Productivity Improvement of Manufacturing SMEs via Technology Innovation in Korea

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Abstract: The competitive strength of small and medium enterprises (SMEs) based on technological innovation is one of the most important managerial strategies for holding a dominant position under the fierce global competition. In this study, a decision tree is used to grasp SMEs' innovation activities hierarchically for technological innovation, where the increase of annual productivity rate is used as a proxy target variable for innovation while SMEs' various innovative activities are used as explanatory variables in the form of information acquisition, technological cooperation, technology acquisition, government support, patenting, and compensation. Based on the results of our decision tree analysis, we suggest some insightful strategies for successful innovation of SMEs. It is expected that our study can provide a means for improvement of productivity based on technological innovation.

Key-Words: Technological innovation, Decision tree, Small and Medium Enterprise, Data mining

1 Introduction

Manufacturing SMEs in Korea suffer from competitiveness of cost and quality due to decreases or increases in the technology gap, high salaries, and exchange rate fluctuations. Korean SMEs have been losing their competitiveness in their products' quality and price recently. Therefore, the importance of technological innovation has been emphasized for Korean SMEs to have domestic and foreign competitiveness. Thus, manufacturing SMEs need to create new value and improve productivity and efficiency in production. To achieve this, continuous technological innovation and diversification of administration are required.

As the market is becoming globalized and computerized, the core competitive advantage of SMEs has changed from a traditional product factor such as capital, labor to technological innovation. Also, information and knowledge can help to create technological innovation. Information is an obtained acquisition process of technology and technological cooperation with other enterprises and research institutes. In other words, technological innovation can accelerate new technology creation through the combination of external technology knowledge of other organizations and the knowledge of one's own organization (Hamel, 1991; Hagedoorn, 1993; Hagedoorn & Schakenraad, 1994; Powell et al., 1996; Tsai & Wang, 2007).

Based on technological innovation, innovative manufacturing SMEs have attained excellent managerial performance. Also, innovative manufacturing SMEs have a great ability to create additional value. Even though top managers of SMEs recognize that technological innovation is a very important factor for success, most SMEs are hesitating to develop technology, because there are still a lot of problems like a lack of policies for SME infrastructure and financing. Because the export of manufacturing products has been a significant portion of total exports from Korea, a lack of international competitiveness in SMEs could be a huge obstacle to developing competitiveness on a national level.

The purpose of this paper is to present the solutions of problems that previous SMEs have had. It will contribute to enabling uninnovative SMEs to easily develop technological innovations with proper support.

In this paper, we defined the performance of SMEs' innovation as annual productivity improvement and assumed that information resources, technological cooperation, technology acquisition process, governmental support, patents, and compensation are influencing productivity improvement. Also, we analyzed how these variables influence productivity improvement using a hierarchical decision tree. From the results, we extracted useful rules for improving the productivity of manufacturing SMEs. Furthermore, we checked various kinds of problems that we extracted from the results. Finally, we proposed the solution to these problems.

The organization of this paper is as follows: Section 2 describes existing research, Section 3 conducts the empirical analysis using data mining methods, and Section 4 presents a proposal for productivity improvement by technological innovation. Finally, Section 5 concludes this paper and describes further study.

2 Building a productivity improvement model

2.1 Data description

This paper uses KIS 2005 (Korean Innovation Survey) data that is possible to access at corporation level from STEPI (Science and Technology Policy Institute). An innovation survey was defined such that innovation includes executing a new organic method as a new marketing method, business process, organization, external relationship, and new or epochal improved product/service process. This guiding principle is proposed by the OECD’s ‘Oslo Manual’ (OECD, 1992) as standardized measurements for researchers to analyze the performance of technological innovation.

Information about the actual conditions of technical improvements were collected in a survey that was given to 2737 corporations.

This paper has referred to existing studies showing that increases in enterprise productivity through an enterprise’s technological innovation have been obtained from the enterprise’s knowledge activity (Carree et al., 2000; Upstill & Hall, 2006; Cozzarin, 2006; Hamel, 1991; Hagedoorn, 1993; Hagedoorn & Schakenraad, 1994; Powell et al., 1996).

We used increased labor productivity, which is one employee per increase of total sales amount, as a dependent variable. More specifically, some SMEs show higher productivity augmentation than the Korean yearly mean manufacturing SMEs' productivity improvement due to technological innovation. Therefore, we have referenced the 2006 productivity international comparison that was published by the Korea Productivity Center (KPC) and OECD's National Accounts of OECD Countries 2006 Editions to the present criterion. Korean labor productivity increased yearly by a mean 3.4% from 2002 to 2004. In addition, the labor productivity of OECD’s advanced nations that had technical improvements was more than double Korea's labor productivity when corrected for exchange rates in the manufacturing industry field during the same period. In other words, we have regarded a corporation in which labor productivity increases steadily at more than double the mean increase of 3.4% for two years as a corporation in which productivity increases due to technical innovation.

we used the following variables: governmental support activity, patents, and compensation for invention or productivity improvement activity. The variables that are used in analysis are clarified in Table 1.

[Table 1] Variable description

Variable	Description
Information resources	Importance of ideas for technical innovation or information resources influencing innovation
Technology acquisition	Technology acquisition partner, degree to which technology acquisition contributes to innovation
Technological cooperation	Technological cooperation partner, degree to which technological cooperation contributes to innovation
Governmental support system	Importance of a governmental innovation support system
Compensation	Whether or not there is compensation for invention or productivity improvement activity or quality improvement activity
Patent	Whether a patent is registered or not for an invention or innovation
Productivity improvement	Productivity improves steadily at double the average productivity improvement ratio

2.2 Factor analysis

We have grasped the contributions of explanatory variables by linear combinations of the following variables: (1) information resources of technical innovation, which consists of 24 variables; (2) contribution of cooperative activity; (3) technology acquisition partners, which consists of 20 variables; and (4) government support systems, which consists of eight variables. We calculated principal components in order of volatility explained, and then we used Varimax, a vertical rotation method based on principal component analysis (PCA) that uses partial correlation. We have extracted factors with eigenvalues greater than 1, and analyzed reliability using Cronbach's alpha coefficient to maintain inner consistency. Therefore, we could find the factors that influence productivity among information resources, cooperative activity, technology acquisition, and government support systems.

2.2.1 Information resources

Information resources of SMEs are used in the first or middle stages of technical innovation activity, and are an important factor in SMEs’ innovation. They consist of 24 variables. Information resource is divided into four factors: general information media, exterior enterprise and market, interior enterprise, and non-profit institutes and universities. The results of the reliability analysis, Cronbach's alpha coefficients, to measure the four factors’ internal consistencies are more than 0.6. This means that the factor analysis result is acceptable.

2.2.2 Technology acquisition

Technology acquisition means buying existing technology, knowledge, or machine/equipment/software without interaction with information resources. This expresses a contribution that influences SMEs' innovation. It consists of 10 variables. Technology acquisition is divided into two factors: enterprise partner and institutional partner. The results of the reliability analysis, Cronbach's alpha coefficients, to measure the two factors' internal consistencies are more than 0.6, signifying that the factor analysis result is acceptable.

2.2.3 Technological cooperation

Cooperative activity means active participation in cooperative R&D or innovation projects with another structure, unlike a purely external source where there is no active participation or cooperation. These contributions influence the innovation in SMEs. Cooperative activity consists of 10 variables, as does technology acquisition. Technological cooperation is divided into two factors: enterprise partner and institutional partner. The result of the reliability analysis, Cronbach's alpha coefficient, to measure the enterprise partner factor's internal consistencies is more than 0.7, indicating that the factor analysis result is acceptable. However, Cronbach's alpha coefficient for the institutional partner factor is 0.57, which is not an acceptable level. Therefore, the institutional partner factor should be removed because of its lack of consistency with the category as a whole. In other words, the institutional partner factor does not show correlation between the four variables in its category. However, Cronbach's alpha coefficient for the institutional partner factor is near 0.6, and we assumed that technological cooperation influenced SMEs' innovation as mentioned above. Thus, we used this factor rather than excluding it.

2.2.4 Government support system

Government support system refers to the degree of practical use of systems provided by the government for a manufacturing SMEs' technological innovation and administration environment. This consists of eight variables. Based on the factor analysis of government support systems, only one factor was appeared which has an eigenvalue grater then 1. It means that, specific characters of the factors are not so evident that they can be distinguished from each other. Therefore, we created three factors that explained more than 70% for easy analysis.

Government support systems are divided into three factors: technology, education and marketing, and finance. The results of the reliability analysis, Cronbach's alpha coefficients, to measure the three factors' internal consistencies are greater than 0.6, indicating that the factor analysis result is acceptable.

2.3 Cluster analysis

In this study, SMEs are classified into groups according to various features, and these groups are compared. For this, we carried out hierarchical cluster analysis to decide the most suitable number of clusters using K-means clustering.

In the above data, the probability that a 'middle' value is a response that does not have a significant meaning is high when considering the survey's properties and purpose of analysis. Therefore, we considered these features and examined the characteristics of the clusters.

2.3.1 Cluster analysis for information resources

Cluster 0 is the group that does not utilize the resource of information at all. Cluster 2 is the group that utilizes all types of information, especially those in non-profit institute and university resources and exterior enterprises and markets. Cluster 3 is the group that heavily utilizes interior enterprise resources. Cluster 1 is the group which, in contrast with Cluster 2, does not take advantage of many information resources.

We found that most SMEs fall into Cluster 0 or Cluster 1. This means that most owners of SMEs are lacking awareness about the importance of information. Consequently, we can conclude that they are depending mainly on existing knowledge.

2.3.2 Cluster analysis for technology acquisition

Cluster 0 is the group in which there is no technology acquisition. Cluster 1 is a group that buys technology connected with technical innovation from institutional partners. Cluster 2 is a group that acquires technology from enterprise partners, but this degree of contribution in technical innovation is low.

We found that most SMEs fall into the cluster that does not attempt technology acquisition. Also, technology acquisition with a private institute, university, or nonprofit organization leads to more contributions in productivity improvement through technical innovation. Based on these results, we can conclude that many SMEs are acquiring technology from institutional partners. SMEs are also acquiring technology from enterprise partners; however, this is not contributing much to technical innovation.

2.3.3 Cluster analysis for technological cooperation

Cluster 0 is a group in which there is no technological cooperative activity at all. Cluster 1 is a group that is cooperating in activities with enterprise partners where cooperative activity is contributing significantly to innovation. Cluster 2 is a group that is cooperating in activities with an institutional partner, but cooperative activity is hardly contributing to productivity through innovation.

We can conclude that an SME's cooperative activity is at a very low level, similarly to technological acquisition. Technological cooperative activity with an enterprise partner contributes more to technical innovation and productivity improvement than cooperation with an institutional partner. This result is contradictory with that for technical acquisition, signifying that SMEs are taking a serious view of a hands-on background in technical cooperation.

2.3.4 Cluster analysis for government support systems

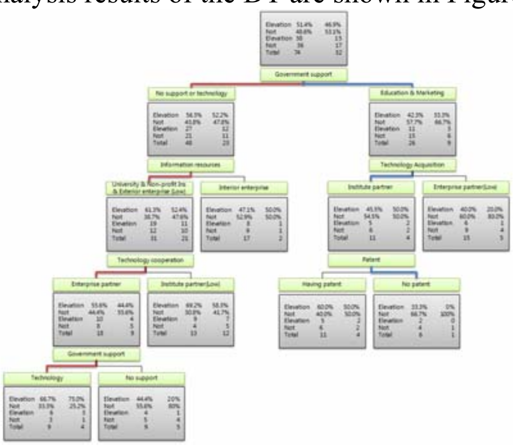
All SMEs received support from the government. However, governmental support of SMEs has shortcomings that are not distinguished, as evident in the above factor analysis result. As shown in Table 9, the SMEs in Cluster 2, which includes most SMEs, reported that the various government support systems were hardly important for technical innovation and productivity. Cluster 1 is a group that felt that technology support factors and finance support had very important roles in productivity improvement and technical innovation. Cluster 3 is a group that felt that all government support systems had a very important role in productivity improvement and technical innovation, especially education and marketing.

2.4 Decision tree analysis

DT is applicable to closely examine causes of innovation, which is an improvement of an SME's productivity, and make simple rules to describe them. We considered independent variables for corporations that had steady increases in productivity more than double the mean yearly increase labor productivity, attributing these productivity increases to technical innovation performance.

The DT model was applied to a classification model using a basic algorithm of SAS E-minor, CHAID (Chi-squared Automatic Interaction Detector), as well as CART (Classification and Regression Tree) and C4.5. As a result, the performance of the C4.5 algorithm that used an entropy method appeared the most superior.

The analysis results of the DT are shown in Figure 1.



[Figure1] Results of decision tree

Rule 1. Manufacturing SMEs that receive technological support, get information resources from a university, laboratory, or outside enterprise, and have technical cooperation with a partner from some form of enterprise, achieving productivity improvement.

Rule 2. Manufacturing SMEs that have marketing and education support but receive less contributions to innovation from outside enterprises do not achieve productivity improvement

Additionally, examining the results diagram and rules from the DT analysis carefully, SMEs that received a patent and technology support from the government had a higher probability of productivity improvement.

3. Proposal for productivity improvement

We have analyzed problems connected with government support, technical cooperation, and patent acquisition, and propose alternative plans to improve the labor productivity as following.

3.1 Government support system

In order to solve such problems of the government support system, we have proposed several solutions as follows: (1) We found through DT analysis that a technology promotion system, such as offering a technology information or enforcement of training institute for technicians or supporting government technology, highly contributes to a corporation's innovation and productivity improvement. Therefore, the government must encourage technical support for technological innovation. (2) Through fair and correct technology value estimation, the government must improve its current evaluation policy of focusing on the total amount of sales by improving the technology finance support system. Thus, the government may address the stringency of capital of manufacturing SMEs that have superior technique and profitability. (3) The government must establish a detailed strategy for SMEs' technical innovation such as Ireland's 'Innovation Voucher Program' or the German 'High-Tech Masterplan' as a fundamental procedure.

3.2 Technological cooperation

We have presented solutions for improvement of technical cooperative activity as follows: (1) The government authorities must establish strategies that can formulate win-win situations between universities and SMEs to encourage academic-industrial cooperation programs. This strategy can develop SMEs' technology and assist universities to vary their research subjects. (2) The Government Donation Research Institute and Public Research Institution must promote empirical and exploratory research that can contribute to the activation of SMEs' innovation, rather than policy-oriented research. (3) The government must identify problems of technical cooperative activity by collaboration with enterprises, prepare "business to business (B2B)" information networks, and try to further develop the social atmosphere to maintain a complementary relationship between major companies and SMEs.

3.3 Patents

We have presented a solution for these patent problems as follows: (1) The system's reformation and a plan for the activation of technology transactions for patent granting are urgently needed. In order to execute this, a proper patent value evaluation system needs to be designed. (2) An environment should be established that can contribute to new technology creation by facilitating patent and active technology transactions for the technological circulation system. (3) For investment and support of technicians and researchers to develop of SMEs' patents, the governmental financial support and tax systems must be improved.

4. Conclusion and further research

4.1 Conclusion

Manufacturing SMEs that are essential to Korean industry are threatened internally and externally as technology differences decrease. Innovative manufacturing SMEs show excellent administration as compared with general manufacturing SMEs; also, these SMEs' additional value in creative ability is very high. Therefore, we wish to increase the competitiveness of manufacturing SMEs and prepare a stepping stone for national growth by improving productivity through technical innovation. To this end, an empirical analysis of technical innovation decision factors that influence productivity improvement is required.

We have assumed that information resources, technological cooperation, technology acquisition, governmental support, patents, and compensation influence productivity improvement, based on a literature review. Accordingly, we have hierarchically analyzed how these variables influence productivity improvement using a data mining method. Therefore, this paper is an empirical analysis for detecting a decision factor that influences productivity improvement through technical innovation. We regarded corporations that had steady increases of more than double the mean national increase per year in labor productivity as corporations that demonstrated productivity increases by technical innovation performance.

Therefore, we have conducted factor analysis to detect important elements connected with the information acquisition process, technical cooperation process, technical acquisition process, and government support systems using the Korea Innovation Survey 2005 (KIS 2005), which is possible to access at the corporation level via STEPI (Science and Technology Policy Institute). We also have conducted cluster analysis and examined the characteristics of each cluster. Consequently, we used each cluster that was created according to cluster analysis results as explanatory variables and executed a DT analysis to examine the hierarchical factors that influence SME's productivity improvement.

Government support systems, technical acquisition, information resources, patents, and technical cooperation were described by significant variables that influence productivity. Moreover, useful rules were extracted from the proposed model. We also have examined various kinds of problems that appear according to analysis results, and presented proposals to settle these problems.

Therefore, this paper contributes suggestions to revitalize the innovation performance of SMEs that are not technically innovative, and we propose guidelines for improvement of the government support system.

4.2 Further study

The following topics are left for areas for further study: (1) We have analyzed productivity increases that are a result of technical innovation based on only three years of financial data because of the lack of data. However, the results of technical innovation that were judged cannot be limited to three years. Therefore, we need to consider many years' results. (2) Because technical innovation is a complicated model that considers mutually influential relationships, we need to analyze this using various variables in addition to the variables used in this analysis. (3) Our analysis did not consider various types of business of manufacturing SMEs. Therefore, we did not analyze problems by the characteristics of industrial classification and solution. (4) In order to help the government in designing innovation policy and selecting innovative SMEs, a technical innovation SME estimation model needs to be developed using a logistic model or artificial neural network other than DT.

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