Heterogeneous Firms, Factor Productivity and Trade

Abstract

Melitz (2003) showed that trade liberalization induces intra-industry reallocation and enhances average industry productivity. Our discussion will concentrate on firm productivity under uncertainty. From our view, firm productivity might be rooted at factor uses and institution. Before entry, a firm’s expectation for firm productivity should be close to average factor productivity. In addition, institutional difference might generate uncertainty of factor productivity because factor uses are regulated in institution. The uncertainty of factor productivity can be important issue for the model of firm heterogeneity. Specially, uncertainty of labor productivity might be sharply different across countries due to some inherited attributes. In the work of Melitz, endowment and fixed cost determine the selection effect, which arises from firm dynamics of entry and exit. Our theory predicts that same endowment and same fixed cost can yield different pattern of firm selection due to the uncertainty of factor productivity. Our work sheds light on impact of uncertainty on trade pattern and firm dynamics.

Key Words: Heterogeneous Firm, International Trade, Monopolistic Competition, Uncertainty

JEL Classifications: F12, C73, L13

**I. Introduction**

Melitz (2003) showed that trade liberalization induces intra-industry reallocation from less productive firms to more productive firms. With dynamic firm entry and exit,[[1]](#footnote-1) he derived stationary equilibrium for model of monopolistic competition and heterogeneous firm. Export incurs additional transportation cost. Thus, only sufficiently productive firms can export for competition in foreign countries. Using firm-level data, Bernard, Eaton, Jensen, and Kortum (2003) showed that exporting firms tend to be larger and more competent than non-exporting firms. Firms in industry are not identical. They are different. Since the work of Melitz (2003), the assumption of firm heterogeneity has played a big role in the area of trade theory. Melitz assumed that firm productivity is exogenously distributed for all firms. From our view, the distribution of firm productivity may not be entirely exogenous. Firms make self-adjustment for productivity improvement. In trade theory, the self-adjustment leads to discussion of innovation and technology adoption. There are empirical findings that trade liberalization induces self-adjustments for productivity improvement. Bustos (2011) found that the Mercosur trade liberalization agreement substantially had increased Argentina firms’ spending on technologies. Verhoogen (2008) found a similar result with the data of Mexican firms. Lileeva and Trefler (2010) found that US import tariff-cut had induced product innovations and adoptions of advanced manufacturing technologies for Canadian exporting firms. Using data for Taiwanese firms, Aw, Roberts and Xu (2011) showed that productivity of Taiwanese firms evolves endogenously and is affected mainly by R&D investment and exporting. Differently from the models of heterogeneous firm, Ederington and McCalm (2008) assumed endogenous distribution of firm productivity. That is, all firms are homogenous but they become heterogeneous after adopting different technology. The model of endogenous technology adoption is complementary to the model of self-selection. They showed that trade positively impact the speed of technology diffusion. Costantini and Melitz (2008) emphasized that firms improve own productivity through self-adjustment to market openness. In their work, innovation is assumed to succeed stochastically and to make possible one-time improvement in productivity. In the current research, we are going to reconsider the model of Melitz (2003) in which firm productivity follows the random distribution and the firms do not recognize the level of own productivity. They can observe it only after entry. The point of our question is on that the firms might be able to expect the level of own productivity using available information. The best indicators are factor productivity and institutional character. How does factor productivity affect the distribution of firm productivity? Suppose that a firm wants to enter the industry in one country. Before entry, the firm’ expectation for own firm productivity should be close to average factor productivity: combination of capital productivity and labor productivity. Factor productivity might be random and exogenously distributed. However, variance of factor productivity can be different across industries or countries. For example, suppose that labor uses one unit of capital. Then marginal product of capital depends on the labor using the capital. The labor has incentive to hide own action. A labor-union led strike stops the work of capital, and let marginal product of capital be zero. Uncertainty of labor productivity can be generated depending on country. Similarly, uncertainty of capital can be generated. However, distribution of capital productivity is less volatile than distribution of labor productivity. Uncertainty of factor productivity can affect uncertainty of firm productivity. From the perspective of a foreign investor, firm productivity can be expected as low if labor-unions lead strike frequently in the country. In the model of Ricardo, marginal product of labor determines comparative advantage across two countries. Melitz (2003) highlighted selection effect such that more productive firms export and less productive firms exit. From our view, comparative advantage and the selection effect can be reconsidered as uncertainty of factor productivity places effect on firm decision. According to the theory of Melitz (2003), identical endowment and fixed cost between two countries yield identical mass of firms in the two countries. However, our theory predicts that a mass of firms can be differently realized in the countries despite same endowment and fixed cost. This is mainly because distributions of factor productivity are different. For example, given same average of factor productivity, different variances would lead to different pattern of entry and exit. Uncertainty of factor productivity might be generated from various sources. Culture, institution, and organization can be picked as leading sources. Cunat and Melitz (2012) insisted that institutional difference yields comparative advantage. For example, firms prefer flexible labor market to rigid one. Flexibility can be a determinant of firm entries. Extending the idea, the flexibility can be regarded as reducing uncertainty of labor productivity. Caliendo and Rossi-Hansberg (2012) emphasized organization of firm as a determinant of firm productivity, and analyzed the impact of international trade on organization. Simply, exporting firms can renew own organization by increasing the layer of management. Organizational analysis is beyond the scope of our paper. Thus focus of our argument will be on factor productivity and its uncertainty, which occurs differently across countries. We will show that differences in the uncertainty yield asymmetric results across countries although factor endowments are identical. As far as we know, how uncertainty of factor productivity affects the dynamics of heterogeneous-firm model has not been discussed yet in the area of international trade. It is strikingly simple to show the affection by augmenting Melitz’s model. In his seminal work, uncertainty of firm productivity was not taken into account. If productivity for both labor and capital statistically generates variance, firm productivity is to have variance, which represents a degree of uncertainty. Our mission is to incorporate uncertainty of firm productivity and insurance into the model of Melitz. As a result, firm selection would occur with not only firm productivity but uncertainty (variance). Trade liberalization induces firm selection due to increase in the fixed cost. One major finding is that presence of productivity uncertainty makes the selection effect more drastic due to cost of insurance. The intuition is simple. Firms respond to the presence of uncertainty. We assume that factor productivity is not interrelated between labor and capital. Strategic interaction between firms can make the result more interesting. Incorporating strategic interaction, Neary (2010) established a new concept of equilibrium, being referred as general ‘Oligopolistic’ equilibrium. However, we rule out possibility of strategic interaction. The rest of our paper will be constituted of as follows. In chapter II, the benchmarked model will be introduced and be extended to analyze the effect of productivity uncertainty. In chapter III and IV, equilibrium of closed and open economy will be found, respectively. Chapter V shows that differences of productivity uncertainty yield asymmetric results. Chapter VI concludes.

**II. Benchmarked Model and Extension**

We benchmark the model of Melitz (2003), which incorporates firm heterogeneity into the model of monopolistic competition. In his model, firm productivity determines firm profit. A firm of higher productivity can sell its product at lower price. We extend the model of Melitz by encompassing productivity uncertainty. Productivity uncertainty influences firm entries to an industry.

1. Preference

Preference is same as in Melitz (2003). A consumer’s preference is defined over consumed goods, which are produced in numerable sectors : , where .

Within each sector , a continuum of horizontally differentiated varieties is available for consumption. The preference takes Constant Elasticity of Substitution (CES) (Dixit and Stiglitz (1977)) as follows.

, , . (2-1)

Then the utility is a function of varieties. Substituting demanded quantities into the utility function yields relative weight of expenditure on the product, where the weight depends on quality. By denoting as income, the Cobb-Douglas utility function implies that the consumer spends on the varieties of sector . Within sector , demand for each variety is obtained as follows.

, where . (2-2)

,

where , the price index, is defined as .

Since all firms within a continuum are under perfect competition, each firm takes as given; no firm can affect .

2. Technology and Insurance

In Melitz (2003), only labor was factor. For our discussion, capital is included as a factor as well. Without productivity uncertainty, inclusion of capital does not yield a result substantially different from that of Melitz. However, when uncertainty occurs for factor productivity, interactive terms is generated across the factors, labor and capital. For simplicity, we assume that factor prices are equal across countries. Various kinds of composite factors can be imagined. Labor can be either skillful or unskillful. Similarly, capital can be either physical or financial. We will focus on the interactive terms across different factors, generate uncertainty. Thus composite factors are not considered. There are two types of costs such as variable and fixed cost. Fixed cost is generated for both factors before production. Formally, the fixed costs[[2]](#footnote-2) of and are incurred when a firm enters a sector , where input supplies are given and for labor and capital, respectively. The supply is determined endogenously in a multi-sector setting. Across all sectors, sum of input supplies should be equal as endowments, (labor) and (capital) in the country. Within the sector, all firms supply a horizontally differentiated variety. Each variety is assumed to be produced using fixed proportion of both factors. Then producing each variety generates fixed cost, and variable cost, . The variable cost increases proportionally in quantity, and decreases in firm productivity, which is a function of (labor productivity) and (capital productivity). Random variables, and are defined in that , , , and . Because production uses fixed proportion of factors, factor productivity works in combination as . Prior to entry, firms do not observe the realization of the combined value. They know the distribution: mean and variance. Consider a production function, . The parameters and represent how the production requires factors. For expositional simplicity, we assume that . The technology is assumed to exhibit constant return to scale; . In extending the model of Melitz, it becomes that input costs for units of a variety are obtained as follows.

Labor: . (2-3)

Capital: . (2-4)

Uncertainty of factor productivity induces firms to demand coverage of insurance. In other words, firms want to avert the risk of poor levels of factor productivity. For general equilibrium, an insurer earns zero profit from selling insurance coverage because the market is perfectly competitive. Overall, total premium of insurance is denoted as for sector . Then there are two conditions for a general equilibrium such that

Condition of product market, , and (2-5)

Condition of insurance market, . (2-6)

In general equilibrium, premium payments should be equal as total charges to factor suppliers. All workers and capitals are evenly charged and repaid to the employers, who buy coverage of insurance. It can be said that a part of total production is depreciated due to productivity uncertainty.

3. Firm Behavior

Our argument focuses on equilibrium in a given sector and drop subscript for convenience. Under monopolistic competition, each firm can find an optimal price, which maximizes profit subject to the given sectoral demand. Constant elasticity is where . From first-order condition for profit maximization, equilibrium price for each variety can be found as a variable mark-up over the marginal cost, :

, . (2-7)

Again, firm productivity is inherited from all production factors like labor, capital and so on. For example, suppose that one labor works with one unit of capital. In hiring the worker, productivity occurs from combination of labor and capital. Firm productivity occurs from all the hired labor and capital. It is possible that factor productivity is different across countries. In one country, higher productivity of one factor relative to another can determine comparative advantage of the industry. However, a firm never recognizes factor productivity before hiring the factors. Only distribution is known for and . Then, the firm’s profit at equilibrium is

, (2-8)

where is payment of premium. Using (2-7), the profit function can be rewritten as

,

,

, where

. (2-9)

By setting , (2-9) becomes as follows.

, where . (2-10)

Since , .

As similar as in Melitz (2003), output and revenue ratios for any two firms can be derived as follows.

, .

The ratios depend only on the ratio of different levels of firm productivity, combination of and .

**III. Equilibrium in Closed Economy**

1. A Mass of Firms and Aggregation

There are a mass of firms (hence products) in any given sector of the country. Unlike the work of Melitz (2003), is a function of labor productivity and capital productivity. If either or has large variance in a sector, risk-averse firms would reconsider entry to the sector because of the possibility of poor productivity. Melitz considered firm productivity as exogenously distributed. From our view, there two attributes to firm productivity such as factor and institution. Factor might be a main determinant of firm productivity while institution provides incentive for factors to self-improve. That is, factors determine exogenous distribution of firm productivity while institution endogenizes the exogenous distribution. However, we do not consider the role of institution for our discussion. Firms do not have information about the level of own productivity, and they expect the level prior to entry. Risk-neutral firms concern about only average but risk-averse firms concern about variance as well. Thus variance of random distribution is to affect firm decision. In the sector, firms have same information. When probability densities are and for labor productivity and capital productivity, the Melitz’s aggregate price can be extended as

. (3-1)

The aggregate price is a function of mass of firms and price . Since two variables and are independent each other, is a function of averages and as follows.

. (3-2)

, where ,

and .

Expectation for mass of firms is equal as a mass of firms at the averages of and .

, (3-3)

where and .

By using the definition, aggregate quantity can be written as follows.

 , (3-4)

Then, .

Then, ,

,

Thus, .

That is, all values of industry level are function of the averages of factor productivity: labor and capital.

2. Firm Entry and Exit

As stated before, firms draw own productivity, determined by factors and institution. Since the factors are used in fixed proportion, variability of firm productivity should occur in two directions. Because the distributions of and are independent each other, fixed proportion implies that production requires not only minimum demands of labor and capital but also minimum levels of factor productivity. Otherwise, production remains at zero. The minimum levels for labor productivity and capital productivity are denoted as and , respectively. When a firm starts producing, probability of successful production is conditional upon that and coincidentally exceed the minimum levels, and . Thus the conditional probability is as follows.

 if , and . (3-5)

Otherwise, .

 is the cumulative probability that is less than , while the cumulative productivity that is less than . Thus the probability that is greater than is while the probability that is greater than is . Ex-ante probability of successful entry is . For producing firms, levels of aggregate factor productivity should be as follows.

, (3-6)

. (3-7)

3. Zero Cutoff Profit condition

For a producing firm, average revenue and profit are determined by the cutoff levels and . At the levels of and , a firm’s profit should be zero given that entry and exit are perfectly free. If either factor’s productivity is lower than the cutoff level, the firm should exit. The firm can have a positive profit only if own labor productivity and factor productivity are simultaneously greater than and , respectively. Let denote firm revenue, which is at the cutoff levels and . Then firm profit at the levels is obtained as below.

 . (3-8)

The profit should be zero at the equilibrium: . Using the ratio, , average revenue is equivalent as the revenue at average productivity, and .

Consider the ratio, . Then, .

, where .

.

4. Free Entry and the Value of Firms

From above, averaged profit of incumbent firms is positive. The present value of average profit can be represented as follows.

, where is a discount factor of time.

Remind that ex-ante probability of successful entry is . Suppose that a firm is about to enter the industry for producing a variety. Then the net value of entry should be defined as follows.

, where is an investment cost.

In sense of general equilibrium, the firm faces two conditions as follows. First, the firm should make zero profit at the cutoff levels of productivity, and . Second, the net value of entry should be zero. Otherwise, no stationary equilibrium exists. The following conditions should be held.

1) (3-9)

2) (3-10)

That the two conditions are held implies the existence of stationary equilibrium. In the equilibrium, aggregate variables can be found. In every period, a mass of firms attempt to enter the sector. Among those firms, only a mass can succeed and substitute the mass of incumbents who exit due to a bad shock. That is, . Within the sector, the available resources are and . Let subscript and denote firm production and firm pre-investment for entry. Then production uses and while pre-investment uses and , where and . Total payments, for production are equal as . This is the factor-market clearing condition for production. Another factor-market clearing condition for pre-investment is that . Using the clearing condition, we can find that .

Then aggregate revenue can be found as follows.

. (3-11)

The clearing condition for insurance market is that . That is, the risks can be covered at the expenses of factor owners. They take responsibility for the risks (i.e. poor productivity) that they generate. , when the clearing condition holds.

From and , a mass of firms can be obtained as .

From the zero profit condition,

, where . (3-12)

Then . Thus .

Remind that . Then , where .

As stated already, is a function of random variables such as and . Thus it can be expected as follows.

 (3-13)

where .

Expected contains and . As variance increases, decreases. Implicatively, decreases too. Differently from the work of Melitz, we show that a firm of mass is determined by uncertainty, which occurs from factor uses.

**IV. Equilibrium in Open Economy**

In an open economy, export price is shifted as much as trade cost, including transportation cost and tariff. For the case of open economy, our discussion proceeds similarly as in the case of closed economy. Melitz (2003) expressed export price as a result from increase in marginal cost. Let d and x denote ‘domestic’ and ‘export’, respectively. Then export price can be represented as when domestic price is . From domestic market, firm revenue is obtained as below.

. (4-1)

From foreign market, firm revenue is obtained as follows.

. (4-2)

From both domestic and foreign markets, firm revenue is obtained as follows.

. (4-3)

1. Firm Entry, Exit, and Export

In open economy, the fixed cost increases from to when firm exports. That is, export incurs a cost. Simply, reduction of the cost makes possible that the firm stands in advantage to compete for price. Higher productivity can yield the cost reduction. Let and denote average labor productivity for exporting firm and average capital productivity for exporting firm, respectively. Then the revenue ratio becomes as follows.

. (4-4)

From equation (4-4), we see that the term, , can be written using the term, , and the ratio of fixed costs. It shows that due to selection effect average factor productivity of exporting firms should be greater than that of non-exporting firms. Exporting firm’s profit can be obtained as follows.

, (4-5)

where .

Using (4-4), (4-5) becomes the following.

 . (4-6)

Using the equality, , (4-6) can be rewritten as follows.

. (4-7)

(4-7) actually becomes zero according to the zero profit condition.

. (4-8)

Thus .

2. Aggregation

In the work of Meltiz (2003), one point is that average industry productivity is enhanced as economy is open. Average industry productivity is an aggregation as follows.

. (4-9)

indicates the number of foreign countries to which firms of the country can export. In a two-country model, should be 1. By aggregation, price, quantity, and revenue can be obtained as follows.

, , and .

, ,

3. Equilibrium Conditions

From the zero profit conditions, the following equation holds.

. (4-10)

After opening the economy, average firm profit becomes

. (4-11)

(4-11) can be simplified as follows.

. (4-12)

In a similar fashion, average firm revenue is obtained as below.

, where , and .

It should be simplified as .

Obviously, average firm revenue increases from to when firms export. Due to increase of average firm revenue, more firms would be willing to enter the industry. Thus a mass of firms increases from to . Like , contains random factor , reflecting uncertainty of factor productivity, but main determinants are fixed cost and resource endowment. can be expected as follows.

 , (4-13)

.

(4-13) implies two. First, in consistency with the work of Melitz, exporting firms are selected because export increases the fixed cost. Second, size of the selection depends on degree of uncertainty from factors. The selection itself reduces the uncertainty of factors. Then it can generate a similar effect as reduction of the fixed cost. The increase of fixed cost can be offset by less uncertainty. According to (4-13), the mass of firms export and only the mass can survive from bad shock. Thus, total mass of firm increases from to after the economy is open. In one country, there exists an equilibrium mass of firms for the given sector before the economy is open. As it is open, firms of higher productivity can export to foreign countries. Only those firms can afford higher cost, which is comprised of the fixed cost and transportation cost. Open economy is chance for firms of higher productivity. Average industry productivity should be enhanced. However, uncertainty of factor productivity represses entries of risk-averse firms. Without openness, equilibrium mass of firms is definitely less due to the uncertainty of factor productivity in our model than in Melitz’s model. However, with openness, change in the equilibrium mass is ambiguous because uncertainty of factor productivity is reduced. The reduction of uncertainty offsets the increase in fixed cost. Thus the equilibrium mass of firms is greater than that of Melitz. In the next chapter, our discussion will focus on asymmetric countries. Asymmetry occurs in not resource endowment but degree of productivity uncertainty.

**V. Asymmetry: Difference of Uncertainty**

Between the two countries, the asymmetric uncertainty of productivity leaves an effect on the mass of firms. That is, although two countries have same endowment of resources, a different equilibrium mass of firms is possible because of the different uncertainty of productivity. The country of greater uncertainty would attract a less mass of firms than another country of smaller uncertainty, regardless of whether the economy is closed or open. We can compare the masses of firms for both cases in turn.

1. Closed Economy

Suppose two countries, which are endowed same resources but different degrees of productivity uncertainty. For example, union-led strikes are assumed to occur more frequently in one country (Country 1) than another country (Country 2). Here, we do not discuss reasons why strikes happen. According to the assumption, firms encounter the greater uncertainty of labor productivity in Country 1: Country 1 has the larger variance, relative to in Country 2. Then masses, and , can be calculated as follows.

, (5-1)

.

. (5-2)

.

In short, when .

If uncertainty differently occurs for production factors, a mass of firms will depend on combination of variances as follows. Since production requires fixed proportion of the factors, the combination of variances represents total uncertainty of firm productivity in the industry of each country. Equality or inequalities between and are briefly summarized as follows.

 if .

 if

 if

2. Open Economy

In open economy, pattern of a mass of firms is actually similar as that in closed economy. Overall, the mass of firms in open economy should be retracted due to competition effect. As similarly as in the preceding chapter, the masses, and , can be expected as follows.

. (5-3)

. (5-4)

 if Country 1 faces the greater uncertainty of productivity. In note, the fixed cost of exporting determines the mass of firms. If the fixed cost of exporting occurs to Country 1 more largely than to Country 2, difference of the fixed costs can offset the difference of uncertainty between the two countries. That is, ‘fixed-cost’ effect dominates ‘productivity-uncertainty’ effect. In case that one country faces the less uncertainty of productivity, the larger fixed cost can cause less mass of firms in the county. Although endowments are equal in both countries, distributional differences of factor productivity can affect firm decisions for entry. Greater uncertainty of factor productivity raises issue of risk-aversion, which demands coverage of insurance, additional cost. The additional cost obstructs potential entries. denotes equilibrium mass of firms for only domestic market while mass of exporting firms. denotes total mass of firms. Implicatively, varieties of are available to consumers in the country. Thus the consumers can enjoy more varieties under openness of the country. As previously stated, mass of exporting firms depend on combination of variances. Equality or inequalities between and are derived as follows.

 if .

 if

 if

Besides the equality, the inequalities have further implications as below.

 , then

 , then

In summary, we can derive the following inequalities from the combination of variances.

If ,

If ,

The linear combination of variances determines exact mass of total firms for the industry in the country. From perspective of the consumers, the welfare improves because of more varieties available in their market. They enjoy more varieties in the country.

**VI. Conclusion**

Trade liberalization can enhance average industry productivity. Melitz found the theoretic model to derive general equilibrium: number of firms and average firm productivity. Simply, trade intensifies competition, and the competition lifts up average firm productivity. Thus average industry productivity is enhanced. Differently from the previous articles, our arguing focus has been on firm productivity and its uncertainty. Melitz did not take into account uncertainty of firm productivity. From our insight, firm productivity results from factor uses and institution. Factor productivity might be different across countries. Moreover, uncertainty of factor productivity might be drastically different across countries. Then risk-averse firms are unwilling to enter the industry of the country, which faces greater uncertainty of firm productivity. Uncertainty of firm productivity obstructs firm entry. Despite same endowment of resources, different degree of uncertainty can lead to different pattern of entry. Our result provides important policy implication. Since uncertainty of factor productivity deters firm entry, the government as policy-maker should consider how to reduce the uncertainty for firm entries. The consideration should be extended to all policies and regulations relating to factor supplies.

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1. The concept of firm dynamics was adopted from the work of Hopenhayn (1992). [↑](#footnote-ref-1)
2. Subscripts L and K denote labor and capital, respectively. [↑](#footnote-ref-2)