{\alpha}_2^*(\bar{t}_p))$, we obtain $M_2(\tilde{\alpha}_2^*(t_p)) - M_1(\theta) = (g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta))(2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2-$

β_2^2), which can be used to simplify $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) - \hat{V}_1^N(\theta)$ to

$$\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) - \hat{V}_1^N(\theta) = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2}\left[g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta)\right].$$

As $\theta > \tilde{\alpha}_2^*(\bar{t}_p)$ and $g'(\alpha) < 0$, we find that $g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta) > 0$. Thus, if $\lambda_2/\lambda_1 > \beta_2/\beta_1$, $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) < \hat{V}_1^N(\theta)$. ■

Proof of Proposition 13. We learn from our argument in the proof of Proposition 2 that $\partial^2 V^N(\alpha)/\partial\alpha^2 < 0$ for $\alpha \in [0,1]$, and $g\prime(\alpha) > 0$. Thus, one of the following three cases must happen.

1. $V^N(\alpha)$ is strictly decreasing in α. That is, $\partial V^N(\alpha)/\partial\alpha < 0$. Because $V^N(\alpha)$ is a strictly concave function, this case happens if and only if $\partial V^N(\alpha)/\partial\alpha|_{\alpha=0} \le 0$, or, $\gamma(0) \ge S$. Therefore, the optimal $\alpha^* = 0$.

2. $V^N(\alpha)$ is a unimodal, concave function of α. That is, $\partial V^N(\alpha)/\partial\alpha|_{\alpha=0} > 0$ and $\partial V^N(\alpha)/\partial\alpha|_{\alpha=1} < 0$. It follows from the first-order condition that the optimal $\alpha^* = \alpha^0$, where α^0 satisfies $\gamma(\alpha^0) = S$.

3. $V^N(\alpha)$ is strictly increasing in α. That is, $\partial V^N(\alpha)/\partial\alpha > 0$. Because $V^N(\alpha)$ is a strictly concave function, this case happens if and only if $\partial V^N(\alpha)/\partial\alpha|_{\alpha=1} \ge 0$, or, $\gamma(1) \le S$. Hence, the optimal $\alpha^* = 1$.

■

Proof of Proposition 14. Similar to the proof of Proposition 5, we first investigate the impact of λ_1 on $\hat{p}^N(\alpha^*)$ in the following three cases.

Case 1. $\lambda_1 \le \lambda_1^0$. The optimal $\alpha^* = 0$. From (8) we obtain

$$\hat{p}^N(0) = \frac{1}{4\beta_1^2 - \beta_2^2}\{\beta_1\beta_2 M(0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g(0) + 2\beta_1^2\hat{C} + \beta_2(kA - \lambda_2) + 2\beta_1[(1-k)A + \lambda_1]\}.$$

It follows that

$$\frac{\partial\hat{p}^N(0)}{\partial\lambda_1} = \frac{\beta_2 g(0) + 2\beta_1}{4\beta_1^2 - \beta_2^2} > 0, \text{ and } \frac{\partial\hat{p}^N(0)}{\partial\lambda_2} = -\frac{2\beta_1 g(0) + \beta_2}{4\beta_1^2 - \beta_2^2} < 0.$$

Thus $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_1 \le \lambda_1^0$.

Case 2. $\lambda_1^0 < \lambda_1 < \lambda_1^1$. The optimal $\alpha^* = \alpha^0$. We differentiate $\hat{p}^N(\alpha^0)$ in (8) once w.r.t. λ_1 and λ_2, respectively, and obtain

$$\frac{\partial\hat{p}^N(\alpha^0)}{\partial\lambda_1} = \frac{\beta_1\beta_2 M'(\alpha^0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha^0)}{4\beta_1^2 - \beta_2^2}\frac{\partial\alpha^0}{\partial\lambda_1} + \frac{\beta_2 g(\alpha^0) + 2\beta_1}{4\beta_1^2 - \beta_2^2},$$

and

$$\frac{\partial\hat{p}^N(\alpha^0)}{\partial\lambda_2} = \frac{\beta_1\beta_2 M'(\alpha^0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha^0)}{4\beta_1^2 - \beta_2^2}\frac{\partial\alpha^0}{\partial\lambda_2} - \frac{2\beta_1 g(\alpha^0) + \beta_2}{4\beta_1^2 - \beta_2^2}.$$

Because $\gamma(\alpha^0) = S$, we find that

$$(2\lambda_1\beta_1 - \lambda_2\beta_2)\, g'(\alpha^0) - \left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0) = 0,$$

which gives $M'(\alpha^0) = \left[(2\lambda_1\beta_1 - \lambda_2\beta_2)\, g'(\alpha^0)\right] / \left(2\beta_1^2 - \beta_2^2\right)$. Then, we can rewrite the above two expressions as

$$\frac{\partial \hat{p}^N(\alpha^0)}{\partial \lambda_1} = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2} g'(\alpha^0) \frac{\partial \alpha^0}{\partial \lambda_1} + \frac{\beta_2 g(\alpha^0) + 2\beta_1}{4\beta_1^2 - \beta_2^2},$$

and

$$\frac{\partial \hat{p}^N(\alpha^0)}{\partial \lambda_2} = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2} g'(\alpha^0) \frac{\partial \alpha^0}{\partial \lambda_2} - \frac{2\beta_1 g(\alpha^0) + \beta_2}{4\beta_1^2 - \beta_2^2}.$$

We note that $\partial\alpha^0/\partial\lambda_1 < 0$ and $\partial\alpha^0/\partial\lambda_2 > 0$, and learn from Section 6 that $g'(\alpha^0) > 0$. Therefore, if $\lambda_1\beta_2 - \lambda_2\beta_1 \le 0$, then $\partial\hat{p}^N(\alpha^0)/\partial\lambda_1 > 0$ and $\partial\hat{p}^N(\alpha^0)/\partial\lambda_2 < 0$. That is, if $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$, then $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_1^0 < \lambda_1 < \lambda_1^1$.

Case 3. $\lambda_1 \ge \lambda_1^1$**.** The optimal $\alpha^* = 1$. Similar to the analysis of Case 1, we obtain that

$$\frac{\partial \hat{p}^N(1)}{\partial \lambda_1} = \frac{\beta_2 g(1) + 2\beta_1}{4\beta_1^2 - \beta_2^2} > 0, \text{ and } \frac{\partial \hat{p}^N(1)}{\partial \lambda_2} = -\frac{2\beta_1 g(1) + \beta_2}{4\beta_1^2 - \beta_2^2} < 0.$$

Thus $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_1 \ge \lambda_1^1$.

According to (19), α^* is a continuous function of λ_1. Thus, the results in the above three cases imply that $\hat{p}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$. Because $\hat{V}^N(\alpha^*) = \hat{p}^N(\alpha^*) - \hat{C}$ (according to (6)) and the local firm's unit cost $\hat{C}$ is constant, $\hat{V}^N(\alpha^*)$ is increasing in λ_1 and decreasing in λ_2 when $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$. We find from (10) that $\hat{D}^N(\alpha^*) = \beta_1\hat{V}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*) = \beta_1(\hat{V}^N(\alpha^*))^2$. Thus, both $\hat{D}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*)$ are increasing in λ_1 and decreasing in λ_2 when $\lambda_2/\lambda_1 \ge \beta_2/\beta_1$. ■

Proof of Proposition 15. We learn from (10) that $\hat{D}^N(\alpha^*) = \beta_1\hat{V}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*) = \beta_1(\hat{V}^N(\alpha^*))^2$, which indicates that the impacts of t on $\hat{D}^N(\alpha^*)$ and $\hat{\Pi}^N(\alpha^*)$ are dependent on the impact of t on $\hat{V}^N(\alpha^*)$. Similar to the proof of Proposition 5, we consider two tariff rates t_1 and t_2, with $t_1 < t_2$. Thus, the multinational firm's corresponding optimal local content rates $\alpha_{t_1}^*$ and $\alpha_{t_2}^*$ satisfy $\alpha_{t_1}^* \le \alpha_{t_2}^*$. Denote the local firm's unit profit when $t = t_i$ by $\hat{V}_{t_i}^N(\alpha^*) \equiv \hat{V}^N(\alpha^*)|_{t=t_i}$, for $i = 1, 2$.

The first-order derivative of $\hat{p}^N(\alpha^0)$ w.r.t. t is computed as

$$\frac{d\hat{p}^N(\alpha^0)}{dt} = \frac{1}{4\beta_1^2 - \beta_2^2}\left\{\beta_1\beta_2 C(\alpha^0)(1-\alpha^0) + \frac{\partial\alpha^0}{\partial t}\left[\beta_1\beta_2 M'(\alpha^0) + (\lambda_1\beta_2 - 2\lambda_2\beta_1) g'(\alpha^0)\right]\right\}.$$

Because $\left(2\beta_1^2 - \beta_2^2\right) M'(\alpha^0) + (\lambda_2\beta_2 - 2\lambda_1\beta_1)\, g'(\alpha^0) = 0$ as in the proof of Proposition 5, we can simplify $d\hat{p}^N(\alpha^0)/dt$ to

$$\frac{d\hat{p}^N(\alpha^0)}{dt} = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2} g'(\alpha^0)\frac{\partial\alpha^0}{\partial t} + \frac{\beta_1\beta_2}{4\beta_1^2 - \beta_2^2} C(\alpha^0)(1-\alpha^0).$$

Because we have assumed $g'(\alpha^0) > 0$ in Section 6, and it has been shown that $\partial\alpha^0/\partial t > 0$ for

$\alpha^0 \in (0,1)$, we obtain that $[(\lambda_1\beta_2 - \lambda_2\beta_1)/(2\beta_1^2 - \beta_2^2)]g'(\alpha^0)(\partial\alpha^0/\partial t) \geq 0$ when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$, and hence $d\hat{p}^N(\alpha^0)/dt > 0$, that is, $\hat{p}_{t_1}^N(\alpha_{t_1}^*) < \hat{p}_{t_2}^N(\alpha_{t_2}^*)$. We also find that $d\hat{V}^N(\alpha^0)/dt = d\hat{p}^N(\alpha^0)/dt > 0$, and thus $\hat{V}_{t_1}^N(\alpha_{t_1}^*) < \hat{V}_{t_2}^N(\alpha_{t_2}^*)$.

In conclusion, $\hat{p}^N(\alpha^*)$ and $\hat{V}^N(\alpha^*)$ are increasing in t when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$. Thus, the local firm's demand $\hat{D}(\alpha^*)$ and total profit $\hat{V}(\alpha^*)$ are increasing in t when $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$. ■

Proof of Proposition 16. The proof for the impact of θ on the multinational firm is similar to that of Proposition 10 and is thus omitted here. We only present the proof for the impact of θ on the local firm below.

We learn from (10) that the impacts of θ on $\hat{D}^N(\tilde{\alpha}^*)$ and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are similar to that on $\hat{V}^N(\tilde{\alpha}^*)$. Thus, we only need to analyze the impact of θ on $\hat{V}^N(\tilde{\alpha}^*)$ in this proof. Similar to the proof of Proposition 10, we can express the local firm's maximum unit profit $\hat{V}^N(\tilde{\alpha}^*)$ as

$$\hat{V}^N(\tilde{\alpha}^*) = \begin{cases} \hat{V}_1(\tilde{\alpha}_1^*) & \text{if } \theta \leq \tilde{\alpha}_1^*, \\ \hat{V}_1(\theta), & \text{if } \tilde{\alpha}_1^* < \theta < \bar{\theta}, \\ \hat{V}_2(\tilde{\alpha}_2^*), & \text{if } \theta \geq \bar{\theta}, \end{cases}$$

where $\hat{V}_i(\tilde{\alpha}_i^*)$ $(i = 1,2)$ are independent of θ. When the value of θ increases, $\hat{V}^N(\tilde{\alpha}^*)$ is the constant $\hat{V}_1(\tilde{\alpha}_1^*)$ for $\theta \leq \tilde{\alpha}_1^*$ and the constant $\hat{V}_2(\tilde{\alpha}_2^*)$ for $\theta \geq \bar{\theta}$.

Differentiating $\hat{V}_1(\alpha)$ once w.r.t. α yields

$$\frac{\partial\hat{V}_1(\alpha)}{\partial\alpha} = \frac{\beta_1\beta_2 M_1'(\alpha) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha)}{4\beta_1^2 - \beta_2^2}.$$

Because $V_1(\alpha)$ is a strictly concave function and $\tilde{\alpha}_1^*$ maximizes $V_1(\alpha)$, we find that for $\alpha \in (\tilde{\alpha}_1^*, \bar{\theta})$, $\partial V_1(\alpha)/\partial\alpha = \left[\left(\beta_2^2 - 2\beta_1^2\right) M_1'(\alpha) + \left(2\lambda_1\beta_1 - \lambda_2\beta_2\right) g'(\alpha)\right] / \left(4\beta_1^2 - \beta_2^2\right) < 0$, which gives $M_1'(\alpha) > \left[\left(2\lambda_1\beta_1 - \lambda_2\beta_2\right) g'(\alpha)\right] / \left(2\beta_1^2 - \beta_2^2\right)$. Thus, we obtain

$$\frac{\partial\hat{V}_1(\alpha)}{\partial\alpha} > \frac{1}{4\beta_1^2 - \beta_2^2}\left[\frac{\beta_1\beta_2\left(2\lambda_1\beta_1 - \lambda_2\beta_2\right) g'(\alpha)}{2\beta_1^2 - \beta_2^2} + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g'(\alpha)\right] = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2}g'(\alpha).$$

Because $g'(\alpha) > 0$ in a developed country, if $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$, we have $\partial\hat{V}_1(\alpha)/\partial\alpha > 0$. That is, if $\lambda_2/\lambda_1 \leq \beta_2/\beta_1$, $\hat{V}_1(\theta)$ is strictly increasing in θ for $\theta \in (\tilde{\alpha}_1^*, \bar{\theta})$. Otherwise, if $\lambda_2/\lambda_1 > \beta_2/\beta_1$, because it is shown above that $\gamma_1(\alpha) = M_1'(\alpha)/g'(\alpha) > (2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2 - \beta_2^2)$ for $\alpha \in (\tilde{\alpha}_1^*, \bar{\theta})$, we find that when

$$\frac{2\lambda_2\beta_1 - \lambda_1\beta_2}{\beta_1\beta_2} > \gamma_1(\theta) = \frac{M_1'(\theta)}{g'(\theta)} > \frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2},$$

$\partial\hat{V}_1(\alpha)/\partial\alpha\Big|_{\alpha=\theta} < 0$, and $\hat{V}_1(\theta)$ is decreasing in θ. The condition holds because

$$\frac{2\lambda_2\beta_1 - \lambda_1\beta_2}{\beta_1\beta_2} - \frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2} = \frac{(4\beta_1^2 - \beta_2^2)(\lambda_2\beta_1 - \lambda_1\beta_2)}{\beta_1\beta_2(2\beta_1^2 - \beta_2^2)} > 0.$$

In addition, when $\gamma_1(\theta) > (2\lambda_2\beta_1 - \lambda_1\beta_2)/(\beta_1\beta_2)$, $\partial\hat{V}_1(\alpha)/\partial\alpha\Big|_{\alpha=\theta} > 0$, and $\hat{V}_1(\theta)$ is increasing in θ.

Next, using (12), we obtain

$$\hat{V}_2(\tilde{\alpha}_2^*) - \hat{V}_1(\bar{\theta}) = \frac{1}{4\beta_1^2 - \beta_2^2}[\beta_1\beta_2\left(M_2(\tilde{\alpha}_2^*) - M_1(\bar{\theta})\right) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)\left(g(\tilde{\alpha}_2^*) - g(\bar{\theta})\right)].$$

It follows from $V_1\left(\bar{\theta}\right) = V_2\left(\tilde{\alpha}_2^*\right)$ that $M_2(\tilde{\alpha}_2^*) - M_1(\bar{\theta}) = (g(\tilde{\alpha}_2^*) - g(\bar{\theta}))(2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2 - \beta_2^2)$, and thus

$$\hat{V}_2(\tilde{\alpha}_2^*) - \hat{V}_1(\bar{\theta}) = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2}\left(g(\tilde{\alpha}_2^*) - g(\bar{\theta})\right).$$

Because $g'(\alpha) > 0$ and $\tilde{\alpha}_2^* < \bar{\theta}$, we have $g(\tilde{\alpha}_2^*) - g(\bar{\theta}) < 0$. Thus, if $\lambda_2/\lambda_1 < \beta_2/\beta_1$, $\hat{V}_2(\tilde{\alpha}_2^*) - \hat{V}_1(\bar{\theta}) < 0$, i.e., $\hat{V}_2(\tilde{\alpha}_2^*) < \hat{V}_1(\bar{\theta})$; if $\lambda_2/\lambda_1 > \beta_2/\beta_1$, $\hat{V}_2(\tilde{\alpha}_2^*) > \hat{V}_1(\bar{\theta})$.

Then, we investigate the impact of t_p. We learn from (10) that the impacts of t_p on $\hat{D}^N\left(\tilde{\alpha}^*\right)$ and $\hat{\Pi}^N\left(\tilde{\alpha}^*\right)$ are similar to that on $\hat{V}^N(\tilde{\alpha}^*)$. Thus, we need only to analyze the impact of t_p on $\hat{V}^N(\tilde{\alpha}^*)$. When $\theta > \tilde{\alpha}_1^*$, we obtain that

$$\tilde{\alpha}^* = \begin{cases} \theta, & \text{if } t_p \geq \bar{t}_p, \\ \tilde{\alpha}_2^*, & \text{if } t_p < \bar{t}_p; \end{cases}$$

and

$$\hat{V}^N\left(\tilde{\alpha}^*\right) = \begin{cases} \hat{V}_1(\theta), & \text{if } t_p \geq \bar{t}_p, \\ \hat{V}_2(\tilde{\alpha}_2^*), & \text{if } t_p < \bar{t}_p. \end{cases}$$

Thus, $\hat{V}^N\left(\tilde{\alpha}^*\right)$ is a constant $\hat{V}_1(\theta)$ for $t_p \geq \bar{t}_p$.

Next, we show that $\hat{V}^N(\tilde{\alpha}^*)$ is strictly increasing in t_p for $t_p < \bar{t}_p$. Differentiating $\hat{V}_2\left(\alpha\right)$ once with respect to α yields

$$\frac{\partial\hat{V}_2(\alpha)}{\partial\alpha} = \frac{\beta_1\beta_2 M_2'(\alpha) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g_2'(\alpha)}{4\beta_1^2 - \beta_2^2}.$$

Because $(\partial V_2(\alpha)/\partial\alpha)|_{\alpha=\tilde{\alpha}_2^*} = 0$, we obtain

$$M_2'(\tilde{\alpha}_2^*) - \frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2}g'(\tilde{\alpha}_2^*) = 0,$$

and

$$\left.\frac{\partial\hat{V}_2(\alpha)}{\partial\alpha}\right|_{\alpha=\tilde{\alpha}_2^*} = \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right)\frac{\lambda_2\beta_2}{2\beta_1^2 - \beta_2^2}g'(\tilde{\alpha}_2^*).$$

Then, we obtain the first-order derivative of $\hat{V}_2(\tilde{\alpha}_2^*)$ with respect to t_p as

$$\begin{aligned} \frac{d\hat{V}_2(\tilde{\alpha}_2^*)}{dt_p} &= \left.\frac{\partial\hat{V}_2(\alpha)}{\partial\alpha}\right|_{\alpha=\tilde{\alpha}_2^*} \times \frac{d\tilde{\alpha}_2^*}{dt_p} + \frac{\partial\hat{V}_2(\tilde{\alpha}_2^*)}{\partial t_p} \\ &= \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right)\frac{\lambda_2\beta_2}{2\beta_1^2 - \beta_2^2}g'(\tilde{\alpha}_2^*)\frac{d\tilde{\alpha}_2^*}{dt_p} + \frac{\beta_1\beta_2 C(\tilde{\alpha}_2^*)(1 - \tilde{\alpha}_2^*)}{4\beta_1^2 - \beta_2^2} \\ &> \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right)\frac{\lambda_2\beta_2}{2\beta_1^2 - \beta_2^2}g'(\tilde{\alpha}_2^*)\frac{d\tilde{\alpha}_2^*}{dt_p}. \end{aligned}$$

Because $d\tilde{\alpha}_2^*/dt_p \geq 0$ for $t_p < \bar{t}_p$ as shown in Proposition 11 and $g'(\tilde{\alpha}_2^*) > 0$ in a developed country, we find that when $\lambda_2/\lambda_1 < \beta_2/\beta_1$, $d\hat{V}_2(\tilde{\alpha}_2^*)/dt_p > 0$, i.e., $\hat{V}_2(\tilde{\alpha}_2^*)$ is strictly increasing in t_p.

Furthermore, we show that $\hat{V}_2^N(\tilde{\alpha}_2^*(\bar{t}_p)) < \hat{V}_1^N(\theta)$. The difference between $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p))$ and $\hat{V}_1^N(\theta)$ is calculated as

$$\hat{V}_2^N(\tilde{\alpha}_2^*(\bar{t}_p)) - \hat{V}_1^N(\theta) = \frac{1}{4\beta_1^2 - \beta_2^2}[\beta_1\beta_2\left(M_2(\tilde{\alpha}_2^*(\bar{t}_p)) - M_1(\theta)\right) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)\left(g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta)\right)].$$

Because $V_1(\theta) = V_2(\tilde{\alpha}_2^*(\bar{t}_p))$, we obtain $M_2(\tilde{\alpha}_2^*(t_p)) - M_1(\theta) = (g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta))\,(2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2 - \beta_2^2)$, which can be used to simplify $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) - \hat{V}_1^N(\theta)$ to

$$\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) - \hat{V}_1^N(\theta) = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2 - \beta_2^2}\left(g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta)\right).$$

As $\theta > \tilde{\alpha}_2^*(\bar{t}_p)$ and $g'(\alpha) > 0$, we find that $g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta) < 0$. Thus, if $\lambda_2/\lambda_1 < \beta_2/\beta_1$, $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) < \hat{V}_1^N(\theta)$. ■

Proof of Proposition 17. The proof for the impact of t_p on the multinational firm is similar to that of Proposition 12 and is thus omitted here. We only present the proof for the impact of t_p on the local firm below.

We learn from the discussion in Section 4.1.2 that the impacts of t_p on $\hat{p}^N(\tilde{\alpha}^*)$, $\hat{D}^N(\tilde{\alpha}^*)$, and $\hat{\Pi}^N(\tilde{\alpha}^*)$ are similar to that on $\hat{V}^N(\tilde{\alpha}^*)$. Thus, we only need to analyze the impact of t_p on $\hat{V}^N(\tilde{\alpha}^*)$.

When $\theta > \tilde{\alpha}_1^*$, similar to the proof of Proposition 12, we find that

$$\tilde{\alpha}^* = \begin{cases} \theta, & \text{if } t_p \geq \bar{t}_p, \\ \tilde{\alpha}_2^*, & \text{if } t_p < \bar{t}_p, \end{cases}$$

and

$$\hat{V}^N(\tilde{\alpha}^*) = \begin{cases} \hat{V}_1(\theta), & \text{if } t_p \geq \bar{t}_p, \\ \hat{V}_2(\tilde{\alpha}_2^*), & \text{if } t_p < \bar{t}_p. \end{cases}$$

Thus, $\hat{V}^N(\tilde{\alpha}^*)$ is a constant $\hat{V}_1(\theta)$ for $t_p \geq \bar{t}_p$.

Next, we show that $\hat{V}^N(\tilde{\alpha}^*)$ is strictly increasing in t_p for $t_p < \bar{t}_p$. Differentiating $\hat{V}_2(\alpha)$ once with respect to α yields

$$\frac{\partial \hat{V}_2(\alpha)}{\partial \alpha} = \frac{\beta_1\beta_2 M_2'(\alpha) + (\lambda_1\beta_2 - 2\lambda_2\beta_1)g_2'(\alpha)}{4\beta_1^2 - \beta_2^2}.$$

Because $(\partial V_2(\alpha)/\partial\alpha)|_{\alpha=\tilde{\alpha}_2^*} = 0$, we obtain

$$M_2'(\tilde{\alpha}_2^*) - \frac{2\lambda_1\beta_1 - \lambda_2\beta_2}{2\beta_1^2 - \beta_2^2}g'(\tilde{\alpha}_2^*) = 0,$$

and

$$\left.\frac{\partial \hat{V}_2(\alpha)}{\partial \alpha}\right|_{\alpha=\tilde{\alpha}_2^*} = \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right)\frac{\lambda_2\beta_2}{2\beta_1^2 - \beta_2^2}g'(\tilde{\alpha}_2^*).$$

Then, we obtain the first-order derivative of $\hat{V}_2(\tilde{\alpha}_2^*)$ with respect to t_p as

$$\begin{aligned}\frac{d\hat{V}_2(\tilde{\alpha}_2^*)}{dt_p} &= \left.\frac{\partial \hat{V}_2(\alpha)}{\partial \alpha}\right|_{\alpha=\tilde{\alpha}_2^*} \times \frac{d\tilde{\alpha}_2^*}{dt_p} + \frac{\partial \hat{V}_2(\tilde{\alpha}_2^*)}{\partial t_p} \\ &= \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right)\frac{\lambda_2\beta_2}{2\beta_1^2-\beta_2^2} g'(\tilde{\alpha}_2^*)\frac{d\tilde{\alpha}_2^*}{dt_p} + \frac{\beta_1\beta_2 C(\tilde{\alpha}_2^*)(1-\tilde{\alpha}_2^*)}{4\beta_1^2-\beta_2^2} \\ &> \left(\frac{\lambda_1}{\lambda_2} - \frac{\beta_1}{\beta_2}\right)\frac{\lambda_2\beta_2}{2\beta_1^2-\beta_2^2} g'(\tilde{\alpha}_2^*)\frac{d\tilde{\alpha}_2^*}{dt_p}.\end{aligned}$$

Because $d\tilde{\alpha}_2^*/dt_p > 0$ for $t_p < \bar{t}_p$ and it is assumed that $g'(\tilde{\alpha}_2^*) > 0$, we find that when $\lambda_2/\lambda_1 < \beta_2/\beta_1$, $d\hat{V}_2(\tilde{\alpha}_2^*)/dt_p > 0$, i.e., $\hat{V}_2(\tilde{\alpha}_2^*)$ is strictly increasing in t_p.

Furthermore, we show that $\hat{V}_2^N(\tilde{\alpha}_2^*(\bar{t}_p)) < \hat{V}_1^N(\theta)$. Using (12), the difference between $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p))$ and $\hat{V}_1^N(\theta)$ is calculated as

$$\hat{V}_2^N(\tilde{\alpha}_2^*(\bar{t}_p)) - \hat{V}_1^N(\theta) = \frac{1}{4\beta_1^2-\beta_2^2}[\beta_1\beta_2\left(M_2(\tilde{\alpha}_2^*(\bar{t}_p)) - M_1(\theta)\right) + \left(\lambda_1\beta_2 - 2\lambda_2\beta_1\right)\left(g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta)\right)].$$

Because $V_1(\theta) = V_2(\tilde{\alpha}_2^*(\bar{t}_p))$, we obtain $M_2(\tilde{\alpha}_2^*(t_p)) - M_1(\theta) = \left(g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta)\right)(2\lambda_1\beta_1 - \lambda_2\beta_2)/(2\beta_1^2 - \beta_2^2)$, which can be used to simplify $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) - \hat{V}_1^N(\theta)$ to

$$\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) - \hat{V}_1^N(\theta) = \frac{\lambda_1\beta_2 - \lambda_2\beta_1}{2\beta_1^2-\beta_2^2}\left[g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta)\right].$$

As $\theta > \tilde{\alpha}_2^*(\bar{t}_p)$ and $g'(\alpha) > 0$, we find that $g(\tilde{\alpha}_2^*(\bar{t}_p)) - g(\theta) > 0$. Thus, if $\lambda_2/\lambda_1 < \beta_2/\beta_1$, $\hat{V}_2^N(\tilde{\alpha}_2^*(t_p)) < \hat{V}_1^N(\theta)$. ■

Appendix C Additional Results

C.1 Result in Section 5.1

Based on (12), (12), and (13), we can rewrite (14) as

$$\tilde{\alpha}^* = \begin{cases} 0, & \text{if } \gamma_2(0) \le S \text{ and } M_1(\theta) - Sg(\theta) > M_2(0) - Sg(0); \\ \alpha_2^0, & \text{if } \gamma_1(\theta) < S < \gamma_2(0) \text{ and } M_1(\theta) - Sg(\theta) \ge M_2(\alpha_2^0) - Sg(\alpha_2^0); \\ \theta, & \text{if } \gamma_1(\theta) < S < \gamma_2(0) \text{ and } M_1(\theta) - Sg(\theta) \le M_2(\alpha_2^0) - Sg(\alpha_2^0); \\ & \text{or, if } \gamma_2(0) \le S \text{ and } M_1(\theta) - Sg(\theta) \le M_2(0) - Sg(0); \\ \alpha_1^0, & \text{if } \gamma_1(1) < S \le \gamma_1(\theta); \\ 1, & \text{if } \gamma_1(1) \ge S. \end{cases}$$

We examine the impact of S on the optimal local content rate $\tilde{\alpha}^*$ for different results of $\tilde{\alpha}^*$. If $\tilde{\alpha}^* = \alpha_i^0$, then $\partial\tilde{\alpha}^*/\partial S = 1/\gamma_i'(\alpha_i^0) < 0$ for $i = 1, 2$, which means that $\tilde{\alpha}^*$ is decreasing in S. Otherwise, $\tilde{\alpha}^*$ is a constant (i.e., 0, θ, or 1). Because S is a function of the parameters λ_1, λ_2, β_1, and β_2, we find that when $\tilde{\alpha}^* = \alpha_i^0$, the effects of λ_1, λ_2, β_1, and β_2 on $\tilde{\alpha}^*$ are the same as those in Proposition 3. Otherwise, $\tilde{\alpha}^*$ is a constant (i.e., 0, θ, or 1).

C.2 Result in Section 6.2

Similar to Proposition 9, we can write the multinational firm's optimal local content rate $\tilde{\alpha}^*$ under an LCR as

$$\tilde{\alpha}^* = \begin{cases} 0, & \text{if } \gamma_2(0) \geq S \text{ and } M_1(\theta) - Sg(\theta) > M_2(0) - Sg(0); \\ \alpha_2^0, & \text{if } \gamma_2(0) < S < \gamma_1(\theta) \text{ and } M_1(\theta) - Sg(\theta) \geq M_2(\alpha_2^0) - Sg(\alpha_2^0); \\ \theta, & \text{if } \gamma_2(0) < S < \gamma_1(\theta) \text{ and } M_1(\theta) - Sg(\theta) \leq M_2(\alpha_2^0) - Sg(\alpha_2^0); \\ & \text{or, if } \gamma_2(0) \geq S \text{ and } M_1(\theta) - Sg(\theta) \leq M_2(0) - Sg(0); \\ \alpha_1^0, & \text{if } \gamma_1(\theta) \leq S < \gamma_1(1); \\ 1, & \text{if } \gamma_1(1) \leq S. \end{cases}$$

We examine the impact of S on the optimal local content rate $\tilde{\alpha}^*$ for different results of $\tilde{\alpha}^*$. If $\tilde{\alpha}^* = \alpha_i^0$, then $\partial\tilde{\alpha}^*/\partial S = 1/\gamma_i'(\alpha_i^0) > 0$ for $i = 1, 2$, which means that $\tilde{\alpha}^*$ is increasing in S. Otherwise, $\tilde{\alpha}^*$ is a constant (i.e., 0, θ, or 1). Because S is a function of the parameters λ_1, λ_2, β_1, and β_2, we find that when $\tilde{\alpha}^* = \alpha_i^0$, the effects of λ_1, λ_2, β_1, and β_2 on $\tilde{\alpha}^*$ are the same as those discussed in Section 6.1. Otherwise, $\tilde{\alpha}^*$ is a constant (i.e., 0, θ, or 1).