A Modeling Study on the System Dynamics of Industry-University-Research Institute Cooperative Innovation in the Innovative Factor Agglomeration Center in Developing Countries——Illustrated by the Case in Sichuan Province, China

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Abstract. According to the feedback mechanism of system dynamics, based on the structure and function of the internal ecology of the innovation factor agglomeration zone, a scientific system dynamic model (industry, university and research institute) is constructed, and the interactive operation process of the factor flow in the system is studied and analyzed by using the causal loop diagram and the system flow diagram; and the change relationship and influence mechanism between the factor flows are discussed. In this way, the synergy law of cooperation and innovation among industries, universities and research institutes in developing countries can be controlled in depth.

1. The system dynamics model for the industry-university-research cooperative innovation in the innovative element agglomeration center in developing countries

This study mainly explores the industry-university-research cooperative projects of enterprises, science institutes and governments, and aims to transform other external factors related to such cooperation into government investment in such cooperative projects. Below is an analysis on the industry-university-research cooperative innovation system in the innovative element agglomeration center in developing countries from the perspectives of the enterprise, the research institute and the government.

1.1 Analysis of the factors that might influence enterprise participation in industry-university-research cooperative innovation

Usually there are two approaches for enterprises to acquire technology: one is by conducting independent R&D and the other is by purchasing technology from other enterprises, research institutes or individuals. The R&D activity of an enterprise is a typical investment-outcome process. A study of 28 South Korean enterprises conducted by M. Lee (1996), a South Korean scholar, suggests a more reliable and effective system to measure the R&D performance of enterprises. The system contains 15 indicators in total (as shown in table 1). This system is of great significance to this study.

| Systemic stage | Measurement indicators |
|----------------|------------------------|

Table 1. Indicators for measuring the R&D performance of enterprises.
| Investment | Intermediate process | Outcome | Conclusion |
|------------|----------------------|---------|------------|
| Sufficient R&D investment; adequate R&D equipment; professional skill; competence of the R&D staff | Feasibility of the R&D plan; validity of the chosen R&D project; cooperation between the R&D department and manufacturing/marketing department; effort made for the execution of the plan; adequate information management; expansion and diversity of the research field | How many objectives have been met; effectiveness of the developed technology | Expected profit growth; effect of the management improvement |

The enterprise’s willingness to cooperate is one of the components for the success of industry-university-research cooperation in the regional innovation system. The increase of the cooperation success rate will surely attract more support for other projects from the government and lead to an increase in project funding, which will promote the transformation of research institutes and again affect the technological output. The scientific and technological output of science research is a primary source for the knowledge acquisition of research institutes. Enterprise investment is on the one hand shown as an increase in project funding and an increase in enterprise expectation on the other. At the same time, investment in industry-university-research cooperation made by enterprises is considered as a cost to the company, and therefore may have a negative impact on profits; at the same time, an increase in the enterprise’s investment is also related to its outcome. The increase in enterprise output is equivalent to the increase in profit, resulting in a positive correlation. And the correlation between enterprise investment, knowledge resources and their outcome is still subject to statistical analysis. In addition, whether the influence of the cooperation project on the budget allocation of the enterprise may impact the corporate investment in industry-university-research cooperation, and the degree of such impact are also subject to statistical analysis (the strength of the unknown causal relationship mentioned above is shown as “+(?)” in Figure 1); the corporate profit growth and cost growth act on each other. By identifying the corporate expectation-profit ratio, we get the willingness of the company for shaping cooperation. If such willingness is high, the company will increase its investment in the cooperation project. The procedure mentioned above may be summarized as a causal relationship and feedback control diagram on the company’s participation in industry-university-research cooperation (refer to figure 1). Of these relationships, the causal relationship between corporate investment and the project funding obtained, and the causal relationship between corporate output, investment and the knowledge received still require further statistical analysis.

![Figure 1. The causal relationship for the industry-university-research cooperation from the perspective of enterprises.](image-url)
(1) Determination of the system boundaries

In industry-university-research cooperation under the regional innovation system, the cooperation between enterprises and research institutes form a network structure. Therefore, different enterprises may be indirectly influenced by the investment and output. As such indirect influence may require the transformation of research institutes and government, only the direct relations between the enterprises, research institutes and government are considered. In addition, enterprises will increase research output by increasing R&D investment, which will lead to the increase of know-how investment in the project and the promotion of project deliverables. This process is not reliant upon the internal operations of the research institutes or the government. Therefore, the following definitions have been given to the system boundaries, constituting the corporate operation model as shown in Figure 2.

1. The company’s direct investment in the project and the direct output are the vertical boundaries of the evaluation system.
2. The willingness of the company to cooperate, and the funds and knowledge provided to the company by external systems (including research institutes and government) are the horizontal boundaries of the evaluation system.

![Figure 2. Corporate operation model for industry-university-research cooperation.](image)

(2) Definitions of the influencing factors

To companies, the ultimate goal is to achieve maximum profits. Hence, the indicators adopted in evaluating the operation performance in the cooperation are mainly derived from financial figures that may not necessarily produce economic benefits straight away but may promote long-term development of the company such as talent introduction, corporate brand competitiveness, and corporate reputation. Huo Yan (2009) takes administrators as the subject of her evaluation and creates a three-level evaluation system for industry-university-research cooperation by dividing industry-university-research cooperation into three stages, namely investment, production, and output. She also proposes a method for evaluating the industry-university-research cooperation by referring to the standard deviation method. The production factors may include the importance given by the management and equipment conversion rate. As the importance given by the management will ultimately be reflected as the company’s increase in the project investment, whereas the equipment conversion rate is reflected as the direct increase in corporate profits, all production factors may be shown in the form of investment and output:

1. Corporate investment (IIP): the cost incurred to the company during the industry-university-research cooperation.
2. Corporate output (IOP): the results achieved by the company during the industry-university-research cooperation.
3. The knowledge resources acquired by the company (IK): the knowledge support obtained from research institutes by the company by participating in the industry-university-research cooperation.
4. Corporate profit (IR): the net income achieved by the company from the industry-university-
research cooperation, which is expressed as the difference between the output and the investment.

5. Corporate cost growth rate (ICR): the increase of the investment in the industry-university-research cooperation by the company.

6. Corporate profit growth rate (IBR): the increase of profits made by the company by participating in the industry-university-research cooperation.

7. The willingness of the company to participate in the cooperation (ICI): how enthusiastic the company is about participating in the industry-university-research cooperation.

1.2 Factors that might influence the research institutes’ participation in the industry-university-research cooperative innovation

This study aims to constitute a project-directed effect evaluation system for research institutes’ industry-university-research cooperation.

The willingness of research institutes to cooperate depends on whether the project can provide them with economic benefits. These benefits are not only economic benefits, but also include talent training, academic papers and awards. Research profits refer to the net income arising from the project. Generally speaking, the larger the profits for research institutes, the more they are willing to participate in the project. However, research institutes will have some expectations from their research investment. In this regard, we think the willingness of the research institutes is related not only to the profits, but also the investment, and this willingness is subject to the influence of the difference between their profits and costs. In cooperative alliances, higher willingness of the research institutes to cooperate will lead to the success of the project, winning more government support, attracting more attention from enterprises and increasing project funding. When the fund allocation is translated into an increase in research funding, it will again bring more profits for research institutes. In addition, to research institutes, their willingness to participate in the project will force them to increase investment, and this increase in investment may again bring down their profit growth in the cooperation, which is shown as two negative feedback loops (as shown by the thick arrow control loop in Figure 3). The question is: will the increase in research funding acquired by research institutes drive them to increase their investment in the project? Will the increase in research necessarily lead to an increase in output? The relations between the two pairs of factors still depend on statistical analysis (the unknown causal relationship mentioned above is shown as “+(?)”in Figure 3).

Figure 3. The causal relationship for the industry-university-research cooperation from the perspective of research institutes.

(1) Identification of the system boundaries
In reality, project success rate relies upon the willingness of all participants to cooperate. The proportion of research funding in the total project funding decides the investment of the research institutes. The causal relationship between research output (subject to the research investment) and research investment is actually very hard to define in any particular formula. For this reason, we define the system boundaries for the operation of research institutes during industry-university-research cooperation as follows:

1. Vertical boundaries: the direct investment of research institutes in the cooperation project and the direct output are the vertical boundaries of the evaluation system.

2. Horizontal boundaries: research funding investment as a result of an increase in the willingness of research institutes to cooperate, strength of government support, and importance attached by enterprises is the horizontal boundary of the evaluation system.

According to the definitions of the system boundaries and by focusing on the control loop of research institutes, we get the operation model for research institutes in the industry-university-research cooperation (as shown in Figure 4):

![Figure 4. The operation model of research institutes in the industry-university-research cooperation.](image)

(2) Definitions of the influencing factors

The operation model of research institutes shows that the factors that may affect the operating effectiveness of research institutes in the industry-university-research cooperation include:

1. Research investment (UIP): the cost spent on the industry-university-research cooperation by the research institute.

2. Research output (UOP): the achievements realized during the industry-university-research cooperation by the research institute.

3. Research funding (UF): the external funds acquired for participating in the industry-university-research cooperation by the research institute.

4. Research profit (UB): the net income received from the industry-university-research cooperation by the research institute. Such net income is expressed in the form of the difference between the output and the investment.

5. Research cost growth rate (UCR): the cost growth incurred from the industry-university-research cooperation to the research institute.

6. Research profit growth rate (UBR): the profit growth achieved from the industry-university-research cooperation by the research institute.

7. Willingness of the research institute to cooperate: the initiative shown by the research institute in participating in the industry-university-research cooperation.

1.3 Analysis of the factors influencing the government’s participation in industry-university-research cooperative innovation

Governments are engaged in formulating various policies to promote industry-university-research
integration, including preferential policies, policies on science and technology rewards, government support policies, financial support policies, and other policies and measures. Such policies provide funds and technical support, create a superior external environment, and strengthen industry-university-research integration. For that purpose, the completeness of government support policies made for industry-university-research integration is a key indicator for evaluating the effectiveness of industry-university-research integration in a particular region.

The implementation of government functions during industry-university-research integration may be appraised by combining qualitative analysis and quantitative analysis. During the evaluation process, we arrange, calculate and analyze relevant data on the one hand, and on the other hand we classify the indicators created during our investigation process. The analysis on the implementation of government functions is carried out by referring to professional advice and the feedback given by the industrial players, universities and research institutes.

In promoting and strengthening industry-university-research cooperation under the local innovation system, the government plays an important role in encouraging and supporting innovation cooperation among universities and enterprises, improving the innovation system, creating an innovative environment, accelerating the development and promotion of general, key, and forward-looking technologies in key industries, driving industrial and technological upgrading, providing macro-control measures and a friendly environment for cooperation participants. According to the analysis on government functions in the industry-university-research integration, government investment is on the one hand expressed as capital support for industry-university-research integration, and as improving the industry-university-research integration environment on the other, both of which will directly impact the success of the cooperation. In addition, the fiscal expenditure of the government within a certain period is fixed. Under such circumstances, government investment in industry-university-research integration will have an impact on its investments made in other forms to society, and have an influence on local economic development. The aforementioned influence will eventually be shown as a positive and a negative feedback loop (as shown by the thick arrow in Figure 5). However, the questions are: will the local economic growth encourage the local government to increase investment in the project? How big are the influences? The answers to both questions are still subject to further statistical analysis (shown as “+(?)” in Figure 5).

Figure 5. The causal relationship for industry-university-research cooperation from the perspective of the government.

(1) Identification of the system boundaries
Firstly, government’s support for local industry-university-research cooperation is on the one hand
achieved by increasing investment in the project for the purpose of improving the willingness of enterpises and research institutes to cooperate and eventually improve the project success rate; on the other hand it tries to improve the cooperation environment to directly promote the project success rate. For this reason, we define the system boundaries for the operation of research institutes during industry-university-research cooperation as follows: government’s investment in the industry-university-research cooperation and the local economic development caused by the project success are the vertical boundaries of this evaluation system.

Secondly, government support and project success rate are the horizontal boundaries of this evaluation system. By referring to the definition of system boundary, the hidden cooperative relationship between enterprises and research institutes, and the government control loop, we get the government operation model during the industry-university-research cooperation as shown below (refer to Figure 6).

Figure 6. The operation model of government in the industry-university-research cooperation.

(2) Definition of influencing factors
a. Government support (GSP): the success of industry-university-research cooperation will drive local economic development, which in turn encourages the government to increase support for industry-university-research cooperation project.

b. Government investment (GI): an expression of the government’s support for industry-university-research cooperation.

c. Other societal investment: investments after deducting the investment in industry-university-research cooperation from the government fiscal expenditure.

d. Cooperation success rate (PCS): the success rate is subject to the efforts of the government, enterprises and research institutes.

e. Local economic development (LED): local social development shows the promotional force of industry-university-research cooperation on the local economy.

1.4 System dynamics model of industry-university-research cooperative innovation
The industry-university-research cooperative innovation system of the innovative element agglomeration center in developing countries based on the local innovation system includes the enterprise, the research institute and government sub-systems mentioned previously. According to the system dynamics modeling principles, the industry-university-research collaborative innovation system of the innovative element agglomeration center in developing countries may be described by using the following variables shown in table 2:
Table 2. Setting of variables for the operation model of industry-university-research cooperation based on local innovation.

| Number | Name of the variable | Unit     | Type of variable | Variable equation setting |
|--------|----------------------|----------|------------------|---------------------------|
| 1      | Corporate funds      | 10,000   | A                | (1-c₈) *government       |
|        |                      | Yuan     |                  | investment*cooperation success rate | |
| 2      | Local development    | 10,000   | R                | Cooperation success rate * (corporate output + research output) | |
| 3      | Government support   | --       | L                | Local development/local economic development | |
| 4      | Government investment| 10,000   | A                | Government support *(local economic development*0.806-27544.7) | |
| 5      | Local economic       | 10,000   | R                | Local GDP*GDP growth rate | |
|        | development           | Yuan     |                  |                           | |
| 6      | GDP growth rate      | --       | C                | C₁₂                        | |

*Note: L is a state variable; A is an auxiliary variable; C is a constant; C₁₂ is the GDP growth rate that can be adjusted within a certain range.

According to the systemic analysis of the enterprises, research institutes and the government listed above and by referring to the variables shown in table 2, we get the system dynamics model for the industry-university-research collaborative innovation of the innovative element agglomeration center in developing countries as shown in Figure 7. In this model, we assume that the region where this project is located has been developing steadily. In view of the rapid social economic growth in the mean time, we think ten years is sufficient for evaluating the operating effectiveness of the system. Under such circumstances, we have simulated the operation of the industry-university-research cooperation system under the local innovation system. By adjusting the GDP C₁₂ value within a range from 0.01-0.2, we find that although the values for various variables may alter slightly, the general trend is consistent. Hence we are only discussing the evolution of the cooperation system with a fixed GDP growth rate (0.1 is chosen in this instance):

Figure 7. System dynamic evolution of the industry-university-research cooperation under the local innovation system.
The willingness of enterprises to cooperate
Corporate profit
Government support
Local development
The willingness of the research institutes to cooperate
Research profit

(a). level of system cooperation (b). system profit

Figure 8. The operating effectiveness of the industry-university-research cooperation system under the local innovation system.

Figure 8(a) shows that in the industry-university-research cooperation system, with government interference, all participants have shown positive willingness to cooperate and government support remains at 1, showing full support; the cooperative willingness of the enterprises and research institutes starts to remain consistent from year 3 onwards, which means the industry-university-research cooperation system under the local innovation system has a highly favorable developing prospect. Figure 8(b) also shows that the profits of all participants have been constantly growing, very much attributed to the contribution made by the cooperation system to local development, which to some extent explains why the government is able to fully support industry-university-research cooperation. Figure 8(b) also shows that the growth of corporate profit, although maintaining high growth like research profits and local development, is flattening out, which could be fatal to profit-seeking institutions and severely affect corporate willingness to cooperate if the situation remains the same over a long term.

2. Empirical research on industry-university-research collaborative innovation in the innovative element agglomeration center in developing countries

Innovative capability has become one of the core competencies for national, regional, and corporate competition and one of the driving forces for economic development. China, a representative developing country, is transforming from a manufacturing country into an innovation-based country. And Sichuan Province, an innovative element agglomeration center in China, has a great number of famous universities and research institutes, including Sichuan University, the University of Electronic Science and Technology of China, Southwest Jiaotong University, the Chinese Academy of Sciences Chengdu Branch, and the Southwestern Institute of Physics. For that reason, it has attracted a number of research centers of famous multinational corporations including Ericson, Cisco, Siemens, SAP, and Oracle. Therefore, taking Sichuan Province as a typical innovative element agglomeration center in China for the study of industry-university-research cooperation will be valuable for exploring the general rules of creating a regional innovation system in developing countries. Hence, on the basis of Part 2, this paper establishes a system dynamics model for the industry-university-research cooperation under a local innovation system in Sichuan Province, statistically analyzes the industry-university-research effectiveness in Sichuan Province between 2000 and 2010, studies the influence of various factors on industry-university-research cooperation from the perspective of the industry-university-research cooperation participants, and provides a series of specific suggestions for future improvement.

2.1 Statistical data collection and analysis

Due to the lack of particular industry-university-research-related data in Sichuan Province, R&D refers to the creative activities conducted in the field of science and technology field for the purpose of
increasing the total capacity of knowledge (including knowledge on human culture and social understanding) and applying such knowledge in new applications. Such activities include fundamental research, applied research, and experimental development, which form a good summary of the features of the industry-university-research cooperation participants. By referring to the input and output of R&D activities related to industry-university-research cooperation in Sichuan Province from 2000 to 2010 listed in the Sichuan Science and Technology Information Network, we come up with the data as shown in table 3-5 according to the unit price of the output (unit: 10,000 Yuan):

### Table 3. Government Input and Output*

| Year | R&D capital investment | Government policies | GDP | Achievements and awards |
|------|------------------------|---------------------|-----|------------------------|
| 2000 | 264780.2               | 49858.7             | 392820 | 762                  |
| 2001 | 368776.7               | 74768.5             | 429350 | 700                  |
| 2002 | 299558.0               | 102986.0            | 472500 | 700                  |
| 2003 | 441330.7               | 95378.6             | 533310 | 758                  |
| 2004 | 361700.8               | 61414.4             | 637960 | 748                  |
| 2005 | 438399.3               | 67877.4             | 738510 | 865                  |
| 2006 | 473458.0               | 50891.0             | 869024 | 933                  |
| 2007 | 586403.0               | 72903.0             | 1056239 | 918          |
| 2008 | 768660.0               | 66898.0             | 1260123 | 928          |
| 2009 | 1044100.0              | 104282.1            | 1415128 | 926          |
| 2010 | 1495037.0              | 58647.0             | 1689859 | 995          |

* Source: Sichuan Science and Technology Information Network.

### Table 4. Corporate Input and Output*

| Year | R&D capital investment | R&D staff cost | Device and equipment cost | Government funding | Knowledge resource | Direct benefits | Patent sales | Technological findings |
|------|------------------------|----------------|--------------------------|--------------------|--------------------|-----------------|--------------|------------------------|
| 2000 | 119390.1               | 19082.8        | 42004.7                  | 58269.6            | 15061.7            | 38538.6         | 5270         | 340.6                  |
| 2001 | 131167.2               | 36557.4        | 87271.3                  | 31432.4            | 13911.4            | 127020.4        | 1840         | 343.4                  |
| 2002 | 216689.0               | 49592.2        | 64764.1                  | 63861.0            | 6217.7             | 226053.0        | 3070         | 366.8                  |
| 2003 | 257501.5               | 67991.0        | 184785.0                 | 64504.0            | 23256.0            | 258186.0        | 7500         | 388.8                  |
| 2004 | 356950.8               | 78424.0        | 236759.0                 | 59253.0            | 24011.0            | 317780.1        | 11780        | 400.8                  |
| 2005 | 456173.4               | 87210.0        | 326941.0                 | 86181.0            | 89255.0            | 422936.3        | 5650         | 257.2                  |
| 2006 | 551311.0               | 118628.0       | 381011.0                 | 111697.0           | 41791.0            | 507879.0        | 18530        | 237.0                  |
| 2007 | 731824.0               | 166099.0       | 471358.0                 | 80320.0            | 10935.0            | 3512106.0       | 8640         | 211.0                  |
Table 5. Research institute’s input and output.

| Year | R&D investment | R&D staff cost | Device and equipment cost | Budget allocation | Patent sales | Academic papers | Monograph publications |
|------|----------------|----------------|---------------------------|-------------------|-------------|-----------------|----------------------|
| 2000 | 49714.0        | 66477.6        | 168360.5                 | 292056.3          | 248         | 12223.8         | 1066                 |
| 2001 | 62951.0        | 80772.0        | 246316.0                 | 390039.0          | 274         | 13327.2         | 1376                 |
| 2002 | 34637.1        | 11122.2        | 244223.0                 | 382283.0          | 856         | 8856.0          | 1248                 |
| 2003 | 52269.0        | 71196.0        | 391547.0                 | 525011.9          | 390         | 17519.4         | 1302                 |
| 2004 | 63998.0        | 92107.0        | 295413.0                 | 451518.2          | 1388        | 21223.2         | 1457                 |
| 2005 | 58745.0        | 114950.0       | 356441.0                 | 530136.1          | 1772        | 23634.6         | 1246                 |
| 2006 | 82789.0        | 123720.0       | 351939.0                 | 558448.0          | 3276        | 27885.6         | 1286                 |
| 2007 | 105660.0       | 186498.0       | 440045.0                 | 732203.0          | 4460        | 30928.2         | 1317                 |
| 2008 | 1257009.0      | 430271.0       | 214000.0                 | 875889.0          | 1510        | 54114.0         | 1581                 |
| 2009 | 863273.0       | 236599.0       | 184230.0                 | 1184102.0         | 648         | 55307.0         | 1559                 |
| 2010 | 1081548.0      | 273673.0       | 248159.0                 | 1603380.0         | 405         | 58060.0         | 1446                 |

2.2 The construction and operation of the system dynamics model

The computation of budget allocation data in enterprises and research institutes participating in industry-university-research cooperation shown in table 3-5 has been taken as the input parameters for the system dynamics model. The willingness of each participant to cooperate in the industry-university-research cooperation dynamics model under the local innovation system will in the end affect its investment in the industry-university-research cooperation. As this model is fully based on historical statistical data for determining the input and output of each participant, it is believed that a lack of willingness to cooperate will have an impact on the investment of the participant. The system dynamics evolution model for the industry-university-research cooperation in Sichuan Province has also been created (as shown in Figure 9):
Figure 9. System dynamic evolution of industry-university-research cooperation in Sichuan Province under the local innovation system.

By using the Vensim PLE simulation software for running the aforementioned system dynamics model, we get the willingness of each participant to cooperate in the industry-university-research project in Sichuan Province. The success of the project is the joint act of the willingness of the enterprises and research institutes to cooperate and government support. Suppose that the willingness of each participant and government support are both set as 1, the willingness of the enterprises and research institutes account for 30% each, and government support accounts for 40%, and all budgets are evenly distributed, we get the willingness of each participant in the cooperation system and the success curve below (refer to Figure 10):

![Figure 10](image)

Figure 10. The willingness of each participant for industry-university-research cooperation in Sichuan Province under the local innovation system.

The willingness of each participant is generally increasing. Although no significant change has been seen in government and corporate investment in industry-university-research in 2008, the inter-relationship between the variables has shown that both the government’s support for industry-university-research and the enterprises’ willingness have grown tremendously, which confirms the emergent effect of a complicated system. Relatively speaking, due to global depression, the cooperation rate dropped in 2009 and didn’t improve until 2010.
2.2.1 Analysis on the sensitivity of funding allocation among enterprises and research institutes during industry-university-research cooperation.
If we change p, the funding allocation proportion between enterprises and research institutes within 0.1-0.9, we get the willingness of the enterprises and research institutes under different funding allocation proportions:

Note: p refers to the funding allocation proportion acquired by the enterprises during the cooperation (p=1-C₄)

Figure 11. Comparison of corporate willingness to cooperate under different allocation proportions.

Note: p refers to the funding allocation proportion acquired by the enterprises during the cooperation (p=1-C₄)

Figure 12. Comparison of research institutes' willingness to cooperate under different allocation proportions.

Note: p refers to the funding allocation proportion acquired by the enterprises during the cooperation (p=1-C₄)

Figure 13. Comparison of the cooperation success rate under different allocation proportions.
The change curve for the willingness of enterprises and research institutes to cooperate can reflect the influence of external funding support on the cooperation participant. Relatively speaking, research institutes are more sensitive to the funding allocation proportion (as shown in Figure 12) whereas enterprises are more sensitive to the general funding conditions (as shown in Figure 11). The change in the funding allocation proportion during the cooperation is classified as the change of internal factors and can be canceled out. Hence the cooperation success rate remains almost unchanged (as shown in Figure 13).

2.2.2 Analysis of government investment in industry-university-research cooperation.
To study the influence of government investment on the success rate of the project, the variable q is set as the mean proportion of government investment in GDP during 2000 and 2010 (i.e. \( q = \frac{\text{government investment}}{\text{local economic development}} \)), and the willingness of each participant to cooperate will influence the investment in the cooperation for the next year. The operating results are shown in Figure 14:

![Figure 14. The willingness of each participant, whose investment is subject to the willingness to cooperate, in the industry-university-research system in Sichuan Province.](image1)

Change \( q \), the government investment proportion, within 0.5-1 and we get the willingness of each participant and the cooperation success rate:

![Figure 15. Comparison of corporate willingness under different levels of government investment.](image2)
Figure 16. Comparison of the research institutes' willingness under different levels of government investment.

Figure 17. Comparison of the cooperation success rate under different levels of government investment.

Statistical analysis (refer to table 3) shows that on average government investment accounts for 78.8% of GDP. A growth rate that is lower than 0.78 causes a greater influence on the willingness of each participant than a growth rate that is higher than 0.78. However, it is still unable to effectively improve the success rate of industry-university-research cooperation (refer to Figure 15-Figure 17). The findings from the study for each participant of the industry-university-research cooperation show that government support still lags behind, which is very much subject to the closeness of the relationship among the local industry-university-research partners (i.e. the local innovation environment created by the government). The industry-university-research partners under the local innovation system shall have the participation of many research institutes and enterprises that are interrelated to each other. Such relationship will eventually be reflected as the contribution of industry-university-research cooperation to the growth of the local economic development.

2.2.3 Policy recommendations.

The results of system dynamics analysis made for the industry-university-research cooperation system of the research institutes and enterprises in Sichuan Province show that although Sichuan government is attaching greater importance to the establishment of an industry-university-research alliance under the local innovation system, technological investment into society is still insufficient, technological innovation competency is still inadequate, and the number of products with independent intellectual property rights is still too limited; the government’s guiding role in technological innovation in society is weakening, the scientific management system at the macro level is still incomplete, technological power is rather decentralized and unable to bring the agglomeration and coordination strengths into full play, and technological and innovative resources still need restructuring; the strength of the technological and innovative incentive policies is insufficient and the innovation environment needs to
be improved; science and technology distribution is not adequately closely related to the local objectives and is not strong enough to support the economic and social development; the enterprise-research institute innovation interaction system hasn’t been established; technological talent brain drain still exists; the lack of high-quality interdisciplinary talents required for technological innovation will not be able to provide effective support for the technical innovation and development of high- and new technology in the enterprises. Therefore, the following proposals are put forward:

1) Provide stronger policy support

Currently the local innovation system in Sichuan Province is still at an early stage and requires the government's guidance, participation, support, coordination, administration, service, and specifications in making use of supporting measures, incentive policies, making use of the functions of enterprises and research institutes in industry-university-research cooperation, creating cooperation channels, and forming a networked cooperation alliance. Provincial government should, according to the particular conditions of the local innovation system, prepare and improve regulations on technological achievement transfer to make sure that justice and legal assistance are available when infringement occurs.

2) Standardize market mechanism

Meeting market demand is one of the key motives for industry-university-research cooperation. Using market demand to guide and restrict industry-university-research cooperation can be considered as an effective measure. Hence the industry-university-research cooperation in Sichuan Province needs to refer to the local industrial structure in forming a market-driven industry-university-research cooperation alliance and attracting capital market investment in the cooperation. In addition, with the deepening reform policy in the market economy, the demand for high-technology products in the market has been increasingly growing. With complete and outstanding technological competencies, new and high-technology enterprises shall be able to produce world-leading and more distinctive technological, economic and social benefits once they have formed a profound and close cooperative relationship with research institutes. As Sichuan enjoys its own unique strengths in information technology, biopharmaceutical, new material and other high and new-technology industries, it should have access to more support, and attract more external capital market investment by establishing financial leverage in order to achieve a leapfrogging local economic development in Sichuan Province. (3) Extend the scale of industry-university-research cooperation and form a multi-level networked alliance. Currently, industry-university-research cooperation in Sichuan is still based on a one university/research institute one enterprise model, which usually results in limited research achievements and is only useful for certain particular enterprises. Therefore, technical improvement is required. In this approach, engineering problems, in lieu of technical breakthroughs, will become the new focus. Large-scale application of research results not only cuts down research and development costs but also substantially shortens the period required for research result transformation. Thus the government should make full use of its policy and guidance role in creating a networked local innovation environment and laying the foundation for the establishment of a local innovation system.

3. Conclusion

On the basis of local innovation theory, industry-university-research cooperative innovation theory, and system dynamics theory, by studying the industry-university-research cooperative innovation model in the innovation element agglomeration center in developing countries, and through analyzing the system boundaries and innovation influencing factors of the government, research institutes and enterprises under the local innovation system, we put forward a causal relationship diagram for three sub-systems comprising the government, research institutes and enterprises. On top of this, we also establish a system dynamics model for industry-university-research cooperative innovation in the innovation element agglomeration center in developing countries. We have also conducted empirical study in Sichuan Province in China, a typical innovation element agglomeration center in China. Our research findings show that: ① industry-university-research cooperative innovation will significantly push the technological and economic development in the innovation element agglomeration center in developing
countries forward: ② to developing countries, government policies have a distinctive influence on the performance of industry-university-research cooperative innovation in the innovation element agglomeration center; ③ industry-university-research cooperative innovation in the innovation element agglomeration in developing countries has just started and still has a lot of problems regarding policy-making and market operation, which will be a problem faced by all developing countries during the process of improving independent innovation competency and constructing a national innovation system.

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