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OPTIMAL TRADE POLICIES UNDER PRODUCT DIFFERENTIATIONS

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Abstract. This article focuses on the optimal international trade policy considered product differentiations. A duopoly model with a home firm in a developing country and a foreign firm in a developed country is established. The findings indicate that, the optimal tariff relies on the product differentiations significantly. On one hand, higher marginal cost of home firms have opposite effects on optimal tariff compared to higher marginal cost of foreign firms. On the other hand, the optimal tariff is monotonically decreasing in the amount of consumers caring about brands and increasing in the scale of consumers not caring about brands. Moreover, an increase in the marginal cost and transportation cost of imported goods triggers price rising in domestic market as the market power of home firms is consolidated. In addition, a foreign firm may withdraw from domestic market if its competitive advantages vanishes under high tariffs.

Keywords: product differentiations, tariff, trade policies, brand, duopoly model, consumer preference, market power.

JEL Classification: F13, L11, L51.

Introduction

International trade plays an extremely important role in the modern global economy. Both developed and developing countries participate in international trade to stimulate economic growth. For instance, export is defined as one of the Troika spurring the economic growth in China, while the trade dependence was up to 33.6% in 2017 (China National Bureau of Statistics, 2018). Another example is, in 2015, the exports of India and the U.S. amounted to $264 billion and $1504 billion, and their imports amounted to $391 billion and $2307 billion, respectively (United Nations Statistics Division, 2017).

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In the era of economic globalization, more foreign firms enter domestic market through international trade, resulting in much more fierce competition and crowding-out effects of the market share of domestic firms. As the market scale would not enlarge in a short time, both domestic firms and foreign firms have to compete with each other to attract consumers. Except pricing strategy, product differentiation is also a common option for the runners in the competition. Especially, compared to domestic firms, foreign firms have to face extra costs, such as tariff and multi-national transportation cost. Then, if the products are homogenous, foreign firms could hardly earn profits in the tournament with domestic firms. That is why product differentiation is one of the key characteristics in international trade. Most enterprises especially those occupy large market share such as Apple, Siemens and P&G highlight their product characteristics through specific brands.

Obviously, the entrance of foreign firms creates more consumption alternatives and lower price to domestic consumers, and heavier competition pressure to domestic firms. Naturally, consumers benefit from the entrance of foreign firms while domestic firms may face losses due to the crowding-out effects and lower price. For the government, how to formulate trade policies especially tariff policy to maximize the welfare in the trade is a major concern. On one hand, consumer surplus is one of the main considerations of the welfare objectives, indicating an encouragement of the entrance of foreign firms. On the other hand, the government need to utilize trade policies to protect the development of domestic firms. Among the trade policies, tariff is the most commonly used policy for trade protection, which creates higher entrance barrier for foreign firms. Such evidence could be easily found in the recent trade war initiated by Trump government of the U.S. with an increase of the tariff on imported goods from other countries like Canada, China, and Mexico. In the trade war, Trump's tariff policy becomes more unpredictable as the imports hit by high tariff rate in the United States. One representative case is that Trump raised tariffs on Chinese goods several times. In 2018, $50 billion and another $200 billion of Chinese goods suffered 25% and 10% tariff, respectively. In 2019, the tariff rate imposed on the $200 billion of Chinese goods was raised up to 25% from 10% as the negotiation got stranded (CNN, 2019). The trade policy mentioned above causes some debates because whether it is the optimum is controversial. The trade war highlights that, how to formulate the optimal trade policy is crucial to maximize social welfare.

As the concerns of trade policies arise in practice recently, the purpose of this paper is to investigate the optimal international trade policy under product differentiations. As is shown, taking product differentiation into account is necessary to achieve the rational trade policies. In general, a duopoly model with a home firm in a developing country and a foreign firm in a developed country is established. The major findings indicate that, product differentiations have significant impacts on the optimal trade policies, while the distribution of consumer preference also matters.

The rest of this paper is organized as follows. First, a summary of related literature would be conducted in the next section. Then, the duopoly model is outlined in Section 2. In this model, the government maximizes the function of social welfare. In Section 3, the model is further discussed in detail. The concluding remarks are presented in the final section.

1. Literature review

The relationship between international trade and economic growth is one of the major concerns in academic researches (Singh, 2010). Hye and Lau (2015) identified the close linkage between trade and economic growth. Baldwin and Robert-Nicoud (2008) addressed international trade and economic growth with heterogeneous firms. Zhou (2010) studied the Ricardian model of international trade to confirm the effects of international trade on domestic markets. Shimbov et al. (2019) found that participation in international trade stimulates economic growth through sophistication in technology-intensive goods. Furthermore, Bouët and Cassagnard (2013) addressed the strategic trade policy under asymmetric information.

As is known, the development of international trade relies on trade policies, especially the intensity of tariffs. Harry (1953) initially proposed the optimal tariffs in international trade theory. Then, further researches following Harry (1953) arose as extensive extensions. On one hand, much recent literature captured the mechanism to implement optimal trade policies (Chen et al., 2019; Nie, 2014, 2018). In detailed, Eaton and Grossman (1986) found that subsidies are always indicated for Cournot behavior, but taxes are generally optimal if firms engage in Bertrand competition. Krugman (1997) argued that negotiation is an efficient measure to achieve optimal trade policies. Amador and Bagwell (2012), and Ossa (2011) developed the negotiation theory to attain optimal trade policies. Soderbery (2018) studied the optimal trade policy upon non-cooperative scenario with consideration of supply elasticities.

On the other hand, some studies focused on the influential factors of trade policies, such as income differences, product properties, international relationships, and firms' strategies in economics (Etro, 2014; Melitz & Redding, 2015; Chen et al., 2015; Yang et al., 2018). It has been recognized that, the factors mentioned above deeply affect trade policies all over the world. Krugman (1979) and Dixit (1984) explored the effects of the market power on trade policies. Goh (2000) addressed optimal trade policies based on the opportunity cost. Hwang et al. (2007) discussed optimal trade policies if the technology is considered. Waugh (2010) investigated in the relationship between international trade and income differences. Bhattacharjea (1995) pointed out that implementing a subsidy might be troublesome for numerous reasons, which arise from the high information content required to implement the optimal subsidy to the distorting effects of taxes necessary to finance the subsidy. Michael and Žigić (2004) explored optimal trade policies under vertical product differentiation. Cosar and Demir (2016) highlighted that internal transportation infrastructure matters for trade policies. Likewise, Soderbery (2018) argued that the optimal tariffs vary in accordance to heterogeneous supply elasticities. Acharya (2018) revealed that lobbying has significant effects on trade policy, resulting in government preference for import tariffs over export subsidies. Moreover, Akcigit et al. (2018) provided some empirical evidence of the potential welfare losses generated from tariffs.

In addition, the effect of trade policies is also one of the major concerns in related researches. Feng et al. (2017) found that an increase in trade policy uncertainty would reduce exports. Likewise, Eichengreen (2019) identified the effects of trade policy uncertainty on macroeconomic fluctuations. Kohl et al. (2016) employed a gravity model to capture the effects of trade agreements. Mccalman et al. (2019) pointed out that appropriate utilization of trade policies may increase market efficiency, but excessive use of the contingent trade policies may cause potential economic losses.

This paper further follows Harry's work (1953) and considers the effects of product differentiation, including vertical product differentiation and horizontal product differentiation, on trade policies. In practice, product differentiation is crucial in production and competition because it affects firms' strategies, taxes and so on (Häckner & Herzing, 2016). In particular, this article focuses on the concept of an optimal tariff, following the work of Michael and Žigić (2004). Compared to the research of Michael and Žigić (2004), this paper considers products without functional differentiation, while both brand differentiation (or vertical product differentiation) and marginal cost differentiation (or horizontal product differentiation) are taken into account. While Michael and Žigić (2004) stressed on innovation, this study focuses on the optimal tariff. Compared with Harry (1953), this paper examines the effects of product differentiations on optimal trade policies. About the measure to reach optimal trade policies, this paper addresses optimal taxes, which is similar to the researching angle of Eaton and Grossman (1986), and different from that in Amador and Bagwell (2012), and Ossa (2011). Moreover, this paper also stresses the effects of the market power on trade tariff. Compared to the studies of Krugman (1979) and Dixit (1984), this paper introduces product differentiations in the model.

The main contributions of this paper lie in two aspects. On one hand, taking product differentiations into account, a theoretical model is formally established to derive the optimal tariff. Notice that product differentiation is one of the representative factors of firm heterogeneities, which are major concerns in recent researches of international trade. Considering product differentiations in the analysis of tariff helps to identify and capture the welfare effects of trade policies better. On the other hand, factors to deter foreign firms from entering into a domestic market are discussed in this paper. The discussion provide some further insight into the welfare implications of tariff.

2. Model

Here the theoretical model with two countries, including a home country and a foreign country, is formally established to capture the effects of trade policies. Note that the home country is a developing country while the foreign country is a developed country. There are a representative home firm in the developing country and a representative foreign firm in the developed country. The two firms produce some functionally identical products with different brands in the same industry. The brand from the foreign firm is famous, while the other brand from the home firm is unknown. Such cases could be easily found in cosmetics industry and apparel industry. For instance, Burberry from the UK and Goelia from China produce functionally identical clothes, but the popularity of the two brands are quite different.

Consumers. There are N consumers in this market. The consumers are divided into two types. One type of consumers does not care about brand, and the other type of consumers attach importance to the brand. The first type includes $N_1 < N$ consumers, and the second type includes $N_2 = N - N_1$ consumers. This assumption differs to the study of Michael and Žigić (2004), while they assumed that domestic consumers are of the same type.

For the first type of consumers, given price p, the utility value to consume a unit product is

$$u = u_0 - p, \tag{1}$$

where $u_0 > 0$ is a constant. For the second type of consumers, given brand value θ and price p, the utility value to consume a unit product is

$$u = u_0 + \theta - p. \tag{2}$$

The brand value θ is a stochastic variable, which observes a uniform distribution at $[0,1]$ with a dense function $f(\theta) = 1$.

Firms. For the home firm, the brand value is assumed to be zero. The marginal cost is c_H $(c_H > 0)$. The price is p_H, and q_H denotes the quantity of outputs. The profit function of the home firm is

$$\pi_H = p_H q_H - c_H q_H. \tag{3}$$

The foreign firm produces product with famous trademark. The marginal cost is c_F $(c_F > c_H)$. The price is p_F, while q_F denotes the quantity of outputs and τ denotes the tariff on each unit of product. The foreign firm incurs iceberg transportation costs at the rate of $(0 < t < 1)$. The profit function of the foreign firm is

$$\pi_F = p_F(1-t)q_F - c_F q_F - \tau q_F. \tag{4}$$

The third term of Eq. (4) implies the tariff imposed on the foreign firm. For the two firms, due to the difference in marginal costs, horizontal product differentiations are considered. Similarly, due to the brand differences, vertical product differentiations are introduced. A linear cost function and uniform distribution are utilized to simplify the model so that it can be extended to a general situation. Further, the assumptions $p_F > p_H$ and $p_F - p_H < 1$ hold, implying that the price difference is always not very large.

Government. The consumer surplus (CS) is given by

$$CS = N_1(u_0 - p_H) + N_2(u_0 - p_H)(p_F - p_H) + N_2 \int_{p_F - p_H}^{1} (u_0 + \theta - p_F)\,d\theta. \tag{5}$$

The government imposes tariff to maximize the following social welfare is

$$SW = CS + \pi_H + \Lambda \tau q_F, \tag{6}$$

where $\Lambda > 0$ is often called the social cost of the public fund. This occurs when taxes distort productivity and create dead weight losses. $\Lambda > 0$ is viewed as exogenous in the regulated industry. Eq. (6) appears to indicate a regulation objection, which is similar to that proposed by Michael and Žigić (2004). Besides, Eq. (6) takes the social cost of the public fund into consideration that differs from Michael and Žigić (2004).

In general, t is a small, positive constant, and $\Lambda > 0$ is much larger than zero. Without loss of generality, assume that $\Lambda > \frac{1}{2(1-t)}$. Moreover, the hypothesis of $\Lambda > \frac{1}{2(1-t)}$ guarantees the existence and the uniqueness of a solution to the social welfare function.

This study assumes that the foreign firm from developed countries produces well-known products with higher marginal cost, while the home firm in developing countries produces not that famous products with lower marginal cost. This is logical while analyzing this social phenomenon in developing countries.

3. Analysis

The model in the above section would be further analyzed in this section. Applying the stipulations that $p_F > p_H$ and $p_F - p_H < 1$, the demand functions of the home firm and the foreign firm are given as

$$q_H = N_1 + N_2\left(p_F - p_H\right); \tag{7}$$

$$q_F = N_2\left(1 + p_H - p_F\right). \tag{8}$$

Then, Eq. (3) and Eq. (4) could be restated as follows:

$$\pi_H = \left(p_H - c_H\right)\left[N_1 + N_2\left(p_F - p_H\right)\right]; \tag{9}$$

$$\pi_F = N_2\left[p_F\left(1-t\right) - c_F - \tau\right]\left(1 + p_H - p_F\right). \tag{10}$$

3.1. Equilibrium

It is apparent that π_H is strictly concave in p_H and π_F is strictly concave in p_F. Therefore, there exists a unique solution to Eq. (9) and Eq. (10). The optimal conditions are outlined as:

$$\frac{\partial \pi_H}{\partial p_H} = N_1 + N_2\left(p_F - 2p_H\right) + N_2 c_H = 0; \tag{11}$$

$$\frac{\partial \pi_F}{\partial p_F} = N_2\left[\left(1-t\right)\left(1 + p_H - 2p_F\right) + c_F + \tau\right] = 0. \tag{12}$$

Eq. (11) and Eq. (12) yield the following equilibrium price

$$p_F^* = \frac{N_1}{3N_2} + \frac{c_H}{3} + \frac{2\left(c_F + \tau\right)}{3\left(1-t\right)} + \frac{2}{3}; \tag{13}$$

$$p_H^* = \frac{2N_1}{3N_2} + \frac{2c_H}{3} + \frac{c_F + \tau}{3\left(1-t\right)} + \frac{1}{3}. \tag{14}$$

Then, the equilibrium of the corresponding outputs of the two firms are determined as

$$q_H^* = N_1 + N_2\left[\frac{c_F + \tau}{3\left(1-t\right)} + \frac{1}{3} - \frac{N_1}{3N_2} - \frac{c_H}{3}\right]; \tag{15}$$

$$q_F^* = N_2\left[\frac{2}{3} - \frac{c_F + \tau}{3\left(1-t\right)} + \frac{N_1}{3N_2} + \frac{c_H}{3}\right]. \tag{16}$$

Based on Eq. (6), the optimal tariff could be addressed. The government maximizes the social welfare given in Eq. (6) by imposing tariffs. That is, the regulator maximizes the integration of consumer surplus, weighted producer surplus and weighted taxes. In this work, to simplify the problem, the weighted producer surplus is assumed to be 1. Then, the social welfare function could be outlined as follows.

$$SW = CS + \pi_H + \Lambda\tau q_F = \left(N_1 + N_2\right)u_0 - c_H\left(N_1 + N_2\right) +$$

$$N_2\left[\frac{2}{3} - \frac{c_F + \tau}{3\left(1-t\right)} + \frac{N_1}{3N_2} + \frac{c_H}{3}\right]\left[\Lambda\tau - \frac{c_F + \tau}{2\left(1-t\right)} - \frac{N_1}{2N_2} + \frac{c_H}{2}\right]. \quad (17)$$

Apparently, the above formula is concave at τ if $\Lambda > \frac{1}{2\left(1-t\right)}$. Hence, there exists a unique solution to Eq. (17). The first optimal condition is

$$\frac{\partial SW}{\partial \tau} = -\tau N_2 \frac{2\left(1-t\right)\Lambda - 1}{3(1-t)^2} - \frac{N_2}{3\left(1-t\right)} + N_2\Lambda\left(\frac{2}{3} + \frac{N_1}{3N_2} + \frac{c_H}{3} - \frac{c_F}{3\left(1-t\right)}\right) - \frac{N_2 c_H}{3\left(1-t\right)} + \frac{N_2 c_F}{3(1-t)^2} = 0. \quad (18)$$

Then, Eq. (18) yields

$$\tau^* = \frac{1}{2}\left(1-t\right)\left(2 + \frac{N_1}{N_2} + c_H - \frac{c_F}{1-t}\right) - \frac{0.5\left(1-t\right)c_H}{2\left(1-t\right)\Lambda - 1} + \frac{0.5 c_F}{2\left(1-t\right)\Lambda - 1} + \frac{0.5\frac{N_1}{N_2}}{2\left(1-t\right)\Lambda - 1}. \quad (19)$$

Equations (13)–(16) and (19) present the equilibrium solutions. In the next subsection, more discussion of the equilibrium would be given.

3.2. The analysis of the equilibrium solution

From the optimal tariff given in Eq. (19), the following conclusion arises.

Proposition 1. By static comparative analysis to Eq. (19), $\frac{\partial \tau^*}{\partial c_F}\frac{\partial \tau^*}{\partial c_H} \leq 0$ holds. In addition, τ^* is monotonically decreasing in N_2 and increasing in N_1. Moreover, $\frac{\partial \tau^*}{\partial \Lambda} < 0$.

Proof: See the Appendix. ▪

Remarks: The above result highlights the optimal tariff given in Eq. (19). According to Proposition 1, higher marginal cost of home firms have opposite effects on optimal tariff compared to higher marginal cost of foreign firms. Larger market size of the first type (consumers not caring about brand) yields a higher tariff. Additionally, $\frac{\partial \tau^*}{\partial \Lambda} < 0$ implies that the optimal tariff decreases as the efficiency of public fund increases.

It is rational that the optimal tariff should be set in accordance to the marginal costs of home firms and foreign firms, and the distribution of consumers with different preference. In most cases, higher marginal cost of home firms and more consumers caring about brands yield higher tariff as foreign firms are more competitive in domestic market. In contrast, the optimal tariff decreases as home firms become more competitive while marginal cost of foreign firms is high and less consumers caring about brands. For example, India charges high tariffs on American paper products and motorcycles for the purpose to protect local firms producing goods at relatively higher marginal cost. One of the well-known American motorcycle brand, Harley-Davidson, has to pay a 100% tariff in Indian market once. Absolutely, a higher tariff rate improves the profits of home firms as they get extra advantages in the market, and creates more revenues for the government that presented in the last term of Eq. (6). At the same time, an increase of tariff rate may reduce consumer surplus, thus resulting in less social welfare. As a result, policy makers have to balance the welfare gains as an integration.

Here, the equilibrium price and outputs are further discussed. For Eq. (13) and Eq. (14), by comparative static analysis, the following conclusion arises.

Proposition 2. At the equilibrium state, $\frac{\partial p_F^*}{\partial c_F} > 0$ and $\frac{\partial p_H^*}{\partial c_F} > 0$ hold. Furthermore, $\frac{\partial p_F^*}{\partial t} > 0$, $\frac{\partial p_H^*}{\partial t} > 0$ and p_H^* and p_F^* are all monotonically decreasing at N_2 and increasing at N_1. For outputs, there exist $\frac{\partial q_F^*}{\partial c_F} < 0$, $\frac{\partial q_F^*}{\partial c_H} > 0$, $\frac{\partial q_H^*}{\partial c_F} > 0$, $\frac{\partial q_H^*}{\partial c_H} < 0$, $\frac{\partial q_F^*}{\partial t} < 0$ and $\frac{\partial q_H^*}{\partial t} > 0$. $\frac{\partial p_F^*}{\partial c_H} > 0$ if $2(1-t)\Lambda > \frac{3}{2}$ and $\frac{\partial p_F^*}{\partial c_H} < 0$ if $2(1-t)\Lambda < \frac{3}{2}$. $\frac{\partial p_H^*}{\partial c_H} > 0$ if $2(1-t)\Lambda > \frac{6}{5}$ and $\frac{\partial p_H^*}{\partial c_H} < 0$ if $2(1-t)\Lambda < \frac{6}{5}$.

Proof: See the Appendix. ▪

Remarks: Proposition 2 illustrates that an increase in the marginal cost of foreign firms triggers price rising in domestic market. The findings reveals the fact that there exists strategic interaction in pricing between home firms and foreign firms. As foreign firms have to raise selling price to cover higher production cost, the market power of home firms would be strengthened, thus resulting in a higher price. Under this circumstance, domestic consumers have to pay more for the buying with less consumer surplus.

Meanwhile, a larger scale of consumers caring about brand results in a lower price, whereas a larger amount of consumers not caring about brand leads to a higher price. This conclusion is consistent with Proposition 1 implying that τ^* is monotonically decreasing in N_2 and increasing in N_1. Absolutely, if the majority of consumers concern about brand, charging high tariff would reduce consumer surplus and social welfare significantly. Therefore, charging a relative lower tariff becomes the optimum. Then, for the producers, setting a lower price becomes more feasible due to the reduction of tariff. For instance, as more and more consumers concern about auto brands, China reduces vehicle import tariff from 25% to 15% in 2018. It is estimated that the reduction in tariff would help consumers save a big money because vehicles became cheaper (Customs Tariff Commission of the China State Council, 2018).

Moreover, a larger t is equally increasing the foreign firms' costs, which therefore induces a higher price. As presented in the proposition, there exists $\frac{\partial p_F^*}{\partial c_H} > 0$ if $2(1-t)\Lambda > \frac{3}{2}$ and $\frac{\partial p_F^*}{\partial c_H} < 0$ if $2(1-t)\Lambda < \frac{3}{2}$. $\frac{\partial p_H^*}{\partial c_H} > 0$ if $2(1-t)\Lambda > \frac{6}{5}$ and $\frac{\partial p_H^*}{\partial c_H} < 0$ if $2(1-t)\Lambda < \frac{6}{5}$. This means that higher marginal cost of a home firm yields higher price under more efficient public fund. Similarly, under lower iceberg transportation cost of the foreign firm, an increase in the higher marginal cost of the home firm also results in higher price.

Denote the profits of the home firm and the foreign firm at the equilibrium state as π_H^* and π_F^*, respectively. In this case, the envelop theorem could be employed to analyze Eq. (9) and Eq. (10). Then, the effects of the parameters on the profits of the two firms are addressed.

Proposition 3. At the equilibrium point, there exists $\frac{\partial \pi_H^*}{\partial c_F} > 0$.

If $c_F \geq (1-t)c_H + \frac{2(1-t)\Lambda - 1}{2\Lambda}\left(2 + \frac{N_1}{N_2}\right)$, foreign firm would not enter domestic market. Moreover, there exists $\frac{\partial \pi_H^*}{\partial t} > 0$.

Proof: See in Appendix. ▪

Remarks: An increase in the marginal costs and the iceberg transportation costs of foreign firms improves home firms' profits. Propositions 1, 2 and 3 are consistent with the propositions proposed in other studies (Hwang et al., 2007). Proposition 3 solves the threshold value for foreign firms to enter domestic market under tariffs. Moreover, a high tariff efficiently weaken the ability of foreign firms to compete with home firms in local market. In other words, if the tariff is reduced by bilateral negotiation, the imports from foreign firms may increase significantly. One example is that, due to the China-Chile Free Trade Agreement, the exports of cherry from Chile to China increased from \$1 million in 2006 to \$1 billion in 2018 after the tariff of fruit was removed from the tariff list (Report of Free Trade Agreement, 2019).

Furthermore, the above Proposition also indicates that, not only enlarged cost disadvantage but also a reduction of consumers caring about brands may deter foreign firms from entering into domestic market. Therefore, the equilibrium of the model in Section 2 is achieved. The relationship of parameters and the equilibrium solution is obtained. In addition, product differentiations have strong effects on trade policies, domestic firms and foreign firms.

Conclusions

This study solves the optimal trade policies under product differentiations and the welfare effects are further analyzed. The effects of product differentiations, which include horizontal differentiations referring to the differences in marginal costs and vertical differentiations referring to the differences in brands, on the optimal trade policies are investigated theoretically. The findings indicate that, the optimal tariff relies on the product differentiations between home firms and foreign firms. On one hand, higher marginal cost of home firms have opposite effects on optimal tariff compared to higher marginal cost of foreign firms. On the other hand, the distribution of consumers with different preference highlights the effects of vertical differentiations on the optimal tariff. In general, the optimal tariff is monotonically decreasing in the amount of consumers caring about brands and increasing in the scale of consumers not caring about brands. As more consumers attach importance to the brands, charging a lower tariff becomes the optimum due to the fact that social welfare would be reduced under a high tariff. Moreover, an increase in the marginal cost and transportation cost of foreign firms triggers price rising in domestic market as the market power of home firms is consolidated. In addition, foreign firms may withdraw from domestic market if their competitive advantages vanishes under high tariffs.

In practice, charging punitive tariffs is frequently used as an effective policy alternative to prevent the entrance of foreign firms. The loss of consumer surplus under high tariff, however, is easily to be neglected. The findings of this study highlight the importance to take product differentiations and the distribution of consumer preference into account while formulating trade policies. Generally, for those developing countries importing goods from developed countries, preventing the entrance of foreign firms is always not a rational alternative. To maximize social welfare, the utilization of high tariff policies should be limited while there exist significant differentiations between domestic products and foreign products. Especially, a high tariff rate should not be applied on the imports if the majority of consumers concern about brands. For those developed countries exporting goods to developing countries, product differentiation strategy should be encouraged in international trade because homogeneous goods are more likely to be charged high tariffs than differentiated goods in export.

As regards the limitations of this paper, the equilibrium trade policies upon asymmetric information condition are not analyzed. Especially, in the present model, consumer surplus and firms' profits are assumed to be apparent to the government. In the real world, however, perfect information condition seldom exists, indicating that the government may not formulate optimal trade policies directly. Therefore, the future research can extend the study by introducing in asymmetric information.

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Author contributions

Yong-cong Yang and Pu-yan Nie conceived the study together. Pu-yan Nie was responsible for the establishment of the model. Yong-cong Yang was responsible for model analysis and writing the draft of the article. The authors agreed the final version of the article.

Disclosure statement

The authors of this article do not have any competing financial, professional, or personal interests from other parties.

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APPENDIX

Proof of Proposition 1

By virtue of Eq. (19), there exist $\frac{\partial \tau^*}{\partial c_F} = 0.5(1-t)\left[1 - \frac{1}{2(1-t)\Lambda - 1}\right]$ and $\frac{\partial \tau^*}{\partial c_H} = -0.5(1-t)\left[1 - \frac{1}{2(1-t)\Lambda - 1}\right]$, indicating that $\frac{\partial \tau^*}{\partial c_F}\frac{\partial \tau^*}{\partial c_H} \le 0$. Moreover, $\frac{N_1}{3N_2} = \frac{N - N_2}{3N_2} = \frac{N}{3N_2} - \frac{1}{3}$ and Eq. (19) jointly indicate that τ^* is monotonically decreasing in N_2 and increasing in N_1. Furthermore, according to Eq. (19), there exists $\frac{\partial \tau^*}{\partial \Lambda} < 0$ by virtue of $c_F > c_H$ and $t > 0$.

The conclusion is achieved, and the proof is complete. ▪

Proof of Proposition 2

Eqs. (13) and (14) yield

$$\frac{\partial p_F^*}{\partial c_F} = \frac{2}{3(1-t)} + \frac{2}{3(1-t)}\frac{\partial \tau}{\partial c_F} = \frac{2}{3(1-t)} + \frac{2}{3(1-t)}\left[\frac{0.5}{2(1-t)\Lambda - 1} - 0.5\right] > 0,$$

$$\frac{\partial p_H^*}{\partial c_F} = \frac{1}{3(1-t)} + \frac{1}{3(1-t)}\frac{\partial \tau}{\partial c_F} = \frac{1}{3(1-t)} + \frac{1}{3(1-t)}\left[\frac{0.5}{2(1-t)\Lambda - 1} - 0.5\right] > 0.$$

$\frac{\partial p_F^*}{\partial c_F} > 0$ and $\frac{\partial p_H^*}{\partial c_F} > 0$ are obtained. By their first-order partial differential, Eqs. (13) and (14) suggest $\frac{\partial p_F^*}{\partial t} > 0$ and $\frac{\partial p_H^*}{\partial t} > 0$.

$$\frac{\partial p_H^*}{\partial t} = \frac{c_F + \tau}{3(1-t)^2} + \frac{1}{3(1-t)}\frac{\partial \tau}{\partial t} > 0.$$

The last inequality holds by virtue of $c_F > c_H$ and $t > 0$. Similarly, $\frac{\partial p_F^*}{\partial t} = 2\frac{\partial p_H^*}{\partial t} > 0$ holds.

Moreover, because $\frac{N_1}{3N_2} = \frac{N - N_2}{3N_2} = \frac{N}{3N_2} - \frac{1}{3}$, p_H^* and p_F^* are all monotonically decreasing in N_2 and correspondingly increasing in N_1.

Eqs. (15) and (16) yield the following relationship:

$$\frac{\partial q_F^*}{\partial c_F} = -\frac{N_2}{3(1-t)} - \frac{N_2}{3(1-t)}\frac{\partial \tau}{\partial c_F} = -\frac{N_2}{3(1-t)} - \frac{N_2}{3(1-t)}\left[\frac{0.5}{2(1-t)\Lambda - 1} - 0.5\right] < 0,$$

$$\frac{\partial q_F^*}{\partial c_H} = \frac{N_2}{3} - \frac{N_2}{3(1-t)}\frac{\partial \tau}{\partial c_H} = \frac{N_2}{3} - \frac{N_2}{3(1-t)}\left[0.5(1-t) - \frac{0.5(1-t)}{2(1-t)\Lambda - 1}\right] > 0,$$

$$\frac{\partial q_H^*}{\partial c_F} = \frac{N_2}{3(1-t)} + \frac{N_2}{3(1-t)}\frac{\partial \tau}{\partial c_F} = \frac{N_2}{3(1-t)} + \frac{N_2}{3(1-t)}\left[\frac{0.5}{2(1-t)\Lambda - 1} - 0.5\right] > 0,$$

$$\frac{\partial q_H^*}{\partial c_H}=-\frac{N_2}{3}+\frac{N_2}{3(1-t)}\frac{\partial\tau}{\partial c_H}=-\frac{N_2}{3}+\frac{N_2}{3(1-t)}\left[0.5(1-t)-\frac{0.5(1-t)}{2(1-t)\Lambda-1}\right]<0\,.$$

$\frac{\partial q_F^*}{\partial t}=-\frac{N_2\partial p_H^*}{\partial t}<0$. Similarly, $\frac{\partial q_H^*}{\partial t}=\frac{N_2\partial p_H^*}{\partial t}>0$. If $\frac{\partial q_F^*}{\partial c_F}<0$, $\frac{\partial q_F^*}{\partial c_H}>0$, $\frac{\partial q_H^*}{\partial c_F}>0$, $\frac{\partial q_H^*}{\partial c_H}<0$, $\frac{\partial q_F^*}{\partial t}<0$ and $\frac{\partial q_H^*}{\partial t}>0$ are all achieved, then

$\frac{\partial p_F^*}{\partial c_H}=\frac{1}{3}+\frac{2}{3(1-t)}\frac{\partial\tau}{\partial c_H}=\frac{1}{3}+\frac{2}{3(1-t)}\left[0.5(1-t)-\frac{0.5(1-t)}{2(1-t)\Lambda-1}\right]>0$ if $2(1-t)\Lambda>\frac{3}{2}$ and $\frac{\partial p_F^*}{\partial c_H}<0$ if $2(1-t)\Lambda<\frac{3}{2}$.

$\frac{\partial p_H^*}{\partial c_H}=\frac{2}{3}+\frac{1}{3(1-t)}\frac{\partial\tau}{\partial c_H}=\frac{2}{3}+\frac{1}{3(1-t)}\left[0.5(1-t)-\frac{0.5(1-t)}{2(1-t)\Lambda-1}\right]>0$ if $2(1-t)\Lambda>\frac{6}{5}$ and $\frac{\partial p_H^*}{\partial c_H}<0$ if $2(1-t)\Lambda<\frac{6}{5}$.

The conclusion is achieved, and the proof is complete. ▪

Proof of Proposition 3

From Eq. (9), the following relationship could be yielded:

$$\begin{aligned}\frac{\partial\pi_H^*}{\partial c_F}&=\frac{\partial\pi_H^*}{\partial p_H^*}\left(\frac{\partial p_H^*}{\partial c_F}+\frac{\partial p_H^*}{\partial\tau}\frac{\partial\tau}{\partial c_F}\right)+\frac{\partial\pi_H^*}{\partial p_F^*}\left(\frac{\partial p_F^*}{\partial c_F}+\frac{\partial p_F^*}{\partial\tau}\frac{\partial\tau}{\partial c_F}\right)\\&=\left(p_H^*-c_H\right)N_2\left(\frac{\partial p_F^*}{\partial c_F}+\frac{\partial p_F^*}{\partial\tau}\frac{\partial\tau}{\partial c_F}\right)>0\,.\end{aligned}$$

If $c_F\ge(1-t)c_H+\frac{2(1-t)\Lambda-1}{2\Lambda}\left(2+\frac{N_1}{N_2}\right)$ holds, by simple calculation of Eq. (4) based on Eqs (13)–(16), there exists $\pi_F^*\le 0$ at the equilibrium state. In this situation, either a foreign firm will quit the industry or the high tariff will deter foreign firms from entering into this industry.

Moreover, from Eq. (9), the following relationship is established:

$$\frac{\partial\pi_H^*}{\partial t}=\frac{\partial\pi_H^*}{\partial p_H^*}\frac{\partial p_H^*}{\partial t}+\frac{\partial\pi_H^*}{\partial p_F^*}\frac{\partial p_F^*}{\partial t}=\left(p_H^*-c_H\right)N_2\frac{\partial p_F^*}{\partial t}>0\,.$$

The conclusion is achieved, and the proof is complete. ▪