MPRA
Munich Personal RePEc Archive

Oligopolistic Competition, Firm Heterogeneity, and the Impact of International Trade

Zhou, Haiwen

2010

Online at https://mpra.ub.uni-muenchen.de/77667/
MPRA Paper No. 77667, posted 20 Mar 2017 16:58 UTC

Oligopolistic Competition, Firm Heterogeneity, and the Impact of International Trade

Haiwen Zhou[1]

Abstract

This paper studies the impact of international trade in a general equilibrium model in which heterogeneous firms engage in oligopolistic competition. An increase of the size of the market leads to a decrease of the equilibrium price and an increase of per capita consumption. The opening of international trade leads to an increased degree of competition, a lower price level, and the exit of least efficient firms. Though average profit increases, not all the surviving firms benefit from the opening of international trade.

Keywords: Firm heterogeneity, oligopolistic competition, international trade, increasing returns to scale

JEL Classification Numbers: F12, F15

1. Introduction

For convenience, it is frequently assumed that firms are homogeneous in terms of their production technologies. In reality, firms may employ different technologies with different productivities over long periods of time. For example, in their study of how the West grew rich, Rosenberg and Birdzell [1986] show that water power continued to be used long after the introduction of the steam engine (p. 154) and the power loom and handloom coexisted for more than fifty years before the handloom finally disappeared (p. 160). For international difference in technologies, Chandler [1990, Chapter 7] shows that at the beginning of the twentieth century, technologies used by British firms in many capital-intensive industries were systematically less efficient than technologies used by counterpart firms in the United States.

Modern production is associated with the extensive use of machines. Machines are fixed costs of production. With the existence of significant fixed costs of production, a firm with a higher level of output has a cost advantage over a firm with a lower level of output and an industry may be monopolized. However, many countries have anti-trust laws that can be used to prevent monopoly from happening. As a result, many industries are characterized by oligopolistic competition [Chandler, 1990]. The significance of

[1] I thank Gilbert L. Skillman for his extremely detailed and insightful suggestions. I also thank an anonymous referee for valuable suggestions. The usual disclaimer applies.

oligopolistic competition is recognized in standard textbooks on industrial organization; for example Pindyck and Rubinfeld [2005, p. 441] write “oligopoly is a prevalent form of market structure. Examples of oligopolistic industries include automobiles, steel, aluminum, petrochemicals, electrical equipment, and computers.” The relevance of oligopolistic competition to international trade is even greater as firms engaging in international trade on average are larger than firms that do not engage in trade [Bleaney and Wakelin, 2002, p. 3]. Thus, firms engaging in international trade are likely to have market power and engage in oligopolistic competition.

The opening of international trade may intensify the degree of competition and lead to the exit of less efficient firms and an increase in average productivity. Empirical studies have shown that the exit of less efficient firms is an important source of the gains from trade.[2] To address the exit of less efficient firms, models based on heterogeneous firms are needed. With heterogeneous firms, the market structure can be either monopolistic competition or oligopolistic competition. With monopolistic competition and a constant elasticity of demand, a firm’s price is affected only by the marginal cost and the elasticity of demand and does not change with the size of the market [Neary, 2001, 2003]. As there is only one firm producing each product, the opening of international trade does not change the degree of competition. Thus a potential channel of the impact of the opening of trade through an increase in the degree of competition is excluded.

This paper contributes to the literature by studying the impact of international trade in a general equilibrium model in which heterogeneous firms engage in oligopolistic competition. In this model, to learn its marginal cost of production, a firm must first incur a fixed sampling cost.[3] After learning its marginal cost, a firm chooses output optimally to maximize its profit. A firm’s price as a markup over marginal cost of production decreases with the size of the market. Even with a general utility function, this oligopolistic competition framework is very tractable and comparative static results are available. In a closed economy, we show that an increase in the size of the market leads to a decrease in the equilibrium price and an increase in per capita consumption.

[2] For example, Gu et al. [2003] show that the exit of less efficient firms is an important source of productivity gain for Canadian firms in their study of the impact of the Canada-U.S. Free Trade Agreement.
[3] This is similar to the approach of McAfee and McMillan [1987], in which a bidder must pay a fixed fee in order to learn her true valuation of the item to be sold.

The opening of international trade leads to the exit of less efficient firms and not all the surviving firms benefit from the opening of trade. These results are similar to those under monopolistic competition. However, the mechanisms under different types of competition are different. Under monopolistic competition, as the opening of trade increases the number of varieties produced by firms with lower marginal costs, firms with higher marginal costs can not cover their fixed costs and they exit. Under oligopolistic competition, as the opening of trade decreases the price level, this leads to the exit of less efficient firms.

In the literature, Lahiri and Ono [1988] studied the impact of international trade with intra-country firm heterogeneity in which firms engage in oligopolistic competition. Montagna [1995] and Melitz [2003] addressed the impact of international trade in models featuring heterogeneous firms engage in monopolistic competition. Lahiri and Ono [2004] considered various types of analysis in asymmetric oligopoly models. Qiu and Zhou [2007] examined incentives for firms to merge when they engage in oligopolisitic competition. They show that firm heterogeneity is a necessary condition for mergers to occur.

The rest of the paper is organized as follows. Section 2 sets up the model. Section 3 studies the equilibrium in a closed economy. Section 4 establishes the existence of a unique equilibrium in an open economy. Section 5 addresses the impact of the opening of international trade. Section 6 discusses some extensions and generalizations of the model and concludes.

2. The model

In this section, we set up the model. First, we study a consumer's utility maximization problem. Second, we study a firm's decision process. Third, we study the determination of the cutoff level of marginal cost in equilibrium. Finally, the implications of free entry and exit are explored.

First, consider the utility maximization problem of a representative consumer. The number of consumers in a country is exogenously given and is denoted by L. There is a continuum of products on the interval $[0,1]$, indexed by ω. All the goods are assumed to enter into a consumer's utility function symmetrically. Let $c(\omega)$ denote a consumer's consumption of product ω. A consumer's utility is then given by $\int_0^1 U(c(\omega))d\omega$. It is assumed that $U'>0$ and $U''<0$. Labor is the only factor of production. Each consumer supplies one unit of labor inelastically. The wage rate is w and it is normalized to one in this paper: $w \equiv 1$. The price level of product ϖ is $p(\varpi)$. This consumer's budget constraint requires total spending on all products equals wage income:

(1) $$\int_0^1 p(\omega)c(\omega)d\omega = w.$$

A consumer takes the wage rate and prices of goods as given and chooses quantities of consumption to maximize utility. Let λ denote the Lagrangian multiplier associated with a consumer's utility maximization. A consumer's utility maximization leads to $U' = \lambda p$. A consumer's elasticity of demand is defined as $\varepsilon(c) \equiv -\frac{U'(c)}{cU''(c)}$, a positive number.

Second, we study a firm's profit maximization. Each product is produced by multiple firms. Similar to Neary [2003a, 2003b] and Zhou [2004, 2007a, 2007b], firms producing the same product are assumed to engage in Cournot competition. Firms producing positive levels of output have the same level of fixed costs of production f. However, they may differ in their marginal costs of production.[4] A firm's constant marginal cost β is distributed on a closed interval $[\underline{\beta}, \overline{\beta}]$.[5] The cumulative distribution function of β is $G(\beta)$ and its corresponding density function is $g(\beta)$. For simplicity, it is assumed that $g(\beta)$ is continuous. To learn its marginal cost of production, a firm must first incur a fixed sampling cost $f_e > 0$.[6] After learning its marginal cost, a firm decides whether to exit or begin to produce. As a firm's expected profit decreases with its marginal cost, a firm with a marginal cost higher than a cutoff level is not able to recover its fixed

[4] One source of fixed cost is the amount of time spent on learning. A higher amount of time spent on learning leads to more knowledge and this can decrease the marginal cost of producing each unit of output.

[5] In this model, firms with relatively high marginal costs are able to sell positive levels of output in a market with some firms having relatively low marginal costs. This is valid if $\overline{\beta} - \underline{\beta}$ is not too large.

[6] This sampling cost approach is unnecessary to derive the results. What is needed is firm heterogeneity with respect to cost. For a sufficiently high value of sampling cost and a sufficiently narrow spread of potential values for marginal cost, it would pay a firm to forgo sampling and base its production decision on the expected value of marginal cost. I thank Gilbert Skillman for this insight.

cost f and will exit. A firm takes the wage rate as given and chooses its level of output to maximize profit.[7] Let q denote a firm's level of output. A firm's profit is $pq - f - \beta q$. Optimal choice of output leads to

$$p\left(1+\frac{q}{p}\frac{\partial p}{\partial q}\right)=\beta . \tag{2}$$

For each product, let Q denote the aggregate output produced by all firms. The total supply of a product is Q and the total demand for a product is Lc. Goods market equilibrium requires that supply equals demand:

$$Q = Lc . \tag{3}$$

In a symmetric equilibrium, prices of all goods are the same and a consumer purchases the same amount of all goods. This leads to $pc = 1$. Combining this with equation (3) yields

$$pQ = L .^{8} \tag{4}$$

In a Cournot equilibrium, a firm views other firms' output as given when it chooses its level of output. From a firm's point of view, the partial derivative of p with respect to q is equal to the partial derivative of p with respect to Q. With this point in mind, differentiation of both sides of equation (3) leads to $\frac{\partial q}{\partial p} = L\frac{\partial c}{\partial p}$. Combination of this result with equation (2) yields a firm's elasticity of demand:

$$\frac{\partial p}{\partial q}\frac{q}{p} = -\frac{q}{\varepsilon Q} . \tag{5}$$

Plugging equation (5) into equation (2) leads to a firm's level of output:

$$q = \frac{(p-\beta)\varepsilon Q}{p} . \tag{6}$$

Equation (6) expresses a firm's output as a function of its marginal cost, a consumer's elasticity of demand, the price level, and aggregate output. When firms are homogeneous, it degenerates to the well-established result that a firm's price as a markup over marginal

[7] As there is a continuum of products and each product is produced by multiple firms, a change of one firm's demand for labor does not affect the wage rate. However, a firm does have market power in the output market since each product is produced by a small number of firms.

[8] Equation (4) can be derived in a different way. The total value of output is pQ. Since a firm's expected profit before learning its marginal cost is zero, total expected profit is zero. Thus, total factor payment is L. Equalization of the value of output and total factor payment leads to equation (4).

cost under Cournot competition decreases with the number of competing firms.[9] Equation (6) is consistent with our intuition that a firm's market share decreases with its marginal cost.

Third, we study the determination of the cutoff level of marginal cost of production β^*. A firm with marginal cost β^* earns a profit of zero and a firm drawing a marginal cost higher than β^* will exit and never produce. From equation (6), a firm with a marginal cost of β has a profit of $\frac{(p-\beta)^2 \varepsilon Q}{p} - f$. Thus the cutoff level of marginal cost β^* is defined by

(7) $$\frac{(p-\beta^*)^2 \varepsilon Q}{p} - f = 0.$$

Finally, with free entry, a firm's expected profit before learning its marginal cost should be equal to zero. Since the fixed sampling cost is f_e, zero profit requires that

(8) $$G(\beta^*)\int_{\underline{\beta}}^{\beta^*} \left(\frac{(p-\beta)^2 \varepsilon Q}{p} - f \right) g(\beta) d\beta - f_e = 0.$$

As all the goods are symmetric, equation (1) leads to

(9) $$c = \frac{1}{p}.$$

By plugging the value of Q from equation (4) and the value of c from equation (9) into equations (7) and (8), we get

(10a) $$A_1 \equiv \frac{(p-\beta^*)^2 \varepsilon L}{p^2} - f = 0,$$

(10b) $$A_2 \equiv G(\beta^*)\int_{\underline{\beta}}^{\beta^*} \left(\frac{(p-\beta)^2 \varepsilon L}{p^2} - f \right) g(\beta) d\beta - f_e = 0.$$

From its definition, ε is a function of c. From equation (9), c is a function of p. Thus, ε is a function of p. Equations (10a) and (10b) form a system of two equations defining

---

[9] When there are N homogeneous firms, $Q = Nq$. Equation (6) changes to $p = \frac{\varepsilon N}{\varepsilon N + 1}\beta$, which is the profit maximizing markup for Cournot oligopoly.

two variables p and β^* as functions of exogenous parameters. An equilibrium in a closed economy is a vector (p , β^*) satisfying equations (10a) and (10b).[10]

3. Analysis of the equilibrium in a closed economy

In this section, we establish the existence of a unique equilibrium in a closed economy. Then we conduct some comparative static studies to explore properties of this equilibrium.

The following assumption is made:

Assumption 1: $\partial\left(\dfrac{(p-\beta)^2\varepsilon}{p^2}\right)/\partial p > 0$.

The interpretation of Assumption 1 is as follows. Since $p-\beta$ is a firm's per unit profit and $\dfrac{(p-\beta)\varepsilon L}{p^2}$ is a firm's optimal quantity of production, $\dfrac{(p-\beta)^2\varepsilon L}{p^2}$ is a firm's profit excluding fixed costs. Assumption 1 requires that a firm's maximized profit excluding fixed costs increases with the price level. One sufficient condition for Assumption 1 to be satisfied is that $\dfrac{d\varepsilon}{dc} \le 0$. Thus it is valid for the constant elasticity utility function ($\dfrac{d\varepsilon}{dc} = 0$) frequently used in the international trade literature. If $\dfrac{d\varepsilon}{dc} > 0$, it is still possible that $\dfrac{\partial A_1}{\partial p} > 0$ if $\dfrac{d\varepsilon}{dc}$ is not too positive.

The following example will be useful in clarifying this assumption. For simplicity, suppose there is only one firm. Let the relationship between price and quantity be $q = q(p)$. For a firm it tries to maximize profit pq. The first order condition with respect to p is $q + p\dfrac{\partial q}{\partial p} = 0$. From this first order condition, we get $q = -\dfrac{\partial q}{\partial p}p$. Plugging this

[10] As the average units of labor required to produce a unit of output is p, the total demand for labor is pQ. The total supply of labor is L. Equalization of labor supply and demand leads to equation (4). Thus the labor market is also in equilibrium when equations (10a) and (10b) are satisfied.

value of q into pq, the profit for a firm's profit reduces to $-p^2 \partial q / \partial p$. Then Assumption 1 requires that the derivative of $-p^2 \partial q / \partial p$ with respect to p is positive. By specifying the utility function appropriately, the inverse demand function can become $p = a - bq$, where a and b are positive constants, then $-\partial q / \partial p = 1/b$. In this case, Assumption 1 requires that the derivative of p^2 / b with respect to p is positive.

The following proposition establishes the existence of a unique equilibrium in a closed economy.

Proposition 1: Assumption 1 is a sufficient condition for the existence of a unique equilibrium in a closed economy.

Proof: From equation (10a), $\frac{\partial A_1}{\partial \beta^*} < 0$. With Assumption 1, $\frac{\partial A_1}{\partial p} > 0$. Thus A_1 represents a positive relationship between p and β^*. From equation (10b), $\frac{\partial A_2}{\partial \beta^*} > 0$. With Assumption 1, $\frac{\partial A_2}{\partial p} > 0$. Thus A_2 represents a negative relationship between p and β^*. For $\beta = \underline{\beta}$, the value of p in A_1 is finite. In A_2, as β goes to $\underline{\beta}$, p can be higher than any finite number. Thus the value of p in A_1 is lower than the value of p in A_2. For $\beta = \overline{\beta}$, the value of p in A_1 is higher than the value of p in A_2. It follows that there exists a unique set of p and β^* satisfying equations (10a) and (10b). QED

The intuition behind the proof of Proposition 1 can be visualized from Figure 1. The horizontal axis represents the price level and the vertical axis represents the cutoff level of marginal cost. Equation (10a) is shown as the curve labeled as the cutoff MC condition and equation (10b) is shown as the curve labeled as the free entry condition. The two curves intersect and intersect only once.

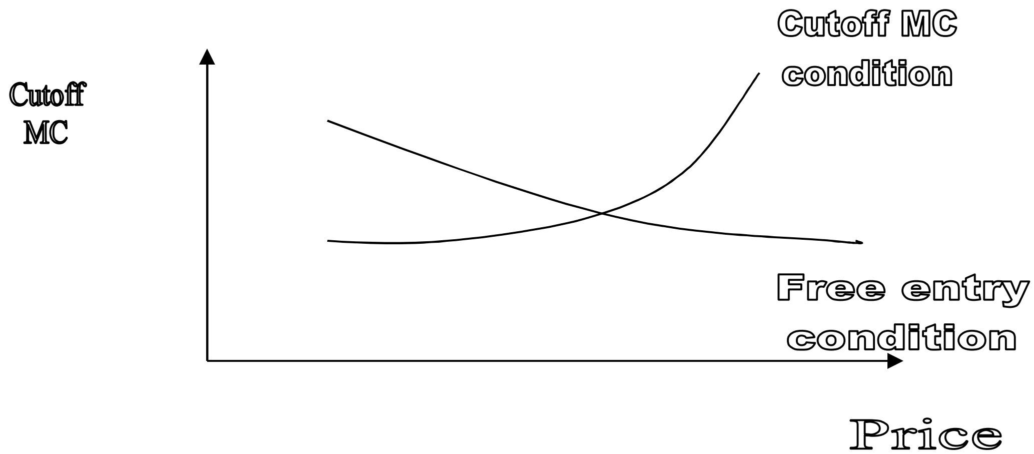

Figure 1: Determination of the equilibrium

Total differentiation of equations (10a) and (10b) with respect to p, β^*, and L leads to

$$\begin{pmatrix} \frac{\partial A_1}{\partial p} & \frac{\partial A_1}{\partial \beta^*} \\ \frac{\partial A_2}{\partial p} & \frac{\partial A_2}{\partial \beta^*} \end{pmatrix} \begin{pmatrix} dp \\ d\beta^* \end{pmatrix} = \begin{pmatrix} -\frac{\partial A_1}{\partial L} \\ -\frac{\partial A_2}{\partial L} \end{pmatrix} dL .$$

The determinant of the coefficient matrix is given by $\Delta \equiv \frac{\partial A_1}{\partial p}\frac{\partial A_2}{\partial \beta^*} - \frac{\partial A_1}{\partial \beta^*}\frac{\partial A_2}{\partial p}$. Assumption 1 is sufficient for $\Delta > 0$.[11]

With monopolistic competition, a firm's price is independent of the size of labor endowment. The following proposition shows that under Cournot competition, the price decreases and per capita consumption increases with an increase of labor endowment.

Proposition 2: Assumption 1 is sufficient for the equilibrium price to decrease with the endowment of labor and per capita consumption to increase with the endowment of labor.

[11] For utility functions with constant elasticity of demand, for example, Δ is always positive.

Proof: Define $\Delta_p \equiv \frac{\partial A_1}{\partial \beta^*}\frac{\partial A_2}{\partial L} - \frac{\partial A_1}{\partial L}\frac{\partial A_2}{\partial \beta^*}$. Since $\frac{\partial A_1}{\partial L} > 0$, and $\frac{\partial A_2}{\partial L} > 0$, it follows that $\Delta_p < 0$. An application of Cramer's rule leads to $\frac{dp}{dL} = \frac{\Delta_p}{\Delta} < 0$.

From equation (9), a decrease of the price level is associated with an increase of per capita consumption. QED

From Proposition 2, an increase of labor endowment decreases the price level. From equation (6), a firm's market share increases with the price level. Thus an increase of labor endowment leads to a decrease of market share of all existing firms. This is achieved through an increase in the number of firms producing the same product. Thus an increase of labor endowment increases the degree of competition. An increase of the number of firms may be achieved through either of two channels. One channel is an increase in the cutoff level of marginal cost. The other one is through an increase in the number of firms sampling to learn their marginal costs.

Following the proof of Proposition 2, the impact of an increase of labor endowment on the cutoff level of marginal cost is ambiguous. An increase of labor endowment leads to two effects working in opposite directions. First, it increases the size of the market. This benefits every firm and is likely to increase the cutoff level of marginal cost. Second, it decreases the price level. Other things given, this decreases a firm's profit and is likely to decrease the cutoff level of marginal cost. Without adding new structure to this model, it is not clear which effect dominates.

What is the impact of an increase of labor endowment on average profit of all firms producing positive levels of output? From equation (10b), average profit is $f_e / G(\beta^*)$. Since it is not clear whether β^* increases or not, the impact of an increase of labor endowment on average profit is ambiguous. The reason is that an increase of labor endowment L increases the size of the market and the degree of competition at the same time. If the cutoff level of marginal cost β^* decreases, average profit increases. Otherwise, average profit decreases.

A higher elasticity of demand means a consumer is more responsive to a price change. In this sense, a market with a higher elasticity of demand is more competitive.

For the special case that the elasticity of demand is constant, similar to the proof of Proposition 2, an application of Cramer's rule yields that an increase of elasticity decreases the price level. This result is consistent with our intuition that a market with a higher elasticity of demand is associated with a lower price. The impact of an increase of this elasticity on the cutoff level of marginal cost is ambiguous.

4. The equilibrium in an open economy

In this section, we establish the existence of a unique equilibrium in an open economy. The number of foreign countries is n. All foreign countries are assumed to have the same production technologies and labor endowments as the home country. Thus in equilibrium the wage rate in all countries will be the same. Transportation cost between different countries is of the "iceberg" type: if τ units of a product is sent, only one unit is received, where $\tau > 1$.[12] Variables related with international trade are denoted with a subscript T. For example, for each product, Q_T denotes the sum of output sold in the domestic market produced by all domestic and foreign firms.

For domestic firms, the cutoff level of marginal cost to earn a non-negative profit in the domestic market is defined by

$$\frac{(p_T - \beta_T{*})^2 \varepsilon Q_T}{p_T} - f = 0, \tag{11}$$

where ε is a function of p_T.

Let f_x denote a domestic firm's fixed cost of selling in each of the foreign markets.[13] With a fixed cost, some domestic firms may not export.[14] As all countries are symmetric, a firm either exports to all foreign countries or does not export to any of them.

[12] When there is no transportation cost and no fixed cost of entering foreign markets, the opening of trade has an impact similar to an increase in domestic population. As demonstrated in Section 3, this does not necessarily leads to the exit of less efficient firms.

[13] Fixed costs in exporting may include costs to set up distribution facilities in foreign countries, costs to learn foreign countries' regulations, and other costs not related to export volume. In their empirical study, Roberts and Tybout [1997] find that the existence of fixed costs is a significant factor affecting a firm's decision to export.

[14] Early on, fixed costs are used in Harris [1995] to separate firms producing for domestic markets only and firms engaging in international trade.

Let $\beta_x *$ denote the cutoff level of marginal cost for a domestic firm to export. This cutoff level of marginal cost $\beta_x *$ is defined by

(12) $$\frac{(p_T - \beta_x * \tau)^2 \varepsilon Q_T}{p_T} - f_x = 0 .$$

From equations (11) and (12), $\beta_x * < \beta_x$ if and only if

(13) $$1 - \sqrt{\frac{f_x}{L\varepsilon}} < \tau\left(1 - \sqrt{\frac{f}{L\varepsilon}}\right).$$

One sufficient condition for inequality (13) to be valid is that the fixed cost of international trade is higher than the fixed cost of operating in the home country.

For a firm selling in both domestic and foreign markets, this firm's sales revenue in the home country is higher than its sales revenue from any foreign country. This can be demonstrated as follows. From equation (6), a firm's output in a market is inversely related to its marginal cost. A firm's marginal cost at home is β, while its marginal cost in a foreign country incorporating transportation costs is $\beta\tau$. Thus, a firm's quantity of sales in the domestic market is higher than that in any of the foreign markets. As prices in all countries are the same, this firm's domestic revenue is higher than its revenue from any foreign market.

As countries are symmetric, the sum of all foreign firms' revenue in the home country is equal to the sum of all domestic firms' revenue in all foreign countries. Thus the total revenue of all domestic firms with trade is $p_T Q_T$. As the wage rate is normalized to one, total domestic factor income is L. Equalization of the total revenue of all domestic firms and total domestic factor income leads to

(14) $$p_T Q_T = L .$$

For domestic firms with marginal costs between $\underline{\beta}$ and $\beta_T *$, they earn profit $\frac{(p_T - \beta)^2 \varepsilon Q_T}{p_T} - f$ from the domestic market. For domestic firms with marginal costs between $\underline{\beta}$ and $\beta_x *$, they also earn profit $\frac{(p_T - \beta\tau)^2 \varepsilon Q_T}{p_T} - f_x$ from each of the n foreign markets. The zero expected profit condition with international trade is given by

(15) $$G(\beta_T{}^*)\int_{\underline{\beta}}^{\beta_T{}^*}\left(\frac{(p_T-\beta)^2\,\varepsilon Q_T}{p_T}-f\right)g(\beta)d\beta$$

$$+\,nG(\beta_T{}^*)\int_{\underline{\beta}}^{\beta_x{}^*}\left(\frac{(p_T-\beta\tau)^2\,\varepsilon Q_T}{p_T}-f_x\right)g(\beta)d\beta-f_e=0\,.$$

Equations (11) and (14) lead to

(16a) $$T_1\equiv\frac{(p_T-\beta_T{}^*)^2\,\varepsilon L}{p_T{}^2}-f=0\,.$$

Equation (12) yields the following equation defining $\beta_x{}^*$ as a function of p_T,

(17) $$\beta_x{}^*(p_T)=\frac{1}{\tau}\left(1-\sqrt{\frac{f_x}{L\varepsilon}}\right)p_T\,.$$

Plugging the value of $\beta_x{}^*$ defined in equation (17) into equation (15) leads to

(16b) $$T_2\equiv G(\beta_T{}^*)\int_{\underline{\beta}}^{\beta_T{}^*}\left(\frac{(p_T-\beta)^2\,L\varepsilon}{p_T{}^2}-f\right)g(\beta)d\beta$$

$$+\,nG(\beta_T{}^*)\int_{\underline{\beta}}^{\beta_x{}^*(p_T)}\left(\frac{(p_T-\beta\tau)^2\,L\varepsilon}{p_T{}^2}-f_x\right)g(\beta)d\beta-f_e=0\,.$$

Equations (16a) and (16b) form a system of two equations defining p_T and $\beta_T{}^*$ as functions of exogenous parameters. An equilibrium with international trade is a vector (p_T, $\beta_T{}^*$) satisfying equations (16a) and (16b). The following proposition addresses the existence and uniqueness of an equilibrium in an open economy.

Proposition 3: Assumption 1 is a sufficient condition for the existence of a unique equilibrium in an open economy.

Proof: From equation (16a), $\frac{\partial T_1}{\partial \beta_T{}^*}<0$. Assumption 1 is sufficient for $\frac{\partial T_1}{\partial p_T}>0$. From equation (16b), $\frac{\partial T_2}{\partial \beta_T{}^*}>0$. Assumption 1 is sufficient for $\frac{\partial T_2}{\partial p_T}>0$. While T_1 represents a positive relationship between p_T and $\beta_T{}^*$, T_2 represents a negative relationship between p_T and $\beta_T{}^*$. For $\beta=\underline{\beta}$, the value of p_T in T_1 is lower than the value of p_T in T_2 as the value of p_T in T_2 needs to go to infinity. For $\beta = \overline{\beta}$, the value of p_T in T_1 is higher than the value of p_T in T_2. It follows that there exists a unique set of p_T and β_T * satisfying equations (16a) and (16b). QED

5. The impact of the opening of international trade

In this section, we study the impact of the opening of international trade.

Total differentiation of equations (16a) and (16b) leads to

(18) $$\begin{pmatrix} \frac{\partial T_1}{\partial p_T} & \frac{\partial T_1}{\partial \beta_T *} \\ \frac{\partial T_2}{\partial p_T} & \frac{\partial T_2}{\partial \beta_T *} \end{pmatrix} \begin{pmatrix} dp_T \\ d\beta_T * \end{pmatrix} = -\begin{pmatrix} 0 \\ \frac{\partial T_2}{\partial n} \end{pmatrix} dn - \begin{pmatrix} 0 \\ \frac{\partial T_2}{\partial \tau} \end{pmatrix} d\tau - \begin{pmatrix} 0 \\ \frac{\partial T_2}{\partial f_x} \end{pmatrix} df_x .$$

The determinant of the coefficient matrix is given by $\Delta_T \equiv \frac{\partial T_1}{\partial p_T}\frac{\partial T_2}{\partial \beta_T *} - \frac{\partial T_1}{\partial \beta_T *}\frac{\partial T_2}{\partial p_T}$.

Assumption 1 is sufficient for Δ_T to be positive.

Historically, as illustrated in Pomeranz [2000], industrialization in the Britain was associated with the expansion of trade with the New World. In modern times, an important motivation for the expansion of the European Union is to create a larger market size. Other things equal, the size of the market increases with the number of countries engaging in international trade. The following proposition studies implications of a change in the number of foreign countries.

Proposition 4: (a) Assumption 1 is sufficient for a representative consumer's welfare to increase with the number of foreign countries. Specifically, the opening of trade increases a consumer's welfare. (b) Assumption 1 is sufficient for the cutoff level of marginal cost to decrease with the number of foreign countries. Specifically, the opening of trade leads to the exit of less efficient firms.

Proof: (a) From equation (16b), it can be shown that $\frac{\partial T_2}{\partial n} > 0$. By setting $d\tau = df_x = 0$ in the system (18), an application of Cramer's rule leads to

$$\frac{d\,p_T}{d\,n} = \frac{\partial T_1}{\partial \beta_x}\frac{\partial T_2}{\partial n}\Big/\Delta_T < 0\,.$$

As the price decreases with the number of foreign countries and the wage rate is normalized to one, a consumer's welfare increases with the number of foreign countries.

To prove the opening of trade increases a consumer's welfare, it is sufficient to show that the impact of the opening of trade is a change of n from zero to a positive number.

(b) An application of Cramer's rule leads to

$$\frac{d\,\beta_T\,*}{d\,n} = -\frac{\partial T_1}{\partial\, p_T}\frac{\partial T_2}{\partial n}\Big/\Delta_T < 0\,.$$ [15]

To prove the opening of trade leads to the exit of less efficient firms, it is sufficient to show that the impact of the opening of trade is a change of n from zero to a positive number. QED

While both monopolistic competition and oligopolistic competition models lead to the result that the opening of trade leads to the exit of less efficient firms, the mechanisms in the two cases are different. Under monopolistic competition, as a consumer's elasticity of demand is larger than one, a firm charging a lower price has a higher level of revenue. A firm with a lower marginal cost of production charges a lower price and thus has a level of revenue higher than a firm with a higher marginal cost. As the opening of trade increases the number of varieties produced by firms with lower marginal costs, firms with higher marginal costs could not generate enough revenue to cover their fixed costs and they exit. Under oligopolistic competition, the number of varieties does not change with trade. Regardless of a consumer's elasticity of demand, a firm with a lower marginal cost sells more than a firm with a higher marginal cost. As the opening of trade decreases the price level, this leads to the exit of less efficient firms.

[15] The following is an alternative proof that the opening of trade leads to the exit of less efficient firms. By comparing equations (10b) and (16b), it can be shown that the zero expected profit condition moves down with the opening of trade. As the equation defining the cutoff level of marginal cost does not change, the equilibrium with international trade has a lower level of cutoff marginal cost. That is, some less efficient firms exit.

The following proposition shows that while average profit increases with the opening of trade, some firms lose from it.

Proposition 5: (a) The opening of trade leads to an increase of average profit. (b) Less efficient firms lose from trade and more efficient firms gain from trade.

Proof: (a) From equation (10b), average profit without trade is $f_e / G(\beta^*)$. From equation (16b), average profit with international trade is $f_e / G(\beta_T{}^*)$. Since $\beta_T{}^* < \beta^*$, average profit increases.

(b) A firm's profit is

$$\pi(\beta) = \frac{(p-\beta)^2 L\varepsilon}{p^2} - f .$$

Differentiation of this equation with respect to the price level shows that a firm's profit decreases with the price level. As the opening of trade leads to a decrease of the price level, profits of these surviving firms who do not export decrease. It can be shown that a firm's profit decreases with its marginal cost. As firms on average earn a higher level of profit, profits of more efficient firms must increase with the opening of international trade.

QED

In the literature, the opening of international trade increases a firm's scale of production when firms are homogeneous, as shown in Lahiri and Ono [1995]. This output expansion decreases average cost of production and leads to the gains from trade. In this model, with firm heterogeneity, the impact of the opening of trade on average firm size is ambiguous.

Government policies can change the level of entry costs of foreign firms. Changes of transportation technologies can decrease the level of transportation costs. Historical changes of tariffs and transportation costs are documented in Williamson [2006]. The following proposition studies some implications of changes in transportation costs and entry cost.

Proposition 6: Given Assumption 1, a decrease in transportation costs or entry cost reduces the equilibrium levels of price and the cutoff value of marginal cost.

Proof: By setting $d\,n = d\,f_x = 0$ in the system (18), an application of Cramer's rule leads to $\frac{d\,p_T}{d\,\tau} > 0$, and $\frac{d\,\beta_T\,*}{d\,\tau} > 0$.

By setting $d\,n = d\,\tau = 0$ in the system (18), an application of Cramer's rule leads to $\frac{d\,p_T}{d\,f_x} > 0$, and $\frac{d\,\beta_T\,*}{d\,f_x} > 0$. QED

Proposition 6 shows that a decrease of entry cost such as caused by a trade liberalization or a decrease in transportation costs leads to a lower price and higher consumer welfare.

6. Conclusion

In this paper, we have studied the impact of international trade in a general equilibrium model in which heterogeneous firms engage in oligopolistic competition. Under oligopolistic competition, a firm's price as a markup over its marginal cost of production decreases with the size of the market. Even with a general utility function, this oligopolistic competition framework is very tractable and comparative static results are easily available. We have established the following results. First, in a closed economy, an increase of the size of the market leads to a decrease of the equilibrium price and an increase of per capita consumption. Second, the opening of trade leads to increased degrees of competition and the exit of less efficient firms. As a result, the price level decreases. Finally, though average profit increases, not all the surviving firms benefit from the opening of international trade.

There are some interesting extensions and generalizations of the model. First, with the incorporation of oligopolistic competition, this framework may be useful in studying implications of international trade in which firms behave strategically, such as building capacities to deter entry. Second, in this model, countries are symmetric and this leads to the result that the opening of international trade leads to the exit of least efficient firms in each country. If all the firms in the partner country are less efficient than all the firms in the home country and the goods market is integrated, then all the firms in the partner country have to exit first before any firm in the home country exits. In this case, the impact of the opening of international trade on a country with less efficient firms will be complicated. Finally, the model can be generalized to a dynamic way by incorporating a firm's development of new technologies.

References

Bleaney, Michael, and Katharine Wakelin. 2002. Efficiency, Innovation and Exports. *Oxford Bulletin of Economics and Statistics,* 64(3): 3-15.

Brander, James. 1995. Strategic Trade Policy. In: Grossman, Gene, Rogoff, Kenneth, Eds., *Handbook of International Economics*, Volume 3, Amsterdam: North-Holland.

Chandler, Alfred. 1990. *Scale and Scope: The Dynamics of Industrial Capitalism*. Cambridge, MA: Harvard University Press.

Gu, Wulong, Gary Sawchuk, and Lori Whewell. 2003. The Effect of Tariff Reductions on Firm Size and Firm Turnover in Canadian Manufacturing. *Weltwirtschaftliches Archiv/Review of World Economics,* 139(3): 440-459.

Harris, Richard. 1995. Trade and Communication Costs. *Canadian Journal of Economics,* 28(s1): S46-S75.

Lahiri, Sajal, and Yoshiyasu Ono. 1988. Helping Minor Firms Reduces Welfare. *Economic Journal,* 98(393): 1199-1202.

Lahiri, Sajal, and Yoshiyasu Ono. 1995. The Role of Free Entry in an Oligopolistic Hecksher-Ohlin Model. *International Economic Review,* 36(3): 609-624.

Lahiri, Sajal, and Yoshiyasu Ono. 2004. *Trade and Industrial Policy under International Oligopoly*. Cambridge, UK: Cambridge University Press.

McAfee, R. Preston, and John McMillan. 1987. Auctions with Entry. *Economics Letters,* 23(4): 343-347.

Melitz, Marc. 2003. The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity. *Econometrica,* 71(6): 1695-1725.

Montagna, Catia. 1995. Monopolistic Competition with Firm-specific Costs. *Oxford Economic Papers,* 47(2): 318-328.

Neary, Peter, J. 2001. Of Hype and Hyperbolas: Introducing the New Economic Geography. *Journal of Economic Literature,* 39(2): 536-561.

Neary, Peter, J. 2003a. Globalization and Market Structure. *Journal of the European Economic Association,* 1(2-3): 245-271.

Neary, Peter, J. 2003b. The Road Less Traveled: Oligopoly and Competition Policy in General Equilibrium. In: R. Arnott, B. Greenwald, R. Kanbur and B. Nalebuff (eds.): Economics for an Imperfect World: Essays in Honor of Joseph E. Stiglitz, Cambridge, MA: MIT Press.

Pomeranz, Kenneth. 2000. *The Great Divergence: China, Europe, and the Making of the Modern World Economy*. Princeton, NJ: Princeton University Press.

Qiu, Larry, D. and Wen Zhou. 2007. Merger Waves: A Model of Endogenous Mergers. *Rand Journal of Economics*, 30(1): 214-226.

Roberts, Mark and James Tybout. 1997. The Decision to Export in Colombia: an Empirical Model of Entry with Sunk Costs. *American Economic Review,* 87(4): 545-564.

Pindyck , Robert, and Rubinfeld, Daniel. 2005. *Microeconomics*, sixth edition, Upper Saddle River, New Jersey: Pearson Education.

Rosenberg, Nathan, and Luther Earle Birdzell Jr. 1986. *How the West Grew Rich*, Basic Books, New York.

Williamson, Jeffery. 2006. *Globalization and the Poor Periphery before 1950*. Cambridge, MA: MIT Press.

Zhou, Haiwen. 2004. The Division of Labor and the Extent of the Market. *Economic Theory*, 24(1): 195-209.

Zhou, Haiwen. 2007a. Increasing Returns, the Choice of Technology, and the Gains from Trade. *Southern Economic Journal,* 74(2): 581-600.

Zhou, Haiwen. 2007b. Oligopolistic Competition and Economic Geography. *Journal of Regional Science,* 47(5): 915-933.