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PANEL DATA ANALYSIS OF SOURCES OF PRODUCTIVITY GROWTH IN KOREAN MANUFACTURING PLANTS

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ABSTRACT

The importance of acquiring and diffusing technological knowledge became clear in South Korea immediately following the Asian monetary crisis in 1997. This is reflected in the micro data, where the absolute number and the ratio of firms that invested in Research and Development (R&D) have increased dramatically in many industries.

Chapter 1 will examine the nature and process of technology upgrading among South Korea firms and the underlying productivity dynamics that is implied using micro panel data from the Census of Manufacture in South Korea between 1991 and 1999. In this chapter, we will see important aspects of firm behavior on improving productivity. The empirical models are reduced form specifications of theoretical models. We first estimate firms' discrete decisions to export and invest in R&D, two important activities that are believed to lead to higher firm productivity. We then estimate how participation in these activities feeds back into a plant's future productivity trajectory using a standard Heckman selection model that accounts for the endogenous nature of a firm's decision to exit the industry.

Our results indicate that productivity plays an important role in determining a firm's R&D decision and exporting. In addition, past experiences in exporting and/or investment in R&D increase the likelihood that a firm currently export and/or invest in R&D. These results imply the existence of sunk entry cost in export markets and the continuity of R&D investment. Since R&D investment takes some times to be realized as a useful input, firms that invest in R&D currently are more likely to continue their

investment in the next period. Firms that either export or invest in R&D have significantly high productivity. Furthermore, firms that export and invest in R&D simultaneously have significantly higher productivity than firms that participate in one of investment activities. These findings are consistent with the hypothesis of compounding effects of two types of investments, export and R&D.

Chapter 2 investigates how location proximity among firms influences a firm's productivity. Knowledge spillovers have been recognized as an important source of innovation and economic growth in both industry-level and firm-level data. A firm may reap benefits by locating near other firms in the same geographical region. In this Chapter, we take a look at how physical proximity helps a firm to increase its future productivity and its survival possibility in the market. We estimate five different specifications of the theoretical model. The predictions of the theoretical model are confirmed by the estimated parameters in our empirical model. Our results indicate that a firm located in a region with a high median Total Factor Productivity (TFP) gains productivity from other firms that locate in the same region. One possible explanation is that such a firm has the opportunity to access superior external knowledge and to produce more new ideas. Our results also indicate these the productivity enhancing characteristics do not seem to be industry-specific. Finally, we find that high productivity firms are the only significant sources of knowledge spillovers, suggesting that firms benefit most from combining their internal knowledge with the external knowledge of neighboring firms with high TFP on average.

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Chapter 1

Investment in R&D and Firms-level Productivity Growth and Survival

1.1 Introduction

Over the past three decades the countries in East Asia have achieved high and sustained rates of economic growth, a phenomenon that many believed stem from unusually high rates of saving and capital accumulation. Understanding the source of this growth has been the goal of many economists interested in applying the “East Asian Model” to other developing countries. Many of these countries that have small-sized domestic market such as South Korea have participated actively in the export market. Before 1980 most of these exports comprises of light-industry products such as footwear, and apparel. After the mid-1980s, however, the composition of exports changed to focus on heavy industry products such as semiconductor, computer and automobile products which use of sophisticated technologies.[1]

In the 1950s, Korea’s per capita GNP was less than $600 (in 1988 dollar prices). With the energetic execution of export-oriented growth strategy since the early of 1960s, however, annual commodity exports expanded from less than $30 million in the 1950s to $60 billion in the end of 1980s. The growth rate of the Korean economy jumped from about 4 percent per annum on average in 1953-1961 to about 9 percent in 1967-1988.

[1] The amount of export of light industry products has been decreased. The ratio was 48% in 1980, 40% in 1990, and 18% in 2000. On the contrary, that of heavy industry produce has been increased since 1980. They were 12.8%, 54%, and 74% in each year. (Source : Korea Customs Service)

Case studies of Asian economic miracle indicate that the source of much of the new technology came from foreign buyers of their exports[2]. This is especially true in the case of Korean exporters. Rhee, Ross-Larson, and Pursell (1984) find that foreign customers often share their knowledge about new and improved technology with their Korean suppliers, suggesting that the export orientation of Korea may be an important factor in their productivity growth because contacts with foreign customers give domestic producers access to product design specifics and processing technology that they would not otherwise have[3]. However there is only very weak and inconclusive econometric evidence at the firm-level of any such learning-by-exporting. Many of these studies conclude that the observed higher productivity of exporters can be better explained by the self-selection of more efficient firms into the export market.

One of the key variables omitted in the studies to date focusing on the robust positive relationship between export and productivity is the resources expended by the firm to absorb the new technology. According to researchers who have closely analyzed the technology development process in developing countries, the ones that are most effective in assimilating the new foreign technology are the ones who have invested in their in-house technological capability. It is believed a firm's investments in R&D improve a firm's ability to develop new technologies of its own as well as to absorb and adapt new technologies from external sources.

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[2] Young (1995) well compares historical patterns of output growth, and productivity growth in the newly industrializing countries; Hong Kong, Singapore, South Korea, and Taiwan.

[3] Rhee, Purshell, and Ross-Larson (1984) describe the role of foreign buyers in the development of Korean manufacturing industries as "The relationship between Korea firms and the foreign buyers went far beyond the negotiation and fulfillment of contracts. Almost half of the firms said they had directly benefited from the technical information foreign buyers provided: through visits their plants by engineers or other staff of the foreign buyers, through …, and through feedback on the design, quality and technical performance of their products"

In this paper, we consider an important explanation for a firm's productivity evolution using micro-level data: internal knowledge spillovers captured by a firm's investment in research and development (R&D). In addition we take a firm's export experience as another important factor in explaining its productivity evolution and survival in the market[4]. This chapter examines a model centered on deepening our understanding of the sources of firms' productivity growth by looking at internal knowledge spillover through its R&D investment and export participation[5].

In the model, we first estimate firms' discrete decisions to participate in the export market and make investments in R&D using a multinomial logit model. The reduced form specifications of the empirical model are based on a theoretical model that describes a plant's dynamic decision to export, to invest in R&D, and to exit. Since we are particularly interested in a firm's R&D investments than in the combined activities of export and R&D investment, we pay attention to a firm's R&D investment decision and analyze its decision using Tobit regression model. We then estimate how participation in these activities feeds back into a plant's future productivity trajectory using a standard Heckman selection model that accounts for the endogenous nature of a plant's decision to exit the industry. We use plant-level data from the Census of Manufactures from the South Korea conducted annually from 1991 to 1999 to address these issues.

In the next section, we explain Korean government's policy changes on exporting and R&D investment, and then we review the literature on the theoretical and empirical

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[4] Many of researches emphasized the potential importance of export activity on firm's growth such as Clerides, Lach, and Tybout(1998), and Bernard and Jenson(1999). Based on their findings, I will use a firm's export activity as explanatory variable in the regression equation.
[5] There are some other possible explanations of knowledge spillovers. Research and development (R&D), foreign direct investment (FDI) and export experience are possible sources of knowledge spillovers.

models that incorporates R&D and/or export decisions into the firm's productivity evolution, and survival in the section 3. Section 4 describes the patterns of export participation and R&D investment from the dataset. Section 5 describes the theoretical model on which our empirical work is based. In the sixth section we describe the empirical counterparts of the theoretical model. Finally we summarize and conclude in the seventh section.

1.2. Policies on Export and R&D

South Korea's policy has developed over the past several decades based both on domestic needs and the international environment. The Korean government's industrial policy was instituted in the early 1960s under a new military government. A series of Five Year Economic Development Plans started in 1962. The first five-year-plan aimed at promoting import-substituting industries. Export of labor-intensive, light manufacturing goods were aggressively promoted. This promotion was based on Korea's comparative advantage in industries intensive in the use of its large pool of well-educated, but low-wage labor force. To support those industries, Korean government provided many policy tools such as import restrictions, and financial incentives such as tax-free import of raw materials encouraging the promotion of export goods. As a result, there was a significant decrease in the export of raw materials but manufacturing goods exports rose.

The second five-year-plan of 1967 sought to modernize the industrial structure and continue to develop a foundation of self-sustaining growth. During this period, selected industries such as steel, electronics, and chemicals were promoted by the government. In 1969, the Local Industrial Development Law was passed along with the construction of an industrial complex in eleven local sites. These law and complexes provided many reforms that supported the export-led growth strategy. Under the provision of the law, the government allowed exemptions from income and corporate taxes for industries locating in the designated estates.

In the third five-year-plan (1972 to 1976), the government continued to develop a self-reliant economy and focused on promotion of heavy and chemical industries. Furthermore, the government instituted the General Trading Company in order to promote further exports. In addition, the government promoted assembly industries of final goods such as machinery and electronics. Firms in those industries often depended on reverse engineering as a major source of learning.

In the fourth five-year-plan starting in 1977, there were several major changes in the country's trade policy. Exporters were allowed to cheaply import goods required for the manufacturing of their export goods. In addition, this plan included more loan subsidies, tax benefits, and foreign loans to exporting firms. Those government policies stimulated a tremendous economic growth in support of the export-led growth strategy.

The main objectives of the fifth and sixth five-year-plans (1982 to 1991) were to solve the problems caused by the rapid economic growth that had occurred since 1960s as well as to continue economic growth. Policies that were imposed on firms increased their efficiency and competitiveness of export firms in the world market through reducing the degree of government subsidies, and tax benefits. The plans continue to emphasize the movement away from heavy industries toward export-oriented consumer products, including electronics and high-technology industries. This accomplishment marked the success of the export-led growth strategy. The last five-year-plan (1993 to 1997) sought to strengthen the competitiveness of firms by allowing them to form large and powerful conglomerates. They also allowed Korean products to be sold in the foreign markets rather than being contained in the domestic market.

It is believed that the adoption of the export-led growth strategy boosted by five-year-plans in South Korea is a key factor behind the country's tremendous economic growth in the last three decades. Since the 1980s, the Korean government started to support private R&D investment, which is viewed to be a key ingredient of productivity growth in manufacturing sectors.

R&D activities in the 1960s and 1970s were heavily dependent upon imitation and importation of technologies from the developed countries. In the 1960s, to support first five-year-plan, the major technology strategies involved building up a technological infrastructure. During the 1970s and throughout the 1980s, a number of laws were enacted to establish government research institutes in the fields of machinery, chemicals, electronics, and electricity to expand the national capacity for technology education and to accelerate technology development.

The first explicit R&D promotion policy in Korea is contained in the Technology Development Promotion Law of 1972. This law contains provisions for financial and tax incentives to encourage and facilitate technology development activities of private enterprises. In the 1980s, policy was geared toward structural adjustment by continuing to expand technology-intensive industries and improving the productivity of firms in the manufacturing sector. The 1981 amendment of the Technology Development Promotion Law facilitated various policy tools to promote private R&D. The government introduced the Industrial Research Association system that spurred the formations of R&D consortia.

Between 1982 and 1997, 190 R&D consortia existed in Korea. Compared to the previous R&D policies, the new policy was geared toward both direct and indirect promotion of technology-intensive industries in their R&D stages. The direct promotion included subsidies for research expenses, exemptions of tariffs, reduction of taxes up to 10% of R&D allotments, and priority purchase of products from cooperative development. The indirect promotion policy included provisions of low-interest loans through the banking sector, promotion of exchange and cooperation among R&D personnel, and promotion of cooperative utilization of R&D facilities and information. In the 1990s, the Korean government has recognized hard realities and has placed a special emphasis on strengthening its scientific and technological capacity based on international standards. A series of R&D policies geared toward concentrating technological capability have played a crucial role in developing scientific creativeness and in building a strong foundation for sustaining economic development. The electronics and machinery industries accounted for 55% of Korean R&D expenditures, which indicates that the Korean government concentrated its efforts to promote R&D in those industries. However, given the short history of R&D, Korean firms have not developed cutting-edge R&D capabilities, concentrating more on applied technology.

1.3. Literature review

In this section, we will review theoretical and empirical studies that have examined the sources of productivity growth. First, we consider the relationship between exports and firm growth before switching the focus to the role of R&D investments in explaining firm growth.

During the 1970s, many developing countries that pursued import-substituting trade policy shifted towards a greater emphasis of the export promotion strategy. Krugman (1986) and Krueger (1998) refer to the success stories of Asian countries, notably South Korea, Taiwan and Hong Kong, who experienced massive increase in exports following their drive towards outward orientation.

This focus on exports led many researchers interested in firm growth to examine the role of export activity. Many studies investigated the causality between a firm's productivity growth and export market participation. There are two main mechanisms that explain the causality between productivity and exporting. The first mechanism is referred as the self-selection hypothesis whereby only the most productive firms are able to survive in highly competitive export market. Hence, only high productivity firms will find it profitable to enter the export market. The second mechanism is the so called learning-by-exporting hypothesis. By participating in the export markets, a firm gains more productivity growth than non-exporters. Exporting firms learn from their export activity and are able to apply this knowledge to their sales in the domestic market.

Numerous firm-level studies have confirmed that exporters are generally more productive than non-exporters. Furthermore, many researchers, in their attempt to establish the direction of causality in the correlation between exporting and productivity, have found that the self-selection of more efficient plants into the export market explains much of this correlation. If entry into export market is characterized by sunk costs, only firms with high productivity have the capability of entering the more competitive export market. Therefore, better-performing firms in an industry are more likely to be exporters. Therefore, better-performing firms in an industry are more likely to be exporters.

Bernard and Wagner (1997) examine the relationship between productivity and exporting experience using German manufacturing plants from 1978 to 1992. They find that exporters have significantly lower wage growth, productivity growth, and growth in sales and sales per worker in the subsequent period than non-exporters, despite the fact that only the more productive firms tend to export. Clerides, Lach, and Tybout (1998) study export-led productivity growth using a panel dataset of manufacturers in Colombia, Mexico, and Morocco. By using average variable cost and labor productivity as performance indicators, they examine the effect of a firm's exporting history (exports in year *t*-1, *t*-2, and *t*-3) on future cost reduction. They find that low cost firms are more likely to enter the export market and that recent exporting experience makes a firm more likely to continue exporting. They confirm that exporting firms are more efficient than non-exporting firms, but they find little evidence of learning from exporting. Using a panel dataset of U.S. manufacturing firms, Bernard and Jensen (1999) examine the differences of productivity growth before and after entry into export markets and estimate the effect of exporting on firm's performance measured in terms of employment growth and labor productivity growth. Their findings suggest that exporting is associated with a higher subsequent growth rate of employment and sales, but not of subsequent productivity growth.

One common method applied in all the above studies is to compare the performance of mutually exclusive groups, such as exporters and non-exporters. The problem under this setup is that not all exporters have the same level of engagement in export markets. That is while some firms devote considerable resources to their export activities, others are only marginally involved in exporting, with little potential scope for learning. If learning is subject to sharply diminishing returns, successfully established exporters are unlikely to learn from exporting. Therefore, their presence in the group of exporters is also likely to generate a downward bias in the effect of learning-by-exporting.

A recent study that arrived at a different conclusion from above is by Aw, Chung, and Roberts (2000). They look at the performance of exporters in Korea and Taiwan. They find evidence consistent with the learning-by-exporting hypothesis in a few selected industries in Taiwan such as textiles, electronics and plastics. However, in Korea, they find no effect at all of exporting on productivity gain. Because the study uses data between late 1980s and early 1990s, a time by which both Taiwan and Korea had already developed successful export-oriented technology industries, it is possible that the major benefits of exporting had already been realized in prior decades. Another reason for the different results in each country may be related to the different market structure. While Taiwan facilitated many small and medium size firms, Korean government encouraged an industrial structure based on large firms and concentrated market power. Those successfully established firms in Korea compared to those in Taiwan are less likely to learn from exporting.

The literature reviewed omits a potentially important element of the process of technical change, namely, the effort expended by plants to absorb, assimilate, and manage technical change. Research and Development (R&D) by firms has been regarded as a major source of a firm's growth in many macro or micro-based models for a long time[6]. There are several reasons that a firm undertakes costly R&D investment. A firm may wish to

[6] The relationship between R&D expenditure and productivity growth at industry and firm level is documented in a compilation of paper by Griliches (1998). The bulk of papers estimated a standard production function with a measure of a firm's stock of knowledge and interpreted the coefficient on this stock as the returns to knowledge.

generate new ideas that help to produce new goods in order to enjoy monopolistic profit. Hence, today's R&D expenditure can be compensated from monopolistic margin in the future. Another reason for R&D expenditure by the firm is the cost advantage over other competing firms or other potential entrants. That is, the firm may wish to reduce its production cost per unit of output or marginal cost. By investing in R&D today, a firm can reduce its future production cost and hence increase its future profit margin. A monopolist that enjoys high profit margin is also willing to invest in R&D to achieve more profits in the future.[7]

Theoretical models of R&D investment such as Schumpeter (1947) argue that large firms in concentrated markets are more likely to support innovation, so called the "Schumpeterian Hypothesis". There is a qualitative difference between technological innovation at smaller companies and those at larger companies. The Schumpeterian Hypothesis has been interpreted as meaning that larger companies will be disproportionately active in technological innovation compared to their size, and that this will be more the case the more concentrated and monopolistic the market becomes. He points out that the pace of innovation is related to market structure. Market structure and innovation are simultaneously shaped by underlying market characteristics such as innovative opportunities. Schumpeter stresses the importance of large established firms that can institutionalize the innovation process with the creation of R&D laboratories filled with

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[7] This is consistent with the model in Ericson and Pakes (1995) that shows investment will vary with the level of firm productivity. They define two different thresholds that give rise to three different investment behaviors. A firm with below lower threshold will not find it profitable to invest and a firm with above upper threshold also will not invest because this limit reflects investment increases the probability of moving to higher future productivity levels, so that the return to additional investment will be low for high productivity firms. Hence, only firms whose productivities are between these thresholds will have incentive to improve their productivity through R&D activity.

researchers, technicians, and engineers. In this view, a larger firm may have scale advantages in the R&D process and a larger firm may be able to support a larger portfolio of R&D efforts, increasing the likelihood that it will develop an improved product or process[8]. Schumpeter underlines the key role of monopoly power in bringing about innovation.

Dasgupta and Stiglitz (1980) address the effects of government policy on R&D subsidies, market concentration, and firm size. The paper provides an analytical framework relating market structure to the nature of inventive activity[9], exploring the relationship between the degree of concentration and the nature of innovative activity. The idea of their paper is that there is a positive association between concentration and innovation provided that the degree of concentration is not too high and that barriers to entry are not too strong. When entry is small, in concentrated industries there may be an insufficient incentive to undertake R&D expenditure.

The above theories have stimulated many empirical works[10]. Levin and Reiss (1984) test the Schumpeterian hypothesis regarding the effects of firm size and intensity of rivalry on the pace of R&D investment within a static framework. They show R&D and concentration in simultaneous equation model controlling for technical opportunity condition using survey data. They find that R&D intensity is inversely related to market concentration.

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[8] However, Arrow (1962) shows that a competitor can profit more than a monopolist from innovation. He concludes that the incentive to invest is smaller under monopolistic than under competitive environment.

[10] Mairesse and Sassenou (1991) have extensively reviewed research investigating the relationship between R&D investment and productivity at firm level.

Pakes and Griliches (1984) study the relationship between R&D and patents, using a short time period from 1968 to 1975 for a large number of firms in the U.S. They find a strong and positive relationship between R&D and the number of patents at the firm level at the cross-section level. More precisely, if the firm has made a success of its R&D investment by being more innovative, higher overall productivity should be expected. Consequently, the interaction of R&D and innovation is likely to have a positive effect on productivity. Since outputs of innovation activity are not directly observable, they use the counts of patents assigned to firms as a proxy for knowledge capital. One problem of Pakes and Griliches's knowledge production function is that R&D expenditures are treated as endogenous. This assumption allows no causal relation between factors like innovative success, productivity and R&D investment.

The majority of empirical studies addressing the direct effect of R&D on productivity are based on Cobb-Douglas production functions[11]. Griliches (1980) address the issue of whether the slowdown in productivity growth in the U.S. can be explained by the slowdown in the growth of real R&D expenditure using a panel of 3-digit manufacturing industry data from 1959 to 1977. He finds that the estimate of the R&D coefficient is sensitive to the time period under study; for the period 1959 to 1968, he finds a positive and significant coefficient of 0.07 while he finds that the coefficient is close to zero for the period from 1969 to 1977. Mansfield (1988) compares the effects of industrial R&D and productivity growth between Japan and the United States using a cross-section of industries averaging the data for the period 1960 to 1979 for Japan and for the period 1948 to 1966 for the United States. He finds a high positive coefficient for applied R&D in Japan

[11] Nadri (1993) is an excellent review of this literature.

but a negative and statistically insignificant coefficient for basic research. In the United States, the coefficient for applied research is 0.07 and for basic research, 1.49. This result is mainly due to the differences in the characteristics of R&D in the two countries. While American firms devote about two-third of their R&D expenditures to improving product technology and about one-third to improving process technology, investment in R&D in Japanese firms follow opposite patterns. Japan's greater emphasis on process technology probably accounts in part for its relatively high coefficient on R&D return to productivity.

In general, studies have examined either the effects of exports or R&D, but not the compounding effects of both taken together except for Aw and Batra (1998). They analyze the links between a firm's productivity and its export participation, investment in R&D, and worker training using a cross section data of the Taiwan Census of Manufactures. They find evidence of interactions between these two activities. However, given that these results are based on cross sectional data, they are unable to separate a firm's endogenous decision to export and/or invest in R&D from the effects of these activities. The first paper to examine the firms' discrete decisions to participate in the export market and/or make investment in R&D together is Aw, Roberts, and Winston (2002) which is based on three years (1986, 1991 and 1996) of Census data from the Taiwanese Manufacturing sector. They find that export orientation and investment in R&D reinforced each other in productivity growth at the firm level in the Taiwanese electronics industry. That is, participation in the export markets has a strong positive effect on a firm's productivity growth and this effect is especially strong if the firm also invests in R&D. Even though their findings are generally consistent with many of hypotheses set fourth by long-time observers of Taiwan's rapid economic growth, the data used in the paper is limited to a set of mostly large firms and is not continuous.

1.4. Patterns of Export Participation and R&D

The data used here are drawn from annual surveys conducted by Korea National Statistical Office (KNSO). The raw dataset covers every plant with more than five employees in 23 manufacturing sectors between 1991 and 1999. Table 1.1 shows the ratio of R&D intensity measured by the ratio of total R&D expenditure to GNP from 1980-1997. The ratio of R&D expenditure to GNP increased steadily, but it was not until in the 1990s when Korea finally reached the level of Western countries[12]. Before 1980, this ratio stood at less than 1 percent. After 1991, the rate exceeded 2 percent. The table also shows the patterns of R&D investment between government and private sector since 1980. Before 1980s, the role of the government in R&D promotion was limited to the establishment of national research to support industrial technological learning, and funding university R&D. Government-supported R&D institutes were established in the fields of machinery, shipbuilding, electronics, and electricity. However, the Korean government did not play a significant role in R&D promotion. The 1981 amendment of the Technology Development Promotion Law facilitated various tools to promote R&D activity in private sector. Industrial R&D policy was directed to transforming the industrial structure into one based on technology-intensive industries such as machinery and electronics. Compared to the previous industrial R&D policy of the 1970s, the new policy was geared toward both direct

[12] R&D intensity measured by the ratio of R&D expenditure to GDP in western countries such as U.S. France, Japan, and Germany are about 2 percent higher than that of Korea.(See Sakakibara and Cho (2000))

and indirect promotion of technology-intensive industries in their R&D stages. The direct promotion programs included subsidies for research expenses, exemptions of tariffs, special consumption taxes and value-added taxes, reduction of taxes up to 10% of R&D allotments. The indirect promotion programs included provision of low-interest loans through the banking sector, promotion of exchange and cooperation among R&D personnel.

From the dataset, we selected five industries: machinery, electronics, electrical machinery, automobile and other transport equipment. The key reason for the choice of these five industries is that both R&D and export activities are prevalent in these industries. Table 1.2 shows that the average percentages of plants that invest in R&D and participate in the export market in those five industries are 10.88% and 14.44% respectively. The average percentages of plants in the other industries that participate in R&D activity and export market are 5.26% and 12.78%. Some industries such as cigarette, leather-related products, petroleum & atomic fuel industries shows high rate of participation in the export market, but we exclude those industries in our empirical analysis because of the small number of observations in those industries or no participation in R&D investment at all. More detailed descriptions of the dataset including the data overview, deflation, and data cleaning are given in Appendix A.

Financial incentives such as tax-free imports of raw materials encourage the production of export goods, stimulating growth of light manufacturing (such as textile, electrical machinery, and small appliance) industries. In the 1970s, with light manufacturing becoming less important, heavy manufacturing (machinery, electronics, electricals) became Korea's new engine for exports share as reflected in the change of composition of export. Since 1980, the share of export of light industry products in total exports fell down 48% in 1980 to 40% in 1990 and finally to 18% in 2000. In contrast, the share of heavy industry products in total exports increased from 12.8% in 1980 t0 54% 1990 and finally to 74% in 2000.

Estimating the effect of exporting and investment in R&D on the productivity of firms and accurately assessing the investment decisions themselves requires sufficient variation in the investment and export decisions in the cross sectional data as well as sufficient switching in and out of each activity over time. Table 1.3 presents counts of firms to demonstrate cross-sectional and inter-temporal patterns or participation in the export market and investment in R&D. Table 1.3 classifies each firm according to whether it participated in neither activity, export only, R&D only or both activities and reports the number of firms in the survey in each group in each year. The survey is random sample of all producers in the industry. In each year a substantial share of the exporting firms chose to invest in R&D as well. Over the period covered by the panel, between 11 and 28 percent participated in both activities and between 36 and 61 percent of the firms in each year did not participate in either activity. Overall, the export activity was more prevalent than participation in R&D. While 18 to 24 percent of firms in each year choose to export but not invest in R&D, there are relatively few firms between 9 and 11 percent in each year that invested only in R&D.

While Table 1.3 summarizes firms' investment behaviors in each cross-section, it does not indicate how firms' participation decisions persist or change over time. Table 1.4 summarizes information about changes in firms' investment choices and illustrates how the initial state of investment activities is related to the decision to start or stop each activity. The columns in Table 1.4 report the number (and share) of firms that initiate or cease each investment activity in period $t+1$, conditional on each firm's initial state in period t. For example, column 2 reports the number and proportion of firms in each of the four initial states that began investing in R&D.

Table 1.4 shows two general transition patterns. First, regardless of their initial state, a higher proportion of firms began exporting than initiated investment in R&D and a lower proportion of firms ceased exporting than ceased investing in R&D. For example, of the 16,499 firms that did not participate in either activity in the initial period, 29 percent began exporting in the next period whereas 20 percent began R&D. Further, of the 3,796 firms that participated in both activities in the initial year, 53 percent ceased to export while 61 percent stopped R&D investment in the next year. Second, firms that participated in more activities in the initial year were less likely to cease their initial activity and more likely to have added an additional activity in year $t+1$. For example, in column 3, while 61 percent of the firms that participated in both activities in the initial year ceased their investment in R&D, 66 percent of the firms that only invested in R&D in the initial year ceased that activity. Similarly, in the next column, while 28 percent of firms that did not participated in either activity in the initial year chose to start exporting, 29 percent of firms that invested in R&D in the initial year chose to start exporting.

Taken together, there is evidence from counts of various activities in the panel data that history matters substantially in determining current investment choices.

1.5. The Theoretical Model

In this section, we develop a theoretical model of a firm's investment in two types of activities. We assume that a firm can invest in R&D that produces knowledge in production within the firm and that this investment primarily improves the ability of the firm to invent and absorb new technologies. A firm can choose to participate in R&D activity in each period. In addition, we assume that through a firm's export, the firm is exposed to knowledge external to the firm.

The theoretical model treats these two activities as producing a flow of new information that enters directly into the firm's production function as a productive input. Following Olley and Pakes (1996) and Ericson and Pakes (1995) we suppose that current investment in these activities affects a firm's likely future productivity level.

We also assume that the firm's marginal cost of production is constant and it faces a downward-sloping demand curve for its output in the market. Firms are heterogeneous in terms of the level of productivity, ω_t. A firm's maximized domestic profit from production in year t is represented as $\pi_t^d(\omega_t, Z_t^d)$[13]. A firm's profit depends on its current level of productivity, ω_t, a set of domestic demand and marginal cost shifters at time t, Z_t^d. A firm's maximized profit in the export markets is represented as $\pi_t^f(\omega_t, Z_t^f)$

The state variables of interest in this model are firm's productivity, ω_t, and stock of knowledge R and X. Let r_t and x_t denote the flow of R&D investment in year t and the flow of access to external knowledge. The knowledge stock evolves over time according to

(1) $R_{t+1} = \delta R_t + r_t$

$X_{t+1} = \delta X_t + x_t$

where the δ's are detention rates for each of knowledge stock.

[13] A theoretical model developed by Ericson and Pakes (1995) supposes that the distribution of a firm's future productivity depends on both a firm's current productivity and a single continuous investment variable.

A firm's productivity evolves over time according to a Markov process that depends on past level of productivity, the flows of R&D investment, and export participation. The evolution of firm productivity over time is described by a distribution function:

(2) $F(\omega_{t+1} | \omega_t, r_t, x_t, R_t, X_t)$

We assume a firm's future productivity depends upon its current productivity, the decisions to R&D and export, and the knowledge stocks of two activities. We expect that a firm would have higher future productivity if a firm makes investment in R&D and exporting than a firm does not. Furthermore, we expect that a firm's knowledge stocks of exporting and R&D investment will increase its future productivity level.

There are two costs associated with each investment activity. The cost from investing in R&D is represented as $C(R, r)$, which is increasing in the amount of unit of knowledge that a firm generates while it is decreasing in the stock of R&D that a firm possesses. Since the knowledge in R&D is accumulated over time, current cost incurred from R&D depends upon the past accumulation of internal knowledge. The more knowledge a firm has, the less cost it costs the firm. In addition, exporting incurs sunk entry cost, Γ, that is paid whenever a firm begins exporting. Based on the finding in Roberts and Tybout (1997), we assume a firm that was out of export market at least one year has to repay sunk entry cost to enter export markets. However, a firm that continuously participates in the export market does not have to pay sunk entry cost again.

Each firm has to decide whether to continue to produce or stop and get out of the market, taking the scrap value of the firm, Θ. If the expected discounted value of its profit stream is greater than the scrap value at time, a firm would decide to continue in production, if not it would stop producing. Since each firm's state variables and expected profits in year *t* can be expressed in terms of its state variables and investments in the previous period, a firm's value function in year *t* is expressed as:

$$(3)\, V_t(\omega_t, R_t, X_t) = \max\{\Theta_t, \max_{r_t, x_t}[\pi_t^d(\omega_t, Z_t^d) + \pi_t^f(\omega_t, Z_t^f)x_t - C(R_t, r_t)$$

$$-\Gamma(1 - x_{t-1})x_t + \beta E V_{t+1}(\omega_{t+1}, R_{t+1}, X_{t+1}) | \Omega_t]\}$$

where β is a discount rate and the inner maximization is obtained with considering current R&D investment and exporting decisions given the information set available to the firm in year *t*.

The solution to this optimization problem generates a shut-down rule for the firm, an investment demand function for *r*. The shut-down rule takes the form:

$$(4) \quad S_t = 1 \;\; if \;\; \omega_t \geq \underline{\omega_t}(R_t, X_t)$$

$$= 0 \;\; otherwise$$

S_t is a discrete random variable which equals 1 if the firm remains in business in year *t*. This shut-down rule says that if a firm's productivity is not high enough, that is if it is below the threshold level in the industry, $\underline{\omega_t}(R_t, X_t)$, then the firm will choose to exit market and take scrap value. This discrete decision is one of the equations we estimate in the empirical section.

The model produces demand equations for the R&D investment variable,

$$(5) \quad r_t = r_t(\omega_{t-1}, Z_t, R_{t-1}, X_{t-1})$$

Ericson and Pakes (1995) deal with one investment variable and show that investment decision will vary with the level of firm productivity. We will adopt their result and apply to our model with some modifications. In this model, we will assume that R&D/sales ratio or the decision to invest in R&D at time *t* will depend on a firm's previous productivity, a firm's characteristics and the stock of R&D and export experience accumulated up to time *t-1*. There are two distinct regions for firm productivity that will give rise to different investment outcomes. A firm with low levels of productivity will not find it profitable to invest in R&D. Once its productivity passes the threshold, the firm will actively invest in R&D to improve its future productivity[14].

The model also produces an equation describing the discrete decision to export as

$$(6)\quad x_t = 1 \quad if \quad \pi_t^f(\omega_t, Z_t^f) + \beta\{[EV_{t+1}|x_t = 1] - [EV_{t+1}|x_t = 0]\} \geq \Gamma(1 - x_{t-1})$$

$$= 0 \quad otherwise$$

A firm will decide to participate or stay in export markets in the year *t* if its profit gained from export markets plus the increment to future expected profits from being an exporter in year *t* is greater than the relevant entry cost. If a firm was in export market and decided to stay in the market, the relevant cost is zero and if a firm is newly appeared in the export market in year *t* it should pay entry cost Γ. This equation shows there is an explicit role for past export participation, x_{t-1}, in the current export decision because of the presence of sunk cost.

The period *t* state variables, ω_t, R_t, and X_t are determinants of the firm's decision to shut down, and invest in R&D, and export (equations 4, 5 and 6). In addition, exogenous demand and cost shifters, such as variable factor prices, output prices, and the levels of

[14] Unlike Aw, Roberts and Winston (2002), I do not suppose the upper threshold of productivity. They set the upper threshold level of productivity and a firm with higher productivity than this level will not invest in R&D because they consider the fact that investment increases the probability of moving to higher future productivity levels, so that the returns to additional investment will be low for high productivity firms.

fixed factors are also determinants of profits and are necessary as controls. An empirical representation of the three equations estimated in the next section. An empirical representation will be developed and estimated in Section 1.6. For a description of the data used in this chapter is explained in Appendix A, and index measure of productivity used in the empirical analysis is described in Appendix B.

1.6. The Empirical Model

The empirical model consists of the reduced-form investment expenditure equations, the productivity evolution equation, and an equation describing the probability of firm survival. In this section, we will quantify the relationship between a firm's productivity and its investment choices, R&D investment and export market participation. Finally, we will test if there are intertemporal links among them. We would also like to verify the hypothesis of complementarities between R&D investment and export participation,

In the theoretical model section, equation (5) describes a firm's R&D investment / sales ratio expenditures in year t or R&D expenditure itself as a function of its previous productivity, its stocks of R&D and export experience at the beginning of year t as well as other profit shifting firm characteristics. A firm's discrete R&D investment decision is unlikely to be made independently of its discrete export participation decision. Recognizing the potential complementarity of those two activities, we characterize the firm's investment decisions with a multinomial discrete choice model that specifies the probability of choosing each of the four possible combinations of activities: both export and R&D, export only, R&D only, or no export and no R&D. We estimate a multinomial logit model that treats each combination of activities as a separate choice and accounts for the inherent relationships between the activities.

A firm's discrete export participation decision also depends upon its stock of R&D and the stock of export experience at the beginning of each period. In addition, each decision depends on the firm's past productivity, ω_{it-1}, and demand and marginal cost shifters in the markets represented by Z. Since the discrete investment decisions are made jointly, we model three separate choices: one for each possible combination of the two discrete choices. The equations for a firm's discrete investment choice is

$$(6)\; I(Choice_{ijt}) = \alpha + \alpha_t + \alpha_1 \log(a_{it}) + \alpha_2 \log(k_{it}) + \alpha_3 \log(pw_{it}) + \alpha_4 \omega_{it-1} + \alpha_5 (\omega_{it-1})^2 + \sum_{j=6}^{8} \alpha_j I(Choice_{ij-5t-1}) + \varepsilon_{ij}$$

The variable $I(choice_{ijt})$ is a discrete variable equal to one if the firm *i* chooses option *j* at time *t* and zero otherwise. The choice 1 is both R&D and export, choice 2 is export but no R&D, choice 3 is R&D but not in export, and choice 4 is neither R&D nor export. The explanatory variables, in order, are a constant term, year dummy, the log of the firm's age, the log of the firm's capital stock, the log of firm's average production worker's wage. These variables capture the demand and marginal cost shifters specified by *Z.* The remaining explanatory variables that affect the decision of investment are past productivity, productivity squared, three dummy variables that capture investments in R&D and/or participation in the export market in year *t*-1.

Since we are particularly interested in a firm's R&D investment, we specify an empirical Tobit equation of a firm's R&D investment as

$$(8) \quad R\&D_{it} = \alpha + \alpha_t + \alpha_1 \log(a_{it}) + \alpha_2 \log(k_{it}) + \alpha_3 \omega_{it-1} + \alpha_4 (\omega_{it-1})^2$$

$$+ \alpha_5 I(Export_{it-1}) * (R\&D_{it-1}) + \alpha_6 I(Export\,only_{it-1}) + \alpha_7 R\&D_{it-1} + \varepsilon_{it}$$

The dependent variable, $R\&D_{it}$, represents a firm's R&D intensity measured as R&D expenditures to sales ratio at time *t*. Instead of using lagged dummy variables for a firm's activities on export and R&D, we use three interaction terms between export dummy variable and R&D expenditure. These terms will capture how a firm's past experiences of export participation and past R&D intensity will affect its current decision on R&D intensity. The variable $I(Export_{it-1})$ is a dummy variable that take a value of one if a plant *i* participated in the export markets in year *t-1* and zero otherwise.

In the theoretical model, a plant's shut down rule depends on its current productivity. If a plant's productivity is higher than the average industry (threshold) productivity level, the plant will remain in the market. This productivity threshold as well as and plant's current productivity depend on other state variables such as the stock of R&D investment, and other profit shifters that enter into the plant's investment decisions. Thus, we specify a firm survival equation that predicts the probability that a plant remains in operation in year *t*+1 as

$$(9)\; S_{it+1} = \gamma_0 + \gamma_t + \gamma_1 \log(a_{it}) + \gamma_2 I(E_{it}) + \gamma_3 \log(k_{it}) + \gamma_4 \{\log(k_{it})\}^2 + \log(pw_{it})$$

$$+ \gamma_5 \log(pw_{it}) + \gamma_6 \omega_{it} + \gamma_7 I(Export_{it}) * R\&D_{it} + \gamma_8 I(ExportOnly_{it})$$

$$+ \gamma_9 R\&D_{it} + \varsigma_{it}$$

A firm's productivity evolves according to the Markov process specified in equation (2). This productivity process is conditional on a plant's investment in R&D and export activity. In the literature of Hopenhayn (1992) and Olley and Pakes (1996), a firm's productivity follows an exogenous Markov process and a firm's investment plays no role in altering the distribution of a firm's future productivity. However, following Ericson and Pakes (1995) model, a firm's future productivity depends on the firm's current decision in R&D investment. Their model of industry dynamics is based on a stochastic model of the entry and growth of firms that invest in research and exploration activities to enhance their capability to earn profits.

The empirical specification of equation (2) estimates the marginal contribution of current investments in R&D to the mean level of a plant's productivity in year *t*+1 while controlling for the firm's current level of productivity. Considering all of those, the productivity evolution equation can be written as

(10) $\omega_{t+1} = \chi_0 + \chi_1\omega_{it} + \chi_2 I(Export_{it}) * R * D_{it} + \chi_3(ExportOnly_{it}) + \chi_4 R \& D_{it} + \upsilon_{it}$

Estimating the productivity evolution equation generates another econometric issue. A plant's productivity in year *t*+1 is observed only for surviving plants, excluding all of the plants that exited between *t* and *t*+1. Because of this problem, the estimated parameters of the model are biased if the random factors that affect a firm's survival to period *t*+1 also affect its productivity in that year. To solve this problem, we follow Heckman's sample selection framework and jointly estimate the survival equation and productivity evolution equation using maximum likelihood method. The model includes one additional parameter, the $Corr(\zeta_{it+1}, \upsilon_{it+1})$, which measures the correlation between the errors in the survival and productivity equations. The evolution equation is estimated with the set of two digit industry dummies to control for level differences in the evolution of productivity in different industries. However, it does not include some of the other variables such as entrant dummy, log(age), log(k), $(\log(k))^2$, log($pwage$) that are used in the selection equation. This specification helps in the identification of the model because the selection correction is estimated with information that is not utilized in the productivity evolution equation.

Aw, Roberts and Winston (2002) estimate firms' discrete decisions to participate in the export markets and/or make investment in R&D and/or worker training using multinomial probit model in Taiwan electronics industry.

Our approach differs from Aw, Roberts and Winstons (2002) in two ways. First, instead of using multinomial probit model, we use a multinomial logit model to estimate firms' discrete decisions to exporting market and R&D export. The main assumption adopting probit model is the normality of error term. As shown in Table 1.3, more than half of firms did not participate in any activity at all, and 11 to 28 percent participated in both activities. This, in turn, implies the data did not show the normal distribution of R&D and exporting decisions. Second, while Aw, Roberts, and Winston (2002) use a panel dataset constructed from surveys of large electronic firms in 1986, 1991, and 1996, we use an annual dataset firms in five key Korean industries during of 1991 to 1999. Because ARW use the discontinuous data, they can not capture the exact patterns of entry and exit, and firms' decisions to those activities may not reflect the exact relationship between productivity and firms' experiences on exporting and investment in R&D. We hope we can capture more exact patterns of firms' entry and exit and in addition we can capture better effect of R&D on future productivity and survival from our new dataset.

1.7. Estimation Results

Given that the effect of exporting on a firm's productivity may depend on its investment in R&D, enabling the firm to absorb new technology gained from foreign customers, we estimate the multinomial logit model consisting of the R&D investment equation as well as its participation in the export market accounting for potential complementarities between exporting and investing in R&D. A firm's incentive to invest in R&D may depend on its access to new technology through its relationship with foreign suppliers. Hence, it is reasonable to model to assess the individual and interactive effects of export participation and investment in R&D.

In our empirical model, Choice 1 refers to firms which participate in both export activity and R&D investment activity, Choice 2 refers to firms that participate in exporting, but do not invest in R&D, Choice 3 refers to firms that invest in R&D, but do not export, finally Choice 4 refers to firms that do not participate in any activity. The empirical result of our model is reported in Table 1.6. There are several similarities in the results across the three choice equations although the estimated parameters vary in their magnitude and significance. Each equation includes year dummies, industry dummies, the natural log of a firm's age, the natural log of capital, the natural log of average production worker's wage, the natural log of productivity, its square, and three dummies of lagged choice[15].

Except for the Choice 2 equation, age has a positive and statistically significant effect on firm's decision to participate in the export and R&D investment activities. Old firms are more likely to invest in R&D regardless of whether they are in export markets. Older plants may have a greater incentive to invest in new technology to create and maintain the profits

[15] The coefficients on the year dummies are not reported.

from market than younger plants. They may also be in a better position to learn the importance of technology from experience.

The coefficient on $\log(k_{it})$ is positive and significant in all three equations. Given that the capital variable is a proxy for firm size, this result suggests that larger firms are more likely to participate in both activities. Comparing the magnitudes of coefficients on $\log(k_{it})$ in all three equations, we conclude that the probability to participate in both activities is the highest as firm size grows (0.383). However, the size effect is smallest in the probability for a firm to decide to participate in export market (0.152). One explanation may be related to the size of the entry cost that is incurred at the beginning of each activity. Investment in R&D may require more capital than participation in the export market. It may require a new factory, new machines, and high skilled labors which is not required for export participation. These results indicate that the net benefits of Choice 1 and Choice 3 depend more on a firm's size than the benefits of only exporting. From these two coefficients, firm size and business experience do matter in determining the participation in exporting and/or investing in R&D. The coefficient on average production worker's wage is positive but insignificant in all equations except Choice 2 equation.

The coefficient on ω_{it-1} is positive and significant for both Choice 1 and Choice 3 equations. This finding implies that plants with higher past productivity are more likely to participate in R&D investment regardless of whether they export at the same time. The more efficient firms tend to participate in creating internal knowledge through R&D investment for sure, but are less likely to participate in the foreign market without investing in R&D. In three equations, there are differences in the effects of productivity across the various choices. The marginal impact of increased productivity on the likelihood of participating in both activities (0.536) is much larger than the estimated effect on the likelihood of only R&D (0.351) and of only Export (0.001). This result suggests that the benefits of investing R&D are less sensitive to differences in productivity than the benefits of Choice 1.

The lagged choice variables are used as proxies for a firm's stock of knowledge in each activity. All coefficients of lagged choice dummies are positive and significant, which indicates past experiences play a key role to determine a firm's participation in any activity. Interesting results are the magnitudes of coefficient. In each equation, its own past experience plays the most important role in determining its decision. For example, the coefficient of lagged Choice 1 dummy in Choice 1 equation (4.414) has the largest effect on the likelihood that a firm participates in both activities than lagged Choice 2 and 3 dummy, 2.606 and 1.770 respectively. In second (third) column, the coefficient of lagged Choice 2 (lagged Choice 3) has the largest effect on the likelihood that a firm participates in Only Export (Only R&D) than any other participation.

Next, since we are particularly interested in a firm's R&D behavior, we run regressions of various models using Tobit model in which the R&D-sales ratio is used as a dependent variable in the regression based on the investment, productivity evolution and firm survival equations. The results are reported in Table 1.7 through Table 1.9 respectively.

In Table 1.7, all variables except for production worker's wage variable are statistically significant. Older and larger firms are more likely to invest more in R&D. These findings are somewhat consistent of the results of same variables of Choice 1 and 3 equations in Table 1.6. That is, older and larger firms tend to participate in R&D investment and furthermore they spend more in R&D as well. The coefficient on ω_{it-1} is positive and significant, but it has diminishing effect. A firm that was more productive last period is more likely to spend more in investment. There are three lagged dummy variables in regression model. The coefficient on lagged of only export dummy is negative and significant, which implies that a firm who participates in export market but not invest in R&D last period is less likely to spend in R&D investment. However, dummy variables related to R&D last period shows positive and significant coefficients. A firm that invests in R&D only last period is more likely to increase R&D expenditure this year than a firm that involves both activities last period. This is because of the property of R&D. R&D activity usually takes a few years to gain successful results rather than one year. Therefore, a firm that devotes itself to R&D activity is more likely to continue investing in R&D than a firm that has alternative way of improving its productivity.

As we explained in theoretical model, we estimate productivity evolution model and firm survival equation simultaneously by using a standard Heckman model. The estimated parameters reported in Table 1.8 and Table 1.9 indicate that entrant status, capital stock, age of plant, production worker's wage, and productivity are important determinants of a plant's survival.

We estimated two different models of the productivity evolution equation. The last column in Table 1.9 includes current choice dummy variables. Without considering those dummy variables, we found that the current productivity is the only variable that has significantly positive effect on a firm's future productivity growth while most of variables have significant effect on a firm's survival. When we add choice dummy variables to see how current investment activities influences future productivity, we found that all different kinds of activities give a positive effect on a firm's future productivity, but the magnitudes are different. A firm's future production depends more on R&D investment activity. A firm that participates in both activities is more like to enjoy higher productivity (0.027) in the future than a firm that participates in only one activity such as R&D only (0.019) and Export only (0.015). We find that a firm participating in R&D investment is more likely to have higher productivity than a firm that participating in export only. Even when a firm combines these two activities, it will gain more productivity in the near future. This result indicates the presence of complementarities between R&D and exporting.

Table 1.8 shows the regression result of firm survival. On average, older and bigger firms are more likely to survive. We find a negative effect of production worker's wage on a firm's survival[16]. It does not necessarily imply that high wage will make a firm fail. One possible explanation is that high wages in the production sector make it more difficult to produce in Korea. Cheaper labor in other countries such as Vietnam, and China are likely to result in Korean firms moving their production facilities to those countries. Since the data count those plants as failures in production, we cannot exclude this possibility of explanation from the negative and significant coefficient on production worker's wage. More productive firms are more likely to be in production next period as we predicted in theoretical model. A firm that sell its product toward export market and has high R&D-sales ratio will have high possibility to survive next period (0.420) than a firm that only participates in export market (0.039). This implies that finding customers in foreign market

[16] We may need to check if the relationship between the increasing rate of worker's wage and the volume of import from China. This may make us to be able to figure out why there is negative sign on production worker's wage in survival equation. That is, increase of wage drives firms to move their facilities to China. Those firms will be reported in failure in data.

is important source for a firm to success in business, but if a firm tries to generate new ideas through R&D investment then the effect will be much higher. Interestingly the effort in R&D investment without exporting is not helpful to a firm to survive.

Finally positive and significant correlation estimate (0.166 in the second column or 0.172 in the last column) in the bottom of Table 1.9 indicates random shocks that increase a firm's chance of survival are positively correlated with its future productivity if it does survive. The likelihood ratio test can reject the hypothesis of independence between the survival equation and the productivity evolution equation.

In addition, we estimate three same equations with some modifications. First we replace R&D/sales ratio with R&D expenditure ratio as a dependent variable. Second, we replace dummy variables of R&D and export participation in interaction terms. The results are shown in Table 1.10 through Table 1.12.

The results are similar to those in Table 1.7 through Table 1.9. Older and bigger firms are more likely to invest in R&D, but the coefficient on the age variable is not significant. More productive firms tend to invest more. When we compare the magnitudes of three lagged variables in Table 1.10, a firm that has experiences on both R&D and exporting activity invests the most. On the contrary, marginal increase of R&D investment by a firm that exported last period is the smallest.

Table 1.11 and Table 1.12 report results of a firm's survival and productivity evolution equations. We replace R&D ratio with binary dummy variables in the regressions. First, the results of survival equation regression are very similar to those in Table 1.8. Older and bigger firms have higher probability to survive and new entrants have lower probability to survive in the future. A firm's productivity is important factor to affect a firm's survival as we found in Table 1.8. When we compare coefficients on three dummy variables, we can conclude that a firm that participates in both activities has highest probability to survive next period (0.336). A firm that participates in export market alone has also high probability to survive, but the magnitude of probability is about half of it (0.182). The coefficient on dummy for only R&D participation is positive but not significant (0.073). Hence, from first two coefficients of dummy variables, we can say export is key factor for a firm's survival, but the probability can be doubled if a firm invests in R&D as well.

Table 1.12 reports results of a firm's productivity growth in terms of its current productivity and a firm's choice dummy variables on activities. We find that a firm's R&D activity is an important factor to increase a firm's future productivity (0.017), and it can be increased slightly if a firm participates in export market (0.023). On the contrary, if a firm participates in export market alone, the probability of production gain is smallest (0.014).

It is worthwhile to compare the coefficients on dummy variables in Table 1.11 and Table 1.12 regarding the determinants of a firm's survival. Participation in export market is an important factor, but it can be doubled if a firm participates in R&D investment activity. However, in terms of a firm's productivity growth, R&D activity is a key factor, and future productivity will slightly increase if a firm exports as well. This is very plausible results. By expanding a firm's supply ability to foreign markets, a firm can spread uncertainty risk into other markets and this will help a firm to survive in the future. Participation in the export market gives a firm to external knowledge that affects its future productivity. However, internal knowledge generated from a firm's R&D investment has more impact on its productivity growth. These suggest that both internal and external knowledge spillovers on productivity exist and both are important for a firm to survive and to grow.

Additionally we estimate two discrete choice models by separating the data sets into two groups, small and medium sized plants, and large sized plants to see how the discrete choices are made differently by these two groups[17]. The results are reported in Table 1.13 and Table 1.14. Even a firm's age gives a positive effect on the choice of R&D (with or without exporting) for a large firm, age variable gives a negative effect on a firm's participation in Choice 1. This is because of the capital availability of smaller firms. Since small firms are likely to have less capital, they do not have room to invest in R&D or export in the foreign market. Instead they concentrate on domestic market without participating in any activity. As capital increases, the probability (0.329) that a large sized firm participate in both activities are higher than the probability (0.132 or 0.184) that a firm participate in any one activity. On the contrary, a small and medium sized firm is likely to invest in R&D only (0.266) as its capital grows than participating in both activities (0.209). Since smaller sized firms have capital constraint, it shows different pattern from large sized firms. Past productivity is an important factor to determine a firm's choice in both groups.

Our results differ from those in Aw, Roberts, and Winston (2002) on Taiwan in two key ways. First, while ARW find that a firm with high current productivity is more likely to participate in exporting, we find that a firm with high productivity in t-1 is more likely to invest in R&D. Second, ARW find firms that the exporting activities, by itself or combined with R&D investment, is associated with higher future productivity. R&D activity on its

[17] According to Korean industry standard, it was defined by the number of employees. A firm that hires more than 300 employees it is called a large sized firm. If not, it belongs to small and medium sized firms.

own is not related to higher future productivity. Our results for South Korea firms indicate that export and/or investment in R&D in the current period are more productive in the next period. In contrast to Taiwan, investments in R&D by itself are closely associated with higher future productivity. These results are consistent with our observations of the relative importance of the export and R&D activities in the two countries. Taiwan's rapid export growth occurred a full decade after export boom in Korea[18]. By the 1980s, R&D in the private sector was boosted by Korean government. But in Taiwan R&D investment was less emphasized than Korea at that time[19].

Despite the above differences in findings between ARW and this chapter, both find evidence of complementary effects of R&D and export experience on a firm's productivity. Firms that invest in R&D in addition to exporting should experience an additional return on their exposure to the export market.

1.8. Summary and Conclusion

As an economy grows, firms recognize the importance of new ideas to compete domestic competitors and foreign suppliers as well. Those new ideas may stem from a firm's successive R&D investment and/or export market participation. A domestic firm can gain efficient way of production process, managerial skills, and new ideas from foreign supplier. Those gains from trade are embedded in a firm' productivity and increase a firm's

[18] Since 1985, output and export of the Taiwan electronic industry grew tremendously. For example, between 1985 and 1988, the rate of export was almost 37% at an average annual output growth. By 1987 electronics was Taiwan's largest industry and accounted for over 25% of total exports. This pattern is very similar to that of Korea in the 1960s and 1070s. The average annual export growth rate of Korean industries was 40% in the 1960s and 1970s, but fell to 25% in the 1980s and to 11.5% in the 1990s.

[19] The Korean industries actively started to invest in R&D by several supportive government policies, especially Technology Development Promotion Law of 1981.

future profit. In addition, a firm tries to generate new ideas by investing in Research and Development (R&D) activity itself.

In this chapter, we have seen these important aspects of firms' behaviors on improving their current and future productivity. The empirical models consist of reduced-form specifications of the elements of the theoretical models. First of all, we estimate a firm's discrete decision to export and/or invest in R&D to figure out the kinds of factors that influences a firm's investment decision. To account for the fact that these decisions are made jointly, we estimated a multinomial logit model that treats each combination of participation in the two activities as a separate choice. Overall, the productivity plays an important role in determining a firm's decision on each activity. In addition, a firm that involves each activity last period is more likely to participate in each activity this period. Lastly, older and larger firms are more likely to participate in both activities.

Then, we estimated R&D investment equation using tobit regression method using R&D/sales ratio as a dependent variable. Except for production worker's wage, all variables have significant effects on a firm's R&D/sales ratio. As we expected in theoretical model, we found that a firm's own productivity has a significantly positive effect on its R&D decision and the older and larger firm are likely to invest in R&D. To account for firms' endogenous exit decisions, we use a standard Heckman selection model to estimate the evolution of firms' productivities.

In both survival and productivity evolution equations, we found that a firm's current level of productivity plays an important role in firms' survival and productivity growth in the future. A firm that participates in both export and R&D activities is more likely to survive and is more likely to gain productivity in the future. In terms of survival, a firm's export participation is more helpful while a firm's R&D investment is a good source to increase a firm's productivity in the future. By exporting its products into the foreign market, a firm can gain instant profits from the foreign customers, which helps a firm survive in the domestic market. While exporters enjoy a little of productivity gain, R&D investors enjoy higher productivity growth. On the contrary, a firm that invests in R&D can gain productivity growth in the future, but experience of R&D investment does not increase a firm's survival possibility. Since R&D investment takes times to make new ideas, it may not help a firm survive. Actually it can decrease its survival probability if the investment is not successful. However, firms maximize their survival possibility and productivity growth by participating in both R&D and export activities. These findings imply there is a compounding effect between firms' two activities, which increase firms' future productivity and possibility of survival.

Since 1960s, Korean government recognized the importance of export-oriented growth and R&D investment led by the government sector to boost its economic growth even R&D in private sectors was supported by Technology Development Promotion Law enacted in 1981. With several strong policies on export and R&D investment started from 1960s, the Korean economy has experienced tremendous economic growth. In this chapter, we examined the importance of those activities on productivity growth using micro panel data of Korean manufacturing industries from 1991 to 1999. Our empirical findings suggest that a firm's participation in R&D investment improves its future productivity and this effect will be maximized when it exports also. To boost and sustain high economic growth in competitive domestic and foreign market, it is necessary to recognize the importance of R&D and the government should guide firms to invest in applied technology as well as cutting-edge technology.

Table 1.1 The Ratio of R&D/GNP, and R&D Ratio in Government and Non-Government Sector, 1980- 1997

Year	R&D/GNP	R&D conducted by	
		Government (%)	Non-Govn't (%)
1980	0.77	63.72	36.28
1981	0.81	54.96	45.04
1982	1.02	49.58	50.42
1983	1.10	33.89	66.11
1984	1.28	27.72	72.28
1985	1.56	24.80	75.20
1986	1.73	23.29	76.71
1987	1.81	24.69	75.31
1988	1.87	21.31	78.69
1989	1.90	20.41	79.59
1990	1.88	19.43	80.57
1991	1.92	19.62	80.38
1992	2.03	17.61	82.39
1993	2.22	16.89	83.11
1994	2.45	15.96	84.04
1995	2.51	18.86	81.14
1996	2.61	22.17	77.83
1997	2.70	23.49	76.51

Table 1.2 Percentage of Plants with Positive R&D and Exporting by Industry, 1991~1999

SIC & Industry	R&D (%)	Export (%)
15 Food & Beverage	7.15	13.38
16 Cigarette	0	35.88
17 Textile	3.27	18.17
18 Apparel	1.67	9.21
19 Leather, Bag & Footwear	4.20	25.73
20 Wood & Wooden products	1.71	4.90
21 Pulp, and paper products	3.63	10.24
22 Publications	2.02	1.89
23 Petroleum & Atomic fuel	26.27	39.39
24 Chemicals	24.05	25.56
25 Rubber & Plastics	7.20	13.50
26 Nonmetal mineral	6.55	9.16
27 Basic Metal	8.34	18.84
28 Fabricated Metals	4.94	9.12
29 Machinery	10.00	10.86
30 Office related machinery	20.00	20.55
31 Electronics	12.24	16.34
32 Communication equipment	16.59	24.62
33 Precision instrument	14.67	24.60

34 Automobile	5.96	11.02
35 Other transport equipment	7.51	10.22
36 Furniture	4.66	18.04
37 Recycle material processing	2.88	5.69

Table 1.3 Summary of Investment Activities in Korea data, 1991 ~ 1999

(Number of plants in each combination of activities, Percent of row total)
total observation : 67,256

	Activity Combination			
Year	No Export No R&D	Only R&D	Only Export	Export and R&D
1991	2,141 (55.76)	384 (10.00)	840 (21.88)	475 (12.37)
1992	1,942 (53.72)	353 (9.76)	853 (23.60)	467 (12.92)
1993	2,310 (59.12)	386 (9.88)	765 (19.58)	446 (11.42)
1994	2,264 (59.33)	360 (9.43)	770 (20.18)	422 (11.06)
1995	2,176 (59.11)	363 (9.86)	720 (19.56)	422 (11.46)
1996	2,169 (61.32)	345 (9.75)	647 (18.29)	376 (10.63)
1997	1,804 (57.91)	314 (10.08)	611 (19.61)	386 (12.39)
1998	1,202 (51.35)	248 (10.59)	490 (20.93)	401 (17.13)
1999	490 (35.77)	158 (11.53)	333 (24.31)	389 (28.39)

Table 1.4. Transition Matrix of Investment Activities for Plants in Year *t* and *t*+1, 1991~1999

Investment Activity in year *t* (Number of plants in *t*)	Year *t*+1			
	START R&D	STOP R&D	START Exporting	STOP Exporting
No R&D, No Export (16,499)	3,235 (19.60)		4,739 (28.72)	
Only R&D (2,913)		1,927 (66.15)	847 (29.08)	
Only Export (6,030)	1,180 (19.57)			3,509 (58.19)
R&D and Export (3,796)		2,322 (61.17)		2,027 (53.39)

Table 1.5. Number of Plants in Each Industry

Industry	1991	1992	1993	1994	1995	1996	1997	1998	1999
General Machinery	1710	1589	1757	1709	1655	1618	1412	1001	517
Electronics	810	748	785	774	719	564	504	406	258
Electrical Machinery	724	703	762	731	735	701	581	455	288
Autos	505	481	497	491	469	455	406	316	235
Other Transports	91	94	105	111	103	83	104	88	51

Table 1.6. Discrete R&D Investment Expenditure Equation: Multinomial Logit Model

Sample size = 20,675

	Choice1 R&D and Export	Choice2 Only Export	Choice3 Only R&D
Intercept	-6.380 (1.552)*	-3.632 (1.617)*	-3.787 (1.601)*
log(age)	0.193 (0.075)*	-0.020 (0.062)	0.079 (0.027)*
log(k_t)	0.383 (0.063)*	0.152 (0.027)*	0.257 (0.022)*
log($pwage_t$)	0.150 (0.109)	0.280 (0.032)*	0.028 (0.057)
(ω_{it-1})	0.536 (0.042)*	0.001 (0.028)	0.351 (0.008)*
$(\omega_{it-1})^2$	-0.043 (0.039)	0.127 (0.042)*	-0.198 (0.028)*
Lagged choice1 dummy	4.414 (0.027)*	2.914 (0.021)*	1.990 (0.030)*
Lagged choice2 dummy	2.606 (0.040)*	3.000 (0.018)*	0.088 (0.033)*
Lagged choice3 dummy	1.770 (0.039)*	0.248 (0.025)*	2.055 (0.012)*
Industry dummies			
Machinery	-0.628 (0.064)*	-0.554 (0.077)*	-0.462 (0.031)*
Electronics	-0.694 (0.141)*	-0.565 (0.149)*	-0.328 (0.042)*
Automobile	-0.956 (0.148)*	0.955 (0.132)*	-0.283 (0.042)*
Other transportation equipment	-0.705 (0.208)*	-0.609 (0.175)*	-0.757 (0.075)*

Table 1.7. R&D Investment Equation: Tobit regression

Sample size : 20,622

Dependent variable : (R&D/ Sale ratio)$_t$

Variables	Coefficients
Intercept	-0.205 (0.008)*
log(age)	0.013 (0.003)*
log(k_t)	0.017 (0.001)*
log($pwage_t$)	-0.003 (0.003)
ω_{it-1}	0.025 (0.004)*
$(\omega_{it-1})^2$	-0.008 (0.004)*
Lagged(export dummy * R&D ratio)	0.178 (0.034)*
Lagged(only export dummy)	-0.031 (0.003)*
Lagged(R&D ratio)	0.259 (0.018)*
Industry dummies	
Machinery	-0.026 (0.003)*
Electronics	-0.021 (0.003)*
Automobile	-0.023 (0.004)*
Other transportation equipment	-0.043 (0.007)*

Table 1.8. Survival Equation Estimates

Maximum Likelihood Estimation of Sample Selection Model with industry dummies

Dependent variables: S_{t+1}

Variables	Coefficients
Intercept	0.238 (0.051)*
Entrant dummy	0.093 (0.022)*
log(age)	0.128 (0.007)*
$\log(k_t)$	0.053 (0.014)*
$\{\log(k_t)\}^2$	0.0002(0.001)
$\log(pwage_t)$	-0.085 (0.011)*
ω_{it}	0.219 (0.012)*
$(\omega_{it})^2$	-0.027 (0.010)*
export dummy * R&D ratio$_{it}$	0.420 (0.132)*
only export dummy$_{it}$	0.039 (0.009)*
R&D ratio$_{it}$	-0.005 (0.065)
Industry dummies	
Machinery	0.026 (0.014)
Electronics	0.044 (0.017)*
Automobile	0.101 (0.019)*
Other transportation equipment	0.095 (0.034)*

Table 1.9. Productivity Evolution Estimates
Maximum Likelihood Estimation of Selection Model with 2-digit industry dummies

Dependent variable : Productivity in period *t+1*, ω_{t+1}

Variables	Coefficients	
Intercept	-0.023 (0.009)*	-0.042 (0.010)*
ω_{it}	0.618 (0.007)*	0.603 (0.028)*
export dummy$_{it}$ * R&D ratio$_{it}$	0.107 (0.103)	
only export dummy$_{it}$	0.006 (0.006)	
R&D ratio$_{it}$	-0.098 (0.055)	
Choice 1 dummy$_{it}$		0.027 (0.009)*
Choice 2 dummy$_{it}$		0.015 (0.007)*
Choice 3 dummy$_{it}$		0.019 (0.010)*
Industry dummies		
Machinery	-0.006 (0.007)	-0.012 (0.008)
Electronics	0.023 (0.008)*	0.024 (0.009)*
Automobile	-0.007 (0.009)	-0.021 (0.010)*
Other transportation equipment	-0.056 (0.016)*	-0.050 (0.018)*
Log likelihood	-21,765	-15,086
$Corr(\zeta_{it+1}, \upsilon_{it+1})$	0.166 (0.029)*	0.172 (0.032)*

Table 1.10. R&D Investment Equation : Tobit regression

Sample size : 20,622

Dependent variable : The value of R&D at time *t*

Variables	Coefficients
Intercept	-30524.92 (1107)*
log(age)	238.57 (356)
log(k_t)	2073.13 (124)*
log($pwage_t$)	688.66 (408)
ω_{it-1}	1834.52 (456)*
$(\omega_{it-1})^2$	-437.63 (399)
Lagged dummy (R&D and Export)	6680.87 (404)*
Lagged(Only Export)	965.32 (362)*
Lagged(Only R&D)	6273.34 (400)*
Industry dummies	
Machinery	-1735.53 (405)*
Electronics	-1818.87 (470)*
Automobile	-769.96 (509)*
Other transportation equipment	-1903.82 (981)*

Table 1.11. Survival Equation Estimates

Maximum Likelihood Estimation of Sample Selection Model with industry dummies

Dependent variables: S_{t+1}

Variables	Coefficients
Intercept	0.105 (0.114)
Entrant dummy	-0.419 (0.025)*
log(age)	0.282 (0.013)*
$\log(k_t)$	0.084 (0.032)*
$\{\log(k_t)\}^2$	0.002 (0.002)
$\log(pwage_t)$	-0.202 (0.025)*
ω_{it}	0.466 (0.028)*
$(\omega_{it})^2$	-0.047 (0.025)**
Dummy (R&D and Export)	0.336 (0.036)*
Dummy (Only Export)	0.182 (0.024)*
Dummy (Only R&D)	0.073 (0.031)
Industry dummies	
Machinery	0.074 (0.024)*
Electronics	0.106 (0.028)*
Automobile	0.236 (0.033)*
Other transportation equipment	0.231 (0.058)*

Table 1.12. Productivity Evolution Estimates

Maximum Likelihood Estimation of Selection Model with 2-digit industry dummies

Dependent variable : Productivity in period *t+1*, ω_{t+1}

Variables	Coefficients
Intercept	-0.034 (0.010)*
ω_{it}	0.617 (0.007)*
Dummy (R&D and Export)	0.023 (0.008)*
Dummy (Only Export)	0.014 (0.007)*
Dummy (Only R&D)	0.017 (0.009)**
Industry dummies	
Machinery	-0.002 (0.007)
Electronics	0.026 (0.008)*
Automobile	-0.005 (0.009)
Other transportation equipment	-0.052 (0.016)*
Log likelihood	-21,726
$Corr(\zeta_{it+1}, \upsilon_{it+1})$	0.167 (0.032)*

Table 1.13. Discrete R&D Investment Expenditure Equation Multinomial Logit Model (Small & Medium sized plants)

Sample size = 7,188

	Choice1 R&D and Export	Choice2 Only Export	Choice3 Only R&D
Intercept	-4.644 (1.614)*	-2.493 (1.617)*	-3.201(1.664)
log(age)	-0.375 (0.136)*	-0.048 (0.074)	0.037 (0.046)
log(k_t)	0.209 (0.042)*	-0.025 (0.014)	0.266 (0.012)*
log($pwage_t$)	-0.117 (0.089)	0.211 (0.025)*	-0.208 (0.042)*
(ω_{it-1})	0.423 (0.099)*	-0.238 (0.045)*	0.197 (0.019)*
$(\omega_{it-1})^2$	-0.163 (0.137)	0.158 (0.059)*	-0.177 (0.034)*
Lagged choice1 dummy	4.690 (0.021)*	3.210 (0.049)*	1.816 (0.026)*
Lagged choice2 dummy	2.859 (0.026)*	3.191 (0.007)*	-0.348 (0.007)*
Lagged choice3 dummy	1.240 (0.012)*	0.615 (0.015)*	2.065 (0.005)*
Industry dummies			
Machinery	-0.459 (0.034)*	-0.430 (0.040)*	-0.446 (0.035)*
Electronics	-0.365 (0.137)*	-0.382 (0.130)*	-0.333 (0.083)*
Automobile	-1.835 (0.302)*	-0.745 (0.193)*	-0.725 (0.024)*
Other transportation equipment	-0.163 (0.237)*	-0.683 (0.232)*	-0.596 (0.087)*

Table 1.14. Discrete R&D Investment Expenditure Equation Multinomial Logit Model (Large sized plants)

Sample size = 13,487

	Choice1 R&D and Export	Choice2 Only Export	Choice3 Only R&D
Intercept	-5.219 (1.707)*	-2.938 (1.604)	-2.891(1.657)
log(age)	0.198 (0.045)*	-0.025 (0.040)	0.065 (0.023)*
log(k_t)	0.329 (0.045)*	0.132 (0.020)*	0.184 (0.018)*
log($pwage_t$)	-0.018 (0.146)	0.135 (0.041)*	-0.051 (0.077)
(ω_{it-1})	0.284 (0.055)*	0.011 (0.070)	0.300 (0.010)*
$(\omega_{it-1})^2$	-0.024 (0.066)	0.058 (0.063)	-0.252 (0.036)*
Lagged choice1 dummy	4.273 (0.010)*	2.773 (0.006)*	1.965 (0.023)*
Lagged choice2 dummy	2.514 (0.026)*	2.899 (0.013)*	0.157 (0.026)*
Lagged choice3 dummy	1.702 (0.036)*	0.085 (0.020)*	2.019 (0.008)*
Industry dummies			
Machinery	-0.648 (0.067)*	-0.567 (0.078)*	-0.468 (0.046)*
Electronics	-0.742 (0.136)*	-0.622 (0.147)*	-0.328 (0.054)*
Automobile	-0.996 (0.127)*	-1.024 (0.112)*	-0.249 (0.036)*
Other transportation equipment	-0.798 (0.186)*	-0.647 (0.164)*	-0.864 (0.067)*

Chapter 2

Local Proximity and Knowledge Spillover

2.1 Introduction

Knowledge spillover has been recognized as an important source of innovation and economic growth in both industry-level and firm-level analysis. Knowledge stock[20] that a firm possesses can be spread to other firms through several channels such as trade group membership, labor force movement, location proximity and so on. Among all of those factors, a firm's location may be an important factor to explain a firm's evolution in the sense that firms that are located together with other high productivity firms have the opportunity to watch and learn new advanced technology or managerial skill from them. Therefore, location proximity may help firms' productivity growth and survival as well.

For more than a century, many geographers and economists have developed theories relating to spatial agglomeration of economic activity in response to economic growth. In a book written by Marshall (1920), the author describes the geographical concentration of producers all over medieval England, provides a general theory of economic geography. He suggests that firms would benefit from locating near one another. Such geographical concentration of related firms is usually explained by positive externalities known as "agglomeration economies". As a result of neighbors observing and imitating one another, location itself has important productivity enhancing effects for

[20] Since knowledge is invisible, many researches have tried to measure it in various ways. Jaffe (1986) and Jaffe, Trajtenberg, and Henderson(1993) use patent data as knowledge stock variable. On the other hand, Winston (2000), and Aw and Palangkaraya (2003) use a firm's total factor productivity calculated by using inputs and output as knowledge stock.

individual firms. The existence of spatial externalities embodied in Marshall's hypothesis relies on the assumption of human interaction as an important vehicle for knowledge transfers. In particular, geographical proximity is an important determinant of the diffusion of tacit knowledge. Following Marshall (1920), many researches highlight the fact that firms benefit from their location by sharing the fixed costs of common resource such as a pooled market for workers with specialized skills, the development of specialized inputs and services, and technological spillovers.[21]

While Marshall emphasizes the role of knowledge in determining the physical concentration of firms, Romer (1993) considers the role of growth should focus on *idea gaps* rather than *object gaps* to explain the persistent difference in economic growth between developed and developing countries.[22] He argues that developed countries with more abundant knowledge stock would have more rapid productivity growth and focuses his research on the externalities arising from the non-rival nature of knowledge accumulation. Romer does not explicitly model the connection between economic growth and geographical proximity. Mills (1992) refers to this type of knowledge as ambiguous information that "requires an interactive and convergent set of exchange before the final exchange can be consummated". This ambiguous information of Mills is defined as information that requires negotiation to establish meaning. Baptista (1998) and Feldman (2000) find that knowledge spillovers provide a mechanism for enhancing the innovative performance and growth of firms. Knowledge enhancing a firm's current and future

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[21] The well-known examples of agglomeration of industry are California's Silicon Valley, Hollywood's entertainment industries, and Detroit's car industry.

[22] While developed countries possess both *object* such as factories, raw materials, and infrastructures and *idea* that leads innovation, developing countries lack of either object or ideas or both. This causes the slow growth in poor countries.

productivity depends on access to new ideas which can be created by a firm's own effort or by locating itself with other firms closely. Winston (2001) focuses on a developing country case, and tested intra-industry local knowledge spillovers in the Taiwan electronics industry. He finds local knowledge spillovers are potentially an important source of productivity growth.

The research on spillovers suggests that geographic proximity facilitate the transmission of information, which can be considered a knowledge spillover. Geographic proximity may create opportunities for interactions among firms and trust building necessary to the effective exchange of ideas.

In this chapter, we take a look at how physical proximity helps a firm to increase its future productivity and its survival in the market using micro panel data of selected Korean manufacturing industries between 1991 and 1999. We use a very broad measure of firm knowledge in the form of total factor productivity. TFP can be viewed as being

In the next section of this chapter, we review the literature on the empirical and theoretical models of productivity evolution, and local knowledge spillovers. Section 3 describes the theoretical model on which our empirical work is based. Section 4 describes empirical framework and location data that is used in regression. Section 5 shows the estimation results. Finally we summarize and conclude in the sixth section.

2.2. Literature review

Early case studies on local knowledge spillovers show how specific new technologies spread over some locations. The first empirical work of diffusion of technology is Griliches (1957). He studies the diffusion of hybrid corn seed in the Midwestern United States from

1932 to 1956. He emphasizes the role of economic factors such as expected profits and scale in determining the varying rates of diffusion across the Midwestern areas. His study suggests that location plays an important role in the spread of knowledge. However, the result of this case study is limited to a single technology to represent a firm's knowledge.

Marshall (1920) addresses that spillovers occur more easily due to geographical proximity, in that ideas travel more quickly and easily over shorter distance. He gives three reasons of why industries are concentrated in the same region. The same industries tend to be closely located to other competing firms because (i) of easy access to demands of specialized labor, (ii) of the development of specialized intermediate goods industries, and (iii) of knowledge spillovers among the firms in an industry. Krugman (1991) emphasizes the first two factors since it is certainly less visible and more difficult to measure and ignores the spillover effect.

Some researches interested in spillovers effects have used patent data given the detailed geographic information available about inventors. For example, Jaffe (1986) estimates the spillover effects of firms' R&D expenditure on their neighbors' patent activity in the U.S. To do so, he first develops variables relating to spillovers based on the technological nature of firm's past research. Then, spillover effects are inferred from the estimated effects of the constructed variables on the firm's patent application[23]. He finds that a firm surrounded by neighbors who have high investment rates tends to invest more, and thus, enjoys high profit rates. This finding verifies the existence of spillover effect from neighboring firms. Later Audretsch and Feldman (1996) and Jaffe (1989) provide

[23] The estimation is conducted on a cross-section of 432 firms for two separated time periods, one 1972-74 and the other 1978-80.

evidence that corporate patenting at the state level depends on university research spending after controlling for corporate R&D. Jaffe (1989) is among the first to identify to what extent university and public research is able to effect innovative activity. He finds that firm-level R&D productivity is increased by R&D investment of neighboring firms, and that local university research increases rates of corporate patenting. Audretsch and Feldman (1996) find that the propensity of innovative activity to cluster geographically tends to be greater in industries where new economic knowledge plays a more important role like computer and pharmaceuticals.

Many researchers so far have focused on the relationship among productivity of firms, their own R&D expenditure, and the R&D expenditure of other firms[24]. Jaffe, Trajtenberg, and Henderson (1993) explore where spillover effect goes by comparing the geographic location of patent citations with that of the cited patents. They estimate the probability that two firms that share the same location as a function of whether they have cited each other's patents based on the combination of the patent data in Jaffe (1986) and location data. They find strong evidence of localization of knowledge spillovers on three geographical levels: country, state, and metropolitan statistical area.

While Jaffe (1986) and Jaffe et. al (1993) measure the effect of spillovers on the knowledge production process itself, most studies estimate the effect of spillovers on a firm's productivity. Some find that R&D, FDI, or export experiences have direct effects on a firm's own productivity, and others also find evidence of knowledge spillovers using measures of technological proximity.

[24] Romer (1986, 1990) and Grossmand and Helpman (1991)

R&D expenditures have been used as a measure of knowledge by Basant and Fikkert (1996) and Adams and Jaffe (1996). Basant and Fikkert (1996) discuss the influence of R&D, technology purchase, and spillovers on the productivity using panel data on Indian firms during from 1974 to 1982. They find a strong positive correlation between beneficial spillovers from foreign R&D and foreign direct investment, and increasing levels of domestic R&D and human capital. But they do not address the issue of local knowledge spillovers by including location as a measure of proximity in their study of intra-firm spillovers. On the contrary, Adams and Jaffe (1996) consider both the importance of technological and geographical proximity for R&D spillovers. They match firm-level R&D expenditure to plant-level total factor productivity. They find that total firm-level R&D expenditure affects plant-level productivity, but the number of plants negatively affects these intra-firm spillovers. While they find evidence that spillovers are attenuated by both geographical and technological proximity, the study focuses on spillovers at intra-firm level. The benefit of geographical proximity may vary across industries. They observe that R&D output at a distance place could be beneficial in pharmaceuticals but may be of little value in chemicals.

Studies address the issue of the potential spillovers from foreign direct investment (FDI). Haddad and Harrison (1993) and Aitken and Harrison (1999) fail to find any evidence of technology spillovers from foreign to domestic firms in Morocco and Venezuela respectively. Haddad and Harrison (1993) find a week correlation between plant total productivity growth and presence of foreign firms in the sector using a panel data on Moroccan manufacturing plants for the period 1985-1989. Aitken and Harrison (1999), using data on Venezuelan manufacturing for the period 1979-1989, find that individual plants benefits from foreign investment, at least when those plants are small, but productivity growth in domestic plants is negatively correlated with foreign presence in the sector. They find that competition with foreign-owned firms actually decrease productivity of locally-owned plants.

Exporting may be an important source of knowledge in developing countries. Clerides, Lach, and Tybout (1998) study export-led productivity growth using a panel dataset of manufacturers in Columbia, Mexico, and Morocco. They confirm that exporting firms are more efficient than non-exporting firms and extend the analysis to address the issue of local spillovers from learning-by-exporting. But, they can not find any evidence that non-exporters do not benefit from the knowledge that their neighbors gain through exporting.

The few studies have interest in same issue in developing countries, but they focus on the productivity effects of specific sources of knowledge[25]. Without depending on the specific sources of knowledge, a researcher can measure a firm's productivity using the definition of total factor productivity (TFP) to see the effect of knowledge on it. Each firm may have different TFP because it has different business background such as business experience, product design, processing technologies, managerial skills and so on. Each of these differences among firms can be interpreted as part of a firm's collective knowledge, and each is also a potential source of knowledge spillovers. We can consider a firm's location as a key source of knowledge spillovers in the sense that firms can improve their own TFP by sharing, adopting and improving upon the technologies of their neighbors.

[25] Clerides, Lach and Tybout (1998) and Aitken and Harrison (1999).

One recent empirical work by Winston (2001) finds the location spillover effects among firms based on TFP measurement. He focuses on a developing country case and tests intra-industry local knowledge spillovers in the Taiwan electronics industry. He finds local knowledge spillovers are potentially an important source of productivity growth, which is consistent with the hypothesis that physical proximity facilitates the spread of knowledge among firms. Since Taiwan manufacturing industries are highly decentralized while South Korea manufacturing industries are vertically integrated, we can compare the importance of local knowledge spillovers between countries that have different industrial structures.

2.3. The Theoretical model

In this section, we take a look at a theoretical model of local knowledge spillovers. In the previous chapter, we examine a model in which a firm's knowledge spillover from its own R&D investment decision and export participation. In this chapter, we are interested in looking at a firm's external knowledge spillover from other firms that are located close by. Firms in the same geographic region or same industry group near by may take advantages on the presence of other competing firms. By locating close to each other, they can imitate each other, share management skills, or experienced workers, all of which may result in an increase in firm's productivity. That is physical proximity facilitates the spread of knowledge among firms.

The theoretical model of local knowledge spillovers specifies a knowledge production process whereby firms combine their internal and external knowledge to produce new ideas. The evolution of a firm's knowledge from one period to the next follows a Markov process similar to that specified in Hopenhayn's (1992) model of industry evolution. Hopenhayn solves for the long-run stationary equilibrium of his dynamic model of industry evolution and develops comparative statics to compare populations of firms. In this paper, we assume the existence of such equilibrium and focus on the behavior of individual firms.

A firm combines existing knowledge to generate new ideas. The production of new ideas is modeled as

(1) $ID_{it} = G(\omega_{it}, \Omega_{it}^{I,L})$

ID_t are new ideas a firm can implement and they depend on a firm's productivity (ω_{it}) that is a measure of its internal knowledge and $\Omega_{it}^{I,L}$ that is a measure of a firm's external knowledge stock. It depends on a firm's industry, I, and location, L.

All of those new ideas are not always successful to use in the production process. Some ideas may be very fruitful while others may yield no productivity improvements. Pakes and McGuire (1994) assume probabilities of success and failure of a firm's investment to be realized in its efficiency. Instead of using those probabilities, we deal with the new knowledge that results from implementing a set of new ideas as a random draw. The random draw, τ_t, is drawn from a family of distribution,

(2) $T(ID_{it}, Z_{it})$

where Z_{it} is a vector of other firm characteristics.

We assume that new knowledge is realized next period. As time goes by, the current technology will be out-of-date. Hence, the evolution of a firm's internal knowledge stock over time can be expressed as

(3) $\omega_{it+1} = \delta\omega_{it} + \tau_{it}$

where $1-\delta$ measures the depreciation of knowledge.

Expressions (2) and (3) imply that the evolution of a firm's productivity can be represented as a family of Markov distributions such that

(4) $F(\omega_{it+1} \mid \omega_{it}, \Omega_{it}^{I,L}, Z_{it})$

A firm with higher current internal or external knowledge stock draws its future knowledge from a distribution that first order stochastically dominates the distribution from a firm with lower corresponding knowledge. Since firms combine their internal and external knowledge to produce new knowledge, the Markov distribution captures the effect of knowledge spillovers.

In every period *t*, given its own stock of knowledge, firm *i* produces total output (y_{it}) using labor (l_{it}), capital (k_{it}), materials (m_{it}) according to a production technology represented by $Y_{it}(\omega_{it}, l_{it}, k_{it}, m_{it})$. In addition, the plant forms a rational expectation of its future output in order to decide whether it stays in the market or not. A firm decides whether to stay in or exit by maximizing the present discounted value of its future profits. If a firm decides to exit, it will receive the scrap value, Θ. This implies a productivity threshold is that the plant uses to make exit decision. The threshold varies across plants and depends on a firm's individual characteristics and knowledge evolution process. The firm's binary decision rule can be represented as

(5) $$S_{it} = \begin{cases} 1 & if\ \omega_{it} \geq \underline{\omega}(Z_{it}, \Omega_{it}^{I,L}) \\ 0 & if\ \omega_{it} < \underline{\omega}(Z_{it}, \Omega_{it}^{I,L}) \end{cases}$$

where the firm's productivity threshold, $\underline{\omega_{it}}$, is a latent variable which depends on the firm's individual characteristics such as age and size as well as its external knowledge stock.

Knowledge spillovers exist in the model because the knowledge production process is specified as the source of uncertainty in (4). Therefore, spillovers affect both a firm's knowledge evolution process and its endogenous exit decision.

2.4. Empirical model and Location Data

Empirical models specify the evolution of a firm's knowledge over time and a firm's exit behavior. As in the previous R&D model, reduced forms of these two equations are specified and estimated jointly as a Heckman selection model. TFP is used as a measure of knowledge in both equations.

A firm draws its future knowledge from a distribution that depends on its current internal and external knowledge as well as other firm characteristics, which are a firm's age, capital and whether they are new entrant or not.

(6) $$\omega_{it+1} = \vartheta_0 + \vartheta_1 I(E_{it}) + \vartheta_2 \ln(age_{it}) + \vartheta_3 \omega_{it} + \sum_j \vartheta_j \Omega_{ijt}^{I,L} + \upsilon_{it+1}$$

Since a new firm has not been subject to productivity shock, we include the dummy variable for a new entrant between two periods. The age variable captures possible vintage capital effects that are not accounted for in the index measure of TFP. The local external knowledge stock available to each firm is denoted by $\Omega_{ijt}^{I,L}$. We assume a standard normal distributed error term υ_{it+1}. Each estimated coefficient in equation (6) can be interpreted as the effect of the associated independent variable on the mean of the distribution from which a firm's future knowledge is drawn.

The binary exit decision is similar to the one in R&D investment model. A reduced form of exit decision rule is represented as

(7) $$S_{it+1} = \varphi_0 + \varphi_1 I(E_{it}) + \varphi_2 \ln(age_{it}) + \varphi_3 \ln(k_{it}) + \varphi_4 (\ln(k_{it}))^2 + \varphi_5 \omega_{it} + \sum_j \varphi_j \Omega_{ijt}^{I,L} + \varsigma_{it+1}$$

where $S_{it}=1$ if the firm decides to stay in the market and $S_{it}=0$ if the firm chooses to exit. We assume that ς is random error term with a standard normal distribution.

As we discussed in R&D investment model, a standard Heckman selection model is employed to estimate two equations, productivity evolution and firm survival equation, simultaneously to eliminate the selection bias.

In this reduced form of the model, a firm's geographical information is used to explain local knowledge spillovers among firms. One important issue in this empirical model is how a plant's external knowledge stock, $\Omega_{ijt}^{I,L}$ is measured empirically. We need to use a proxy variable to represent the interaction among plants. The empirical model groups plants according to their location. That is, within each location firms are also grouped in to their 2-digit industry. Each plant's external knowledge is represented as the distribution of the knowledge of other plants in its location and the distribution of the knowledge of other plants in its location and its industry.

We use two proxies for a plant's external knowledge. One is the median TFP of a plant's location and the other is the number of plants in that location. The median TFP in the location that a plant belong to captures the idea that a plant can be better off by surrounding plants with higher TFP. A plant may enjoy new ideas produced by neighbors with higher productivity. The number of plants can be another good proxy for external knowledge in the sense that firms with more neighbors have either more opportunity to produce new ideas or a greater variety of external knowledge. In the next section, we estimated the empirical models to see whether or not the effect of external knowledge on productivity growth and survival matters. With different specifications, we used two different sets of proxies of external knowledge. To estimate the effects of intra-industry local knowledge spillovers, these measures are constructed for each location and for each 2-digit industry within each location.

In this chapter, we used a panel data of Korea manufacturing plants in machinery, electronics, electricals, automobile, and other transport equipment industries between 1991 and 1999. The data contains the information of input, output as well as each plant's geographical location. The Korea National Statistical Office divides South Korea into 16 major geographical areas: seven cities and nine provinces. Those sixteen locations are used to represent physical proximity in the empirical model. Table 2.1 shows the number of plants during the period of 1991~1999 in each location. Two interesting observations can be found from Table 2.1. First, 56 to 65 percent of plants were concentrated in capital areas including Seoul, Inchon and Kyoungki while almost 45% of population is distributed in those areas. Second, the number of plants in each location dramatically fell down after the financial crisis in 1997. For example, the number of plants in capital areas decreased continuously: 12.8% of plants disappeared between 1996 and 1997, and 24.9% of plants exited between 1997 and 1998.

2.5. Estimation Results

Five specifications of the model are estimated to see the empirical importance of intra-industry local knowledge spillover within 2-digit industries. The first specification provides a baseline for the rest of specifications and it does not include measure of external knowledge terms. It includes only a firm's characteristics information. The second specification includes a plant's external knowledge measured from each location's TFP distribution and number of firms in that location. This specification does not consider the effect of intra-industry local knowledge spillovers. The primary goal of estimation is the third specification, which adds measures of external knowledge in each industry within each location to check intra-industry local knowledge spillovers. The fourth specification uses a different characterization of the 2-digit industry-specific local knowledge stocks to support the findings of the third specification. The final specification uses 2 industry quartiles instead of using 4 industry quartiles as used in the fourth specification. The estimation results of each specification are reported in Table 2.2. Furthermore, we report the estimation results of survival equation for each specification in Table 2.3. As we describe in theoretical model, we estimate two equations simultaneously using a standard Heckman selection model.

The first column in Table 2.2 reports the estimated parameters of the baseline TFP evolution specification. It includes year dummies, industry dummies, an entrant dummy, the natural log of firms' age in year, $\ln(age_{it})$, and natural log of firms' TFP, ω_{it}. To save space in table, we do not report the estimated coefficients of year dummies and industry dummies. The corresponding survival equation for baseline specification is reported in the first column in Table 2.3. The firms' survival equation has two extra variables, the natural log of capital and its square. We will explain firm's productivity evolution and survival by each specification of models.

The predictions of the theoretical model are confirmed by the estimated parameters of the empirical knowledge evolution equation. In the first column of Table 2.2, the coefficient of ω_{it} implies that, on average, firms with higher current TFP will draw higher future TFP. That is two firms with current TFP that differ by 10% will draw their respective future TFPs from two distributions with means that differ by 6.8%. The coefficient of an entrant dummy variable is positive and significant implying that a new entrant is more productive next period. The coefficient of age variable indicates that experienced firm will, on average, have higher future productivity. The estimated coefficients on entrant dummy and age variable are not what we expected. Even though we expected the opposite signs for those two coefficients, they showed same sign. But, we need to notice the magnitude of these two coefficients; the coefficient on new entrant variable is greater than that of age variable. The best interpretation that we can make is that new entrants in Korean industries prepared advanced equipments, production process before they start to produce. Hence, this fact is reflected to higher productivity gain in the next year (0.107). But, this effect does not last for long time period. The age variable that represents the experience in production shows statistically positive effect on future productivity, but its rate will be increasing with decreasing rate compared to new entrants (0.037).

In the first column of Table 2.3, new entrants are more likely to survive next period and old firm is less likely to continue in production. In the view of productivity, the more productive firms tend to exit next period. This is not what expected in the theoretical model description. However, when we add local knowledge spillover variables in the regression model, the coefficient on productivity become positive and significant. The covariance reported in Table 2.2 implies that the random shocks that increase a firm's future productivity are negatively correlated with random shocks that increase the likelihood that a firm will chose to continue. This is the different result from the one in the R&D investment model.

The second specification shows measure of each location's TFP distribution and number of firms in that location. $med\omega_{it}^{L}$ measures the natural log of the median TFP of the location and $\#firms_{it}^{L}$ measures the natural log of the number of firms in the location. The positive and significant estimates of $med\omega_{it}^{L}$ verifies the theoretical prediction, which indicates that a high median local TFP offers a firm that opportunity to access superior external knowledge and to produce more new ideas.

It is worth comparing coefficients on a firm's own TFP and on median TFP of the location. The magnitudes are quite plausible. It is reasonable to expect that the effect of a firm's internal knowledge on its future TFP would be stronger than the effect of its external knowledge. In the regression result, a 10% difference in a firm's own TFP would have 6.2% effect on its future TFP, whereas a 10% difference in the median TFP of its location would have 4.1% effect on its future TFP.

The negative and significant coefficient on $\#firms_{it}^{L}$ implies that a firm located in more competitive environment is less likely to survive because of high competitive environment. Comparing with the result of previous specification, the magnitude of coefficient on a firm's own TFP is reduced from 0.677 to 0.618. The reduction in the coefficient on ω_{it} may be attributed to the positive correlation between current TFP and the measures of knowledge stocks, supporting the claim that the model is missing important local characteristics. Overall, the second specification demonstrates that a firm's location is an important element of the evolution of a firm's TFP, but it is unable to distinguish the effects of local knowledge spillovers from the effect of location specific characteristics.

The results of the third specification indicates that the measure of median industry TFP within each location, $med\omega_{it}^{I,L}$, has no significant effect on a firm's future productivity whereas $med\omega_{it}^{L}$ has significantly positive effect on the evolution of a firm's TFP. This result implies that the productivity enhancing local characteristics captured by $med\omega_{it}^{L}$ do not seem to be industry specific. The coefficient on the number of firms in each industry within each location, $\#\,firms_{it}^{I,L}$, indicates that having more opportunities to combine knowledge with neighbors in the same industry has a positive and statistically significant effect on its future TFP.

The last two specifications of the model support the claim that $\#\,firms_{it}^{I,L}$ captures the effects of local knowledge spillovers. If high productivity neighbors are better source of knowledge than low productivity neighbors, then the spillovers associated with the number of high productivity neighbors should be greater than the spillovers associated with the number of low productivity neighbors. To test this hypothesis, we add TFP quartiles in regression models. In the third specification, we add 4 industry quartiles as the characterization of the location and industry TFP distribution instead of using $med\omega_{it}^{L}$ and

$\# firms_{it}^{I,L}$ as in the third specification. For example, $Q1\# firms_{it}^{I,L}$ represents the natural log of the number of firms in the same location and industry that fall in the top quartile of the TFP distribution of the firm's industry and $Q4\# firms_{it}^{I,L}$ represents the one that fall in the bottom quartile of the TFP distribution of the firm's industry.

The empirical results in the fourth and fifth column in Table 2.2 verify the hypothesis as we claimed above. The coefficients on $Q1\# firms_{it}^{I,L}$ and $Q2\# firms_{it}^{I,L}$ are positive while the other are negative even not all of them are significant. However, when we replace top 50% TFP distribution, $High\# firms_{it}^{I,L}$, and low 50% TFP distribution, $Low\# firms_{it}^{I,L}$, the coefficient of high TFP group is positive and significant, and the other has negative and statistically significant. These results indicate that high productivity firms are the only significant sources of knowledge spillovers, which suggests that firms benefits most from combining their internal knowledge with the external knowledge of those neighbors that have the high TFP on average.

We also take a look at the differences between two groups, one located in cities, and the other located in provinces. When we compare the results based on the third specification, we can find that there is no special merit that a firm is located in cities. On the contrary, if a firm locates itself around provinces, and if the average productivity of firms around a firm arises, it enjoys higher external knowledge spillover (0.308) when it locates itself in a city (0.260).

Using TFP as a measure of knowledge, the empirical model produces statistically significant estimates of the positive effects of intra-industry local knowledge spillovers while controlling for the effects of local public goods and endogenous firm exit. The results suggest that spillovers arise from the number of opportunities a firm has to interact with other firms in the same industry and that interactions with high productivity neighbors are most productive.

2.6. Summary and Conclusion

The importance of knowledge spillovers as innovative inputs suggests that firms that depend on innovation for their success and survival not only face a series of strategic decisions about the organization of their own R&D resources but also may consider how location affect their productivity. Together with a firm's effort that enhances a firm's productivity such as R&D investment, being together in the same location may be another source of productivity if firms share information on production, purchase of inputs, and so on.

Literature about economic geography embraced the idea that geographic concentrations of innovative activity generate knowledge spillovers as one firm's activity aids the advancement of other. Knowledge can be obtained from a firm's internal activity such as R&D investment and from an external source such as location proximity. As firms increasingly depend on external knowledge of other firms, location proximity creates opportunities for face-to-face interactions and trust building necessary to the effective of ideas. This, in turn, promotes networking of firms to develop new ideas and to help in R&D activity.

More than a firm's internal knowledge spillovers over its productivity and survival, we are interested in local knowledge spillovers. A firm may have benefits by locating other firms in the same region. They can share any good information that affects its productivity and survival as well. We estimate a firm's productivity evolution and survival simultaneously by considering a firm's characteristics and local information as well. The predictions of the theoretical model are confirmed by the estimated parameters of the empirical knowledge evolution equation. We find that a high median local TFP offers a firm that opportunity to access superior external knowledge and to produce more new ideas. In addition, a firm located in more competitive environment is less likely to survive.

The empirical model tests for intra-industry local knowledge spillovers in the five Korean industries by estimating the dynamic productivity effects of knowledge stocks associated with each 2-digit industry within each city or province. The evolution of a firm's knowledge is specified as a reduced form equation that estimates a firm's future TFP as a function of its current TFP, local industry-specific knowledge stocks, and other characteristics.

The regression results of other specifications imply that the productivity enhancing local characteristics does not seem to be industry specific. We also find that high productivity firms are the only significant sources of knowledge spillovers, which suggests that firms benefits most from combining their internal knowledge with the external knowledge of those neighbors that have high TFP on average.

Table 2.1. Number of Plants in Each Locaton

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cities									
Seoul	680	600	661	560	502	449	361	270	111
Busan	233	227	252	237	241	223	197	165	107
Daegu	159	143	155	162	177	156	135	106	64
Inchon	394	390	433	429	464	430	384	297	155
Kwangju	85	86	88	87	81	84	77	51	31
Daejeon	30	37	37	38	37	43	32	20	16
Ulsan	-	-	-	-	-	78	74	49	38
Provinces									
Kyoungki	1404	1308	1400	1373	1289	1275	1133	843	502
Kangwon	38	38	40	39	39	31	27	22	13
Chungbuk	92	90	95	99	97	92	90	58	40
Chungnam	79	86	91	104	107	119	97	70	48
Jeonbuk	46	40	46	47	53	49	40	33	25
Jeonnam	54	48	45	48	50	45	44	33	22
Kyoungbuk	183	184	191	201	178	178	162	124	82
Kyungnam	352	336	361	391	365	285	261	198	115
Jeju	2	2	2	1	1	1	1	2	1

Table 2.2. Productivity Evolution Estimates

Maximum Likelihood Estimation of Selection Model – Dependent Variable : ω_{it+1}

	Baseline	Location	Location/ Industry	4 Industry Quartiles	2 Industry Quartiles
Constant	0.069* (0.017)	0.103* (0.022)	0.114* (0.023)	0.197* (0.026)	0.179* (0.024)
$I(E_{it})$	0.107* (0.010)	0.106* (0.010)	0.106* (0.010)	0.105* (0.010)	0.107* (0.010)
$ln(age_{it})$	0.037* (0.003)	0.013* (0.003)	0.013* (0.003)	0.013* (0.003)	0.015* (0.003)
ω_{it}	0.677* (0.005)	0.618* (0.005)	0.617* (0.005)	0.613* (0.005)	0.624* (0.005)
$med\omega_{it}^{L}$		0.407* (0.015)	0.382* (0.031)	0.392* (0.015)	0.387* (0.015)
$\# firms_{it}^{L}$		-0.022* (0.002)	-0.030* (0.004)	-0.036* (0.004)	-0.031* (0.004)
$med\omega_{it}^{I,L}$			0.026 (0.028)		
$\# firms_{it}^{I,L}$			0.008* (0.004)		
$Q1\# firms_{it}^{I,L}$				0.007 (0.006)	
$Q2\# firms_{it}^{I,L}$				0.034* (0.007)	
$Q3\# firms_{it}^{I,L}$				-0.003 (0.007)	
$Q4\# firms_{it}^{I,L}$				-0.041* (0.006)	
$High\# firms_{it}^{I,L}$					0.035* (0.006)
$Low\# firms_{it}^{I,L}$					-0.030* (0.006)
$Cov(\varepsilon_{it+1}, u_{it+1})$	-0.264 (0.019)	-0.151 (0.021)	-0.148 (0.021)	-0.165 (0.021)	-0.159 (0.021)
Log likelihood	-48474.71	-44494.56	-44489.15	-43116.51	-44321.33
Sample size	63,909	63,909	63,909	62,152	63,620

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

Table 2.3. Survival Equation Estimates

Maximum Likelihood Estimation of Sample Selection Model – Dependent Variable : S_{t+1}

	Baseline	Location	Location/ Industry	4 industry Quartiles	2 industry Quartiles
Constant	-1.636* (0.086)	-2.283* (0.113)	-2.293* (0.115)	-1.997* (0.125)	-2.092* (0.117)
$I(E_{it})$	0.521* (0.021)	0.894* (0.023)	0.896* (0.023)	0.899* (0.024)	0.899* (0.024)
$ln(age_{it})$	-0.287* (0.010)	-0.205 (0.011)	-0.205* (0.011)	-0.206* (0.012)	-0.212* (0.011)
$\ln(k_{it})$	0.046** (0.026)	-0.171* (0.029)	-0.172* (0.029)	-0.167* (0.030)	-0.152* (0.029)
$(\ln(k_{it}))^2$	0.0004 (0.002)	0.014* (0.002)	0.014* (0.002)	0.013* (0.002)	0.013* (0.002)
ω_{it}	-0.122* (0.017)	0.174* (0.019)	0.180* (0.019)	0.144* (0.019)	0.159* (0.019)
$med\omega_{it}^{L}$		-5.313* (0.070)	-5.082* (0.122)	-5.498* (0.074)	-5.449* (0.072)
$\#\,firms_{it}^{L}$		0.252* (0.009)	0.250* (0.015)	0.223* (0.016)	0.232* (0.015)
$med\omega_{it}^{I,L}$			-0.240* (0.104)		
$\#\,firms_{it}^{I,L}$			0.005 (0.014)		
$Q1\#\,firms_{it}^{I,L}$				0.190* (0.024)	
$Q2\#\,firms_{it}^{I,L}$				0.062* (0.027)	
$Q3\#\,firms_{it}^{I,L}$				-0.118* (0.028)	
$Q4\#\,firms_{it}^{I,L}$				-0.158* (0.024)	
$High\#\,firms_{it}^{I,L}$					0.257* (0.023)
$Low\#\,firms_{it}^{I,L}$					-0.287* (0.026)

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

Table 2.4. Productivity Evolution Estimates by industry
Maximum Likelihood Estimation of Selection Model – Dependent Variable : ω_{it+1}

	Industry									
	Chemical		Electronic		Electrical		Mobile		Other Transport	
constant	0.081** (0.048)	0.048 (0.054)	0.225* (0.078)	0.396* (0.094)	0.289* (0.074)	0.715* (0.124)	0.158** (0.088)	0.124 (0.060)	-0.246 (0.192)	-0.241 (0.192)
$I(E_{it})$	0.117* (0.019)	0.116* (0.019)	0.072* (0.032)	0.078* (0.032)	0.110* (0.031)	0.110* (0.031)	0.102* (0.048)	0.105* (0.048)	0.057 (0.080)	0.059 (0.080)
$ln(age_{it})$	0.012** (0.007)	0.012** (0.007)	0.011 (0.010)	0.009 (0.010)	0.024* (0.010)	0.023* (0.010)	0.024** (0.013)	0.024** (0.013)	-0.008 (0.025)	-0.005 (0.025)
ω_{it}	0.549* (0.012)	0.552* (0.012)	0.595* (0.018)	0.582* (0.019)	0.554* (0.021)	0.555* (0.021)	0.604* (0.023)	0.595* (0.024)	0.737* (0.048)	0.742* (0.051)
$med\omega^{L}_{it}$	0.498* (0.034)	0.731* (0.106)	0.535* (0.049)	0.292* (0.075)	0.569* (0.051)	0.790* (0.146)	0.495* (0.059)	0.120 (0.139)	0.286* (0.116)	0.347* (0.157)
$\# firms^{L}_{it}$	-0.012* (0.005)	0.006 (0.016)	-0.038* (0.008)	-0.079* (0.016)	-0.042* (0.074)	-0.172* (0.032)	-0.022* (0.008)	-0.002 (0.014)	-0.031 (0.019)	-0.023 (0.020)
$med\omega^{I,L}_{it}$		-0.221* (0.097)		0.333* (0.078)		-0.223* (0.132)		0.346* (0.119)		-0.053 (0.129)
$\# firms^{I}_{it}$		-0.017 (0.015)		0.031* (0.011)		0.107* (0.026)		-0.030* (0.016)		-0.031 (0.023)
Sample size	12,451		5,603		5,392		3,620		779	

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

Table 2.5. Survival Equation Estimates by industry

Maximum Likelihood Estimation of Selection Model – Dependent Variable : S_{it+1}

	Industry									
	Machinery		Electronic		Electrical		Mobile		Other Transport	
constant	-2.101*	-1.476*	-2.696*	-3.279*	-2.247*	-4.234*	-1.564*	-1.535*	-1.745*	-1.774*
	(0.248)	(0.265)	(0.370)	(0.400)	(0.404)	(0.570)	(0.513)	(0.517)	(0.903)	(0.905)
$I(E_{it})$	0.917*	0.919*	0.973*	0.962*	0.852*	0.856*	0.785*	0.775*	0.980*	1.013*
	(0.048)	(0.049)	(0.079)	(0.079)	(0.078)	(0.078)	(0.113)	(0.114)	(0.213)	(0.215)
$ln(age_{it})$	-0.231*	-0.226*	-0.171*	-0.162*	-0.193*	-0.183*	-0.250*	-0.253*	-0.146	-0.120
	(0.026)	(0.026)	(0.039)	(0.040)	(0.040)	(0.040)	(0.057)	(0.057)	(0.103)	(0.105)
$\ln(k_{it})$	-0.175*	-0.187*	-0.182*	-0.195*	-0.161	-0.165	-0.319*	-0.314*	-0.314	-0.335
	(0.066)	(0.066)	(0.088)	(0.088)	(0.109)	(0.109)	(0.140)	(0.140)	(0.240)	(0.243)
$(\ln(k_{it}))^2$	0.012*	0.012*	0.016*	0.016*	0.013	0.013	0.023*	0.022*	0.027	0.028
	(0.005)	(0.005)	(0.006)	(0.006)	(0.008)	(0.009)	(0.010)	(0.010)	(0.018)	(0.018)
ω_{it}	0.144*	0.157*	0.121**	0.126*	0.247*	0.230*	0.074	0.102	0.327	0.340
	(0.044)	(0.044)	(0.065)	(0.067)	(0.078)	(0.079)	(0.098)	(0.099)	(0.202)	(0.209)
$med\omega_{it}^{L}$	-5.473*	-4.113*	5.427*	-5.065*	-5.487*	-5.947*	-5.091*	-3.745*	-5.063*	-4.810*
	(0.153)	(0.387)	(0.241)	(0.314)	(0.251)	(0.553)	(0.327)	(0.609)	(0.782)	(0.873)
$\#\,firms_{it}^{L}$	0.237*	-0.114*	0.292*	0.458*	0.240*	0.869*	0.235*	0.177*	0.225*	0.203*
	(0.019)	(0.058)	(0.033)	(0.056)	(0.030)	(0.129)	(0.038)	(0.059)	(0.081)	(0.086)
$med\omega_{it}^{I,L}$		-1.601*		-0.580*		0.410		-1.296*		-0.431
		(0.349)		(0.278)		(0.466)		(0.499)		(0.518)
$\#firms_{it}^{I,L}$		0.360*		-0.134*		-0.528*		0.097		0.073
		(0.055)		(0.038)		(0.106)		(0.066)		(0.901)
Sample size	12,451		5,603		5,392		3,620		779	

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

Table 2.6. Productivity Evolution Estimates (7 Cities)

Maximum Likelihood Estimation of Selection Model – Dependent Variable : ω_{it+1}

	Baseline	Location	Location/Industry	4 Industry Quartiles	2 Industry Quartiles
Constant	0.135* (0.034)	0.216* (0.062)	0.209* (0.062)	0.329* (0.068)	0.274* (0.065)
$I(E_{it})$	0.092* (0.021)	0.097* (0.021)	0.101* (0.021)	0.095* (0.021)	0.097* (0.021)
$ln(age_{it})$	0.032* (0.007)	0.007 (0.007)	0.008 (0.007)	0.006 (0.007)	0.008 (0.007)
ω_{it}	0.656* (0.012)	0.568* (0.013)	0.555* (0.014)	0.557* (0.014)	0.566* (0.013)
$med\omega_{it}^{L}$		0.511* (0.036)	0.260* (0.065)	0.497* (0.037)	0.498* (0.037)
$\#\,firms_{it}^{L}$		-0.032* (0.007)	-0.032* (0.009)	-0.048* (0.010)	-0.041* (0.009)
$med\omega_{it}^{I,L}$			0.261* (0.057)		
$\#\,firms_{it}^{I,L}$			0.001 (0.006)		
$Q1\#\,firms_{it}^{I,L}$				0.052* (0.013)	
$Q2\#\,firms_{it}^{I,L}$				-0.034* (0.016)	
$Q3\#\,firms_{it}^{I,L}$				-0.005 (0.016)	
$Q4\#\,firms_{it}^{I,L}$				-0.010 (0.014)	
$High\#\,firms_{it}^{I,L}$					0.027* (0.013)
$Low\#\,firms_{it}^{I,L}$					-0.024** (0.013)
$Cov(\varepsilon_{it+1}, u_{it+1})$	-0.318 (0.040)	-0.189 (0.047)	-0.183 (0.048)	-0.203 (0.046)	-0.209 (0.045)
Log likelihood	-8744.41	-8000.46	-7986.71	-7651.09	-7925.80
Sample size	11,398	11,398	11,398	10,984	11,332

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

Table 2.7. Survival Equation Estimates (7 Cities)

Maximum Likelihood Estimation of Sample Selection Model – Dependent Variable : S_{t+1}

	Baseline	Location	Location/Industry	4 industry Quartiles	2 industry Quartiles
Constant	-1.514* (0.189)	-2.069* (0.281)	-2.026* (0.282)	-1.245* (0.312)	-1.386* (0.297)
$I(E_{it})$	0.505* (0.046)	0.787* (0.050)	0.785* (0.050)	0.824* (0.051)	0.825* (0.050)
$ln(age_{it})$	-0.272* (0.023)	-0.219* (0.026)	-0.217* (0.026)	-0.195* (0.027)	-0.199* (0.026)
$\ln(k_{it})$	0.003 (0.060)	-0.138* (0.065)	-0.142* (0.066)	-0.147* (0.068)	-0.149* (0.066)
$(\ln(k_{it}))^2$	0.003 (0.005)	0.016* (0.005)	0.011* (0.005)	0.012* (0.005)	0.011* (0.005)
ω_{it}	-0.179* (0.041)	0.151* (0.046)	0.165* (0.047)	0.109* (0.048)	0.107* (0.047)
$med\omega_{it}^{L}$		-4.781* (0.152)	-4.443* (0.232)	-5.198* (0.163)	-5.109* (0.159)
$\#\ firms_{it}^{L}$		0.211* (0.027)	0.175* (0.032)	0.062** (0.036)	0.100* (0.034)
$med\omega_{it}^{I,L}$			-0.379* (0.191)		
$\#\ firms_{it}^{I,L}$			0.046* (0.022)		
$Q1\#\ firms_{it}^{I,L}$				0.236* (0.048)	
$Q2\#\ firms_{it}^{I,L}$				0.195* (0.060)	
$Q3\#\ firms_{it}^{I,L}$				-0.156* (0.060)	
$Q4\#\ firms_{it}^{I,L}$				-0.207* (0.052)	
$High\#\ firms_{it}^{I,L}$					0.400* (0.049)
$Low\#\ firms_{it}^{I,L}$					-0.372* (0.051)

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

Table 2.8. Productivity Evolution Estimates (9 Provinces)

Maximum Likelihood Estimation of Selection Model – Dependent Variable : ω_{it+1}

	Baseline	Location	Location/Industry	4 Indust Quartiles	2 Indust Quartiles
Constant	0.120* (0.029)	0.142* (0.042)	0.272* (0.046)	0.330* (0.055)	0.299* (0.050)
$I(E_{it})$	0.117* (0.018)	0.115* (0.018)	0.119* (0.018)	0.112* (0.018)	0.116* (0.018)
$ln(age_{it})$	0.047* (0.006)	0.017* (0.006)	0.019* (0.006)	0.018* (0.006)	0.020* (0.006)
ω_{it}	0.672* (0.010)	0.593* (0.011)	0.581* (0.011)	0.585* (0.011)	0.586* (0.011)
$med\omega_{it}^{L}$		0.502* (0.029)	0.308* (0.053)	0.494* (0.029)	0.495* (0.029)
$\#\ firms_{it}^{L}$		-0.025* (0.004)	-0.053* (0.008)	-0.065* (0.008)	-0.065* (0.008)
$med\omega_{it}^{I,L}$			0.198* (0.046)		
$\#\ firms_{it}^{I,L}$			0.024* (0.006)		
$Q1\#\ firms_{it}^{I,L}$				-0.031* (0.014)	
$Q2\#\ firms_{it}^{I,L}$				0.068* (0.014)	
$Q3\#\ firms_{it}^{I,L}$				-0.008 (0.014)	
$Q4\#\ firms_{it}^{I,L}$				0.017 (0.013)	
$High\#\ firms_{it}^{I,L}$					0.044* (0.014)
$Low\#\ firms_{it}^{I,L}$					-0.014 (0.014)
$Cov(\varepsilon_{it+1}, u_{it+1})$	-0.270 (0.034)	-0.108 (0.043)	-0.108 (0.043)	-0.113 (0.044)	-0.117 (0.043)
Log likelihood	-11938.64	-10749.96	-10725.99	-10382.75	-10647.48
Sample size	16,447	16,447	16,447	15,955	16,344

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

Table 2.9. Survival Equation Estimates (9 Provinces)

Maximum Likelihood Estimation of Sample Selection Model – Dependent Variable : S_{t+1}

	Baseline	Location	Location/Industry	4 indust Quartiles	2 indust Quartiles
Constant	-1.648* (0.165)	-2.567* (0.226)	-2.577* (0.233)	-2.413* (0.261)	-2.494* (0.248)
$I(E_{it})$	0.543* (0.042)	1.018* (0.048)	1.016* (0.048)	1.017* (0.048)	1.019* (0.048)
$ln(age_{it})$	-0.290* (0.022)	-0.233* (0.024)	-0.235* (0.024)	-0.227* (0.025)	-0.228* (0.024)
$\ln(k_{it})$	0.025 (0.021)	-0.233* (0.059)	-0.229* (0.059)	-0.223* (0.059)	-0.236* (0.059)
$(\ln(k_{it}))^2$	0.001 (0.003)	0.017* (0.004)	0.017* (0.004)	0.016* (0.004)	0.017* (0.004)
ω_{it}	-0.178* (0.036)	0.179* (0.041)	0.191* (0.041)	0.164* (0.042)	0.165* (0.041)
$med\omega_{it}^{L}$		-6.154* (0.154)	-5.861* (0.243)	-6.203* (0.159)	-6.207* (0.156)
$\# firms_{it}^{L}$		0.319* (0.017)	0.316* (0.030)	0.306* (0.031)	0.324* (0.030)
$med\omega_{it}^{I,L}$			-0.298 (0.193)		
$\# firms_{it}^{I,L}$			0.003 (0.023)		
$Q1\# firms_{it}^{I,L}$				-0.023 (0.062)	
$Q2\# firms_{it}^{I,L}$				0.067 (0.060)	
$Q3\# firms_{it}^{I,L}$				0.041 (0.057)	
$Q4\# firms_{it}^{I,L}$				-0.107** (0.055)	
$High\# firms_{it}^{I,}$					0.092 (0.050)
$Low\# firms_{it}^{I,L}$					-0.115** (0.063)

*, ** indicates statistical significance at the 0.05, 0.1 level.

Coefficients of year dummies and industry dummies are not reported in the table.

CONCLUSION

In this thesis we examine the effects of investment in knowledge and knowledge spillovers on the evolution of firms' productivity using micro panel data from Census of Manufacturing of Korea between 1991 and 1999. We analyze these knowledge spillovers that may be facilitated by physical proximity as well. The first chapter focuses on a firm's discrete decision to participate in two activities, exporting and R&D investment, which are believed to impact on its future productivity and survival. The second chapter examines the spillover effect of knowledge accumulation by assessing the impact of geographical proximity among firms on their productivity.

Chapter 1 examines the nature and process of technology upgrading among manufacturing plants in South Korea. Our results indicate that past productivity plays an important role in determining a firm's current decision to export and invest in R&D. In addition, a firm with past experience of export and/or R&D investment is more likely to continue in those activities. We also find that a firm's current level of productivity plays an important role in its survival and productivity growth. While R&D investment is a good source to increase a firm's future productivity, a firm's export participation helps a firm to survive. Even though export participation has a positive effect on a firm's future productivity, the magnitude of this effect is smaller than the productivity effect of a firm that invests in R&D. These results suggest the important role for R&D investment by firms in South Korea where the government policy has strongly encouraged in R&D since the 1980s. Moreover, the findings indicate R&D investment may be even more important for firms in the longer term when export market become increasingly competitive.

Chapter 2 assesses the effect of geographical proximity on firms' productivity. Using two proxies, the median TFP and the number of firms in the location, for a plant's external knowledge, we find the evidence of location spillovers. We find that locations where firms have high median local TFP offer firms the opportunity to access superior external knowledge and to produce more new ideas. Productivity enhancing local characteristics does not seem to be industry-specific. We also find that high productivity firms are the only significant source of knowledge spillover, which suggests that firms benefit most from combining their internal knowledge with the external knowledge of those neighbors that have high TFP on average.

The two chapters of the thesis examined productivity determinants in terms of either a firm's effort through R&D investment and export participation or the external benefits it can obtain through geographic proximity. Both chapters employ plant-level panel data collected by Korea National Statistical Office and utilize many of the same variables to measure a firm's input, output, and performance. The first chapter focuses on the relationship between productivity and R&D investment and/or export participation without accounting for externalities while the second chapter focuses on the potential effects of externalities on future productivity. The results from the two chapters are informative about the importance of two separate sources of productivity with the first arising from the firms' own efforts and the second arising from external sources related geographical proximity.

This thesis has shed light on the importance of diffusion of knowledge. The studies find econometric evidence of both internal diffusion of knowledge from R&D investment of its own in Korean manufacturing sectors and local knowledge diffusion among plants in the same Korean location. Clear evidence of knowledge diffusion in Korea may provide the important aspect of plant-level of R&D investment and geographical proximity to government's policy makers. To achieve rapid economic growth as South Korea experienced in the past, developing countries should pay attention to the important role of exporting as well as R&D investment. In addition, improvement of local business environments such as construction of infrastructures that may increase positive externality in that location is essential for developing countries as well. Laws that can promote R&D investment in private sectors may be essential for Korean firms to boost weaken economic growth since the financial crisis of 1997.

Appendix A. Data

A.1. Data Description

The annual plant-level data used for the analysis in this thesis were collected as part of the Korean Census of Manufacturing conducted by Korea National Statistical Office (KNSO) during the period of 1991 to 1999.[26] KNSO collets the information on input, output as well as other firm activities such as exporting and R&D investment of entire manufacturing plants over twenty three 2-digit industries every five year (1993 and 1998 in the dataset) and collects same information over manufacturing firms whose employees are at least five in every year (1991~1999 except for 1993 and 1998).

The enumeration unit of the dataset is a plant. The plants that are used in regression belong to five industries defined at the 2-digit SIC.[27] These censuses provide detailed information on each plant's geographic location, industry type, age, capital stocks, investment flows, expenditure on labor and intermediate goods, materials, value of output sold in the domestic market. These data allow for the construction of a measure of productivity (TFP) for each plant.

Using this information, we construct output, input, and cost share variables. The value of plant output is measured as the sum of total revenue from sales, repairing and fixing services, the revenue from performing subcontracted work, and the change in inventory of final goods between the beginning and end of the year. The value of output is deflated by a producer price index defined at the 2-digit industry level.

[26]. With the annual dataset, we are able to get the exact patterns of transition of each individual plant over time in contrast to Aw, Roberts and Winston (2002) who used census data collected every five years.
[27]. They are machinery, electronics, electrical machinery, automobile and other transport equipment industries.

Each producer uses four inputs in production such as labor, capital, material, water, electricity, and subcontracting services. The labor input is measured as the number of production and non-production workers. Total payments to labor are measured as total salaries to both groups. The capital input is estimated as the book value of tangible assets, including building, machinery, tools, and transport equipment at the beginning of the year. The material input includes raw materials, fuel, water, and electricity used by plants.

In addition, we have the information on plants' activities such as exporting and R&D expenditure. Information on the export activity of plants is only available in binary form, i.e. whether the plant is an exporter or not. We do not know how much a plant exports from the dataset[28]. Thus, we are not able to examine whether the intensity of exports matters. In each year plants are asked to provide information regarding their expenditure on R&D. R&D expenditures include the costs of improving existing production technology, marketing, upgrading the quality of sales and service, and developing new products. Thus, these expenditures reflect investment to reduce costs by improving the production process and to develop and introduce new and improved products. Since KNSO started to collect the information on each plant's R&D expenditure from 1991, we use

We have matched the individual observation across years to form a panel. This data allows us to observe transitions of individual plants into and out of the export market and R&D investment participation and to control for some important observable plant characteristics that are likely to affect R&D decision.

[28] While we could obtain the value of export in the industry level, we could not get the value of export in the plant level because of confidentiality.

The data contain a geographical location variable as well. There are seven big cities and nine provinces[29]. By using location information, we can estimate how geographical proximity helps firms' efficiency growth among firms.

A.2. Data Cleaning and Deflator

We dropped all plant observations with zero or negative real values of outputs, capitals, labors, and materials. 7-digit business code of its own is endowed to each plant when it was asked to answer the annual survey. We took a look at each plant's production history over 9 years and found that some observations showed discontinuous production patterns. In that case we carefully took a look at if those observations are same plants by examining each observation one by one. We found that when a plant exited in the industry, its business code was given to a new entrant a few years later in some cases while most of business codes of those who exited were never used again. In this case, we took a look at if there is sharp difference in the number of employee and output variables. If there is a sharp jump of decline in those variables, we treated those observations consist of two plants' information and deleted it from the dataset.

We use Producer Price Index (PPI) defined at the 2-digit industry as the deflator for the variable of output. Different values of weight are given to each industry. Since PPIs by industry are available, we use the single corresponding output deflators. These indexes are taken from the monthly indictor released by Korea National Statistical Office. For all input variables such as capital, labor, water, fuel, and material, we use Consumer Price Index (CPI)

[29] Seven cities are Seoul, Busan, Daegu, Inchon, Kwangju, Daejeon, and Ulsan and nine provinces are Kyoungki, Kangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Kyoungbuk, Kyoungnam and Jeju.

of each input variable as the corresponding deflators that are collected by KNSO as well. Since there is no wholesale price index for those variables to the manufacturing sector only, we use a composite index for all manufacturing sectors. By adjusting these deflated changes to the 1995 book value, we scale the rest of years' book values of inputs to the 1995 basis.

Appendix B. The Measurement of Plant-Level Total Factor Productivity(TFP)

Using manufacturing data for Korea, we construct an index of TFP for each plant in each year. Caves, Christensen, and Diewert (1982) develop a multilateral index that is useful for measuring TFP in plant- or firm-level panel data sets. They construct the TFP index as the log of plant's outputs minus a revenue-share-weighted sum of the log of the plant's inputs. In order to guarantee that comparisons between any tow plant-year observations are transitive, each plant's inputs and outputs are expressed as deviations from a single reference point. Caves, Christensen, and Diewert's multilateral index uses as the reference point a hypothetical plant with input revenue shares that equal the arithmetic mean of revenue shares over all observations, and output and input levels that equal the geometric mean of output and inputs over all observations. Each plant's output, inputs, and productivity in each year are measured relative to this hypothetical plant.

Good, Nadiri, and Sickles(1997) discuss an extension of the multilateral index that uses a separate hypothetical-plant reference point for each cross section of observations and then chain-links the reference points together over time in the same way s the conventional Tornqvist index of productivity growth. This productivity index is useful in our application because it provides a consistent way of summarizing the cross-sectional distribution of plant TFP, using only information that is specific to that time period, and describing how the distribution moves over time.

Let each plant f in year t produce a single output Y_{ft} using the set of inputs X_{ift} where i=1,2, …, n. The firm's expenditure on input X_{ift} , as a share of total revenue, is denoted S_{ift}. Let $\overline{S_{it}}$, $\overline{\ln Y_t}$, $\overline{\ln X_{it}}$ be the arithmetic means of the corresponding firm level variables over all firms in year t. The total factor productivity index for firm f in year t is defined as

$$\ln TFP_{ft} = (\ln Y_{ft} - \overline{\ln Y_t}) + \sum_{s=2}^{t}(\overline{\ln Y_s} - \overline{\ln Y_{s-1}})$$

$$-\left[\sum_{i=1}^{n}\frac{1}{2}(S_{ift} + \overline{S_{it}})(\ln X_{ift} - \overline{\ln X_{it}})\right]$$

$$+\sum_{s=2}^{t}\sum_{i=1}^{n}\frac{1}{2}(\overline{S_{is}} + \overline{S_{is-1}})(\overline{\ln X_{is}} - \overline{\ln X_{is-1}})$$

The first line of equation measures firm output and consists of two parts. The first express firm output in year t as a derivation from the mean output in that year and thus embodies the information in the cross-sectional distribution of output. The second part sums the change in the mean output across all years, effectively capturing the shift of the output distribution over time by chain-linking the movement in the output reference point. The next two lines perform the same operation for each input X_i. The inputs are summed using a combination of the input revenue share for the firm S_{ift} and the average revenue share $\overline{S_{it}}$ in each year as weights. The index provides a measure of the proportional difference in TFP for firm f in year t relative to the hypothetical plant in the base time period. In our application, we will use 1991 as the base time period.

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