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Abstract

This study incorporates transport price and endogenous product differentiation in an international oligopoly. Assuming endogenous determination of transport price based on the profit maximization of the transporter and using a three-stage game, we analyze the effect of the degree and difficulty of product differentiation on transport price. We show that both negatively affect the endogenous transport price. The intuition of this result comes from that the positive effect of a decrease in endogenous transport price on the demand for the differentiated products is greater than the negative effect on the price.

JEL classification: L13, L16, F12, F16, O30

Keywords: Endogenous Product Differentiation; International Trade; Oligopoly; Product R&D; Transport Price.

1 Introduction

Transport price is generally treated as a key factor in international trade. In a series of new trade theory, Krugman (1980) revealed that a reduction in trade cost (including transport price) increased the volume of international trade of differentiated goods. In fact, as Hummels (2007) mentioned, with the expansion of world trade, time series have shown a gradual decline in the air transport price index. Many studies on new trade theory assume trade cost as an exogenous variable, so they do not investigate how product differentiation affects trade cost (ef. transport price). An example of this can be seen in the fact that Maserati, known as one of the luxury car brands, transports its latest models by air rather than by sea[1]. In addition to this, Hummels, Lugovskyy, and Skiba (2009) have

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[1] See the following website: https://www.airbridgecargo.com/en/news/228/airbridgecargo-provided-dedicated-lift-for-28-maserati-granturismo-cars

shown that transport prices are endogenously determined by transportation firms. They reveal that the larger the degree of product differentiation, that is, the smaller the price elasticity of (import) demand, the higher the prices imposed by transporters.

In this article, we construct an international oligopoly model with endogenous product differentiation and endogenous transport price. Our main conclusion is that when product differentiation is more difficult, transportation prices will become lower.

In recent years, there have been many studies on endogenous transport price. Notable examples are: Francois and Wooton (2001); Andriamananjara (2004); Behrens and Picard (2011); Takahashi (2011); Abe et. al. (2014); Forslid and Okubo (2015); Ishikawa and Tarui (2018). In addition to this, Takauchi (2015) incorporated cost-reducing R&D into an international oligopoly with endogenous transport prices. Conversely, our model focuses on the product R&D in an international oligopoly with endogenous transport prices.

This article also relates to the context of oligopolistic competition and product R&D. Lin and Saggi (2002) constructed an oligopolistic competition model with both product and process R&D. They employed the utility function of Sing and Vives (1984) and derived the equilibrium not only under the Bertrand competition, but also under the Cournot competition. Bastos and Straume (2012) evolved Lin and Saggi (2002) into an oligopolistic general equilibrium and investigated how trade liberalization has affected product R&D. They revealed that the protection from international trade (an increase in the number of shielded sectors) has ambiguous effects on welfare. In addition to this, Brander and Spencer (2015) showed that additional product differentiation increases trade benefits.

To our knowledge, there are few studies on the relationship between the degree of product differentiation and transport price. This implies that we do not know the mechanism how the degree of differentiation (or quality of products) affects transport price through strategic interaction. Therefore, we have constructed a basic framework that incorporates both product R&D and endogenous transport price and reveals the relationship between the degree of differentiation and transportation price.

This paper is composed of the following sections: Section 2 constructs the basic model; Section 3 provides the main results; and Section 4 concludes.

2 The Model

We assume perfectly symmetric[2] two countries (country one and country two) in an open economy. In this economy, there are two sectors: a differentiated product sector and a homogenous product sector. Homogenous products are non-tradable and producers in this sector are faced with perfect competition. In contrast, differentiated products are tradable and each country has one identical firm that produces its own variety. For simplicity, the marginal cost of

[2]This implies that the analysis of one country can be applied to another.

differentiated products is assumed to be zero. We denote the quantity of the differentiated goods produced in country i and supplied to country j by q_{ij}. To transport one unit of product, the exporter is required to pay a transport price f[3]. To reduce competition, firms can choose varieties through their product R&D investment d_i. As discussed above, the profit of a firm in country i becomes

$$\pi_i = p_{ii}q_{ii} + p_{ij}q_{ij} - fq_{ij} - c(d_i), \tag{1}$$

where p_{ij} is the price of firm i's product in country j and $c(d_i)$ is the cost of R&D when investment level is d_i.

We also assume that consumers are perfectly symmetric. The utility function of consumers in country i is defined by

$$u_i = \alpha(q_{ii} + q_{ji}) - \frac{1}{2}\left[q_{ii}^2 + q_{ji}^2\right] - sq_{ii}q_{ji} + m_i, \tag{2}$$

where $\alpha\,(> 0)$ is a parameter, m_i is the quantity of the homogenous goods, and s is the inverse of the degree of differentiation between two products. The budget constraint of consumers in country i becomes

$$p_{ii}q_{ii} + p_{ji}q_{ji} + m_i = I_i. \tag{3}$$

The utility maximization of both countries implies the following inverse demands

$$\begin{aligned} p_{ii} &= \alpha - q_{ii} - sq_{ji}, & (4)\\ p_{ij} &= \alpha - q_{ij} - sq_{jj}. & (5) \end{aligned}$$

These indicate that higher differentiation (i.e. s is small) implies higher prices p_{ii}, p_{ij}.

We assume that the degree of differentiation is determined by the R&D investment of both firms:

$$s := S - (d_1 + d_2), \tag{6}$$

where S is a measure of difficulty in differentiation[4]. R&D cost function $c(d_i)$ has the following characteristics[5]: $c'(d_i) > 0, c''(d_i) < 0$.

Finally, we assume that the transportation cost is zero and the transporter chooses the transport price f to maximize its profit.

2.1 Analysis

We assume that the procedure of decision-making between the transporter and the differentiated firms is the following three-stage game: In step 1, firms decide their R&D investment level d_i to maximize their profits. In step 2 the transporter chooses the transport price f to maximize its profit. In step 3, based on the above results, firms produce their differentiated products under the Cournot competition.

[3] We will discuss the determination of f later in this section.

[4] In this article, we assume that each industry has identical difficulties in differentiation. For example, S in the luxury car industry would be smaller than S in the Vitamin C industry.

[5] We will specify $c(d_i)$ in Section 2.4.

2.2 Step 3

Based on the degree of differentiation s and the transport price f, firm i chooses the quantities to be supplied to home q_{ii} and foreign q_{ij} in order to maximize its profit:

$$\pi_i = p_{ii}q_{ii} + p_{ij}q_{ij} - fq_{ij} - c(d_i).$$

By the first order conditions and inverse demand functions (4)(5), the optimal quantities become

$$q_{ii} = \frac{(2-s)a + sf}{4-s^2}, q_{ij} = \frac{(2-s)a - 2f}{4-s^2}. \tag{7}$$

It is evident that a higher transport price f has a positive effect on domestic supply q_{ii} and a negative effect on export q_{ij}. This is because if the transport price f is high, it impedes export and mitigates competition between home and foreign firms.

By (8) the effect of the degree of differentiation s to quantities is

$$\frac{\partial q_{ii}}{\partial s} = -\frac{a(-2+s)^2 + f(4+s^2)}{(-4+s^2)^2} < 0, \frac{\partial q_{ij}}{\partial s} = -\frac{a(s-2)^2 + 4fs}{(s^2-4)^2} < 0.$$

The higher level of differentiation (i.e. small s) makes q_{ii} and q_{ij} increase simultaneously through the product differentiation. Using inverse demand functions (4) and (5), we can derive that the higher level of differentiation decreases p_{ii} and p_{ij}.

2.3 Step 2

We assume that to export differentiated products, firms are required to pay the unit transport price f[6] to the transporter. The transporter chooses the transport price f to maximize its profit. Since the marginal cost of transportation is assumed to be zero, the profit of the transporter is

$$\pi^f = f(q_{12} + q_{21}) = 2f\left(\frac{(2-s)a - 2f}{4-s^2}\right). \tag{8}$$

By the first order condition of the profit maximization, the optimal transport price f becomes

$$f = \frac{(2-s)a}{4}. \tag{9}$$

Thus, a higher level of differentiation implies the higher optimal transport price through the reduction of competition.

To summarize (7) and (9), q_{ii} and q_{ij} becomes

$$q_{ii} = \frac{(4+s)(2-s)a}{4(4-s^2)}, q_{ij} = \frac{(2-s)a}{2(4-s^2)}. \tag{10}$$

[6]Being symmetric, the transporter will exhibit the same transport price f.

2.4 Step 1

Using the above discussion, firm i chooses the product R&D investment d_i. By (1) and (6), the optimal R&D investment level d_i is

$$\frac{\partial \pi}{\partial d_i} = 0 \iff \frac{\partial c\left(d_i\right)}{\partial d_i} = \frac{d_i}{\left(S - 2d_i + 2\right)^3}. \tag{11}$$

To make the analysis tractable and derive a closed-form solution, we specify the R&D cost function $c\left(d_i\right)$ as

$$c\left(d_i\right) := \frac{S - 4d_i + 2}{8\left(S - 2d_i + 2\right)^2}. \tag{12}$$

It is easy to verify that this specification satisfies both $c'\left(d_i\right) > 0$ and $c''\left(d_i\right) < 0$. Additionally, this $c\left(d_i\right)$ and the industry specific difficulty in differentiation S have the following relationship:

$$\frac{\partial c\left(d_i\right)}{\partial S} = \frac{1}{8}\frac{\left(2 + a^2\right)\left(2a^4 + a^2\left(S + 14\right) - 2\left(S + 2\right)\right)}{4\left(-2a^2 + S + 2\right)^3}. \tag{13}$$

A sufficient condition of $\frac{\partial c(d_i)}{\partial S} > 0$ is

$$S > 2a^2 + 18 + \frac{32}{a^2 - 2}. \tag{14}$$

This implies that if the industry-specific difficulty in differentiation S is sufficiently high, S promotes R&D investment. Hereafter, we assume this condition. In preparation for the analysis of the optimal product R&D investment, we revisit the relationship between the profit of firm i (1), q_{ii}, and q_{ij}. The first order conditions in Step 3 are

$$\frac{\partial p_{ii}}{\partial q_{ii}} + p_{ii} = 0, \frac{\partial p_{ii}}{\partial q_{ij}} + p_{ij} - f = 0. \tag{15}$$

Using this and (10), the profit of firm i π_i becomes

$$\pi_i = q_{ii}^2 + q_{ij}^2 - c\left(d_i\right) \tag{16}$$

$$= \left[\frac{\left(4 + s\right)\left(2 - s\right)a}{4\left(4 - s^2\right)}\right]^2 + \left[\frac{\left(2 - s\right)a}{2\left(4 - s^2\right)}\right]^2 - c\left(d_i\right). \tag{17}$$

Since $s = S - \left(d_1 + d_2\right)$ and symmetricity, the first order condition in Step 1 becomes

$$-\frac{a^2\left(6 + S - 2d_i\right)}{4\left(S - 2d_i + 2\right)} = \frac{S - 4d_i + 2}{8\left(S - 2d_i + 2\right)^2} \tag{18}$$

Thus, the optimal product R&D investment d_i is

$$d_i = \frac{a^2\left(6 + S\right)}{4 + 2a^2}. \tag{19}$$

3 Comparative Statics

Based on (19), we derive the following proposition.

Proposition 1 *In an industry with high difficulty in differentiation, i.e., large S, the optimal product R&D investment level d_i is also high.*

The intuition of Proposition 1 comes from the positive effect of the decrease in endogenous transport price on the demand of the differentiated product is greater than the negative effect on the price. Proposition 1 is consistent with previous literature including Lin and Saggi (2002). Additionally, using (9) the optimal transport price f becomes

$$f = \frac{\left(4 + 8a^2 - 2S\right) a}{8 + 4a^2}. \tag{20}$$

Thus, the following is derived naturally:

Proposition 2 *In an industry with high difficulty in differentiation, i.e., large S, the optimal transport price f is low.*

When the difficulty in differentiation is high, the industry becomes more competitive and, therefore, firms in this sector are less profitable. In such a situation, because the unit-profit of the differentiated goods is lower, the transport price f and the profit of the transporter are dropped. This also implies the following Corollary 3:

Corollary 3 *In an industry with low difficulty in differentiation, i.e., small S, the optimal transport price f is high.*

An example of Corollary 3 is observed in the luxury car industry, as described in the introduction.

4 Conclusion

In this article we have constructed a symmetric international oligopoly model with endogenous product differentiation and endogenous transport price. The main result of this article is that, when product differentiation is more difficult, firms in differentiated product sector increase their R&D investment and, accordingly, transporter sets transport prices lower. This result is a benchmark in the analysis of the relationship between product differentiation and transportation costs.

An example of how this base model could be expanded to analyze an asymmetric case where each country hasidentical R&D cost functions and transportation fees. Another expansion would be to introduce cost reduction R&D of transporter.[7]

[7]Hummels (2007) indicated that transportation costs have also declined in the second half of the twentieth century as a result of technological change.

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