PERFORMANCE EVALUATION OF AUTOMATION DEVELOPMENT OF CONSTRUCTION SECTOR IN TAIWAN

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Abstract: Since 1990, the ROC government has promoted a 10-year plan of Industry Automation to provide guidance for the automation development of various industries. The construction industry is one of them. According to this plan, in the last decade, the government has invested more than US$15 million and adopted tax reduction, interest subsidy of loan to encourage construction firms for automation. All these measures are intended to encourage the production systems of the construction industry can be upgraded and enhanced.

This paper first overviews the development plan, including the discussions of the contents and relevant measures. Three kinds of criteria are then established to evaluate the performance of construction automation development in Taiwan. First criterion is the construction sector's case share of tax reduction. Second criterion is the technological progress factor according to panel data. And the third criterion is the rate of technological changes in the construction sector according to time-series data. Finally, conclusion and some improving strategies are outlined for the ROC government to implement automation and e-commerce for the construction sector in the 21 century.

Keywords: Automation, Production function, Technological progress

1. INTRODUCTION

The construction industry manages human resources and materials to produce facilities for industry, business, individuals, and governmental agencies. The facilities include plants, buildings, roads, housing, systems to supply water and dispose of wastes, and many others that are required to keep our modern society viable [4]. In Taiwan, the domestic labors employed in the construction industry are about 484 thousand, while the foreign ones are 48 thousand. In 1998, their total value-added output comprises 4.1% of the national gross domestic product.

In the past two decades, Taiwan's construction industry has encountered very difficult situations, such as ever-increasing cost, labor shortage, unstable quality, high accident rate, and late completion. After joining WTO, Taiwan's construction industry will face even more severe worldwide competition than before.

To improve these situations, the government promoted a 10-year plan of Industry Automation to provide guidance for the automation development of various industries in 1990. The construction industry is one of them. According to this plan, the government has invested more than US$15 million and adopted many cooperative measures such as tax reduction, interest subsidy of loan to encourage construction firms for automation. All these measures are intended to encourage the increase of productivity, reduction of costs, stabilization of product quality. It is hoped that the production systems of the construction industry can be enhanced and upgraded.

Many other countries have similar situations as well. Some have taken aggressively responsive actions. For example, the United States and Japan have various plans for construction automation development. Everett and Saito (1996) analyzed the demands for construction automation and robotics by the following three groups in each of these two countries: construction managers and owners, construction craft workers, and the construction industry in general and society at large. They concluded that there is little demand for construction automation and robotics from any of the three groups in the United States, and it is not surprising that technological developments have difficulties in gaining acceptance at worksites. In Japan, however, there is a great deal of demand-pull for automation and robotics, much of it coming from workers and society in general. Technological developments can greatly satisfy workers' and social demands, even managers' and owners' developments are not well-satisfied[2].

In Taiwan, the government agencies play an active role to encourage the construction industry to develop and adopt actions for construction automation[5]. The contents of implementing construction automation by government agencies include the following catagories : planning and design, construction works, management, material, and R&D. The relevant measures of the construction automation development are described below.

Firstly, to dissimilate or exchange the information and experiences related to construction automation techniques and equipment, some responsive government agencies, such as Construction and Planning Administration (CPA) and Architecture Research Institute (ARI), have held over 130 educational actities, such as seminars, workshops, and training courses. More than 12,600 persons, who are engaged in engineering planning, design, and construction, have attended these activities since 1990.

Secondly, the government agencies have introduced 27 cases of newly construction automation techniques and equipment to the construction industry[5]. In addition, the government agencies also promoted construction firms to form engineering technique alliances on the subjects of bridge, tunnel, pre-fabrication, and underground excavation. Through the meetings of these alliance members, the technique diffusion of construction automation is promoted.

Thirdly, the government agencies have also provided technique assistance and consultant for construction firms and, more importantly, established standards for construction materials to facilitate the implementation mechanism for construction automation.

Finally, construction firms who utilize automation equipment or techniques can obtain the advantages of business income tax reduction. In addition, the government agencies have also provided interest subsidy of loan to assist construction firms in procuring newly construction automation techniques. The total amount loan is over US$18 million.

All of the above measures are intended to improve the technological progress of the construction sector. Yet, the following issues are required to clarify before the further investment for the construction automation development: the effectiveness of these construction automation plans, the technological progress of the construction sector due to the automation investment. This paper is primarily aimed to analyze and discuss the above issues.

2. SELECTION OF PERFORMANCE EVALUATION CRITERIA FOR INDUSTRY AUTOMATION PLAN

The main purpose of construction automation development is intended to improve the technological progress of the construction industry. Several papers have discussed the performance evaluation of construction automation development. For example, Tan and Chang (1993) proposed the processes in formulating a system of performance indicators to evaluate the implementation of the National Construction Industry Automation Plan in Taiwan. They presented the system of performance indicators by applying a "Construction Automation Transformation System," which consists of three major components: (1) the inputs, such as funding, manpower, and supports; (2) the sub-systems, such as processing, receiving, and socio-economic sub-system; and (3) the outputs[6].

Wang et al. (1998) established an approach to measuring the overall effectiveness of the automation plan implemented in the construction industry in Taiwan. With this approach, they concluded that significant improvements are achieved due to the launch of the construction automation plan[8]. For example, from 1991 to 1993 (taking 1990 as the base year), 30%, 71%, and 94% increases in commitment aspects, and 15%, 20%, and 24% increases in benefit aspects have been achieved, respectively.

In this paper, three kinds of criteria are used to evaluate the performance of construction automation development. First criterion is the construction sector's case share of tax reduction. Second criterion is the technological progress factor according to panel data. And the third is the rate of technological changes in the construction sector according to time-series data.

2.1 The Case Share of Tax Reduction

In order to upgrade her industry production, the Taiwan Government set up a code, entitled "Implementation of Statute for Upgrading Industries." According to this code, any firms utilizing automation equipment or techniques can enjoy the reduction of business income tax. Comparing the two following values, we can realize whether or not the construction sector makes the best use of tax reduction to promote its automation development: the construction sector's GDP share, the ratio between construciton sector's tax reduction cases and all sectors' ones.

2.2 The Technological Progress Factor

This study employs production function, which is a description of production behavior commonly used in economics, to measure the technological changes of the construction sector in Taiwan. Production function can be estimated based on sample data, which are often classfied into two types: panel data and time series data. Panel data is the observations on a number of firms in a number of time periods, while time series data is the aggregate industry level data observed over a number of time periods[1]. Several papers have developed various methods for estimating the production function of the construction sector. For example, Tan (1996) estimated the production function of singapore's construction industry[7]. Lin (1999) also established the production functions of the construction sectors in Japan and Taiwan, respectively[3].

This study utilizes the Cobb-Douglas production function to describe the relationship between production and its input resources, which typically include land, labors, and capital. For the construction industry case, the capital resource can attribute to investment and construction technologies, which consist of the use of construction equipment and materials. The Cobb-Douglas production function can be expressed as:

$$Q = AK^{\alpha} L^{\beta}, \qquad (1)$$

where Q is the output of construction sector; A is the technological progress factor, K is capital input, L is labor input and α , β are parameters. The production process exhibits constant returns to scale if $\alpha + \beta$ equals 1. Likewise, there shows a decreasing return to scale if $\alpha + \beta$ is greater than 1, and a increasing return to scale if $\alpha + \beta$ is less than 1.

Applying the panel data of the construction sector into equation (1), we can estimate the technological progress factor. From the variations of technological progress factor through a period of several years, we can observe the performance impact on technological changes due to the construction automation development plan.

2.3 The Rate of Technological Changes

We can also utilize the Cobb-Douglas production function to estimate the rate of technological changes in the construction sector by including a time trend variable.

Equation (1) can be rearranged in a log form as:

$$\ln Q = \ln A + \alpha \ln K + \beta \ln L \qquad (2)$$

By adding a time trend variable into equation (2), the Cobb-Douglas production function becomes:

$$\ln Q = b + \alpha \ln K + \beta \ln L + b_t t \qquad (3)$$

where t is a time trend (t=1,2,….,T). The regression coefficient, b_t , provides an estimate of the annual percentage change in output resulting from technological changes.

3. THE RESULTS OF DATA ANALYSIS

In this section, we use sample data to estimate the values of the three criteria which are mentioned in section 2.

3.1 The Case Share of Tax Reduction

During the period of 1993 to 1999, the construction sector's case shares of tax reduction are varied from 0.6% to 5.2%, as listed in the fourth row of Table1. In 1995, the construction sector obtained the highest share, while reached the lowest one in 1997. As compared with the construction sector's share of GDP, the case share of tax reduction is relatively low. This result implies that the construction sector has not made best use of the tax reduction to improve its automation development.

Table 1. Business income tax reduction due to utilizing automation equipment or technique

Fiscal Year	1993	1994	1995	1996	1997	1998	1999	1993-1999
Approved cases of tax reduction of all sectors*	3,657	6,124	3,046	4,503	16,688	9,730	9,255	53,003
Construction sector's applied cases**	156	149	157	200	105	220	174	1161
Construction sector's case share of tax reduction	4.3%	2.4%	5.2%	4.4%	0.6%	2.3%	1.9%	2.2%
Construction sector's share of GDP***	5.3%	5.3%	5.2%	4.8%	4.4%	4.1%	N.A.	

Data source: * Yearbook of financial statistics, 1993-1999, Ministry of Finance.
** Construction and Planning Administration, Ministry of Interior.
*** Yearbook of R.O.C. statistics, DGBAS.

3.2 The Technological Progress Factor

This study applies equation (1) to estimate the technological progress factor "A" according to panel data. This study also collected the output (sales), capital input (assets), and labor input (employee numbers) data of top 8-30 construction firms during the period of 1987-1999. The number of top construction firms surveyed by "Common Wealth Magazine," which is a very well-known magazine in industry development field in Taiwan, is not constant. Based on these data, this study utilized SHAZAM[9] to estimate the Cobb-Douglas production function of equation (1) by ordinary least square (OLS) regression.

The results of the parameteric values in equation (1) from year 1987 to 1999 are listed in Table 2.

Table 2. Results of the regression based on panel data

Year	A	α	β	R-sq.	R-sq. (adj.)	Firms observed
1987	10^(0.3)	0.91	-0.03	0.95	0.92	Top 8
1988	10^(-1)	1.01	0.06	0.97	0.95	Top 8
1989	10^(-0.42)	0.34	0.39	0.95	0.93	Top 9
1990	10^(0.62)	0.74	0.03	0.94	0.92	Top 10
1991	10^(-0.05)	0.48	0.29	0.90	0.88	Top 12
1992	10^(-0.44)	0.24	0.51	0.85	0.83	Top 17
1993	10^(0.25)	0.49	0.27	0.91	0.90	Top 20
1994	10^(0.57)	0.53	0.19	0.90	0.89	Top 30
1995	10^(0.44)	0.50	0.23	0.92	0.91	Top 30
1996	10^(0.88)	0.55	0.12	0.87	0.86	Top 30
1997	10^(1.1)	0.57	0.07	0.91	0.90	Top 24
1998	10^(0.63)	0.42	0.27	0.88	0.87	Top 30
1999	10^(0.86)	0.39	0.25	0.87	0.86	Top 30

As shown in Table 2., the estimated technological progress factor "A" is increasing with the years. Comparing the factor "A" in 1980s with that in 1990s, we can find that the factor "A" is significantly increasing in the late of 1990s. These results imply that the top construction firms' technological changes have apparently been improved during the implementation time period of the Industry Automation Plan.

3.3 The Rate of Technological Changes

For measuring the technological changes, this study makes use of the following parametric data: output of real GDP, capital input of real fixed capital formation, and labor input (in terms of number of employees) of the construction sector during the period of 1973 to 1998. The data was established by the Directorate General of Budgeting, Accounting, and Statistics of the Executive Yuan, ROC. Using the mentioned data, this study estimated the Cobb-Douglas production function of equation (3) by ordinary least square (OLS) regression. The tool used by this study was SHAZAM.

Three time period production functions were estimated. The first period is from year 1973 to 1998, second from 1973-1989, and third from 1990-1998. The parametric values of the production function for the contruction sector within the three time periods are given in Table 3.

Table 3. Results of the regression based on time-series data

Time period	b	α	β	b_t	R-sq.	R-sq. (adj.)
1973-1998	4.81	0.07	0.48	0.043	0.986	0.984
1973-1989	4.56	0.0038	0.55	0.034	0.988	0.985
1990-1998	0.33	0.099	0.86	0.031	0.995	0.992

As shown in Table 3, the estimated annual percentage change in output resulting from technological changes is 0.043 during the time period of 1973 to 1998. The estimated annual percentage change is 0.034 in the time period of 1973-1989, while 0.031 in the time period of 1990-1998. The government implemented the Industry Automation Plan started from 1990. Comparing the annual percentage of technological changes between the two periods 1973-1989 and 1990-1998, this study finds that the technological changes between them is no significant difference, implying that no sufficient evidence shows the technological changes have been improved through the Industry Automation Plan.

4. DISCUSSIONS

Based on the analysis results of section 3, we can have some points to discuss. From the viewpoint of using tax reduction to evaluate the performance impact of construction automation, the construction sector didn't make the best use of the tax reduction to improve its automation development during the period of 1993 to 1999.

From the viewpoint of using technological changes to evaluate the performance impact of construction automation, there is a significant difference between the construction industry level and the top construction firms level during the implementation time period of the Industry Automation Plan. The top construction firms' technological changes have apparently been improved. But, there is no sufficient evidence which shows that the technological changes have been improved at the construction industry level.

Two main reasons could explain the results. Firstly, large construction firms are more willing to adopt newly construction automation techniques and equipment than small construction firms. Similar facts also occur in Japan, where most activities of construction automation R&D are conducted by large construction firms, especially by the big five constructors[2].

Secondly, more than 6,000 new construction firms have entered the markets for the past few years, totaling over 10,000 construction firms in Taiwan now. This unusual events are due to the deregulation of qualification threshold for setting up a construction firm. Most of them are small and median constructors. For small and median constructors in Taiwan, the contract amount of each project shall not exceed US$1 million. Because of the small contract amount of each project, the demand and inducement for these constructors to implement construction automation is limited.

5. CONCLUSION

This study selected three criteria to evaluate the performance impact of construction automation development in Taiwan. The first criterion is the construction sector's case share of applying tax reduction. The data related to this criterion shows that the construction sector didn't make the best use of the tax reduction to improve its automation development.

Based on the analysis results of the second and third criterion, the technological changes have apparently been improved at the top construction firms level. But, at the construction industry level, no sufficient evidence shows that the technological changes have been improved during the implementation time period of the Industry Automation Plan.

At this time, the ROC government has extended the Industry Automation Plan to include e-commerce in the next 4 years. More money will be invested to promote the automation and e-commerce of the construction sector. Encouraging the top or leading constructors to implement automation and e-commerce will be beneficial to the construction sector. If small or median constructors can merge or strategically join together to become bigger ones, the benefits of applying automation and information technologies can be more evidential.

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