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An Analysis on the Labor and Capital Productivity of the Construction Industry

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Abstract

The purpose of this study is to clarify the reality of labor and capital productivity in the construction industry through an industry-level approach and to analyze the relationship between labor and capital productivity using a Cobb-Douglas production function. According to the research results, the construction industry has shown a very high capital productivity, while labor productivity has kept up a low level during the 1980s and 1990s. The reason was because of the lack of skillful construction workers and the decrease of capital. Meanwhile, the construction productivity has greatly increased since 2000 when there was no change in wages. This was because of a large inflow of low-wage foreign workers while the amount of value added has dramatically increased due to the liberalized sale price of apartment buildings. According to the analysis by the Cobb-Douglas production function, the elasticity coefficient of V/L to K/L in the construction industry had decreased from 1.1663 in the 1st period(1971-1988) to 0.4465 in the 2nd period(1989-1997), and to 0.1664 in the 3rd period(1998-2003). Such a result means that the allocation of labor has gradually increased while the allocation of capital has decreased. Moreover there was a big increase in allocation of labor after 1998 due to the excessive deterioration of capital. In conclusion, in order to raise the construction productivity and to avoid labor-intensive production methods, investment for capital should be more increased. In particular, new machinery and equipment that can actually substitute human labor in construction sites should be more developed and applied to construction sites.

Keywords: Labor Productivity, Capital Productivity, Production Function, Mechanization, Automation

1. INTRODUCTION

Recently, while construction work becomes larger and longer, the supply of construction labor force is getting quite difficult. Consequently, low productivity in the construction industry is emerging as an urgent problem to be solved.

However, there are few research papers related to the productivity of the construction industry. When examining the studies related to the productivity in the construction industry, most of research subjects were related to the measuring of productivity at the local construction site level or methods to improve the construction productivity (Tan(1996), Allmon(2000), JFCC, 1993, etc.); there has not been enough research on or analyses of construction productivity at the industrial level.

Accordingly this study tried to clarify the reality of labor and capital productivity in the construction industry of Korea through an industry-level approach. Moreover this study analyzed the characteristic of construction productivity by comparing it with the productivity of the manufacturing industry.

In order to analyze productivity in the construction industry, this study used statistical data published by the Bank of Korea, including gross value added per capita, employment cost to gross value added, ratio of gross value added to tangible fixed assets, and total assets per capita between 1970 and 2003. Also, this study analyzed the relationship between labor and capital productivity using a Cobb-Douglas production function, to find the efficient ways for improving the construction productivity.

2. ESTIMATION AND ANALYSIS OF LABOR PRODUCTIVITY

(1) Gross Value Added per Capita

Productivity is the amount of output created (in terms of goods produced or services rendered) per unit input of used. In particular, labor productivity is typically measured as output per worker or output per labor-hour.(JFCC, 1993)

In this study, the labor productivity in the construction industry was measured and analyzed as value added per unit worker using the data of gross value added and the number of employees from "Financial Statement Analysis" data published by the Bank of Korea.

All time-series data were used after converting them into constant price for year 2000 using the GNP deflator that published by the Bank of Korea. Also, labor productivity in the manufacturing industry was analyzed by the same method like the construction industry in order to find the problems in the labor productivity of the construction industry.

Fig.1 shows gross value added per capita in the construction industry over 34 years, from 1970 to 2003. As shown, though gross value added per capita in the construction industry in 2003 was 36 million won, it was only 57% of 63 million won in the manufacturing industry.

Although gross value added per capita in the construction industry has increased in these days, there had been almost no change over 20 years since 1980. On the contrary, labor productivity in the manufacturing industry had constantly increased since the mid 1980s.

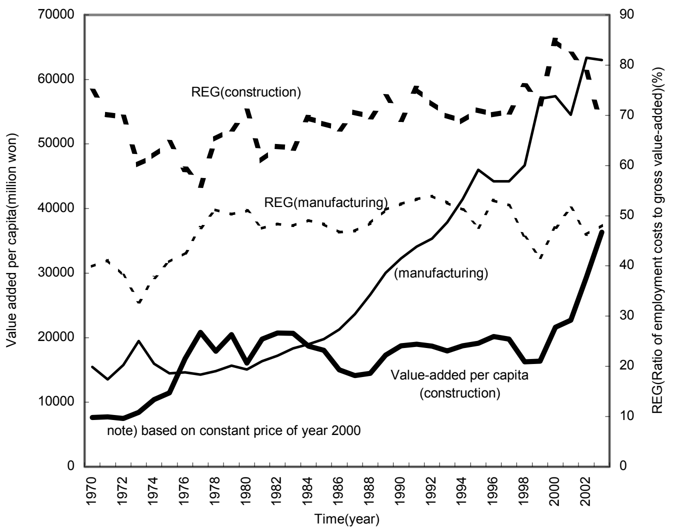

Figure 1. Gross value added per capita and employment costs to gross value added

Source : The Bank of Korea, "Business Management Analysis"

For instance, labor productivity in the manufacturing industry had increased 2.8 times (from 16.3 million won to 46 million won) during 15 years between 1981 and 1995. However, the productivity of the construction industry had decreased a little (from 19.8 million won to 19.1 million won) during the same period. Moreover, considering the fact that there was a big rise in labor cost after the 1990s, there was a possibility that gross value added per capita in the construction industry was overestimated. Therefore, it can be concluded that labor productivity in the construction industry remains at a low level.

The reason is because the construction industry has continuously depended on labor-intensive production methods while the manufacturing industry has improved the productivity by investment for new technologies, training of labor force, and the development of automated factories. Actually, real R&D investment in domestic construction companies don't reach 1% level of the sale amount yet. It is very low level when compared with 2.4% in the manufacturing industry and 2.3% the average of whole industry in 2003.(CAK, 2004)

Moreover, owing to the 3D (dirty, dangerous, difficult) avoidance phenomenon, new labor force has gradually decreased in these days. Accordingly, there is a possibility that the aging of construction workers and the increase of unskilled labor force resulted in the decrease of labor productivity.(Shim, 2001)

(2) Employment Costs to Gross Value Added

The fact that the construction industry still has labor-intensive characteristic can be proved by the ratio of employment costs to gross value added (REG), which shows the problem of labor cost in the amount of gross value added. As shown in Fig. 1, the REG of the construction industry had a yearly average of 69.3% from 1970 to 2003, which was a fairly high level compared to that of the manufacturing industry (49.3%). It can be understood that the construction industry depended more on a labor-intensive production system than the manufacturing industry.

Meanwhile, Fig. 2 is a result which compared gross value added per capita in the construction industry with the wages of construction workers from 1970 to 2003 in order to analyze the effect of wages on labor productivity. Each statistic was converted into a constant price of the 2000 level and was indexed based on the 1970 level for comparison.

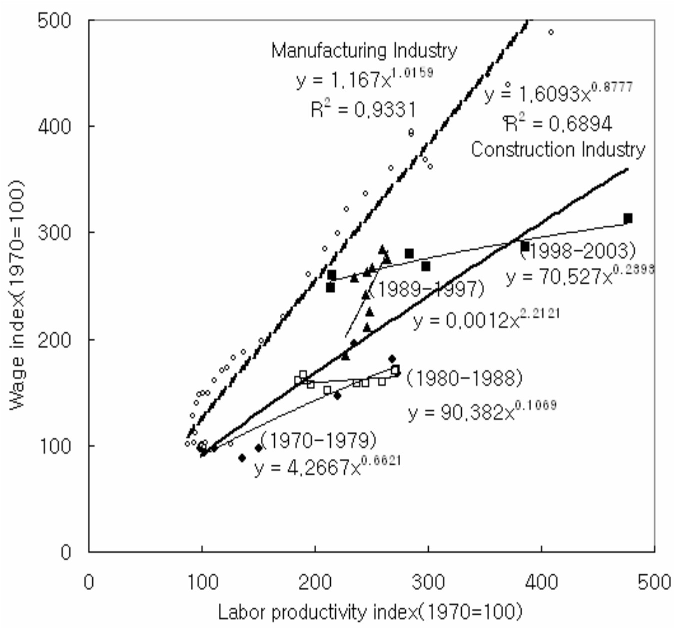

Figure 2. Relationship between labor productivity index and wage index

In Fig. 2, the data of wages and productivity were divided according to the division of four periods and a regression line was determined for quantitative analysis.

As shown in Fig. 2, wage elasticity in the 3^{rd} period (1989-1997) was 2.21, which was very high. The reason was because labor cost had sharply risen due to the lack of construction workers. Consequently the wage index had also increased rapidly without causing any change in labor productivity during that period.

On the contrary, the construction productivity has greatly increased since 2000 while there was no change in wages. The reason was because of the large inflow of low-wage foreign workers. But the amount of value added had dramatically increased due to policy changes, for example, the liberalization in the sale price of apartment buildings. Moreover, such a decrease of wage may have an effect on the rapid decrease of REG since 2000 as shown in Fig. 1.

On the other hand, the elasticity of wage to labor productivity is expressed as the square of x in Fig. 2. If the wage elasticity is greater than 1, it means that the wage growth rate is relatively higher. As shown in Fig. 2, the wage elasticity of the construction industry is 0.87, which is lower than 1.01 of the manufacturing industry.

That is, the wage growth of the construction industry is relatively lower than that of the manufacturing industry. The reason is because construction workers are not organized through a labor union and the number of low-wage foreign workers has been dramatically increased.(Shim, 2001)

On the other hand, contrary to the construction industry, as shown in Fig. 2, R^2 between the labor productivity index and wage index reaches to 0.93 in the manufacturing industry. That is, it can be understood that both wage and productivity have grown at almost the same ratio in the manufacturing industry.

3. ESTIMATION AND ANALYSIS OF CAPITAL PRODUCTIVITY

(1) Ratio of Gross Value Added to Tangible Fixed Assets

Capital productivity is an indicator that represents how much value added is produced by invested capital during one year. If the capital productivity is on the high level, facilities such as lands, machines, and equipments are being efficiently used.

This study used Ratio of Gross Value Added to Tangible Fixed Assets (RGT) and Ratio of Gross Value Added to Machinery and Equipment (RGM) to estimate capital productivity.

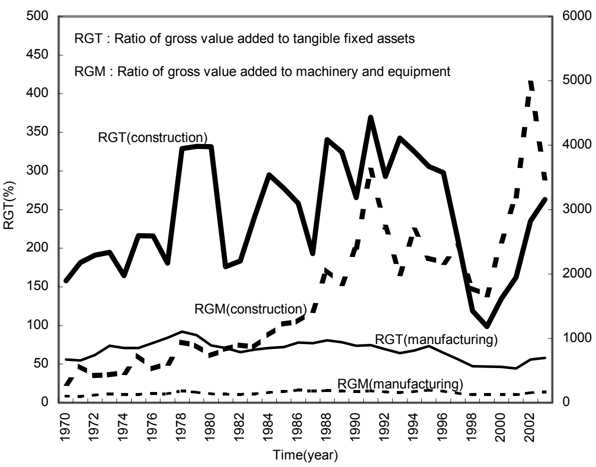

Figure 3. Ratio of gross value added to tangible fixed assets and machinery/equipment

Source : The Bank of Korea, "Business Management Analysis"

Fig. 3 shows the result of measuring the RGT using the data(constant price of 2000) of gross value added per capita and tangible fixed assets from 1970 to 2003. In Fig. 3, it also illustrated the RGT of the manufacturing industry for comparison.

As shown in Fig. 3, the RGT of the construction industry maintains a very high level compared to the manufacturing industry. While the RGT of the manufacturing industry has maintained a nearly same value, the RGT of the construction industry has shown a severe fluctuation.

Examining the construction productivity in aspect of combining labor with capital, if the mechanization and automation of construction process is progressed, while assets will be increased, dependence on labor will be decreased. As a result, the RGT also will be decreased.

That is, if the RGT is high, it means that the industry depends upon a labor-intensive production method under low capital. On the other hand, if there is no change in total capital, the decrease of construction investment can reduce the RGT. For instance, the reason that the RGT of the construction industry had dramatically decreased in the late 1990s was because of the sudden decrease of new construction projects caused by the IMF financial crisis, rather than an increase in assets.

(2) Ratio of Gross Value Added to Machinery and Equipment

Ratio of gross value added to machinery and equipment (RGM), which is a supplementary index of the RGT, is the indicator to explain what relationship machinery and equipment have with the amount of added value.

As shown in Fig. 3, the RGM of the manufacturing industry has maintained at a very low level. On the contrary, though the RGM of the construction industry was 305 in 1970, the ratio reached 3,489 in 2003 and increased 11.4 times. The RGM of the construction industry is greater about twenty times than that of the manufacturing industry, based on the data in 2003. This means that the construction industry is less dependent on machinery and equipments than the manufacturing industry.

Also, the RGM is far greater than the RGT in the construction industry. Therefore, if value added is constant, compared with other investments for assets, it becomes evidence that investment for machinery and equipment was remarkably insufficient. Actually, while investment for land in the construction industry increased, investment for machinery and equipment decreased 54% (from 1,916 million won in 1980 to 885 million won in 2003) based on a constant price of 2000, as shown in table 1.

Table 1. Trends of major tangible fixed assets in the construction industry

(Unit : billion won, constant price of 2000)

	1971	1980	1990	2000	2003
Land	147 (1.0)	366 (2.5)	1,548 (10.6)	7,040 (48.0)	5,263 (35.9)
Buildings/Structures	160 (1.0)	767 (4.8)	2,361 (14.7)	5,040 (31.4)	3,635 (22.7)
Machinery/Equipment	169 (1.0)	1,916 (11.3)	974 (5.8)	735 (4.3)	885 (5.2)
Vehicles/Carriers/Ships	57 (1.0)	555 (9.8)	449 (7.9)	350 (6.2)	405 (7.1)

Note : The values in ( ) are the relative rates based on 1971.
Source : The Bank of Korea, "Financial Statement Analysis"

The fact that investment for machinery and equipment is insufficient in the construction industry means that the mechanization, automation, robotization, and prefabrication of construction production have been delayed. Also, another reason is that the rental of machinery and equipment has greatly increased to reduce the cost for possessing them. However, such a low investment for machinery and equipment may result in weakening long-term competitiveness in the construction industry.

If the RGM is constant, in order to raise the labor productivity, it is necessary to increase the ratio of machinery and equipment per capita. That is, it is necessary to activate the development of machinery and equipment that can reduce labor force as well as applying them at job sites.

4. ANALYSIS OF THE RELATIONSHIP BETWEEN LABOR AND CAPITAL PRODUCTIVITY USING PRODUCTION FUNCTION

(1) The Outline of Production Function

In chapter 3, both labor productivity and capital productivity in the construction industry were examined separately. However, the movement of capital is implicated in the labor productivity. On the contrary, the movement of labor has some influence on the capital productivity.

Therefore, a special analyzing method is needed to find the effects of both movements independently. In this study, in order to explain the relationship between labor and capital in the construction industry, a production function which describes the outputs that may be obtained from combining different quantities of inputs(Cobb, 1928), was adopted. The production function designed in this study adopted both labor and capital as two independent variables as well as output (for example, value added) as a dependent variable.

If above production function can be measured, the distribution between labor and capital which are contributing for construction productivity will be clarified. Moreover the optimal combination between labor and capital in the construction industry can be determined.(Tani, 1978)

On the other hand, the requisites for production do not need to be limited to labor and capital. It is also available to introduce multivariate functions using several production requisites(Tani, 1978). However, for simplifying the arguing points, this study adopted a two-variable production function and analyzed construction productivity.

To simplify the function, the output can be defined as the function between the quantity of capital "K" and the quantity of labor "L". And then, if value–added, which is expressed as V, is adopted as the output, the production function can be written as follows:

$$V = F(K, L) \quad \text{……………………………………..(1)}$$

Here, a profit rate is 'r' and a wage rate is 'w', assuming that value added V consists of a profit and a wage, then the below condition come into existence:

$$V = rK + wL \quad \text{……………………………………(2)}$$

When premising the profit maximization principle, it can be assumed that a profit rate 'r' is the marginal product of capital stock K, as well as that the wage rate 'w' is the marginal product of labor L. Then, the equation (2) can be expressed as follows:

$$V = \frac{\partial V}{\partial K}\cdot K + \frac{\partial V}{\partial L}\cdot L \quad \text{………….………….…..(3)}$$

$$\therefore \frac{\partial V}{\partial K}\cdot\frac{K}{V} + \frac{\partial V}{\partial L}\cdot\frac{L}{V} = 1 \quad \text{………………..……..….(4)}$$

The first term of the left side in the equation (4) is the elastic coefficient of V to K, and the second term becomes the elastic coefficient of V to L, as well. Accordingly, F (K, L) function shall satisfy the condition that the sum of each elastic coefficient concerning capital and labor shall always become 1.

The Cobb-Douglas production function that is one of the representative production functions is expressed as follows.(Cobb & Douglas, 1928)

$$V = AK^{\alpha}L^{1-\alpha} \quad \text{………………………………...(5)}$$

The shape like above function has some advantages. First, α is the elasticity coefficient of K and (1-α) is the elasticity coefficient of L. And then, the sum of both coefficients equals 1 and satisfies the condition of equation (4). Moreover, the function can be expressed as an equation of the first degree as shown below, which is convenient for statistical analysis.

$$\log V = \log A + \alpha \log K + (1-\alpha)\log L \quad \text{…………..(6)}$$

Therefore,

$$\frac{V}{L} = A\left(\frac{K}{L}\right)^{\alpha} \quad \text{……..……………………….…(7)}$$

Also,

$$\log\frac{V}{L} = \log A + \alpha \log\frac{K}{L} \quad \text{……………………….(8)}$$

That is, the function can be transformed into the relationship between K/L and V/L. In this case, there is convenience to measure 'A' and 'a' easily by reducing the number of variables from three to two.

Here, 'a' represents the sharing rate of capital, while (1-a) represents the sharing rate of labor. Accordingly, equation (3) can be rewritten as follows.

$$V = \alpha V + (1-\alpha)V \quad \text{…………………………..(9)}$$

(2) Analysis of the Relationship between Labor and Capital in Construction Productivity by Production Function

The Cobb-Douglas function was measured using time-series data published on "Business Management Analysis" of the Bank of Korea during 33 years from 1971 to 2003.

Value added is represented as "V" and capital as "K", and they were converted into the constant price of 2000 using the GNP deflator. “L” represented the number of employees in the construction industry as announced by the Korea National Statistical Office.

In order to observe the characteristic by periods, the whole period from 1971 to 2003 was divided into three periods: 1st (1971 to 1988), 2nd (1989 to 1997), and 3rd (1998 to 2003). When dividing the periods, we considered the 2 million houses construction project and the IMF crisis in Asia as the starting points of such periods. The result that estimated the relationship between labor and capital using the production function of the equation (8) can be expressed as Fig. 4.

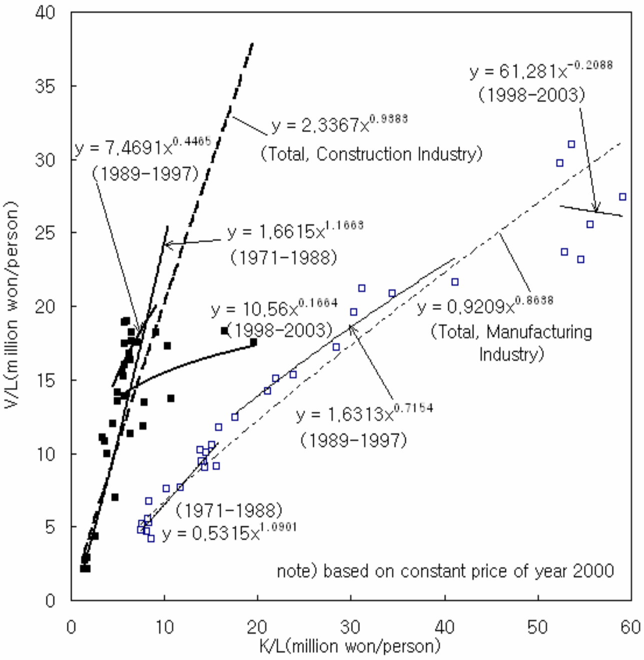

Figure 4. Analysis of construction productivity using the production function of $V=AK^{\alpha}L^{1-\alpha}$

Plotting points have a tendency to converge on the regression line in the construction industry. This is because there was almost no change in the amount of capital and labor, or because both increased at the same time. That is, although there was an increase in capital including machinery and equipment, it had little effect on reducing the amount of labor.

The elasticity coefficient ‘α’, which represents the slope of the equation in Fig. 5, means the sharing rate of capital. The elasticity coefficient of the construction industry had dramatically decreased from 1.1663 in the 1st period, to 0.4465 in the 2nd period, and to 0.1664 in the 3rd period.

As the result, the slope of the equation is getting more flattened between the 1st and 3rd periods. This means that the allocation of labor has increased while the allocation of capital has decreased. In particular, the allocation of labor has sharply increased since 1998. The reason might be because the capital including construction machinery has deteriorated excessively during that period, and then, the deterioration caused “α” to decrease.

On the other hand, the V/L and K/L values in the manufacturing industry have increased over the three periods, as shown in Fig. 4. This was caused by not only increased capital but also decreased labor. That is, it seemed that investment for capital, which was able to promote the mechanization and automation, induced the reduction of labor force in the manufacturing industry.

(3) Analysis of the Production Function Results by the Ratio of Total Assets per Capita

As examined through the production function, the fact that the allocation of labor to the value added increases means that the amount of labor is relatively increased in comparison with the amount of capital. Such a tendency can be explained through the statistics like the total asset per capita or tangible fixed assets per capita, which are indices that indicate how many assets can be attributed to one employee. In general, such indices are low in labor-intensive industries, while they are high in industries that use modern capital based on huge amounts of capital, such as the shipbuilding industry.

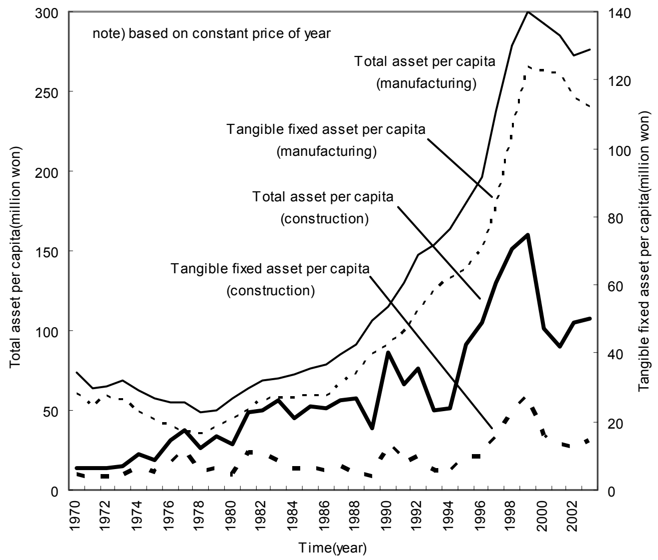

Figure 5. Ratio of total asset and tangible fixed assets per capita
Source : The Bank of Korea, “Business Management Analysis”

Fig. 5 shows the comparison of total assets per capita in the construction industry with those of the manufacturing industry over the 34 years from 1970 to 2003. Actually, the ratio of total asset per capita and the ratio of tangible fixed assets per capita have a tendency to decrease distinctively after 1998 in the construction industry, as shown in Fig. 5.

The reason is because construction companies tended to dispose of lots high-priced construction machines to raise the ratio of owner’s equity(net worth) to cope with IMF financial crisis in those days, besides the investment for construction machinery and equipment was decreased.

Moreover, the ratio of tangible fixed assets per capita in the construction industry is far lower than that of the manufacturing industry, as shown in Fig.5.

While total asset per capita in the construction industry had only increased 2.2 times during 14 years between 1981 and 2003 (from 49 million won to 107.4 million won), it had increased 4.3 times in the manufacturing industry during the same period (from 63.6 million won to 276.6 million won).

This tendency proves that there was rapid mechanization and automation of production facilities in the manufacturing industry during the period. On the contrary, the construction industry has relatively lower investment for mechanization and automation. Moreover, the construction industry has a characteristic that construction machinery and equipment shall be moved whenever a new project starts. After all, it was concluded that the change in production system resulted in a high increase of labor productivity in the manufacturing industry after 1980s.

Although a larger "α", elasticity coefficient of capital, is better, increasing only total asset per capita can not improve the productivity. The reason is because capital must be deteriorated. Therefore, both "α" and new capital should be increased at the same time as well as the aged capital must be improved to raise productivity. After all, in order to the construction productivity, constructors should enforce investment for the latest machinery, for example, unmanned robots that can actually substitute for labor. Furthermore, they should expand the application of latest new machinery in construction sites.

5. CONCLUSION

As examined above, the labor productivity of the construction industry had gradually decreased during the 1980s and 1990s. And then, it could be concluded that the major reason is because of a lack of skillful laborers resulting from the aging of construction workers and reduced inflow of new labor due to 3D avoidance behavior.

According to the results analyzing the RGT and RGM, the construction industry has very high capital productivity compared with the manufacturing industry. However, according to the total asset per capita or tangible fixed assets per capita in the construction industry, it could be concluded that such a result was caused by stagnated or reduced capital rather than by the efficient use of the capital. Furthermore, it was proved that increased capital in the construction industry had very little effect on reducing the labor force.

According to the analysis results using the Cobb-Douglas production function, the allocation of labor has gradually increased in the construction industry, while the allocation of capital has decreased.

The reason was because the construction industry depends upon labor-intensive production methods as ever. Moreover, a decline in total assets or tangible fixed assets per capita, which is caused by the lack of investment for capital resulted in the low productivity. For example, investment for the development of construction technology which can improve the productivity, such as mechanization, automation, and prefabrication, was insufficient as ever.

In conclusion, in order to raise the construction productivity and to avoid labor-intensive production methods, investment for capital should be more increased. In particular, new machinery and equipment that can actually substitute human labor in construction sites, such as unmanned robot, autoclaving machinery, and equipment for all-weather construction, should be more developed and applied to construction sites.

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