Study on the factors for Innovation Capability of Equipment Manufacturing Industry Based on Structural Equation Model: Empirical Analysis of Guizhou Province

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Abstract To enhance the innovation capability of Chinese equipment manufacturing industry and to promote the development of enterprises in the "12th Five-Year" period, based on integration of literature analysis, theoretical studies, spot investigation and questionnaires, this article select five main influencing factors which impact the innovation capability of Chinese equipment manufacturing enterprise, as well as establish a model relating the influencing factors and innovation capability. The Guizhou province was taken as a case to study and the AMOS7.0 software was used to analysis our model. The results indicate that cooperation in research and market are two significant influencing factors that affect the innovation capability of Guizhou's equipment manufacturing enterprise. This study combines qualitative analysis with quantitative analysis, which improves the deficiencies of existing research and enhances the reliability of conclusion.

Keywords Equipment manufacturing industry • Innovation capability • Influencing factors • Structural equation modeling

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1 Introduction

Equipment manufacturing is a general name of the enterprise which produces technical equipment to maintain national economy and security, and is also a general name of manufacturing departments which equips various department of national economy with tools to make low-level reproduction and to expand reproduction [1]. "Equipment Manufacturing" hasn't been proposed in other countries yet, it is a Chinese characteristic noun put forward to distinguish it from the "General Manufacturing". It is a basic industry that should receive highly attention on our way to the fully industrialization and to develop to a bigger and stronger manufacturing country.

Nowadays, the equipment manufacturing becomes a strategic industry of China. As a series of policies have been issued, such as "portfolio of opinions for accelerating the revitalization of equipment manufacturing" and "plans for the restructuring and the revitalization of equipment manufacturing", provinces have established the plan for the development of the equipment manufacturing during "12th Five-Year" period, aiming to accelerate the development of Chinese equipment manufacturing industry and to elevate the level of autonomy of the major technical equipments as well as to strengthen the innovation capability of equipment manufacturing enterprises. This article give a bunch of advices to the equipment manufacturing based on empirical analysis of the leading factors impacting the innovation capability of equipment manufacturing enterprises.

2 Review

Researches on the influencing factors of innovation capability could be divided into two fields: qualitative study and quantitative study. Qualitative study is more common. The views of research are various. From the technical innovation perspective, Zhu analyzed the interaction of different influencing factors [2]. Xu and Zeng analyzed the innovation capability of equipment manufacturing in Chongqing based on the view of independent innovation [3]. Standing on the point of improving the ability of collaborative innovation, Liu and Chen built a collaborative system correlating the producer service industry and manufacturing [4].

The quantitative study discloses deficiencies compared with the qualitative study, which is caused by the difficulty to establish evaluation indicators and to select optimal analytical method and data. Learning from historical literatures, we find that evaluation indicators is established mainly based on two aspects, including inputs and output. With the establishment of the indices of innovation based on outputs and inputs, Hollanders and Esser used the DEA method to analyze efficiency between input and output, and then evaluated the innovation capacity of various countries and their position in the world [5]. On the basis of the distinction of firm size, Fan and Liu used panel data to estimate the function of various factors affecting the technological innovation of Chinese high-tech industry [6].

We find out that qualitative research involves a broad field, but it lacks certain empirical results to support the conclusion. Quantitative research to some extent ensures the practicality of the conclusions, but the empirical analysis also needs to more attempts due to the limitations of the analytical methods. Integrating the qualitative and quantitative analysis, lessons from the inadequacies of the existing research are learned in this article, providing a new direction for the research on influencing factors.

3 Analysis

3.1 Determination of Factors

Analysis of influencing factors is very important. To better reflect the real situation of the equipment manufacturing industry, we determine five main influencing factors that affect the innovation capability of equipment manufacturing enterprises in Guizhou province, on the basis of theoretical analysis, investigation into the companies as well as communicating with the technicians and manager. The factors are the corporate culture, market, innovators, employees' satisfaction and cooperation in research.

The corporate culture is enterprises' invisible soul and cohesive spine. It is the internal driving force, which can direct employees to the goal of enterprise. Since products are market-oriented, it is the external driving force of the market that will create endless power for companies to be innovative. As the main role of innovation, people play the most vital roles in innovation. So the innovators have to become a factor we must concern about. The famous American psychologist Maslow's theory, the hierarchy of needs, tells us that only meet the current demand can people devote themselves to the work. Employees' satisfaction is the requisite to maintain the enterprises' innovation capacity. In the current market environment, when an enterprise plan to undertake independent innovation, no matter in the financial section, human resources section or material resources section, the investment is huge, this would dampen the profit maximization. Therefore, as to most enterprises, cooperation in research which is an approach for enterprises to share resources with other enterprises, it could be quite beneficial for enterprises to cut down costs. The five factors are favorable representative, containing internal and external aspects.

3.2 Hypothesis

Li, Fan, and Zhao found out that supportive culture and innovative culture are conducive to independent innovation of enterprises [7]. Sun proposed that excellent corporate culture would provide incentives and support for technology innovation [8]. A hardware platform can be destroyed, but as long as there exists a kind of excellent

corporate culture in harmony with employees' values, it will provide a steady stream of inner motivation for enterprises to improve the innovation capability. It can be seen that the corporate culture plays a positive role in improvement of innovation capability and encouragement of innovators.

H1: Corporate culture has an effect on innovation capability.
H2: Corporate culture has an effect on innovators.

Han and Wu proposed that Chinese enterprises lack of scientific evaluation systems of selection of innovative products, let alone an enormous market research institution to communicate with the customer [9]. The products not only have low added value, but often disjoined with the market, which results in innovation failure. Market is the driving force to pull enterprise innovation. The more market demand, the stronger enthusiasm would be invested in innovation. Chinese equipment manufacturing enterprises invest most capital into the scientific research, development of new technologies and purchase advanced equipment. The money invested in market research is quite small, which may explain why R&D achievement disjoins with the market and affects the ability to innovate.

H3: Market has an effect on innovation capability.

Many scholars believe that investment into human resources could have a significant impact on innovation, especially the scientific and technological innovators, which would be the basis of scientific and technological innovation. In many enterprises, however, most of the engineers and technicians are busy with the daily production, technical work, as well as the study on traditional disciplines. Only few of them participate in the high-tech development and research in applied disciplines. Therefore, the lack of innovators dampens the capacity of Chinese equipment manufacturing enterprises to promote innovation.

H4: Innovators has an effect on innovation capability.

Chen pointed out that the support from employees for innovation would have a significant impact on technology innovation of enterprise [10]. Employees' positive attitude to innovation is the important guarantee for successful innovation. The effect of investment of innovators on innovation shows not only in the aspect of the amount of the person but also in the aspect of the quality of the person. Learning from the theory of Maslow's hierarchy of needs, if we want to attract talents and to inspire their enthusiasm in innovation, the first step is to meet their demands, which is so-called employees' satisfaction. Only under the circumstance that one's current demands are satisfied can people concentrate on scientific research to improve the efficiency of innovation.

H5: Employees' satisfaction has an effect on innovator.
H6: Employees' satisfaction has an effect on innovation capability.

Han also indicated the factors which affect the novelty of the innovative products are the degree of cooperation between enterprise, the attention on the forefront of world science and technology, foundation and development capabilities of

Table 1 Evaluation indicators of factors

Factors	Evaluation indicators
Corporate culture	Innovation culture concepts (C1) Holding lectures (C2) Rational incentive system (C3) Research achievement discussion (C4)
Market	Market investigation of new products (M1) Products to meet market trends (M2) Meeting customer requirements (M3) Threat of substitutes (M4)
Innovators	Sufficient innovators (I1) Research ability of innovators (I2) Communications between innovators (I3) Innovators' support for innovation (I4) Innovators' participate in innovation (I5)
Employees' satisfaction	Satisfaction of salary and welfare (S1) Satisfaction of space for the promotion and development (S2) satisfaction of work environment (S3) Satisfaction of incentive system (S4) Realization of personal value (S5)
Cooperation in research	Collaborate with college and research institution (R1) Periodic training conducted by experts and scholars (R2) Collaborate with other enterprises (R3)
Innovation capacity	New products (A1) New patent (A2) Breakthrough in technology (A3) Market share of new product (A4) R&D accomplishment on time (A5) Improvement of innovation capability (A6)

technologies [9]. Under the pressure of fierce competition in the market, technical cooperation is the way to shorten product development time, to reduce costs as well as to move towards to international market and thus obtain emerging technologies. Besides, the huge development cost force enterprises to carry out technical cooperation. Cooperation with other enterprises, colleges and scientific research institutions, has become effective approach to improve efficiency of innovation.

H7: Cooperation in research has an effect on innovation capability.

The model we discussed later is established based on the above hypotheses.

3.3 Establishment of Evaluation Indicators

We design the indicators for the five factors and innovation capability based on the existed indicators and discussed with the members of research group. The established evaluation indicators are shown in Table 1.

3.4 Establishment of SEM Model

Structural equation model (SEM) is a method to establish, to estimate and to test causality model, which is a kind of technology that integrates measurement and analysis [11]. Based on the previous hypotheses, we establish the theoretical model (shown in Fig. 1). The boxes represent the influencing factors while the direction of arrows represent paths of effect relationship. In addition, the parameters above the arrows represent influence coefficients.

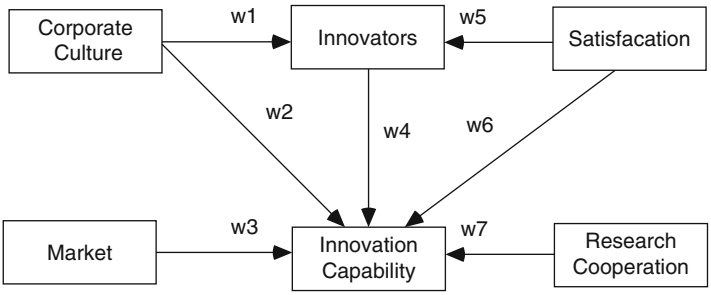

Fig. 1 Path diagram of SEM

4 Empirical Analysis

Since the population of equipment manufacturing enterprises in Guizhou is large, we thus select the equipment manufacturing enterprises in Guizhou province as a case for empirical analysis. Guizhou province is striving to promote implementation of the strategy to achieve a strong industrial province. The achievements of this study would make a positive contribution to the development of equipment manufacturing in Guizhou.

The evaluation indicators are integrated into questionnaire which is distributed to the employees in the equipment manufacturing enterprise in Guizhou. Employees are typically asked whether they agree or disagree with a statement. Responses are range from "strongly agree" to "strongly disagree" with five total answer options. Each option is ascribed a score, for instance, 1 refers to strongly disagree while 5 refers to strongly agree. The survey was performed in the following steps: small-scale distribution of questionnaire, interview, modification of questionnaire, and large-scale distribution of questionnaire. 100 questionnaires were distributed to the equipment manufacturing enterprises in Guizhou and 90 feedbacks were collected. Among them, 71 are valid and the valid rate is 79 %.

4.1 Reliability Test

The reliability of the collected data should be examined before model-fitting. Reliability examination adopts a typical and reliable method, measuring the Cronbach α coefficient. According to the standard of Nunnally, $\alpha > 0.9$ indicated a very high reliability; $0.7 < \alpha < 0.9$ referred to high reliability, $0.35 < \alpha < 0.7$ suggested medium reliability, and $\alpha < 0.35$ meant low reliability [12]. Meanwhile, the corrected item total correlation coefficients should be more than 0.35. We used SPSS 17.0 software to examine the internal consistency reliability of scale. Results are listed in Table 2. The results suggests that $\alpha = 0.944$ and standardized $\alpha = 0.942$, which indicates high reliability of the questionnaires.

Table 2 Reliability statistic

Cronbach's Alpha	Based on standardized items Cronbach's Alpha	Items
.944	.942	27

Table 3 Item total statistic

Item	Corrected item total correlation	Deleted item Cronbach's Alpha
C1	.337	.945
C2	.584	.943
C3	.663	.941
C4	.571	.943
M1	.587	.942
M2	.622	.942
M3	.707	.941
M4	.320	.945
I1	.740	.941
I2	.748	.941
I3	.677	.941
I4	.194	.945
I5	.228	.945
S1	.496	.943
S2	.648	.942
S3	.658	.942
S4	.614	.942
S5	.621	.942
R1	.617	.942
R2	.770	.940
R3	.682	.941
A1	.634	.942
A2	.524	.943
A3	.757	.940
A4	.726	.941
A5	.681	.942
A6	.737	.941

As shown in the Table 3, the corrected item total correlation coefficients of the four shadow items (C1, M4, I4 and I5) are less than 0.35, it means that the four indicators show low correlation with others. Thus they should be safely removed.

4.2 Model Fitting

We apply AMOS7.0 to analyze data. In this study, we choose maximum likelihood estimation to calculate data and modify the model according to the parameters given by AMOS. Through several times of modification, optimal model is obtained and shown in Fig. 2. The indices of optimal model fitting are shown in Table 4.

4.3 Model Evaluation

Compared with the theoretical model, emergence of the new paths and the deletion of the original paths are newly added into the optimal model, which is ascribed to

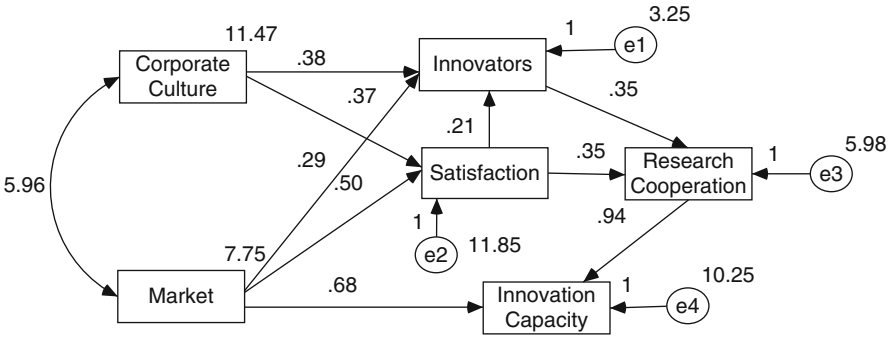

Fig. 2 Optimal model

Table 4 Model fit summary

Indices	χ^2/df	RMSEA	CFI	NFI	IFI	TLI	GFI	AGFI
Value	1.067	0.033	0.999	0.980	0.999	0.996	0.975	0.894
Ideal values	1 ~ 3 [13]	<=0.08 [14]	>=0.9	>=0.9	>=0.9	>=0.9	>=0.9 [15]	>=0.9 [15]

the adjustment of model paths according to parameters given by the AMOS. On the basis of optimal model, we find some new relationships among the factors, and original hypotheses are also verified.

According to the test results shown in Table 4, it is easily to figure out that all indices satisfy the requirements except for AGFI whose value is slightly less than 0.9. The AGFI equals to adjusted R square in multiple regression analysis. Its value will be affected by the number of estimated parameters. The more parameters will be estimated, the bigger value of AGFI [11]. The AGFI value is slightly less than the ideal value. We reckon the reason would be the insufficiency of parameter estimation. Considering that the value of AGFI is slightly varying with the ideal value and the rest of indices are nicely fulfill requirements, we argue that the optimal model is applicable and efficaciously to fit original data.

4.4 Hypothesis Test

The estimated path coefficients of the optimal model are shown in Table 5. The values of P are less than 0.05 while values of CR are more than 1.96, which indicate that nine paths of the optimal model go through test. All of the path coefficients are greater than zero, indicating that each path is a positive correlation. In this model, the new paths include corporate culture to employees' satisfaction, market to employees' satisfaction, market to innovators, employees' satisfaction to cooperation in research, innovators to cooperation in research. It shows that market

Table 5 Estimates

Path	CR	P	Estimation
Culture → Satisfaction	2.344	0.019	0.297
Market → Satisfaction	2.610	.009	.331
Satisfaction → Innovators	3.295	***	.281
Culture → Innovators	4.479	***	.420
Market → Innovators	2.744	.006	.260
Satisfaction → Cooperation	3.885	***	.434
Innovators → Cooperation	2.898	.004	.324
Cooperation → Capacity	7.025	***	.584
Market → Capacity	4.243	***	.353

"***"represent p <= 0.001

Table 6 Effects estimates

Path	Direct effects	Indirect effects	Indirect effects
Market —> Innovators	.260	.093	.353
Market —> Satisfaction	.331	0	.331
Market —> Cooperation	.0	.258	.258
Market —> Capacity	.353	.151	.504
Culture —> Innovators	.420	.083	.503
Culture —> Satisfaction	.297	0	.297
Culture —> Cooperation	0	.293	.293
Culture —> Capacity	0	.171	.171
Satisfaction —> Innovators	.281	0	.281
Satisfaction —> Cooperation	.434	.091	.525
Satisfaction —> Capacity	0	.307	.307
Innovators —> Cooperation	.324	0	.324
Innovators —> Capacity	0	.189	.189
Cooperation —> Capacity	.584	0	.584

and corporate culture have a direct impact on personnel, and personnel have a direct impact on cooperation in research. These relationships are not taken into account in the former assumptions. Besides, three paths, corporate culture to innovation capacity, innovators to innovation capacity, employees' satisfaction to innovation capacity, have been removed, which represent that corporate culture, innovators and employees' satisfaction are not the direct factors affecting innovation capacity, but are indirect factors.

Table 6 interprets the influence coefficient of each path, it can be concluded that cooperation in research is a direct factor and has the greatest impact on innovation ability of enterprise. The total influence coefficient is 0.598, indicating that when other conditions remain unchanged, "innovation capacity" can upgrade a total of 0.589 units with one unit increase of "scientific cooperation". The second largest factor that impacts innovation capacity is market. The total influence coefficient is 0.504. In Addition, the effect of corporate culture on innovators and the effect

of employees' satisfaction on cooperation in research are significant since they both have a total influence coefficient higher than 0.5, which signify the favorable corporate culture would be a incentive for innovators and employees' satisfaction is a guarantee for efficient cooperation in research.

5 Conclusion

Based on the existing research on equipment manufacturing enterprises, methods, such as literature analysis, theoretical studies, spot investigation and questionnaire, are integrated to analyze the problems and shortcomings in the research. Several results are obtained:

1. From the aspect of internal and external factors, this article put forward five main influencing factors that affect the innovation capability of Chinese equipment manufacturing, including corporate culture, market, innovator, employees' satisfaction and cooperation in research.
2. Based on the theoretical analysis, we assume the relationship between influencing factors and innovation capability, the relation model of "influencing factors – innovation capability" is established.
3. Through empirical analysis, model fitting, model modification and hypothesis testing, the correlation between influencing factors and innovation capacity of the equipment manufacturing industry in Guizhou Province is achieved.

The results explain that cooperation in research and market are two important factors influencing the innovation capability of equipment manufacturing enterprises in Guizhou Province. Therefore, in the future, enhancing cooperation in research and improving market competitiveness are the primary task for Guizhou province to develop and to reform the equipment manufacturing industry. Initially, enterprises should make full use of local resources to establish good relationship of communication, exchanges, cooperation with local colleges, universities as well as research institutes, holding meeting regularly to provide staff with a good platform to exchange experience relating research; Secondly, effective approaches should be taken to strengthen pre-market research of new product development in order to reinforce the competitiveness of products in the market and to add value to products. Furthermore, enterprises should spare no efforts to cultivate a good innovative environment for employees in order to attract more research talents. Meanwhile, the improvement of working conditions and rationality of management system should be highlighted to increase employee's job satisfaction. The five influencing factors proposed in this paper have strong relevance between each other, the failure to balance the five factors would lead to the abnormal development of the enterprise and thus enhancing the innovation capability will be difficult.

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References

1. Liu P (2006) Research on the competitiveness of China equipment manufacturing. China Financial Economic Press, Beijing
2. Zhu TB (2009) Research on the interaction between influencing factors of regional equipment manufacturing technical innovation. MA dissertation, Economics, University Science and Technology of Harbin, Harbin, pp 24–27
3. Xu XQ, Zeng Y (2009) Research on the independent innovation ability of equipment manufacturing industry in Chongqing. Forum Sci Technol China 24(11):29–31
4. Liu Y, Chen ZX (2009) Self-organization analysis on collaborative innovation between producer service industry and manufacturing. Sci Technol Prog Policy 26(15):48–50
5. Hollanders H, Esser FC (2007) Measuring innovation efficiency. INNO-Metrics Thematic Paper
6. Fan AJ, Liu Y (2006) The quantitative analysis on influencing factors of hi-tech industry technical innovation of China. Res Econ Manage 26(10):58–62
7. Li Y, Fan S, Zhao YB (2005) The impact of different corporate cultures on tech-innovation. Forecasting 24(4):26–30
8. Sun LJ (2004) Driving influencing on technology innovation exerted by corporate cultures. Stud Sci Sci 22(6):652–657
9. Han XY, Wu TZ (2003) Countermeasures and analysis of factors influenced results of enterprise technology innovation in our country. Sci Sci Manage S & T 24(3):19–23
10. Chen JB (2010) Enterprises' internal factors working on technological innovation. Econ Manage 32(6):151–157
11. Wu ML (2009) Structural equation model – operations and application of Amos. Chongqing University Press, Chongqing
12. Nunnally J (1978) Psychometric theory, 2nd edn. McGraw-Hill, New York
13. Carmines EG, McIver JP (1981) In: Bohrnstedt GW, Borgatta EE (eds) Analysing models with unobservable variables: analysis of covariance structures. Sage, Beverly Hills, pp 65–115
14. Cudeck R, Browne MW (1983) Cross-validation of covariance structure. Multivar Behav Res 18(2):147–167
15. Hu LT, Bentler PM (1999) Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model Multidiscip J 6(1):1–55