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Abstract

In this paper, we construct a simplified general oligopolistic equilibrium (GOLE) model, in which Smith's (1776) famous theory of division of labor is embedded. In the absence of labor market integration with trading countries, we show that trade liberalization promotes a reduction of the number of firms in each country and a deeper division of labor, thus increasing firm productivity and improving welfare. Our model suggests a new interpretation of the trade-induced firm productivity effect.

Keywords: Trade Liberalization; Division of Labor; Firm Productivity; Cournot Competition; General Oligopolistic Equilibrium (GOLE)

JEL classification: L16, F12, F16

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1 Introduction

Does trade liberalization increase firm productivity? Wagner (2012) surveys recent seminal papers that present the relationship between trade liberalization and firm productivity. He summarizes recent results from the studies regarding qualitative evidence as follows: "...We can paint a big picture—exporters and importers are more productive than non-exporters and non-importers, and they were more productive in the years before they started to export or import (self-selection); the number of export markets served increases with firm productivity..." By contrast, there are only a few models based on micro-foundations that explain the trade-induced firm productivity effect.[1)]

In this paper, we construct a simplified general oligopolistic equilibrium (GOLE) model that features division of labor to suggest a new model showing the trade-induced firm productivity effect based on a micro-foundation. This model shows that trade liberalization promotes a reduction in the number of firms. Then, the surviving firms acquire additional laborers who were previously employed in the exiting firms, and the increase in employment in each surviving firm promotes a deeper division of labor and increasing firm productivity. Finally, the welfare in each country improves. In addition, our model shows that trade liberalization without labor market integration with trading countries promotes a reduction in the number of firms in each country and a reduced price, because trade liberalization increases firm productivity and the number of foreign rivals.

Division of labor is an important behavior within firms. Using the example of a pin factory, Smith (1776) shows that a deeper division of labor increases firm productivity.[2)]

Later, Stigler (1951) emphasizes the division of labor dilemma as follows. "Either the division of labor is limited by the extent of the market, and, characteristically, industries are monopolized; or industries are characteristically competitive, and the theorem is false or of little significance."

To solve Stigler's (1951) dilemma, Chaney and Ossa (2013) embed the pin factory into Krugman's (1979) monopolistic competition model and show that an increase in market size promotes a deeper division of labor, increasing firm productivity and the number of firms. In their framework, the division of labor level is measured by the (optimal) number of teams on a firm's production chain. In addition, they state that an increase in the market size is interpreted as trade liberalization, similar to Krugman (1979), and sheds light on a new theory of the firm productivity effect that includes the trade-induced firm productivity effects based on micro-foundations.[3)]

However, Chaney and Ossa (2013) analyze the only case of an increase in the number

1) The trade-induced firm productivity effect is often explained by a multi-product firm model, for example, Eckel and Neary (2010) and Bernard et al. (2011). However, our approach differs from theirs.

2) He provides a famous example of the division of labor in the pin factory and states that "one man draws out the wire; another straights it; a third cuts it; a forth points it; a fifth grinds it at the top for receiving the head (...)"

3) Melitz (2003) discusses that trade liberalization increases the productivity at the industry level, but he does not show that trade liberalization increases the productivity at the firm level (i.e., the reallocation effect). Our model cannot speak to this reallocation effect.

of laborers to show the trade-induced firm productivity effects. In other words, they do not consider how trade liberalization affects firm productivity without labor market integration with trading countries. In addition, Stigler (1951) emphasizes the monopoly power of a firm with division of labor rather than the love of variety among consumers. Hence, we believe that a GOLE model is appropriate for analysis of the division of labor.[4)]

The remainder of this paper is structured as follows. Section 2 constructs a basic model and derives wage, total output, optimal number of teams, and the number of firms in equilibrium. In addition, Section 3 shows that trade liberalization promotes a reduction in the number of firms in each country, which is a deeper division of labor, and, hence, firm productivity and welfare is increased. Section 4 concludes. The Appendix replicates the results of Chaney and Ossa (2013) from our model: We explicitly show that an increase in the market size promotes a deeper division of labor and the entry of new firms.

2 Model

In this section, we consider an open economy and develop a simplified GOLE model with the division of labor that follows the formulation by Chaney and Ossa (2013). Our GOLE model is based on Neary (2002, 2009).

2.1 Preferences

We define consumer behavior. The economy has one production sector and produces one good $\tilde{x}$, and the price of the good is denoted as p. The number of consumers are denoted as $L(>0)$, and their utility functions are identical. Consumers solve the following utility maximization problem:[5)]

$$\max_{\tilde{x}} u(\tilde{x}) = \ln \tilde{x}, \tag{1}$$

$$\text{s.t. } p\tilde{x} \leq I. \tag{2}$$

The inverse demand function is derived from Equation (1) as follows:

$$p = \frac{1}{\lambda \tilde{x}}, \tag{3}$$

4) The reallocation effect of Melitz (2003) and Bernard et al. (2003) is not treated in this paper. We focus only on the firm productivity effect of trade liberalization.

5) In our paper, the utility function is defined as the logarithm. Neary's (2002, 2009) utility function is in the quadratic form. However, the economy has one production sector and one good is produced in our setting. Therefore, this difference does not affect our results.

where λ is the marginal utility of income. In addition, we normalize $\lambda = 1$, which is customary in studies using the GOLE approach.[6)]

2.2 Production

Next, we define firm behavior. The home country trades with $m(> 2)$ countries, which are completely symmetric with each other. The production sector contains n firms. The firms compete *à* la Cournot in the sector. The total output in firm $j \in [0, n]$ is denoted by my_j, and the total sector output is denoted by mx: $x = \int_0^n y_j dj$. Wage is denoted as w. The profit of firm j is defined as follows:

$$\pi_j = mpy_j - c(y_j) - wF, \tag{4}$$

where $c(y_j)$ represents the total variable cost of firm j, and $F(> 0)$ represents the fixed entry cost.[7)] In the following discussion, we assume all firms as identical, such that $y_j = y$. Hence, the profit maximizing condition is derived from Equations (3) and (4), as follows:

$$\frac{d\pi}{dy} = \frac{mn - 1}{m^2 n^2 y} - \frac{\partial c(y)}{\partial y} = 0, \tag{5}$$

where $\tilde{x} = mx = mny$.

2.3 Division of Labor

Here, we define production costs. The firm performs a set number of sequenced tasks to produce a final good. We consider an early task in the sequence as the acquisition of raw materials. We assume that the length of the segment is normalized to 2, which is the production chain. If tasks from 0 to $\omega_1 \in [0, 2]$ are performed, an intermediate good ω_1 is obtained. To produce the final good, firms perform tasks $\omega > \omega_1$. Hence, similarly, if the tasks from ω_1 to $\omega_2 \in [\omega_1, 2]$ are performed, intermediate good ω_2 is obtained, and so on. One complete iteration of sequenced tasks is required to produce one unit of the final good[8)].

To produce the final goods, firms organize teams on the production chain and assign them tasks. The number of teams in each firm is denoted as t. Each team acquires a core competence $q \in [0, 2]$ on the production chain, which requires $f > 0$ units of labor before teams perform their tasks. In addition, firms determine the core competence of each team q. The labor requirements of a team that produces a unit of intermediate good ω_2 are

6) See Neary (2002, 2009).

7) In this paper, we only consider the free entry case, and, hence, our model describes a long-run economy. If we do not allow free entry, then, generally, trade liberalization does not affect firm productivity and welfare.

8) The description of the production process is similar to Dixit and Grossman (1982)

expressed as follows:

$$l(\omega_1, \omega_2) = \frac{1}{2} \int_{\omega_1}^{\omega_2} |q - \omega|^{\gamma} d\omega, \tag{6}$$

where $\gamma > 0$. The teams are symmetric, which implies that γ and f are identical across teams. From Equation (6), the firm's total variable cost, c, is derived as follows:

$$c = w\left(tf + tmy \int_0^{\frac{1}{t}} \omega^{\gamma} d\omega\right) \tag{7}$$

$$= w\left(tf + \frac{myt^{-\gamma}}{1+\gamma}\right). \tag{8}$$

From Equation (7), a firm derives the optimal number of teams $\tilde{t}$ that minimizes c given y:

$$\tilde{t} = \left[\frac{\gamma}{\gamma+1}\frac{my}{f}\right]^{\frac{1}{\gamma+1}}. \tag{9}$$

Substituting Equation (9) into Equation (7), the total variable cost under the optimal number of teams, $\tilde{c}$, is derived as follows:

$$\tilde{c} = wm^{\frac{1}{\gamma+1}} y^{\frac{1}{\gamma+1}} f^{\frac{\gamma}{\gamma+1}} \left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}}. \tag{10}$$

We partially differentiate Equation (10) by y and obtain the marginal cost as follows: the following:

$$\frac{\partial \tilde{c}}{\partial y} = \frac{1}{1+\gamma} wm^{\frac{1}{\gamma+1}} y^{\frac{-\gamma}{\gamma+1}} f^{\frac{\gamma}{\gamma+1}} \left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}}. \tag{11}$$

2.4 Equilibrium

From Equations (5) and (11), we obtain the following:

$$y = \left[\frac{mn-1}{m^2n^2} \cdot \frac{\gamma^{\frac{\gamma}{1+\gamma}}(1+\gamma)^{\frac{1}{1+\gamma}}}{wm^{\frac{1}{1+\gamma}} f^{\frac{\gamma}{1+\gamma}}}\right]^{1+\gamma}. \tag{12}$$

The total number of workers is L. Hence, the labor market-clearing condition is derived as follows:

$$L = n\left[m^{\frac{1}{\gamma+1}} y^{\frac{1}{1+\gamma}} f^{\frac{\gamma}{1+\gamma}} \left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}} + F\right]. \tag{13}$$

Therefore, we derive the total output of each firm $Y(= my)$ from Equation (13) as follows:

$$Y = my = \left[\frac{L/n - F}{f^{\frac{\gamma}{1+\gamma}}\left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}}}\right]^{1+\gamma}. \tag{14}$$

In addition, we derive the wage w from Equations (12) and (13) as follows:

$$w = \frac{mn-1}{m^2 n} \cdot \frac{(1+\gamma)}{L - nF}. \tag{15}$$

In addition, using Equations (14) and (15), the total consumption $\tilde{x}$ is obtained as follows:

$$\tilde{x} = nY = \left[\frac{(L - Fn)n^{-\gamma}}{f^{\frac{\gamma}{1+\gamma}}\left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}}}\right]^{1+\gamma}. \tag{16}$$

Next, we consider the case of the economy that allows the free entry condition: firms enter the sector until their profit is zero.

$$\pi_j = 0 \Leftrightarrow mpy - w\left[m^{\frac{1}{\gamma+1}} y^{\frac{1}{\gamma+1}} f^{\frac{\gamma}{\gamma+1}} \left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}}\right] = wF. \tag{17}$$

From Equation (17) and $n(>0)$ we derive the number of firms in equilibrium as follows:

$$n = \frac{-L\gamma + \sqrt{L^2\gamma^2 + \frac{4FL(1+\gamma)}{m}}}{2F} > 0. \tag{18}$$

In the following section, we consider only the case of $n \geq 2$.

3 Welfare and firm productivity

In this section, we analyze the firm productivity effect of trade liberalization. In the following section, we assume that the number of firm, n, is in equilibrium. From Equation (18), we state the following proposition:

Proposition 1. *Trade liberalization reduces the number of firms.*

Proof of proposition 1. *From Equations (18), we immediately derive*

$$\frac{dn}{dm} = -\frac{L(1+\gamma)}{m^2\sqrt{L^2\gamma^2 + \frac{4FL(1+\gamma)}{m}}} < 0. \tag{19}$$

We explain the intuition of Proposition 1. Trade liberalization implies an increase in the number of foreign rivals. Hence, it reduces the profit of home firms, and, hence, reduces the number of firms in the home country.

Moreover, using Proposition 1, we derive the following proposition.

Proposition 2. *Trade liberalization increases firm productivity.*

Proof of proposition 2. *From Equations (10), (14), and (15), we obtain*

$$\tilde{c} = \frac{mn-1}{m^2n^2}(1+\gamma). \tag{20}$$

Next, if we differentiate Equation (20) with respect to n, we obtain

$$\frac{d\tilde{c}}{dm} = \frac{n(-mn+2)}{m^3n^3} + \frac{m}{n^2n^2}\frac{dn}{dm} < 0, \tag{21}$$

where $\frac{dn}{dm} < 0$ from Proposition 1, and $n(-mn+2) < 0$ from $m \geq 2$ and $n \geq 2$.

From Proposition 1, we know that trade liberalization reduces the number of firms in the home country. Then, the surviving firms acquire the laborers who were employed in the exit firms. Therefore, the increase in employment promotes a deeper division of labor, and, hence, firm productivity increases.

Next, we obtain the following proposition:

Proposition 3. *Trade liberalization increases the total output in the sector and improves welfare of all countries.*

Proof of proposition 3. *The total output in the sector is*

$$\tilde{x} = mny = \left[\frac{(L-Fn)n^{-\gamma}}{f^{\frac{\gamma}{1+\gamma}}}\right]^{1+\gamma}. \tag{22}$$

If we differentiate Equation (22) with respect to m, we obtain

$$\frac{d\tilde{x}}{dm} = -\left[\frac{(L-Fn)n^{-\gamma}}{f^{\frac{\gamma}{1+\gamma}}\left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}}}\right]^{\gamma} \cdot \frac{\gamma(L-Fn)+Fn}{n^{1+\gamma}f^{\frac{\gamma}{1+\gamma}}\left(\frac{1+\gamma}{\gamma}\right)^{\frac{\gamma}{1+\gamma}}} \cdot \frac{dn}{dm} > 0, \tag{23}$$

where $\frac{dn}{dm} < 0$ from Proposition 1.

Moreover, if we differentiate u with respect to m, we obtain

$$\frac{du}{dx} \cdot \frac{d\tilde{x}}{dm} > 0, \tag{24}$$

where $\frac{du}{d\tilde{x}} = \frac{1}{\tilde{x}} > 0$.

We explain the intuition of Proposition 3. From Proposition 2, we know that trade liberalization increases firm productivity. Therefore, an increase in firm productivity increases the total output, and, hence, improves welfare.[9)]

Next, we compare the results of our model with those of Chaney and Ossa (2013). We show that our model is able to analyze the effects of trade liberalization without labor market integration among trading countries. By contrast, Chaney and Ossa (2013) only analyze the effects of an increase in market size, and they interpret these effects as a natural example of trade liberalization. However, the effect is similar to the effect of trade liberalization with labor market integration with trading countries. Hence, the interpretation of our results differs from that of their results. The results of the study by Chaney and Ossa (2013) are as follows. An increase in the market size promotes output of each firm, a deeper division of labor, and an increase the profit of each firm. Therefore, an increase in the market size promotes firm entry. However, without labor market integration with trading countries, trade liberalization promotes a reduction in the number of firms, which is revealed in our model.[10)]

4 Conclusion

We construct a simplified general oligopolistic equilibrium model with division of labor and consider the effects of trade liberalization in the absence of labor market integration with trading countries. Our model suggests a new interpretation of the trade-induced productivity effect. The results are summarized as follows. Trade liberalization promotes a reduction in the number of firm. Then, the surviving firms acquire laborers that were employed by the exit firms. Hence, the surviving firms promote a deeper division of labor, which implies increasing productivity in each firm. Therefore, trade liberalization improves welfare in each country.

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9) If marginal cost is constant in our model, which is similar to the "extreme case" of Neary (2002, 2009), trade liberalization does not affect the total output and welfare. See Neary (2002, 2009) for further discussion.

10) Our model can replicate the market size effects of Chaney and Ossa (2013). See Appendix.

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Appendix

The purpose of this section is to replicate the results of Chaney and Ossa (2013). We show that an increase in the market size causes an increase in the number of firms and firm productivity.

First, from Equation (18), we obtain

$$\frac{dn}{dL} = \frac{-\gamma + \sqrt{\gamma^2 + \frac{2F(1+\gamma)}{mL}}}{2F} > 0. \tag{25}$$

Hence, an increase in the market size promotes entry of new firms.

Second, from Equation (20) and (25), we obtain

$$\frac{d\tilde{c}}{dL} = \frac{(1+\gamma)\cdot(-mn+2)}{m^2n^2}\frac{dn^*}{dL} < 0, \tag{26}$$

where $m \geq 2$, $n \geq 2$, and $\frac{dn}{dL} > 0$. Hence, an increase in the market size increases firm productivity. The result (26) is equivalent to Proposition 2 in Chaney and Ossa (2013).