This paper appeared in the Bank of Korea *Economic Papers*, vol. 3, no. 2, pp.164 \sim 197. November 2000

Inter-industrial Productivity Spillovers in Korean Manufacturing

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This paper posits that sustained productivity growth entails division of labor to evolve and that this can be detected by checking whether inter-industrial productivity spillovers are in operation. It attempts to measure the parameters of a productivity growth model, which is a transformed growth regression model. The parameters of the model consist of economies of scale, suppliers-driven spillovers, and customer-driven spillovers.

The estimation results from analysis of panal data with twenty-two Korean manufacturing industries from 1971 to 1996 show that inter-industrial spillovers, especially supplier-driven spillovers, were meager, while economies of scale were witnessed only in the short run, not in the long run. These findings are interpreted as reflecting the underdevelopment of the materials and parts industry, but more importantly the shallow division of labor in Korean manufacturing.

Estimation results with the sample divided into three periods, $1971 \sim 1979$, $1980 \sim 1988$, and $1989 \sim 1996$, showed few improvements in the later periods in terms of supplier-driven spillovers; rather they indicated a deterioration in the economies of scale parameter over the time periods, until diseconomies of scale prevailed in the last period. Beside this, a comparison of the parameter estimates with those for the U.S.A. confirmed that the division of labor in the Korean manufacturing sector had not evolved to the degree typical of an advanced economy.

The shallow division of labor in Korean manufacturing, in turn, is conjectured to have stemmed not only from the short history of industrial development and the consequent lack of experience in creating new knowledge, but also from the lack of properly working networks, especially a national innovation system promoting competition and cooperation among industries for innovation.

Key words: productivity, spillovers, economies of scale

I. Introduction

It is broadly accepted that the decline in productivity in the real sector of the Korean economy has been the most deeply seated reason for its vulnerability to external shocks, as was shown in the episode of the currency crisis in 1997. This paper is motivated by the perception that a better understanding of the nature of the productivity change in Korea is a prerequisite for deriving the correct lessons and reversing the trend in the productivity.

Researches on economic productivity attribute productivity growth to such factors as technological progress and, in some cases, managerial and social capabilities. In most cases, they rely on the growth accounting approach in supporting their arguments empirically.

One of the recent theoretical developments in the field is that researchers have started to focus on the notion of externalities, especially knowledge spillovers as a source of technological change and economic growth. Endogenous growth models, e.g. Romer(1990), posit that free diffusion of knowledge among researchers provides a fertile ground for creating new knowledge and innovation. This contrasts to the neoclassical growth models which regard externalities as a residual factor or as a factor causing market failure. Rather they closely resemble Adam Smith's explanation of how division of labor promotes productivity and growth.

Empirical researches based on the new growth theory were undertaken shortly after the advent of the new growth theory. Caballero and Lyons(1990) attempted to measure the internal and external economies in the industries of several European economies. And Bartelsman, Caballero and Lyons(1994) divided the latter further into

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customer-driven externalities and supplier-driven externalities and measured them separatedly in an application of the model to U.S. manufacturing industries. When it comes to the Korean case, however, there are few works addressing productivity slowdown in terms of division of labor and productivity spillovers.¹)

This paper starts from the view that productivity growth occurs in accordance with Adam Smith's principle of the division of labor. By observing that the evolution of the division of labor reveals itself in increasing returns to scale or positive external effects among productive agents such as individuals, firms, and industries,²⁾ it attempts to measure the size, on average, of returns to scale of manufacturing industry and the extent of externalities among its constituent subsections. The results provide some clues to understanding the nature of the division of labor in Korean economy and thus whether and why productivity growth has declined.

More specifically, it applies the model of Bartelsman, Caballero and Lyons(1994) to panal data for Korean manufacturing industry. The results show that productivity spillovers among Korean manufacturing industries were very weak. Moreover supplier-driven spillovers, which are interpreted as a hallmark of the division of labor evolving to increase productivity, were absent or were negative. As for returns to scale, the results show them to have been decreasing since the 1970s.

The weak supplier-driven productivity spillovers represent *inter alia* the low degree of division of labor among Korean manufacturing

¹⁾ There are some studies on subcontracting(Imai and Itami 1984, Chun 1999), on geographical clustering of industries(Porter 1990, Park 1999). But none of them attempt at measuring inter-industrial productivity spillovers.

²⁾ In order to keep in line with the empirical model, the discussion hereafter will consider an industry, a subset of the manufacturing sector, as the basic unit.

industries. This stems not only from the short history of industrial development in Korea, and the consequent lack of experience in originating new knowledge, but also the lack of institutions, such as well-developed markets and a national innovation system, for promoting competition and cooperation among individuals and firms with a view to eventually enhancing the rate of innovation. This implies that, in order to improve productivity, more attention should be given to such issues as promoting competition, the development of markets, and the establishment of private and public networks for knowledge diffusion and innovation, what is termed a national innovation system.

The rest of this paper proceeds as follows. Section II defines the meaning of productivity and points out the limitations of existing methods of dealing with productivity. Then it suggests explicitly considering the sources of productivity improvement, i.e., spillover effects and economies of scale, rather than leaving them as a residual. Section III reports the estimates of the degree of productivity spillovers and economies of scale in Korean manufacturing and looks at how the parameters change over time. Beside this, an attempt is made to compare the results with those of comparable study for the U.S.A. manufacturing. Finally, section IV concludes with a discussion and suggests some policy implications.

II. Discussion of Productivity Spillovers

1. Productivity

Productivity is defined to be the relationship between input and output in a production process. It is a characteristic parameter of an economic system and is usually presented as the ratio of output to input. There are two kinds of productivity measures: total factor productivity and partial factor productivity. The former divides output by total input, which is a weighted sum of all inputs used in the process, whereas the latter divides output by individual factor input, such as labor input and capital input.

Productivity has been recognized as an important source of economic growth since Adam Smith. Increases in productivity can bring forth economic growth by enabling firms or an industry to produce more output with the same amount of input. It can also improve economic welfare or the quality of life by allowing wages to increase without causing inflationary pressure. Recently productivity growth has been emphasized as a source of international competitiveness; in order to survive in the increased competition of a globalized environment, productivity improvement is a necessity³).

³⁾ This is in line with the so called productivity norm which maintains that productivity enhancement is a prerequisite for beating inflationary pressure and achieving macroeconomic stability(e.g., Selgin 1990).

2. Limits of Previous Studies on Productivity

The analysis of productivity has been recognized as one of the most important research topics in economics since its establishment as a discipline. But it was not until the advent of neoclassical growth models, e.g., Solow(1956) that empirical researches into productivity took a leap in their development.

Neoclassical growth models derive their micro-foundations for macroeconomic productivity analysis from perfect competition. They usually assume that firms seek to maximize profits under constant returns to scale with no externalities in production. Under these assumptions, a single macroeconomic production function is derived by valuing various inputs and outputs at market prices and aggregate them; thus the task of analyzing economic productivity is reduced to analyzing the characteristics of the macroeconomic production function. Here individual factors, such as labor and capital, by themselves show decreasing returns to scale and total input has the characteristic of constant returns to scale. There is no possibility of increasing returns to scale. Only technological progress can generate increasing returns.

Under this growth accounting approach, it suffices to have data for inputs, outputs, and income shares for measuring productivity, i.e., the ratio of total output to total input, with income shares being used as weights for computing the total input. Here the growth rate of productivity is calculated as a residual, that is, as the growth rate of output less the growth rate of total input. This residual, being the index for total factor productivity growth, is interpreted as representing shifts of a production function.⁴⁾ But generally speaking it represents the part

⁴⁾ This residual is also called a Solow residual because it was calculated for the first

of output growth attributable to factors other than labor, capital, and intermediate inputs.

Neoclassical growth theory recognizes technology as being essential for productivity improvement but it does not model how technology progresses. It usually regards technology as a public good that is freely available to firms, being provided from outside of the market system.

In reality, technology changes mostly as a result of the actions taken by economic agents. Most notably, the role of firms in initiating technological progress through investments in research and development cannot be ignored. This fact is taken seriously in the new growth theory, which tries to endogenize technological progress within a growth model. For example, Romer(1990) asserts that diffusion of knowledge within the research sector is the source of technological progress.

Beside this, some new growth theorists criticize the assumption of zero externalities in the neoclassical model. For example, Murphy, Shleifer, and Vishny(1989) focused on demand spillovers as a source of productivity improvement in a growing economy.

In spite of the heightened understanding of the process of technological progress in the theoretical area, most empirical researches still concentrate measurement and analysis on of total factor productivity (Jorgenson and Griliches 1995). The popular method they employ is first to calculate the Solow residuals and then to regress them on investment in research and development(Griliches 1991), physical capital stocks(Wolff 1991), foreign direct investment(Haddad and Harrison 1993) and finally to test the significance of each independent variable statistically to see the effects of the respective factors on

time by Solow(1957) under his earlier assumptions(1956).

productivity.

These methods are criticized on several accounts. First an analysis by regressing the Solow residuals on several explanatory variables may produce misleading results, such as over- or under-estimation of the parameters, since the errors contained in the residuals may stem from, for example, the assumption of perfect competition; and there are no similar error components in the explanatory variables to offset those in the dependent variable. Second the underlying assumptions in calculating the Solow residuals and in analyzing the determinants thereof may not agree with each other and thus may produce unreliable results. For example, studies that analyze the effects of R&D spillovers on productivity according to this method mostly show that the R&D spillover effects are large(Nadiri 1993). But this is in contrast to the findings of Jorgenson and Fraumeni(1989) who argue that the total spillover effects, including those from R&D investments, are small. Part of the divergence may be explained by the fact that the former tried to measure externalities though they had already assumed perfect competition in calculating the Solow residuals.

One way to overcome these problems is to use growth regressions. These allow the estimation of the output elasticities directly from the regression of the production function instead of substituting income shares for them. In this approach, sources of growth are analyzed by adding explanatory variables for economic growth to factor inputs in the right hand side of the regression. The variables may include R&D investment(Nadiri 1993), human capital(Mankiw, Romer, and Weil 1992), physical capital(De Long and Summers 1991), economic openness(Edwards 1998), financial development(King and Levine 1993).

Another way to measure how much externalities affect productivity

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improvement is to estimate a cost function. In order to measure the effects of spillovers, this variable of the R&D expenditures by other firms is included in the right hand side of the equation for the cost function of a firm(Bernstein 1989, Levin and Reiss 1989). But one shortcoming of this approach is the difficulty in obtaining good quality price data for R&D capital stock. A third method is to measure the technological distance among industries via input-output tables and calculate the technological spillovers of R&D investments (Terleckyj 1974). But with this method, one cannot take the tacit knowledge that are not easily transferred into account.

3. Spillovers and Productivity Improvement

The neoclassical approach to analyzing productivity has limited usefulness in illuminating the actual source of productivity change mainly because the assumptions of the perfect competition model were too strict. The abstraction from external effects can be misleading in that it ignores the importance of the interactions among economic agents in technological progress and productivity improvement.

The actual process of productivity improvement can be more accurately described by the principle of the division of labor.⁵⁾ The division of labor refers to the form of organization in which one production process is divided into several sections and each section is alloted to one worker who specializes in it. Productivity improves as the

⁵⁾ Endogenous growth literature such as Romer(1990) and Rodriguez-Clare(1996) incorporates the division of labor principle as the driving force of technological change and productivity improvement.

division of labor evolves. According to Adam Smith, division of labor contributes to productivity improvement through the following channels(Smith 1976). First, the division of labor enhances the skill of each worker by making him or her specialize in one job. Second, it saves the time needed to move from one job to another in the shop. Last, it allows workers to concentrate on the same job and thus facilitates their improvement of the procedure or invention of new machinery.

The same principle applies to division of labor among firms. Each firm can increase technological knowledge by specializing in core business and improving managerial efficiency. Besides, a new technological fusion may take place as firms with different expertise interact with each other and cultivate new technology.

Seen from this viewpoint, the productivity augmentation can be decomposed into economy of scale and spillover effects. Economies of scale refer to the decrease in the unit cost as output increases whereas dynamic economies of scale, or increasing returns to scale, indicate the fact that outputs are increasing faster than inputs over time.⁶

Increasing returns to scale at an industry level can be traced either to internal economies or to external economies, or both. External economies refer to economies of scale external to an industry but internal to the manufacturing sector as a whole. They are called spillovers or spillover effects in this paper.

Spillovers and externalities refer to different aspects of the same phenomenon. The latter focus on the price-distortion effects whereas the

⁶⁾ The concept of economies of scale and increasing returns to scale may be distinguished in that the former presumes that inputs have been adjusted such that cost is minimized while the latter assumes a fixed input combination.

former focus on the physical aspects of the unpaid side-effects of producers' or consumers' actions.

The division of labor evolves to improve productivity and to realize increasing returns to scale(Allyn Young 1928, Kaldor 1970, Yang and Borland 1991). Suppose a firm with two processes being divided into two independent firms within an industry; some factors that used to be allocated to two processes are now put solely to one of them. Total factor inputs to the two firms as a whole tend to expand. But output grows faster than inputs because not only are the set-up costs being economized but also gains from specialization materialize. This is how division of labor results in internal economies in an industry.

Once division of labor has evolved, each production unit comes to have a direct or indirect relationship with other units. This interdependence is a source of productivity spillovers or external economies.⁷) The process in which productivity spills over across industries can be described as follows. A user firm of the product which embodies the innovation by a firm as intermediate input may benefit from this innovation directly; that is, the new material or capital good may contribute to an increase in productivity. The user industry may also benefit from it indirectly; that is, the embodied technology in the input may either trigger innovation in the user industry or provide clues to managerial reform. These improvements in the user industry may feedback to the input supply industry.

Two kinds of spillovers,⁸⁾ supplier-driven spillovers and

⁷⁾ Productivity can spillover from industries with which the sector in question has no direct transactions. For example, innovation in industries producing complementary products or public services or managerial reform in a related sector may have unpaid side effects on the sector's productivity.

⁸⁾ The concept of inter-industrial productivity spillovers is similar to that of Hirschman(1958, 1987)'s 'linkage effects.' The main difference is that the former

customer-driven spillovers, are identified⁹⁾ The supplier-driven spillovers are those transferred to a user sector from its supplier industries via the embodiment of new technology in material inputs or capital goods. Channels of such supplier-driven spillovers also include disembodied technology spillovers through face-to-face contacts or business alliances with suppliers; these facilitate diffusion of tacit knowledge.¹⁰⁾ Supplier-driven spillovers arise also when the inputs or capital goods are underpriced because the embodied technology cannot be fully appraised *ex ante*. Increase in the variety of intermediate inputs in the supplier industries may lead to a more efficient combination of factors and thus enhance the productivity of an industry(Romer 1990. Rodriguez-Clare 1996). Thus supplier-driven spillovers are closely related to, if not the same as, technological spillovers.¹¹

Customer-driven spillovers are the unpaid side effects of the increased production of customer industries on the productivity of an industry. An expansion of customer industries' production can affect the productivity of the sector not only by increasing the possibility of technology transfer, but more importantly by stimulating the sector to adapt itself to the changes in demand. Furthermore simultaneous expansion of markets lowers searching costs in finding transaction counterparts à *la* Diamond(1982), thus improving the productivity of an industry.

emphasizes the side effects of other producers' actions on the productivity of an industry while the latter focuses on the sequential pattern of industrial investments to be seen in the genetic process of industries in a lagging economy.

⁹⁾ Inter-industrial externalities can be viewed as productivity-augmenting spillover effects. In its terminology, this paper will use spillovers, productivity spillovers, and externalities interchangeably.

¹⁰⁾ Unlike 'technological information,' which is explicit enough to be easily transferred through formal education, most 'technological knowhow' is so tacit that it can be obtained only through participation in the process of its realistic application.

¹¹⁾ If spillovers are transferred through the market, they are called pecuniary externalities(or spillovers).

Customer-driven spillovers are mainly, if not entirely, associated with pecuniary externalities; it is changes in market size or structure that pertain to the customer-driven spillovers. Of course, customers may influence on the technology of a firm. But the extent to which they do so will not be considerable because the customer has the option to turn to imported products instead of transferring technology to suppliers to remedy the flawed inputs. In this respect, the spillover effects from customers in particular may be called demand spillovers.

The effects of inter-industrial spillovers may be either positive or negative on the productivity of the recipient industry. The principle of division of labor among industries implies a positive effect. But negative inter-industrial productivity spillover effects can also appear, for example, if the inter-industrial transactions are supported by regulations that require industries to use domestically produced input materials.

There are limits to the division of labor as Adam Smith pointed out. The gains from specialization may not materialize due to limited market size and product life-cycle.¹²) Moreover, an increase in specialization raises the cost of transactions by individuals, which imposes a limit on the degree of specialization(Yang and Borland 1991). Beside this, the division of labor in an industry subject to natural monopoly may be limited even if the market is sufficiently large.

¹²⁾ Product life-cycles refer to the phenomenon whereby innovative products tend to be produced in advanced economies and standard products in developing countries according to comparative technological advantage(Helpman and Grossman 1994). The faster the pace of innovation, the harder it is for the developing countries to reap a reward from investments in standard technology.

4. Analyzing Inter-industrial Spillovers

Understanding the role of inter-industrial spillovers in the process of productivity improvement is increasingly important. First, spillovers are important because the competitive advantage of an industry goes abreast with that of other domestic industries. According to Porter(1990), development of supply industries and related industries are essential for an industry to enjoy a competitive advantage in the world market.

Second, an empirical analysis of inter-industrial spillovers provides us with a window to diagnose the strength of the inter-industrial networks. A network here indicates an economy or a sector in an economy in which constituent firms trade with each other. The relative magnitude of the parameters of economies of scale, customer-driven spillovers, and supplier-driven spillovers will characterize an economy, or a network since they show respectively the efficiency of industry's own efforts, the customers' influence and the suppliers' influence on productivity. For example, a researcher who assesses the industrial development during the 1970s in Korea to have been successful may expect large economies of scale, but not a positive supplier-driven spillovers parameter. This is because the Korean economy in the 1970s lacked inter-industrial networks for innovation, which are considered to be a prerequisite for supplier-driven spillovers to materialize. That is, without the experience accumulated by an individual industry and network of drawing together different types of expertise for innovation, the tacitness of technological know-how can scarcely be overcome and hence supplier-driven spillovers can not be expected to be significant.

Third, the changes in the parameters may be discussed in relation to changes in industrial policy since government policy plays an important

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role in determining the characteristics of a network especially in a developing economy. For example, the liberalization measures introduced by the Korean government from the early 1980s were expected to encourage the private sector's capacity to innovate. When positive supplier-driven spillovers are observed, the liberalization policy may be evaluated as having been successful in fostering an inter-industrial division of labor.

Lastly, the discussion of inter-industrial spillovers tends to emphasize the role of government as a facilitator of network formation. As an economy develops beyond a certain stage, the division of labor becomes so complex that industrial targeting, a selective intervention policy which concentrates financial and fiscal support on selected industries or activities, becomes almost impossible. It may be pursued but in vain because the government lacks the specific information for selecting the right industry or firms and the right means to promote it. Now the government's role should lie elsewhere, e.g., in helping the private industries to interact with each other or with foreigners to innovate. It is pointed out in particular that in order for the government to obtain effectiveness in industrial policy, it should adopt what is dubbed a systemic approach, in which it identifies the industrial network, or the national innovation system,¹³⁾ and help it work properly and prevent systemic failure(OECD 1997a). In this sense, it is stressed that the government should act to provide the basic infrastructures for innovation and technology diffusion such as "infostructure" (OECD 1999).

¹³⁾ The national innovation system refers to the network among firms, research institutes, universities that participates in the development, imports, modification, and diffusion of new technology.

III. Estimation of Inter-industrial Productivity Spillovers

1. Derivation of the Model¹⁴⁾

A firm is an organization transforming input into output by applying its own technology. In the course of producing, it improves its production technology, i.e., it learns by doing. But it also learns from its trading partners or alliances. Therefore spillovers from other producers are important sources of productivity improvement.

In this respect, the output of an industry i, Y_i is set as the product of spillovers index, E_i , productivity shocks index, U_i , and a production function, F_i , of labor, L_i , capital, K_i , and intermediate goods, M_i , as in equation (1). Spillovers contribute to the occurrence of economies of scale external to an industry but internal to the sector as a whole.¹⁵⁾

(1)
$$Y_i = E_i \cdot F(K_i, L_i, M_i) \cdot U_i$$

The production function F_i is homogeneous of degree γ ($\gamma > 0$) with respect to own inputs of labor, capital, and intermediate goods. That is, for arbitrary constant $\lambda > 0$, the following obtains:

¹⁴⁾ The growth regression model in this paper is the same as that of Bartelsman, Caballero and Lyons(1994). But it is somewhat more explicit in the derivation of the model by referring to both Caballero and Lyons(1990) and Basu and Fernald(1995).

¹⁵⁾ In a sense individual firms do not perceive the spillovers and take them into account in investment *ex ante.* But *ex post* individual firms will find their profits affected by them.

(2)
$$\lambda^{\gamma} E \cdot F(K, L, M) \cdot U = E \cdot F(\lambda K, \lambda L, \lambda M) \cdot U$$

By taking the log-transformation of both sides of equation (1) and totally differentiating, one can obtain equation (3), where the lower case means growth rate, e.g., $y = d \ln Y$.

(3)
$$y_i = \frac{F_K}{Y_i} dK_i + \frac{F_L}{Y_i} dL_i + \frac{F_M}{Y_i} dM_i + e_i + u_i$$

 $\forall F_X = \partial F / \partial X, X : K, L, M$

The difference terms in the right hand side of the equation (3) can be expressed in terms of growth rates as follows.

(4)
$$y_i = \frac{F_K K_i}{Y_i} k_i + \frac{F_L L_i}{Y_i} l_i + \frac{F_M M_i}{Y_i} m_i + e_i + u_i$$

And it follows from the homogeneity condition of the production function that:

(5)
$$\gamma Y_i = F_K K_i + F_L L_i + F_M M_i$$

For simplicity, factor shares in the marginal product were denoted a_{K} , a_{L} , a_{M} as follows,

(6)
$$a_{K} \equiv \frac{F_{K}K}{F_{K}K + F_{L}L + F_{M}M}$$

 $a_{L} \equiv \frac{F_{L}L}{F_{K}K + F_{L}L + F_{M}M}$
 $a_{M} \equiv \frac{F_{M}M}{F_{K}K + F_{L}L + F_{M}M}$

The profit maximization of a firm under a monopolistic product market with perfect factor markets requires that the marginal productivity of each factor be equal to the product of its price in terms of output units and the mark-up rate, μ , which is defined as the ratio of output price to marginal cost.

(7)
$$F_K = \mu \frac{r}{P}$$
, $F_L = \mu \frac{w_L}{P}$, $F_M = \mu \frac{w_M}{P}$
 r : rental rate w_L : wage rate
 w_M : price of intermediate goods P : price of a final good

Substituting these equations (7) into equations (6), it is shown that a_{K} , a_{L} , and a_{M} are in fact cost shares, i.e., the portions of total cost incurred by expenditures on capital, labor, and intermediate goods, respectively. Equation (5) implies that the denominators of equations (6) are all γY . Therefore, it follows:

(8)
$$a_{K} = \frac{rK}{rK + w_{L}L + w_{M}M} = \frac{F_{K}K}{\gamma Y}$$

 $a_{L} = \frac{w_{L}L}{rK + w_{L}L + w_{M}M} = \frac{F_{L}L}{\gamma Y}$

$$a_{M} = \frac{w_{M}M}{rK + w_{L}L + w_{M}M} = \frac{F_{M}M}{\gamma Y}$$

Substituting equations (8) into equation (4) and using the property $a_K + a_L + a_M = 1$, equation (9) is derived.

$$(9) y_{i} = \gamma [(1 - a_{L} - a_{M})k_{i} + a_{L}l_{i} + a_{M}m_{i}] + e_{i} + u_{i}$$

When the growth rate of total factor costs, $(a_L l + a_M m + (1 - a_L - a_M)k)$ is abbreviated as x, equation (9) is simplified as equation (10).

$$(10) \quad y_i = \gamma x_i + e_i + u_i$$

It is worth noting that the weights to be used in calculating the growth rate of total cost, x, are cost shares rather than income shares. The cost shares are not necessarily equal to income shares when the mark-up rate is not equal to 1. Only under perfect competition does mark-up rate become 1 and income shares equal to cost shares. In this sense, the growth accounting approach can be considered as a specific case of model (10), in which the conditions of $\gamma=1$, e=0, and perfect competition are imposed on it.

Total factor productivity growth, b_i , is output growth less total cost growth. That is:

(11)
$$b_i = y_i - x_i$$

Total factor productivity growth can be derived from first estimating equation (10) and then subtracting x from both sides of it and rearranging it into the equation (12). By doing so, productivity growth is decomposed into economies of scale, inter-industrial spillovers, and productivity shocks.

(12)
$$b_i = y_i - x_i$$

= $(\gamma - 1)x_i + e_i + u_i$

Since productivity spillovers are the economies of scale external to an individual industry but internal to the manufacturing sector as a whole, the extent of spillovers can be thought to increase in proportion to the extent of general production activities, which is measured by the input growth rate of the manufacturing sector as a whole.¹⁶⁾ Two aggregate activity indices, x_{-i}^{IW} and $x_{-i}^{OW,17)}$ were computed as a weighted average of the input growth rates of other industries that traded with industry *i*. The weights for deriving x_{-i}^{IW} were the input coefficients of industry *i*, which was a column vector whose elements were the amounts of

¹⁶⁾ External economies are usually represented as a function of total output. For example, $E_i = g(\sum_i Y_i)$ (See Herberg and Kemp 1969, Caballero and Lyons 1990). In some cases, externalties are expressed as a function of the number of firms, or the number of workers, in an economy (See for example Rodriguez-Clare 1996, Manning and McMillan 1979). Beside this, Metcalfe's law, which states that the value of a network increases in proportion to the square of the number of members of the network, also indicates that the extent of external economies grows as the number of the network's member increases (Shapiro and Varian 1999).

¹⁷⁾ The superscripts IW and OW in χ_{-i}^{IW} and χ_{-i}^{OW} denote that the aggregate were "input-weighted" and "output-weighted", respectively. The subscript -i represents "all industries except industry i".

industry j's output(j=1,...,N and $j\neq i$) required to produce one unit of industry i's output. The weights for χ_{-i}^{OW} were the output coefficients of industry i, i.e., the vector whose elements are the shares of industry i's output distributed to industry j's use(j=1,...,N and $j\neq i$). This amounts to using a transaction values matrix, rather than the direct requirements matrix which Bartelsman et al. used, for V_{ij} and V_{ji} of the expressions for χ_{-i}^{IW} and χ_{-i}^{OW} respectively in equation (13) below.¹⁸⁾ The constant δ in equation (13) represents productivity increases due to external factors such as the economy's stock of social overhead capital.

(13)
$$e_i = \delta + \beta^{IW} x_{-i}^{IW} + \beta^{OW} x_{-i}^{OW}, \quad i = 1, \dots N,$$

$$x_{-i}^{IW} = \sum_{j \neq i}^{N} \frac{V_{ji}}{\sum_{j \neq i}^{N} V_{ji}} x_{j} \qquad x_{-i}^{OW} = \sum_{j \neq i}^{N} \frac{V_{jj}}{\sum_{j \neq i}^{N} V_{jj}} x_{j}$$

 $\begin{bmatrix} V_{ij} \end{bmatrix}$: the amount sold by industry i to industry j $\begin{bmatrix} V_{ii} \end{bmatrix}$: the amount bought by industry i from industry j

The combination of the equations (12) and (13) gives the following growth regression model.

¹⁸⁾ Bartelsman et al.(1994) used a direct requirements matrix, or an input-coefficients matrix, for both the V_{ij} and V_{ji} in equation (13). Using an input-coefficients matrix and a transactions table for V_{ij} result in the same estimate of χ^{IW}_{-i} . But they produce different estimates of χ^{OW}_{-i} when used for V_{ji} . Using a transactions matrix for V_{ji} amounts to using an output-coefficients matrix, rather than an input-coefficients matrix, for V_{ji} . Using a transactions matrix is preferable because spillover effects from the more closely linked industries would be larger than those that are less closely linked with the industry *i*.

(14)
$$y_i = \delta + \gamma x_i + \beta^{IW} x_{-i}^{IW} + \beta^{OW} x_{-i}^{OW} + u_i$$

The degree of homogeneity of the production function, γ , shows the extent of the economies of scale, and it can take the values: $\gamma > 1$, $\gamma = 1$, $0 < \gamma < 1$, according to whether returns to scale are increasing, constant or decreasing.

 β^{IW} and β^{OW} show the extent of inter-industrial spillover effects. A positive β^{IW} means that as the activity of suppliers as a whole increases the productivity of industry *i* is improved. Similarly, a positive β^{OW} implies that as the activity of customers as a whole increases, the productivity of industry *i* is positively affected. A negative sign means the opposite.

2. Data

Data for output, capital stock, labour, intermediate input, and income shares of twenty-two Korean manufacturing industries¹⁹⁾ from 1970 to 1996 were used to estimate the model. The capital stock at 1990 prices was taken from Pyo(1998).²⁰⁾ In spite of some criticisms of this data

¹⁹⁾ The original data which include statistics from the Ministry of Labour, the Report on Mining and Manufacturing Survey, the National Accounts, and the Input-Output Tables have different industrial classifications. In order to secure comparability, industries are integrated into twenty-two categories.

²⁰⁾ The net capital stocks during the period $1970 \sim 96$ in Pyo (1998) were estimated by the polynomial-benchmark method using the *National Wealth Survey* for the years 1968, 1977 and 1987 together with total fixed capital formation in the *National Accounts*. There is some criticism of this data set because the depreciation

set, we have used it since it was the only data available at the time of our research.

The source of industrial output at 1990 prices is the National Accounts.²¹⁾ The number of workers was obtained from the Ministry of Labour, basically the *Report on Monthly Labor Survey*²²⁾. Specifically, the yearly data for the period from 1970–90 were taken from the Modified Version of Labour Survey Series II, and those for the remaining years were yearly sums of the monthly data of the *Report on Monthly Labour Survey*. To reflect changes in working hours and the quality of labour, the number of workers was multiplied by the economy-wide labour quality index and the working hour index in Kim and Hong (1996).

The shares of the intermediate inputs and the labour inputs were from two sources: from 1970 to 1993, the source is Hong and Kim and from 1994 onwards, Hong and Kim's 1993 numbers were extrapolated using the 10-industry classification growth rates of the two in the National Accounts.

The input-output tables actually used are the average value of the 1975 transactions table and the 1995 transactions table, both at producer's prices. The reason that transactions tables at producer's prices, instead of domestic transactions tables, were used is because the

rate between benchmark years is assumed to be constant(Kim 1996) and also because it is based on the *National Wealth Survey* whose data have a different trend from those of the *National Accounts*(Timmer and Ark 2000).

²¹⁾ Detailed data on the output of the manufacturing industries was obtained from the Bank of Korea's internal sources. This is based on the Report on Mining and Manufacturing Survey and shows industrial value added as well as industrial total output at 1990 prices.

²²⁾ The *Report on Monthly Labor Survey* includes firms with more than ten employees. Even though this does not comprise the total number of laborers that were employed or self-employed, it is believed that it preserves the time-series property of the total number of workers.

input- and output-coefficients matrices based on the former changed less over time than the latter.²³⁾

Average growth rates of the variables are summarized in Table 1. Due to possible regime shifts in 1979 and 1988,²⁴⁾ the whole sample is divided into three sub-periods²⁵⁾.

Value added v.s. net capital stock in the manufacturing sector



Note : Values are at 1990 prices

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²³⁾ One of the main reasons for the difference is that due to the rapid industrialization during the sample period 1970~96, many of the imports in the early periods came to be produced domestically in the later periods, thus changing the domestic requirements matrix more drastically than the total requirements matrix.

²⁴⁾ There were many changes in terms of economic structure and policy in the years before and after 1979; The labor movement, democratization, and liberalization thereafter resulted in big changes in industrial structure after 1988.

²⁵⁾ The secularly decreasing partial capital productivity is quite evident in the following figure. The partial productivity index, here $\triangle Y / \triangle K$, where $\triangle K$ is yearly increments in net capital stock and $\triangle Y$ is yearly increments in value added, seems to have a shift down around the years 1979 and 1988.

<Table 1>

				%
	$1971 \sim 79$	1980~88	$1989 \sim 96$	$1991 \sim 96$
Output (y)	15.9	12.0	8.1	12.1
Own inputs ($_{\mathcal{X}}$)	14.0	10.4	7.1	10.6
Total factor productivity($y - x$)	1.9	1.6	1.0	1.5
Input-weighted (χ_{-i}^{IW})	17.2	12.1	7.9	12.5
Output-weighted (χ_{-i}^{OW})	17.9	11.9	5.1	11.9

Average growth rates of the variables¹⁾

Note : 1) Each variable is the time-average of each year's industrial output-weighted average growth rate.

3. Estimation of the Model

The model has been specified as in equation (15) since it uses panel data of twenty-two manufacturing industries for the period $1971 \sim 96$. The error term captures technology shocks too.

(15)
$$y_{it} = \delta + \gamma x_{it} + \beta^{IW} x_{-it}^{IW} + \beta^{OW} x_{-it}^{OW} + u_{it}$$

 i : the *i*-th industry δ : a constant
 t : year u_{it} : error term

A. Model Specification Tests

The model in equation (15) was estimated by the ordinary least squares method(OLS) and the validity of the model specification and estimation methods were tested before interpreting the results. First, it

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tested whether the error term $(u_{i,t})$ contains unobserved was industry-specific effects (μ_i). If the error term consists of both random errors and industry-specific effects, i.e., if $u_{it} = \mu_i + \zeta_{it} (\zeta_{i,t})$ independently and identically distributed random variable), then the explanatory variables are no longer orthogonal to the error term and, hence, the OLS estimates become biased and inconsistent.²⁶⁾ In testing whether such effects are present, two estimates are compared: one free of industry-specific effects and the other not free of them. The parameter estimates free of industry-specific effects can be derived from estimation of the equation (16), in which all the variables are transformed into deviations from industrial means. By pooling the data and applying OLS to equation (16), unbiased estimates are obtained.²⁷⁾ The estimated coefficients and covariances are used together with those estimated by applying the generalized least squares(GLS) method to equation (15) to compute a Hausman test statistic (Baltagi 1995) and test whether industry-specific effects are significant. The result shows that there is no correlation.²⁸)

$$\overline{y_i} = \delta + \gamma \overline{x_i} + \beta^{OW} \overline{x_i}^{OW} + \beta^{IW} \overline{x_i}^{IW} + \overline{u_i}$$

The "between" estimators tend to capture the cross-section features of the panel data(Bartelsman, et al. 1994).

28) Both estimates for coefficients were similar. The Hausman test with the null hypothesis that there is no correlation between the explanatory variables and the industry specific effects gave a p-value near 1.00.

²⁶⁾ For instance, when introduction of an innovation in an industry stimulates the constituent firms to expand input uses, both the error term and the aggregate input variables are affected by the same innovation. Thus $E(u_{ii}x_{ii}) \neq 0$. In this case, estimating equation (15) by OLS results in biased and inconsistent estimates.

²⁷⁾ The OLS estimates of the model (16) are called "within" estimators in panel data analysis (Mundlak 1978). Since each variable appears in the form of deviations from means, the within estimators tend to capture the time series features of the panel data. In contrast, the "between" estimator is derived from applying OLS to the model below, which is obtained by transforming the variables of the model (15) into a time-average form.

(16)
$$y_{i,t} - \overline{y_{i}} = \gamma(x_{i,t} - \overline{x_{i}}) + \beta^{OW}(x_{i,t}^{OW} - \overline{x_{i}}^{OW}) + \beta^{IW}(x_{i,t}^{IW} - \overline{x_{i}}^{IW}) + \zeta_{i,t}$$

$$\overline{X}_{i} = \sum_{t=1}^{T} X_{i,t} / T, \quad X : y, \quad x_{i}, \quad x_{-i}^{IW}, \quad x_{-i}^{OW}$$

To determine if there were factors, other than the industry-specific effects, causing simultaneity bias we derived the instrumental variables(IV) estimates of the equation (15) and compared them with OLS estimates of the equation (16) (See Table 2). The IV estimates did not differ much from the OLS estimates and, in addition, the Hausman test statistic using IV estimates from equation (15) and OLS estimates from equation (16) rejected the hypothesis of simultaneity bias²⁹⁾.

Multicollinearity was not severe either; the condition index³⁰⁾ which represents the extent of multicollinearity was 2.68, far below the customary criterion of 20, a level above which, the presence of multicollinearity is roughly indicated.

We also applied the Fuller-Battese method to the equation (15) in order to check autocorrelation and heteroscedasticity.³¹⁾ The variance components analysis from the Fuller-Battese estimation showed a small variance component for cross section and a relatively large one for time

²⁹⁾ Hausman's test statistic m was 0.092 with a p-value of 0.999 at 4 degrees of freedom.
m=(β_{IV}-β_{within})'(V_{IV}-V_{within})⁻¹(β_{IV}-β_{within}), where β_{IV}, β_{within} are the IV and within estimators of the model respectively, and V_{IV}, V_{within} are the covariance matrices for the coefficient estimates.

³⁰⁾ The condition index is the square root of the ratio of the maximum eigen value to the minimum eigen value.

³¹⁾ The Fuller-Battese model includes in the error term an industry-specific effect and a time-specific effect and applies GLS to estimate the coefficients. For more details, refer to SAS/ETS User's Guide (1993).

series; the share was 2.3% for the cross section and 14.2% for time series.³²⁾ In order to test how severe the autocorrelation problem was, the Durbin–Watson type statistic for testing autocorrelation in panel dat $a^{33)}$ was calculated and we came to the conclusion that there was no problem of autocorrelation; the first order autocorrelation test statistic was 1.905, exceeding the upper bound of 1.838 at the 5% significance level.

The model including time and industry dummy variables gave similar estimate coefficients to the model not including the dummy variables as shown in the fourth and the fifth columns in Table 2. Several year-dummies including that for 1979 were significant. However, these seemed to affect only the constant, leaving the coefficient estimates relatively unchanged.

Therefore, it may be maintained that the OLS estimates are relatively free from statistical problems such as simultaneity bias, multicollinearity, autocorrelation, or heteroscedasticity. Hence we have decided to rely on OLS estimates of equation (15).

³²⁾ The variance components for the error term were as follows.Variance Component for Cross Sections : 0.000023Variance Component for Time Series : 0.000143Variance Component for Error : 0.001010

³³⁾ Refer to Bhargava, Franzi and Narendranathan(1982) for a more details of the following statistic: $d_p = \sum_{i=1}^{N} \sum_{t=2}^{T} (\tilde{u}_{i,t} - \tilde{u}_{i,t-1})^2 / \sum_{i=1}^{N} \sum_{t=2}^{T} \tilde{u}_{i,t}^2$.

<Table 2>

Specification tests of model (15)¹⁾²⁾

Variables	OLS	OLS (model 15)	IV ³⁾	OLS ⁴⁾	OLS ⁵⁾	Fuller– Battese
γ	1.041 (0.015)**	1.040 (0.015)**	1.042 (0.145)	1.043 (0.014)**	1.037 (0.015)**	1.041 (0.005)**
β^{IW}	-0.044 (0.028)	-0.052 (0.030)	-0.154 (0.539)	-0.015 (0.033)	-0.039 (0.029)	-0.015 (0.031)
β^{OW}	0.055 (0.022)*	0.046 (0.024)*	0.134 (0.444)	0.051 (0.026) ⁺	0.055 (0.022)*	0.036 (0.024)
Constant(δ)	-0.003 (0.003)	-0.000 (0.001)	0.001 (0.015)	${\overset{-0.014}{(0.007)}}^{*}$	0.005 (0.007)	-0.004 (0.005)
\overline{R}^2	0.934	0.929	0.932	0.942	0.933	0.918
Ho: $\gamma = 1$ p-value	0.005	0.007	0.771	0.002	0.014	0.004
Condition Index	2.68	2.86		10.12	6.83	—
Number of observations	572	572	572	572	572	572

Notes :1) The standard errors are in parenthesis.

- 2) **, *, * indicate that the null hypothesis of γ and β 's being equal to zero can be rejected at the significance levels of 1%, 5%, and 10% respectively.
- 3) The instrumental variables are the ratio of international oil prices to the consumption deflator, the ratio of international oil prices to the investment deflator, the population growth rate, the growth rate of the consumption deflator, the growth rate of defense expenditure, and a dummy variable representing the pre-1987 period.
- 4) This column represents the results from a model including a yearly dummy. The dummies that appeared significant at the 5% significance level are those for the years 1979, 1980, 1981, 1983, 1984, and 1986.
- 5) This column presents the results from a model including industrial dummies. All appeared insignificant at the 5% significance level.

B. Estimation results

The parameters of the model (15) in themselves represent the effects of annual input growth rates on annual output growth rate. However, longer-than-a-year effects may also be extant. Such effects may be captured if the length of log-differencing is increased in calculating the growth rates of the variables. Equation (17) incorporates this idea.

(17)
$$y_{it\tau} = \delta + \gamma x_{it\tau} + \beta^{IW} x_{-it\tau}^{IW} + \beta^{OW} x_{-it\tau}^{OW} + u_{it\tau},$$

 $\tau = 1,...,26$

where τ is the length of log-differencing in calculating growth rates. The equation represents the relationship of annual growth rates when τ is 1, and of biannual growth rates when τ is 2, and so on. τ takes values from 1 to 26. We call the parameter estimates when τ is 1 short-run coefficients and those when τ is 26 long-run coefficients. For the τ 's in-between, the parameter estimates of the model represent the mid-term relations of the variables.³⁴⁾

(Estimation Results of the whole sample: 1971-1996)

Table 3 shows the estimation results from τ taking different values. The whole parameter estimates corresponding to each value of τ from 1 to 26 are shown in Figures 2, 3, and 4.

In the case of τ =1, economies of scale and customer-driven spillovers were present but supplier-driven spillovers appeared to be weak (see the first column in Table 3); the estimate for **v** was 1.041 and the null hypothesis that **v**=1 was rejected at the 1% significance level. The estimate for β^{OW} was 0.055 and significant at the 5%

³⁴⁾ This interpretation is in line with Bartelsman, et al. (1991) who interpreted the "within" estimators as representing a short-run relationship, and the "between" estimators a long-run relationship, between the variables.

significance level. The estimate for β^{IW} was -0.044 but not significantly different from 0.

<Table 3>

	τ=1	τ=2	π=3	∎=5	π=10	τ=15	τ=20	T=26
γ	1.041 (0.015)**	1.054 (0.014)**	1.037 (0.014)**	1.006 (1.015)**	0.988 (0.017)**	0.995 (0.020)**	1.014 (0.023)**	1.017 (0.051)**
β^{IW}	-0.044 (0.028)	-0.055 (0.025)*	-0.052 (0.024)*	-0.040 (0.024)*	-0.023 (0.028)	0.005 (0.034)	$\binom{0.070}{(0.036)^{\dagger}}$	0.090 (0.084)
β^{OW}	0.055 (0.022)*	0.064 (0.020)**	0.077 (0.019)**	0.089 (0.019)**	0.104 (0.022)**	0.132 (0.022)**	0.136 (0.024)**	$\begin{array}{c} 0.130 \ (0.054)^{*} \end{array}$
상수 (-0.003 (0.003)	-0.008 (0.005)	$^{-0.011}_{(0.007)}$	-0.019 (0.011)*	-0.052 (0.026)*	-0.193 (0.043)**	-0.504 (0.075)**	-0.027 (0.009)**
\overline{R}^2	0.934	0.948	0.954	0.959	0.957	0.964	0.971	0.977
Ho: v=1 p-value	0.005	0.0001	0.011	0.663	0.472	0.807	0.539	0.739
Condition Index	2.68	2.74	2.82	3.00	2.85	2.89	2.63	2.34
Number of observations	572	550	528	484	374	264	154	22

Estimation results for the sample period: 1971-96

Notes :1) The standard errors are in the parenthesis.

2) **, *, [†] indicate that the null hypothesis of γ and β 's being equal to zero can be rejected at the significance levels of 1%, 5%, and 10% respectively.

As for $\tau \ge 2$, the economies of scale parameters were significantly greater than one up to $\tau = 3$ but diminished thereafter so as to be only insignificantly different from unity as shown in the figure 2. The supplier-driven spillovers were insignificant except for $\tau = 2 \sim 4$ where they were negative and for $\tau = 20 \sim 22$ where they were positive as shown in the figure 3. In particular, β^{IW} had an insignificant but negative value at $\tau = 1$ and then showed an increasing trend as τ increased. And all the customer-driven spillovers were significantly positive and showed an upward trend as τ increased as shown in the

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figure 4. The estimates for the constant term δ tended to be insignificantly different from zero in the short run, but in the long run they tended to take negative values, which reflects that the supply of infrastructures was insufficient in the long run.

These estimation results can be interpreted as indicating the following features of the productivity improving mechanism in Korean manufacturing. First, that economies of scale were significant in the short-run and insignificant in the long-run implies that an investment strategy of taking advantage of scale economies together with readily available technology was effective in boosting productivity only in the short run, but not in the long run.³⁵⁾

The meager supplier-driven spillovers together with the relatively customer-driven spillovers imply strong that the productivity improvement during the sample period in the manufacturing sector was the result of demand expansion rather than of innovation and division of labor in the sector. Furthermore, that the estimates for the supplier-driven spillovers parameter for $\tau = 1 \sim 13$ were negative, if not significant, reflects in part that an expansion of trade with other domestic industries brought about negative effects on the productivity of an industry in the short- and medium-run. Slight evidence of improvements in this parameter could be perceived only in the 20-year time horizon. In contrast, the positive and increasing β^{OW} in the medium-run implies that demand spillovers contributed substantially to industrial productivity growth. This paper conjectures that the factors that played an important role in such a change include the monopoly

³⁵⁾ The absence of long-run economies of scale may be due to the lack of spillovers among constituent firms of an industry, hampering the realization of dynamic economies of scale from the division of labor within the industry.

position established in some of the manufacturing industries, the policy of protecting some industries from imports, internal input procurements by the big interlinked business groups, or *chaebol*, and the government's policy of encouraging stable subcontracting relationships.³⁶⁾ In particular, internal transactions within large interlinked business groups seem to have contributed not so much to the division of labor as to scale–expansion as will be seen.

³⁶⁾ According to recent empirical research by Jun(1999) a policy of encouraging stable subcontracting relationships between small & medium enterprises and large scale firms has reduced the manufacturing sector's productivity. The main reason was shown to be that too much emphasis on the exclusivity of the relationship lowers the efficiency of subcontracting.



Dynamic profile of economies of scale



Length of log difference τ , unit: years

<Figure 3>

<Figure 4>

Dynamic profile of supplier-driven spillovers





* Note: Dotted lines indicate the 95% confidence interval.

(Estimation by sub-period)

During the sample period, $1971 \sim 96$, the Korean economy had grown rapidly and experienced gradual shift in its institutional framework from dirigisme to a more liberal approach. These changes may have altered the systemic characteristics of productivity-augmenting mechanism in the manufacturing sector. Thus in order to see if this was the case, the sample period was divided in three sub-periods: $1971 \sim 79$, $1980 \sim 88$ and $1989 \sim 96$, and the same model was estimated with respect to each period.

The results are shown in Table 4. In none of the sub-periods did the supplier-driven spillovers appear significantly positive in the short run. In the period 1971~79, economies of scale were present, with γ being greater than 1. But neither β^{IW} nor β^{OW} were other than zero, indicating the absence of inter-industrial productivity spillovers during this period. Estimates from the long-run model of the subsample period, i.e. when $\tau = 8$ or 9, show that both the spillover effects and economies of scale were insignificant.

In contrast, the results from the estimation of the short-run model for the sample period 1980~88 showed constant returns to scale, positive customer-driven spillovers, and negative supplier-driven spillovers in the short run. This seems to reflect a characteristics of the period; that is, manufacturing industries enjoyed demand expansion; at the same time, they suffered from the technological backwardness of domestic suppliers in the wake of the over-investment in chemical and heavy industries during the 1970s. The results from the estimation of the long-run model with $\tau = 9$ showed constant returns to scale and positive

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customer-driven spillovers, but the negative supplier-driven spillovers became insignificant, implying some improvement in the domestic linkages in the long run.

However, the period $1989 \sim 96$ witnessed a deterioration in terms of both economies of scale and spillover effects. The estimation results of the short run model show decreasing returns to scale, positive but smaller customer-driven spillovers, and nonexistent supplier-driven spillovers. The results form the long-run model showed constant returns to scale, implying some improvement over a longer time-horizon. But spillovers from customers and suppliers were absent.

	1971	1-79	1980)-88	1989	1989-96	
	$\tau = 1$	τ =9	$\tau = 1$	τ =9	$\tau = 1$	τ =9	
γ	1.189 (0.021)**	1.038 (0.052)**	0.974 (0.027)**	1.112 (0.091)**	0.906 (0.028)**	1.001 (0.052)**	
β^{IW}	-0.025 (0.039)	0.112 (0.086)	-0.126 (0.060)*	-0.126 (0.180)	0.010 (0.051)	0.001 (0.089)	
β^{OW}	0.001 (0.031)	-0.025 (0.072)	0.131 (0.043)**	0.334 (0.105)**	0.087 (0.042)*	0.077 (0.081)	
Constant	-0.025 (0.006)**	-0.160 (0.145)	0.014 (0.006)*	-0.228 (0.153)	-0.004 (0.005)	-0.057 (0.067)	
\overline{R}^2	0.954	0.968	0.908	0.918	0.894	0.964	
p-value for Ho: $\gamma = 1$	0.001	0.479	0.332	0.233	0.001	0.980	
Condition Index	6.63	2.00	2.56	1.80	1.73	1.87	

 $\langle Table 4 \rangle$ <u>Estimation results by sub-period¹⁾²⁾</u>

Notes :1) The standard errors are in parentheses.

2) **, *, * indicate that the null hypothesis of γ and β 's being equal to zero can be rejected at the significance levels of 1%, 5%, and 10% respectively.

The results imply that the foundation of the mechanism for productivity-enhancement in Korean manufacturing was fragile. This tallies with other research on the productivity of the Korean manufacturing sector. As was observed in Table 1, total factor productivity in the manufacturing sector had actually undergone a slowdown in its growth rate. Beside this, Kwack (1997) also found, with a different data set, that for the period $1971 \sim 93$ total factor productivity grew at 3.0% a year on average. But its growth rates were lower in the later periods; on average it grew at 3.8% a year during the 1970s, 2.4% during the period from 1979 to 1985, 1.0% in the period from 1985 to 1989, and 0.6% in the period from 1989 to 1993.

<Table 5>

Growth rates for the manufacturing sector

				(Unit	: annual gro	owth rate %)
		$1971 \sim 79$	1979~85	1985~89	1989~93	1971~93
Value	e Added(A)	19.6	9.5	13.0	6.8	13.9
	Capital Input(B)	10.7	4.5	6.9	5.8	7.5
Factor Inputs	or Labor ts Input(C)	4.7	1.8	4.4	-0.3	3.0
	Education and training(D)	0.3	0.6	0.6	0.7	0.5
To Prod	tal Factor luctivity(E)	3.8	2.4	1.0	0.6	3.0

Note : E = A - B - C - D.

Source : Kwack (1997) p.27 < Table IV-2>

Given that, during the sample period, industries developed rapidly and the government's industrial policy also underwent a change from a selective to a functional approach (or at least what was intended to be one), the changes in the patterns of γ , β^{IW} and β^{OW} shown above shed light on the various aspects of the productivity decline. For example, the 1970s' realization of economies of scale in the short run together with its failure to generate inter-industrial spillover effects can be seen as reflecting that the growth strategy at that time which utilized such policy instruments as interest rate regulation and selective credit control might have been conducive to the realization of economies of scale at least in the short-run, but they were not conducive, and were even hostile, to the evolution of an industrial division of labor and subsequent productivity improvement in the long run.

The level of the parameters for the period from 1980 to 1988 supports this conjecture. This period is characterized by less selective and more liberal industrial policies than before and the increased role of the big interlinked business groups in resource allocation. The particularly strong demand spillovers witnessed for this period may be attributed to the establishment of domestic demand linkages, especially the activation of intra-group trade, during the period. However, seen from the viewpoint of inter-industrial spillovers, there is no evidence that this tendency was accompanied by significantly positive developments in the division of labor and domestic innovation capabilities.

The last sub-sample provides an embarrassing case. Economic liberalization and opening during the period from 1989 to 1996 had been quite remarkable compared to the preceding periods(The Bank of Korea 2000). But the parameter estimates showed a deterioration both in terms of economies of scale and division of labor, contrary to expectations based on the conventional wisdom: liberalization improves efficiency. The reason seems to be that the environment in which the liberalization policy was introduced was not favorable enough to bring forth the

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theoretically expected improvements. In fact, unexpected negative developments took place. For example, some of the main business groups were able to raise huge amounts of funds more easily than before in the booming stock market and from their newly obtained access to the global capital markets, they were subject to less stringent budget constraints and invested inefficiently.³⁷⁾ The increased competition due to the economic liberalization and opening seems to have failed to spur firms to enhance their innovative capacity.³⁸⁾ Rather, it seems to have helped many of the capital-intensive or domestic demand-oriented industries to experience a boom and bust cycle, leaving them over-crowded with too many incumbents and thus lowering the productivity of the manufacturing sector as a whole.

4. Comparison with the U.S.A.

Table 6 compares the parameter estimates of the short-run model and the long-run model for the Korean manufacturing sector from 1971 to 1996³⁹⁾ with those for the U.S.A. manufacturing sector from 1958 to 1986, as reported in Bartelsman, Caballero and Lyons(1994)⁴⁰⁾. Seen from

³⁷⁾ The empirical research of Demetriades and Fattouh (2000) found that the share of loans given to non-productive activities had increased during the 1990s, implying that soft budget constraints might have contributed to the decrease in productivity in the manufacturing sector.

³⁸⁾ For example the dependence of investment-related technology on foreign sources did not decline. The coefficient of correlation between the net payment of royalties and licenses to foreigners and the domestic total fixed capital formation during the period from 1980 to 1997 was 0.985 and it does not seem to have fallen recently.

³⁹⁾ The output-weighted aggregate activity index χ_{-i}^{OW} for Korea was calculated using the input coefficient matrix, rather than the transaction value as weight, in order to make estimation methods align with those of Bartelsman, et al.

⁴⁰⁾ Comparison of the two empirical results is limited to the extent that the sample periods and data sources are different, but the results of the hypothesis tests may

the viewpoint of inter-industrial productivity spillovers, the U.S.A. manufacturing seems to embody a mechanism of intensive growth at least in the long run. For U.S.A., γ is bigger than 1 in both the short run and the long run, indicating the presence of increasing returns to scale. In the short run, customer-driven spillovers were the main driving force of inter-industrial productivity spillovers while in the long run supplier-driven spillovers replaced the role. This implies that in the U.S.A., the momentum for productivity improvement was given initially by the expansion of inter-industrial markets; the market expansion then stimulated division of labor, especially in the materials and capital goods industries, in the long run; the resultant technological progress was embodied in the products and transmitted to other industries and stimulated further interactions for innovations.

The parameter estimates for Korean manufacturing during the 1971~ 96 period show similarities and differences with those of U.S.A. manufacturing. Economies of scale were present only in the short run, and short-run customer-driven spillovers were also significant. However, the Korean manufacturing industries differed from those of the U.S.A. in of that in the long run economies scale disappeared while supplier-driven spillovers did not materialize even in the long run. This implies that, in contrast to the case of the U.S.A., the Korean industry sector lacks a dynamic mechanism manufacturing for endogenous technological progress.

well be compared since both use the same models and estimation methodology.

<Table 6>

	Short-run τ =1	[Equation 16]	Long-run [Equation 17]		
	U.S.A. Korea		U.S.A.(τ =28)	Korea(τ =26)	
γ	$1.094 \\ (0.007)^{**}$	$1.042 \\ (0.015)^{**}$	$1.090 \\ (0.024)^{**}$	1.015 (0.051)**	
β^{IW}	0.020 (0.028)	-0.036 (0.032)	$\begin{array}{c ccc} -0.036 & 0.313 \\ (0.032) & (0.081)^{**} \end{array} $		
β^{OW}	$0.119 \\ (0.022)^{**}$	$\begin{array}{c} 0.025 \ (0.023)^{*} \end{array}$	0.066 (0.062)	$0.151 \\ (0.063)^*$	
R^2	0.72	0.927	0.85	0.977	

Estimation results for the U.S.A.(1958~1986) and Korea(1971~1996)¹⁾²⁾

Notes: 1) **, *, \dagger indicate the values at which γ and β can be rejected at the 1%, 5%, 10% significance levels respectively for the null hypothesis that they equal 0.

2) The direct requirements matrix (i.e., the input coefficient matrix) from the input-output table was used also in computing Korea's χ_{-i}^{OW} .

Source: Bartelsman, Caballero, and Lyons (1994) p.1079. Table 1.

A decomposition analysis of the sources of industrial growth makes this contrast clearer (See Table 7). In the U.S.A., supplier-driven spillovers contributed a lot to industrial growth but in Korea neither of the two spillover effects contributed significantly in the short run and the meagerness of the contribution of supplier-driven spillovers in Korea was notable in the long run. The contribution to industrial growth by inter-industry productivity spillovers as a whole was 25.8% in the U.S.A. while it was only 17.4% in Korea. In particular, the contribution of supplier-driven spillovers was positive both in the short run at 1.6% and in the long-run at 21.3% for the U.S. while in Korea it was negative at -3.5% in the short-run and a positive 6.9% in the long-run. The main factors that caused the differences between Korea and the U.S. are conjectured to lie in the differences in the level of industrial technology, in the peculiarity of industrial organization and trade policy, and in the relatively small size of the Korean domestic markets.

<Table 7>

			%		
	Growth Easters	Degree of Contribution			
Glowul Factors		Korea	U.S.A.		
	Own inputs	101.1	88.7		
Chart mus	Inter-industrial spillovers	-1.1	11.3		
Short-run	(supplier-driven)	(-3.5)	(1.6)		
	(customer-driven)	(2.4)	(9.7)		
	Own inputs	81.0	74.2		
I and mus	Inter-industrial spillovers	17.4	25.8		
Long-run	(supplier-driven)	(6.9)	(21.3)		
	(customer-driven)	(12.5)	(4.5)		

Contributions to industrial growth by sources¹⁾

Note : 1) The degree of contribution to industrial growth was calculated by the following formula using the estimates in Table 6.

~ ~		~	
γx		γ	
$\widehat{\gamma} \widetilde{x} + \widehat{\beta}^{IW} \widetilde{x}_{-i}^{IW} + \widehat{\beta}^{OW} \widetilde{\beta}$	$\tilde{x}_{-i} \stackrel{OW}{=} \tilde{u} \stackrel{i}{=} \tilde{u}$	$\dot{\gamma} + \hat{\beta}^{I\dot{W}} +$	$\hat{\beta}^{OW}$

IV. Summary and Implications

This paper has approached the issue of productivity enhancement from a different viewpoint than the current productivity researches and focused instead on the importance of augmenting the division of labor and concurrent inter-industrial productivity spillovers. In doing so, we estimated a growth regression model as suggested by Bartelsman, Caballero and Lyons(1994), while reinterpreting it as a productivity growth model, where productivity growth is decomposed into economies of scale and inter-industrial spillovers.

The model was estimated using the data for twenty-two industries in Korean manufacturing. The results show that the inter-industry productivity spillovers in Korean manufacturing were small or absent for the period $1970 \sim 96$. In particular, supplier-driven spillovers were weak in general and negative in the short run. Only customer-driven spillovers appear to have had a positive influence on productivity in the short run and increasingly so in the long run. On the other hand, economies of scale were clearly manifested but only in the short run; they tended to disappear in the medium and long run.

Interpretation of these findings is attempted on the basis of Adam Smith's principle of the division of labor. In the context of the model, increasing returns to scale at the level of the manufacturing sector as a whole derive either from economies of scale at the individual industry level or from inter-industrial spillovers. In particular, the presence of supplier-driven spillovers is interpreted as evidence for the existence of technology spillovers among industries. If they are observed in the long run, they may represent a mechanism of endogenous technological progress in operation. That the empirical results find both sorts of

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inter-industrial spillovers lacking among Korean manufacturing industries can be interpreted as showing the immaturity of the Korean manufacturing sector as a formal or informal network of industries for developing new technologies and diffusing them in the way of daily interactions with each other. The particularly weak supplier-driven spillovers are interpreted as revealing not only the underdevelopment of the materials and parts industry but also the shallow division of labor among the manufacturing industries.

Estimation of the model by dividing the whole sample period to three sub-periods, 1971-79, 1980-88, and 1989-96, was also attempted. It was expected that changes in the economic policy regime and industrial development during the sample period would have changed the productivity parameters. For example, the selective industrial policy seeking realization of economies of scale with borrowed technology from abroad which was characteristic of the first period would result, if successful, in increasing returns to scale at an individual industry level but in no spillovers among industries. In addition, the reform policies such as economic deregulation and opening, characteristic of the second and the third periods, would result in a positive supplier-driven spillover effect if the transition was successful.

These conjectures were generally confirmed for the first period, but not for the other periods. In the first period, even though it disappeared in the long run, economies of scale were clearly present in the short run; and supplier-driven spillovers were not positive even in the long run. This pattern accords with that expected in the case of a late industrialization regime. But, in the second and the third period, things seem to have gotten worse especially in the last period, despite the introduction of the reform measures. The returns to scale in the short

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run model showed a deterioration in productivity over time; they were increasing in the first period, but constant in the second period, and decreasing in the last period. Moreover supplier-driven inter-industrial spillovers were not witnessed in subsequent periods either; they were even negative, though seldom significant, in the short run estimation for the second period.

These results require a second thoughts about the validity of the so-called late-industrialization model in the development literature such as Amsden(1989). A tentative conclusion is that a strategy for late industrialization is effective only in materializing economies of scale in the short run, especially in the early stage of industrial development, for instance, the 1970s for Korea. In later periods when partial liberalization and opening had taken place, only customer-driven spillovers were positive, with supplier-driven spillovers being negative or insignificant. This may imply that the reform measures were of very limited effect in promoting inter-industrial interactions; they were effective only in promoting demand spillovers among industries, not in giving rise to the positive supplier-driven spillovers. This development may be attributed to the increasing role of big business groups in industrial development in the wake of the economic liberalization. But even if they promoted demand spillovers, these were not sufficient to induce inter-industrial interactions for innovations. Moreover, the diseconomies of scale set in the last period speaks for the difficulties for an economy to transit to advanced status in terms of a division of labor which evolves to improve the productivity augmenting process. It may be suggested that this reflects at least partly the difficulties of reforming the institutions initially designed for late-industrialization.

A comparison of the parameters with those for an advanced economy

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was tried; that is, the estimation results for the whole period were compared with those for the U.S.A. manufacturing in Bartelsman, Caballero, and Lyons, which seem to confirm the argument that in an advanced economy supplier-driven spillovers play an important role. In the U.S.A., an advanced economy, customer-driven spillovers among industries manufacturing materialized in the short run and supplier-driven spillovers in the long run. In contrast, the Korean economy resembles the U.S.A. only in the short run with positive demand spillovers. It differs from the U.S.A. in the long run, having no supplier-driven spillovers. Moreover, economies of scale in the U.S.A. obtained both in the short run and in the long run, while in Korea they obtained only in the short run and disappeared in the long run. All these comparisons support the argument that the home base for productivity improvement, especially for indigenous innovation capabilities stemming from a division of labor, has not been well developed in Korea, despite recent policy efforts and developments in the industries.

The above discussion gives rise to some policy implications. Above all, the government's role in setting up the right institutional framework can not be emphasized too much since institutions determine the level of transaction costs and economic uncertainty. Only under a favorable institutional environment will industrial clusters and a "venture valley" of small firms possessing advanced technologies come into existence and flourish.

In addition, it must also be pointed out that industrial policy should not be selective but such that it stimulates the formation of a network that facilitates flows of technology and information in all industries. This is because concentrated efforts to foster an industry have limited

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effectiveness at the current stage of industrial development and because the complexity of the production system and the linkages among firms show how important these spillover effects are in determining productivity growth.

The infrastructure referred to in this paper includes not only transportations and communications but also the setting up of a basic environment for innovation such as a supply of highly skilled labour and a national innovation system. Analysis of the patterns of industrial productivity spillovers, identification and correction of systemic failures, and co-research with private firms will be important tasks for government agencies in developing and operating technology diffusion programs.

This paper has undertaken an empirical analysis of spillovers to grasp the nature of the mechanism for productivity enhancement in Korean manufacturing. Industrial productivity spillovers will become an important issue for years to come in theoretical and empirical research especially with respect to upgrading a late industrializing economy. It is hoped that this paper will trigger further research in that direction. Such research should be more specific or explicit in analyzing the interaction of domestic firms with foreign firms or in relating the policy effects to the parameter patterns. Attempting to locate more detailed spillover effects at the firm level would also be worthwhile.

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