二松学舎大学国際政治経済学部

Discussion Paper Series

Innovation Competition in International Trade

Yumiko Taba

May 20, 2024

Discussion Paper (Econ) No.13

FACULTY OF INTERNATIONAL POLITICS AND ECONOMICS

NISHOGAKUSHA UNIVERSITY

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Yumiko Taba*

Abstract

This paper presents a model that includes innovation competition under a monopolistically competitive market with the CES utility function. The analysis demonstrates that when firms in an importing country encounter an exporter with higher productivity, the firms in the importing country strive to make quality innovations. Furthermore, the paper shows that the reduction of trade barriers causes exporters' product quality to degrade and importers' product quality to improve, leading to increased revenue for both importers and exporters.

*Faculty of International Politics and Economics, Nishogakusha University, 6-16, Sanbancho, Chiyoda-ku, Tokyo, 102-8336, email address: y-taba@nishogakusha-u.ac.jp

1 Introduction

This paper demonstrates an innovation competition between firms under monopolistic competition. To achieve this objective, we extend the Melitz model to one in which productivity and product quality are treated separately, such as Flach and Unger (2022), and Woodland and Pham (2020). In this model, we introduce a quality indicator that represents the difference between concerned firm's quality and the highest quality in the market. By using this normalization, we can describe the interaction between firms' productivity, which exhibits similar effects to those derived from strategic interaction, and provide new insights into firms' innovation incentives.

We found that a rival firm's higher productivity gives a firm an incentive to stimulate its own innovation, referred to as escape competition effects. This mechanism also operates in an open economy, where encountering a rival exporter with higher productivity prompts the importer to strive for innovation.[1] Conversely, if the exporters' productivity is relatively lower than that of importers, it incentivizes a reduction in the innovation efforts of importers.[2] On the other hand, a higher transport cost for the exporter provides the importer with less incentive for innovation, as the importer already holds a price advantage over the exporter. The reduction of trade barriers enhances the importer's product quality and diminishes that of the exporter's, which leads to an increase the sales of both importer and exporter. Furthermore, trade with low-wage countries provides an incentive to firms in high-wage countries to invest more in quality. These results are supported by various empirical research.[3] These results are quite different from those of the

[1]The results is consistent with empirical outcomes, such as Amiti and Khandelwal (2013).

[2]This scenario holds true the case where firms in the US are the importers. See Autor et al. (2020).

[3]Shu and Steinweider (2019) provides a survey of empirical research on the interaction between innovation and import competition, trade liberalization, and so on.

previous Melitz-type theoretical models with monopolistic competition and CES utility function.

Recent notable theoretical studies in the field of international trade, such as Melitz (2003), Aghion et al. (2005), Akcigit and Melitz (2022) , Melitz and Redding (2023), have clarified the relationship between trade, competition, growth and innovation. Aghion et al. (2005) employ the model from Aghion et al. (1997), which revealed the inverted-U relationship between competition and innovation, namely, the escape competition effect and the Schumpeterian effect. Subsequent literature has discussed this relationship in various cases, including different countries and industries.

Other studies have focused on the relationship between firm size, trade and innovation. Specifically, larger firms are more likely to engage in trade and innovate, referred to as intensive margin. Additionally, exporters are substantially more likely to innovate and innovators are more likely to export, known as extensive margin (Aghion et al. (2022)). Aghion et al. (2022) employ a model with monopolistic competition in a new growth theory, focusing on innovations that reduce production costs.

Particularly noteworthy is the contribution of Akcigit et al. (2022). They focus on the innovation incentives for incumbents and apply a dynamic model that incorporates strategic interactions. The innovation that they analyze is for quality improvement. However, their model is based on a quality-ladder model as in Aghion and Howitt (1992) and Grossman and Helpman (1991). Impullitti and Licandro (2018) also considers the strategic interaction between firms and the competition effects on innovation in an oligopolistic market under a dynamic growth model.

Our paper is the first to present the relationship between firms' productivity and innovation of exporters and importers in Melitz model with monopolistic competition.

The reminder of the paper is structured as follows. Section 2 develops a model in a closed economy. Section 3 expands the model to an open economy. Section 4 concludes.

2 The Model

We develop a model that incorporates innovation between firms in exporting and importing countries and introduce a quality indicator as the key factor determining the interaction between firms' productivity. The basic model is based on Melitz (2003) and Flach and Unger (2022). We begin with a closed economy case and later extend this to an open economy.

2.1 Preferences

In a closed economy, there are L consumers each supply one unit of labor. A representative consumer has the following CES utility function over a continuum of goods,

$$U = \left[\int_{\omega \in \Omega} (q_i(\omega) x_i(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}},$$

where ω represents the varieties, Ω denotes the whole variety set of differentiated goods, $x_i(\omega)$ is the consumption of differentiated goods i, $q_i(\omega) > 0$ is its quality and $\sigma > 1$ is the elasticity of substitution between quality-differentiated varieties. The aggregate demand of differentiated goods is given as follows.

$$x(\omega) = q(\omega)^{\sigma-1} p(\omega)^{-\sigma} P^{\sigma-1} Y. \tag{1}$$

where $Y = wL$, Y is aggregate income and w is wage. P is the quality-adjusted aggregate price index of variety, which is defined by

$$P = \left[\int_{\omega \in \Omega} \left(\frac{p_i(\omega)}{q_i(\omega)} \right)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}. \tag{2}$$

2.2 Production

A firm offers one differentiated variety ω under monopolistic competition. Each firm draws the productivity φ from a common probability distribution $g(\varphi)$. φ equals $1/a_L$, where a_L is a labor-per-unit-output. That is, smaller a_L means larger φ. Labor used in the production is l_m. The firm's production cost is represented by

$$l_m(\varphi) = F + \frac{aq_i(\varphi)^\theta}{\varphi} x_i(\varphi), \tag{3}$$

where F is the fixed cost of production and the second term on eq.(3) shows a variable cost. As in Melitz (2003), we take into account that the marginal cost of production is decreasing in firm's productivity φ and increasing in quality $q(\varphi)$, where $0 < \theta < 1$ represents the elasticity of marginal costs with respect to quality. The product R&D expenditure is defined as

$$R(q_i(\varphi)) = \frac{q_i(\varphi)^{2\kappa}}{2\kappa\lambda_i^\kappa}, \qquad \kappa > 1 \tag{4}$$

where $\lambda_i \in (0,\infty)$, which refers to as a quality indicator.[4] Larger λ_i corresponds to higher quality. κ represents research elasticity.[5] The R&D expenditure is a convex function. It means that higher product quality needs more R&D investments. That is, the R&D for quality improvement requires additional endogenous fixed costs. l_R labors are engaged in R&D investments. The profit of firm i is given by

$$\pi_i = p_i(\varphi)x_i(\varphi) - w\left(a\frac{q_i(\varphi)^\theta}{\varphi}x_i(\varphi) + \frac{q_i(\varphi)^{2\kappa}}{2\kappa\lambda_i^\kappa} + F\right), \tag{5}$$

where w is the common wage in the country. The firm first chooses price and then determines its product quality. From the profit maximization, the optimal price of the firm is given by

$$p_i(\varphi) = \frac{\sigma}{\sigma-1}\frac{awq_i(\varphi)^\theta}{\varphi_i}. \tag{6}$$

The optimal price consists of a constant markup on quality-adjusted marginal production cost. The firm's higher productivity makes its price decrease and higher product quality causes its price to increase. A larger σ implies that consumers are more sensitive to price change (Flach and Unger (2022)). Now we get optimal quality. From the profit maximization, the optimal product quality is

[4] Eq.(4) is derived from normalization. We define the additional innovation cost as $c_i = wq_i\bar{q}$. We then normalize the cost by the maximum quality in the market, denoted by $\bar{q}$, such that $\lambda_i(\varphi) = q_i(\varphi)/\bar{q}$. The firms with higher productivity produce higher quality products so that $\lambda(\varphi)$ is greater. If $\lambda_i \geq 1$, the quality of the firm is equal to or greater than the maximum level in the market. Otherwise, the quality is less than the maximum. By applying this normalization, we describe the additional innovation cost as $q_i^{2\kappa}/2\kappa\lambda_i^\kappa$. Larger λ corresponds to higher productivity, making innovation is easier for firms with larger λ.

[5] Pham and Woodland (2022) also employed this translation. Flach and Unger (2022) explains that κ is the technology parameter and determines the convexity of the investment cost function.

given by

$$q_i = \left[\lambda_i^{\kappa}(1-\theta)\left(\frac{\varphi_i}{a}\right)^{\sigma-1}\left(\frac{\sigma-1}{\sigma w}\right)^{\sigma} A\right]^{\frac{1}{\psi}} \tag{7}$$

where $\psi = 2\kappa - (\sigma-1)(1-\theta)$ and $A = YP^{\sigma-1}$. We impose the parameter restriction $0 < (\sigma-1)(1-\theta) < 2\kappa$ to ensure a well-defined optimum. The optimal quality depends on its own productivity φ_i. Higher productivity makes the firm i's quality improve. The optimal quality relies on the expenditure for the differentiated good, $A = YP^{\sigma-1} = wLP^{\sigma-1}$ called as market characteristics. Higher income leads to increase demand for this product, which makes the firm promote to invest in product quality. Larger market size, denoted by L enhances firms' innovation efforts. Conversely, higher wages demotivate firms' innovations. λ_i indicates how far the quality is from the maximum level. If $\lambda_i \geq 1$, the quality is greater than the maximum.

From eqs.(6) and (7), we can get the quality-price ratio as follows.

$$\frac{q_i}{p_i} = \left[\left(\lambda_i^{\kappa}(1-\theta)A\right)^{1-\theta}\left(\frac{\varphi_i}{a}\right)^{2\kappa}\left(\frac{\sigma-1}{\sigma w}\right)^{2\kappa+1-\theta}\right]^{\frac{1}{\psi}}. \tag{8}$$

The quality-price ratio increases in higher its productivity. The higher own productivity will make its price decrease, on the other hand, the higher firm's productivity causes an upgrade in firm's quality q_i. Higher quality results in a higher quality-price ratio. An increase in market size L leads to an upgrade in the quality-price ratio. If the wage is not normalized to 1, the higher wage decreases the quality-pice ratio.

The ratio of any two firms' qualities is

$$\frac{q_i}{q_j} = \left[\left(\frac{\lambda_i}{\lambda_j}\right)^{\kappa} \left(\frac{\varphi_i}{\varphi_j}\right)^{\sigma-1} \right]^{\frac{1}{\psi}} \tag{9}$$

Higher own productivity leads to greater quality. The ratio of any two firms' prices is

$$\frac{p_i}{p_j} = \left[\left(\frac{\lambda_i}{\lambda_j}\right)^{\theta} \left(\frac{\varphi_j}{\varphi_i}\right)^{2\kappa-(\sigma-1)} \right]^{\frac{1}{\psi}}. \tag{10}$$

Higher own productivity decreases its price. Greater own quality increases own price. The ratio of any two firms' outputs is

$$\frac{x_i}{x_j} = \left[\left(\frac{\lambda_i}{\lambda_j}\right)^{\kappa(\sigma-1)-\theta\sigma} \left(\frac{\varphi_i}{\varphi_j}\right)^{2\kappa\sigma+(\sigma-1)} \right]^{\frac{1}{\psi}} \tag{11}$$

Higher productivity and greater quality make own output increase. The ratio of any two firms' revenues is

$$\frac{r_i}{r_j} = \left[\left(\frac{\lambda_i}{\lambda_j}\right)^{1-\theta} \left(\frac{\varphi_i}{\varphi_j}\right)^{2} \right]^{\frac{(\sigma-1)\kappa}{\psi}} \tag{12}$$

Finally, own sale increases as the firm has elevated quality and productivity compared to its rival firm's. In our model, relative qualities, prices, outputs and sales depend on not only productivity differences but also the quality indicators λ. We now rewrite the profit function of the firm, which operates in only domestic market as follows.

$$\pi_i(\varphi) = \frac{\psi A}{\sigma\kappa}\left[\left(\lambda_i^{\kappa}(1-\theta)LP^{\sigma-1}\right)^{1-\theta}\left(\frac{\varphi_i}{aw}\right)^{2\kappa}\left(\frac{\sigma-1}{\sigma}\right)^{2\kappa+1+\theta}\right]^{\frac{\sigma-1}{\psi}} - wF \tag{13}$$

The firm's profit increases in firms' productivity, higher quality and the market size L. The higher own quality increases its own profit. Following Helpman et al. (2004), we now get the implicit solutions for cutoffs as follows.

$$\pi_i = 0 \;\; \Leftrightarrow \;\; \varphi_i^{2\kappa}\lambda_i^{\kappa(1-\theta)}B = F^{\frac{\psi}{(\sigma-1)}} \tag{14}$$

where $B = \left(\frac{\psi}{2\kappa\sigma}\right)^{\frac{\psi}{\sigma-1}}\left(LP^{\sigma-1}\right)^{\frac{2\kappa}{\sigma-1}}(1-\theta)^{1-\theta}\left(\frac{1}{aw}\right)^{2\kappa}\left(\frac{\sigma-1}{\sigma}\right)^{2\kappa+1-\theta}$. The cutoff is expressed by the magnitude of φ and λ. The firm has higher productivity and higher quality can easily enter the market. The cutoff depends on the fixed cost, which means firm size. Higher technology for quality improvement contributes to the entry. If wages increase, firms need higher productivity. From eq.(14), the ratio of profits of any two firms is given by

$$\left(\frac{\lambda_i}{\lambda_j}\right)^{\frac{(1-\theta)}{2}} = \left(\frac{\varphi_j}{\varphi_i}\right) \tag{15}$$

where Eq.(15) shows that the higher productivity of rival firm (φ_j) drives improvements in the firm's own quality (λ_i, which means q_i).

Proposition 1. *The higher productivity of a rival firm stimulates innovation for quality improvement in its own firm*

The intuition behind the result is as follows: Higher productivity improves its own quality, subsequently decreases the price. Consequently, the output increases, suggesting that the firm obtains a larger market share. Thus, a firm encounters firms with higher productivity is incentivized to invest more in quality and increase its output to gain a market share.

3 Open Economy

Now, we turn to the case of open economy. Let's assume that the world consists of two countries. Labor is mobile within a country but immobile across countries. Hence, we apply the same method as used in the case of closed economy case to the open economy. However, when the firms export, they must incur a fixed export cost of $F_x > F$ units of labor and an iceberg variable cost of trade $\tau > 1$ unit to arrive in a foreign country. Variables related to the foreign country or importing country are denoted by f, while exporters from the domestic country are indicated by x. The profit functions of the firms which do not export are the same as in the case of closed economy.

The export profit function of a domestic exporter is

$$\pi_x(\varphi) = p_x(\varphi)x_x(\varphi) - w_d\left(\frac{a\tau q_x(\varphi)^{\theta}}{\varphi_x}x_x(\varphi) + \frac{q_x(\varphi)^{2\kappa}}{2\kappa\lambda_x^{\kappa}} + F_x\right) \tag{16}$$

where w_d is the wage of the export country, and $\lambda_x = q_x/\bar{q}_f$, which shows that the quality of exporter is normalized by the maximum quality among the firm in the importing country.[6] The price which the domestic exports face is $p_x = \tau p$. The profit function of a foreign firm that competes

[6]Only firms with $\lambda_x > 1$ can export in the case where the wage is normalized to 1.

with the imported goods is

$$\pi_f(\varphi) = p_f(\varphi)x_f(\varphi) - w_f\left(\frac{aq_f(\varphi)^\theta}{\varphi_f}x_f(\varphi) + \frac{q_f(\varphi)^{2\kappa}}{2\kappa\lambda_f^\kappa} + F_f\right) \tag{17}$$

where the price which the domestic exports face is $p_f = p$ by the assumption of symmetry. As before, we consider the innovation competition between exporters and foreign firms.

$$q_x = \left[\lambda_x^\kappa(1-\theta)A_f\left(\frac{\sigma-1}{\sigma w_d}\right)^\sigma\left(\frac{\varphi_x}{a}\right)^{\sigma-1}\tau^{1-\sigma}\right]^{\frac{1}{\psi}} \tag{18}$$

where $A_f = Y_f P_f^{\sigma-1}$, Y_f is the aggregate income of the foreign country and P_f is the quality-adjusted aggregate price index of variety in the foreign country. Its own firm's higher productivity gives the exporter an incentive to improve its product quality. On the other hand, an increase in the transport cost τ decreases the quality. That of the foreign firm is

$$q_f = \left[\lambda_f^\kappa(1-\theta)A_f\left(\frac{\sigma-1}{\sigma w_f}\right)^\sigma\left(\frac{\varphi_f}{a}\right)^{\sigma-1}\right]^{\frac{1}{\psi}} \tag{19}$$

Higher productivity makes the foreign firms encourage their innovations. The quality-price ratio of exporter is

$$\frac{q_x}{p_x} = \left[(\lambda_x^\kappa(1-\theta)A_f)^{1-\theta}\left(\frac{\sigma-1}{\sigma w_d}\right)^{2\kappa+1-\theta}\left(\frac{\varphi_x}{a}\right)^{2\kappa}\tau^{-2\kappa}\right]^{\frac{1}{\psi}} \tag{20}$$

The exporter's quality-price ratio improves with higher productivity. An increase in the transport costs lowers exporters' quality-price ratio. This is because higher transport cost decreases quality and increases price. The quality-price ratio of foreign firm is

$$\frac{q_f}{p_f} = \left[(\lambda_f^{\kappa}(1-\theta)A_f)^{1-\theta} \left(\frac{\sigma - 1}{\sigma w_f} \right)^{2\kappa+1-\theta} \left(\frac{\varphi_f}{a_f} \right)^{2\kappa} \right]^{\frac{1}{\psi}} \tag{21}$$

3.1 Cutoff

We obtain equilibrium profits of exporting and importing firms from eqs.(16), (17), (20), and (21). Then, the cutoffs of an exporting and an importing firms are determined by

$$\pi_x = 0 \quad \Leftrightarrow \quad \varphi_x^{2\kappa} \lambda_x^{\kappa(1-\theta)} \mathfrak{B}_x = F_x^{\frac{\psi}{\sigma-1}} \cdot \tau^{2\kappa} \tag{22}$$

$$\pi_f = 0 \quad \Leftrightarrow \quad \varphi_f^{2\kappa} \lambda_f^{\kappa(1-\theta)} \mathfrak{B}_f = F_f^{\frac{\psi}{\sigma-1}} \tag{23}$$

where $\mathfrak{B}_f = (1-\theta)^{1-\theta} \left(\frac{\sigma-1}{\sigma}\right)^{2\kappa+1-\theta} a^{-2\kappa} \left(\frac{\psi}{2\kappa\sigma}\right)^{\frac{\psi}{\sigma-1}} \left(L_f P_f^{\sigma-1}\right)^{\frac{2\kappa}{\sigma-1}} w_f^{-2\kappa}$ and $\mathfrak{B}_x = (1-\theta)^{1-\theta} \left(\frac{\sigma-1}{\sigma}\right)^{2\kappa+1-\theta} a^{-2\kappa} \left(\frac{\psi}{2\kappa\sigma}\right)^{\frac{\psi}{\sigma-1}} \left(L_f P_f^{\sigma-1}\right)^{\frac{2\kappa}{\sigma-1}} \left(\frac{w_f}{w_d^{\sigma}}\right)^{\frac{2\kappa}{\sigma-1}}$. The effects of the fixed costs, the rival firm's quality and its productivity are the same as in the case of closed economy. The higher transport cost raises the magnitude of the cutoff. If the transport cost is directly proportional to the distance to import countries, the cutoff is getting higher. On the other hand, the reduction of transport cost causes to lower the cutoff because a reducing of the transport cost makes exporters innovation decreases, which means λ becomes small. From eqs.(22) and (23), we obtain the relationship between exporting and importing firms.

$$\left(\frac{\lambda_f}{\lambda_x} \right)^{\frac{(1-\theta)}{2}} = \mathscr{D} \left(\frac{\varphi_x}{\varphi_f} \right) \cdot \frac{1}{\tau} \cdot \left(\frac{w_f}{w_d} \right)^{\frac{\sigma}{\sigma-1}} \tag{24}$$

where $\mathscr{D} = \left(\frac{F_f}{F_x}\right)^{\frac{\psi}{2\kappa(\sigma-1)}}$.

Proposition 2. *(a) Higher productivity among exporters incentivizes the improvement of quality of foreign (importing) firms. (b) Conversely, higher transportation costs lead to a decrease in innovation among foreign (importing) firms and to an increase in innovation among exporters. (c) Higher wages of exporting country provide an incentive for firms in the importing country to decrease their innovation efforts.*

The intuition behind these results is as follows: Proposition 2 (a) suggests that firms with higher productivity can produce products of greater quality and larger output, which enabling them to capture a larger market share in the importing country. Consequently, firms in the importing country seeks to enhance their innovation to compete with those of the exporting firms. Proposition 2 (b) indicates that higher transport costs for exporting firms reduce their competitiveness, promoting them to invest in innovation. Conversely, these increased costs lessen competitive pressure for firms in the importing country. Consequently, they may lack incentives to enhance their innovation. From these results, we obtain the effects of trade liberalization on innovation for firms in both exporting and importing countries. Trade liberalization enhances innovations among importing firms, but deteriorates those in exporting firms. We can then predict a scenario in which trade liberalization leads to quality equalization between countries. Proposition 2 (c) presents that the mechanism is the same as Proposition 2 (b). In contrast, higher wages in the importing country enhance the innovation efforts of firms within that country.[7] The first term on the right hand side depicted by $\mathscr{D}$ in Eq.(30) also shows that the intensive margin, indicating that large exporters or

[7]Rivera-Batiz and Romer (1991), and Grossman and Helpman (1993) suggest that similar results in general-equilibrium trade model.

importers are likely to be major innovators.[8]

Finally, let's discuss some empirical outcomes. Empirical research, such as that by Autor et al. (2020), shows the negative impact of rising Chinese competition on innovation in US firms. Suppose f indicates an importer, the USA and x or d denotes an exporter, China in Eq.(24). When firms in the USA are exposed to trade with Chineses firms, they face products produced with low-wage factors. This implies that w_d is lower than w_f in Eq.(24), suggesting that this should motivate an increasing in innovation. However, the productivity of firms in the USA is much higher than that of Chineses firms. This productivity effect surpasses the wage effects. Therefore, innovation by firms in the USA decreases. The current model can explain various cases by combining the effects as shown in Eq.(24).

4 Conclusion

This paper presented a model that incorporates quality competition and the relationship between firms' productivity. The analysis demonstrated that when firms in an importing country encounter exporters with higher productivity, they increase their quality innovations. Furthermore, the paper showed that the reduction of trade barriers leads to a degradation of exporters' product quality and an improvement in importers' product quality, resulting in increased revenue for both importers and exporters. The model is tractable and explains the outcomes from various empirical studies. It can also be easily extended to more specific cases, such as competition between multi-product firms and firms that distribute their products via foreign direct investment. Additionally, it can

[8] In this analysis, the extensive margin automatically holds, as firms with higher productivity produce higher quality products and export them.

explore the implications of government policies.

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