CHEMICAL ENGINEERING TRANSACTIONS
VOL. 46, 2015
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Peiyu Ren, Yancang Li, Huiping Song

ISBN 978-88-95608-37-2; **ISSN** 2283-9216
DOI: 10.3303/CET1546091

Coupling System Model of Sci-tech Innovation and Sci-tech Finance and Its Application

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This paper, on the basis of establishing coupling evaluation system of Sci-tech finance and Sci-tech innovation, sets up index weight by adopting Attribute Hierarchical Model (AHM) and Entropy Weighting Method (EWM). Coupling system model is implemented to conduct empirical study to coordinated development of Sci-tech finance and Sci-tech innovation in Hunan Province from the perspective of space and time Results showed that coordinated development of Sci-tech finance and Sci-tech innovation in 14 cities during 2001 to 2012 has been polarized, and its overall level is still relatively low. Among the cities, Changsha is at good coordinated phase while Zhuzhou, Xiangtan, Hengyang and Yueyang are at fundamental coordinated phase. The other cities are at a moderately or severely imbalanced stage. From the angle of space, Hunan province Sci-tech innovation and Sci-tech finance coordination degree have obvious regional imbalance, the Changsha-Zhuzhou-Xiangtan core region has highest coupling coordination level. The coupling coordination level in the West-Hunan region is lowest and has the slowest development speed. From the comparison of comprehensive evaluation index of these two subsystems, Sci-tech innovation and Sci-tech finance loss together is a common phenomenon in the Sci-tech industry development in Hunan province.

1. Introduction

Capital intensive and high risk in high technology industry determines the close relationship between Sci-tech innovation and Sci-tech finance, and the relationship is a complex unity of opposites' dialectical relationship. On the one hand, science and technology can't turn into productivity without the support from finance. On the other hand, progress in science and technology will improve the ability of financial innovation and ensure financial security. Sci-tech innovation and Sci-tech finance are two engines of regional knowledge economic growth. Their coupling coordinated development is conductive to the sustainable and rapid growth of knowledge economy; otherwise it will severely restrict the development speed of knowledge economy. Therefore, an effective measure of the degree of the coupling coordinated development of Sci-tech innovation and Sci-tech finance could play an important role in government decision making and policy adjustment.
Currently, related studies mainly focus on the role and influence of Sci-tech innovation and Sci-tech finance. Luigi et al. (2008), Ang (2010), Alessandra (2008), and Xiao et al. (2011) analyze the impact of banks, capital market and venture investment on Sci-tech innovation in a financial environment. Berger (2003), Schinckus (2008) and Consoli (2005) investigate the impact of Sci-tech innovation such as information and communication technology on the development of Sci-tech finance. But research on the interaction between Sci-tech innovation and Sci-tech finance are still limited. Perez (2002) analyze the relationship between financial capital and Sci-tech innovation in a techno-economic paradigm evolution perspective and illustrate the constrain relationship between Sci-tech innovation and financial capital. Wang (2012) build a coordination degree model of Sci-tech innovation and financial subsystems' order degree and composite system and carry out an empirical research on China Sci-tech innovation and financial capital data from 2000 to 2010. Yu (2013) based on the provincial panel data, using the Grainger causality test, panel data quantile regression and panel vector auto regression model, analyzes the relationship between Sci-tech innovation and financial market, results show that the financial support for technological innovation needs time, science and technology output have a positive feedback effect on financial market. The theory of Sci-tech finance lags

Please cite this article as: Deng Q.Z., Chen R., Huang L., 2015, Coupling system model of sci-tech innovation and sci-tech finance and its application, Chemical Engineering Transactions, 46, 541-546 DOI:10.3303/CET1546091

behind the practice, and the overall development is slow, which restricts the development of Sci-tech innovations. In 2009, there appeared Sci-tech finance articles, such as You and Zhu (2011), Zhou (2011), and so on from a theoretical angle analyzed Sci-tech finance's content, operating mode, security mechanism, etc. In the current study, more focus on promoting Sci-tech innovation as the focus, the development of Sci-tech finance is set to provide financial service for Sci-tech innovation. It mainly solves the funding needs of innovation of science and technology achievement transformation and industrialization process, while ignoring the requirements of the coupling coordination development of Sci-tech innovation and Sci-tech finance (Xu (2013); He (2014)). The subjective or objective weighting based methods alone lack of subjective and objective combined weight to determine the comprehensive weight model. It is difficult to guarantee the accuracy and scientific of subsequent Sci-tech innovation and Sci-tech finance coordination level measurement. To compensate for the above shortcomings, this paper uses coupling theory from physics, Attribute Hierarchical Model (AHM) and Entropy Weighting Method (EWM), determine the Sci-tech innovation and Sci-tech finance system coupled coordination evaluation index weights from subjective and objective aspects, and construct a coupling system evaluation model. Then based on panel data of 14 Hunan province cities' from 2002 to 2012, we carry out an empirical research on time trends and space differences.

2. Research methods and index system

2.1 Research methods

(1) Attribute Hierarchical Model and Entropy Weighting Method

Set the comprehensive evaluation indexes of Sci-tech innovation subsystem ($f(x,t)$) and Sci-tech finance subsystem ($g(x,t)$) as below:

$$f(x,t)=\sum_{i=1}^{m}\alpha_i x_i^{'} \qquad g(y,t)=\sum_{j=1}^{n}\beta_j y_j^{'} \tag{1}$$

x, y are eigenvectors of the system and t refers to period. $x_i^{'}, y_i^{'}$ refers to the standardized data. α_i, β_j are the weights of selected indexes in the comprehensive evaluation. AHM and EWM are adopted to confirm the subjective and objective weights of each index. Calculate the weighted average value of them and get their final comprehensive index weight. The principle of AHM is: C is a criterion, $b_1, b_2 \ldots, b_n$ are n elements. For criteria C, compare b_i and b_j $(i \neq j)$, their relative significances are μ_{ij} and μ_{ji}. They should satisfy the following attribute measures:

$$\mu_{ij} \geq 0, \mu_{ji} \geq 0, \mu_{ij} + \mu_{ji} = 1, i = j \tag{2}$$

$$\mu_{ij} = 0, i = j, 1 \leq i \leq n, 1 \leq j \leq n \tag{3}$$

μ_{ij} satisfying the equation above is called relative attribute measure. Its n-order matrix $(\mu_{ij})\ 1 \leq i, j \leq n$ is called attribute judgment matrix. $(\mu_{ij})\ 1 \leq i, j \leq n$ is transformed from $(a_{ij})\ 1 \leq i, j \leq n$ by using analytic hierarchy process. The transformation equation is equation (4). k is a positive integer that is equal or greater than 1. The value of a_{ij} is confirmed by 1-9 proportional scales analytic hierarchy process (AHP) proposed by American operational researcher Saaty.

$$\mu_{ij} = \begin{cases} \frac{k}{k+1}, & a_{ij} = k, i \neq j \\ \frac{1}{k+1}, & a_{ij} = \frac{1}{k}, i \neq j \\ 0, & a_{ij} = 1, i = j \end{cases} \tag{4}$$

Attribute judgment matrix has consistency, therefore it is needless to calculate eigenvalue and eigenvector of the matrix, neither is consistency test needed. The calculation equation of attribute weight Wc is:

$$Wc = (Wc(1), Wc(2), \cdots Wc(n))^T = \frac{2}{n(n-1)} \sum_{i=1}^{n} \mu_{ij}, \qquad 1 \leq i \leq n \tag{5}$$

Weight defining steps of EWM are:

1) Proportional transformation of index value:

$$p_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}, (i = 1, 2..., n, j = 1, 2..., m) \quad (6)$$

2) Entropy value of the j_{th} index:

$$e_j = -\frac{1}{\ln^n} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \quad (7)$$

3) Difference degree of the j_{th} index:

$$g_j = 1 - e_j \quad (8)$$

4) Weight of the j_{th} index is w_j :

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j}, (1 \le j \le m) \quad (9)$$

(2) Coupling system model

Based on the physical theory of capacitive coupling and capacity coupling system model, systematic coordination degree of Sci-tech finance and Sci-tech innovation is constructed as:

$$C = \left\{ f(x,t) \times g(x,t) \Big/ \left| \frac{f(x,t) + g(x,t)}{2} \right|^2 \right\}^k \quad (10)$$

C is coordination degree(or coordinated coefficient). K is adjustment coefficient, K =2. The smaller C is, the less coordinated are the two subsystems; the bigger it is, the better is their coordination. However, in situation that two subsystems are scored equally but the values are low, it is possible to have a relatively high coordination degree, which is obviously against the fact. Systematic coupling coordination degree is further optimized as:

$$U = (C \times T)^q \qquad T = af(x,t) + bg(x,t) \quad (11)$$

U is coupling coordination degree and C is coordination degree. T is the comprehensive developmental degree evaluation index. a , b , q are the undetermined coefficients which are all 0.5 in this paper. Based on the analysis above, uniform distribution function is used to divide the categories of coupling coordination development of Sci-tech finance and Sci-tech innovation into good coordinated development (0.80-1.00), moderate coordinated development (0.60-0.80), basic coordinated development (0.40-0.60), moderate imbalanced recession (0.20-0.40) and severe imbalanced recession (0.00-0.20). After that, through comparing the sizes of evaluation indexes of Sci-tech finance and Sci-tech innovation, divide every category into hysteretic type ($f(x,t) < g(x,t)$), synchronized ($f(x,t) = g(x,t)$) and profit and loss ($f(x,t) > g(x,t)$). There are 15 types of evaluation in total.

2.2 Index system and weight setting

In order to scientifically distinguish the specific indexes of Sci-tech innovation and Sci-tech finance, the author took use of literature search engine of China National Knowledge Infrastructure (CNKI) to search all papers that contain words of “Sci-tech”, “finance” and “coordination” in January, 2015. There are totally 32 Chinese papers published during 2000-2014. After high-frequency classification and many modifications, 4 elements which are Research and development ability, the power of transformation, industrialization capacity, market finance and public finance plus 12 indexes are set up. Moreover, two subsystems of Sci-tech innovation and Sci-tech finance are constructed to establish the coupling coordinated development evaluation system and relevant weights as shown in Table 1.

Table 1: Coordinated development system and indicator weights of Sci-tech innovation and Sci-tech finance in Hunan Province

Target layer	System layer	Element layer	Index layer	Unit	AHM weight	EWM weight	Comprehensive weight
Coupling coordination development system of Sci-tech innovation and Sci-tech finance	Sci-tech innovation system	R & D capability	Number of patent applications	Piece	0.19	0.21	0.20
			Effective number of patents	Piece	0.21	0.27	0.24
		Power of transformation	Value of new products	10^4¥	0.11	0.13	0.12
			Sales of new products	10^4¥	0.11	0.13	0.12
		Industrial capacity	Sales of high-tech industry	10^4¥	0.12	0.10	0.11
			Added value of high-tech industry	10^4¥	0.12	0.08	0.10
			Total output value of high-tech industry	10^4¥	0.14	0.08	0.11
	Sci-tech financial system	Finance Market	Financial loans balance	10^8¥	0.53	0.43	0.48
		Public Finance	Scientific and technological activities expenditures	10^8¥	0.21	0.29	0.25
			Science and technology project expenditure	10^8¥	0.26	0.28	0.27

Note: comprehensive weight=(AHM weight + EWM weight)/2.

3. Analysis of empirical test results

3.1 Coupling analysis in time sequence

Comprehensive evaluation indexes of subsystem are gained based on the data of table 1 (see figure 1). Put them into coupling coordination degree equation (11) and calculate the coupling coordination results of Hunan Sci-tech innovation and Sci-tech finance as well as annual average values which are shown in Table 2.

Table 2: Sci-tech innovation and Sci-tech finance coupling coordination degree of 14 cities in Hunan Province from 2001 to 2012

Year	Changsha	Zhuzhou	Xiangtan	Hengyang	Yueyang	Changde	Yiyang	Chenzhou	Loudi	Xiangxi	Shaoyang	Yongzhou	Huaihua	Zhangjiajie
2001	0.99	0.73	0.59	0.50	0.56	0.44	0.26	0.21	0.36	0.19	0.13	0.33	0.26	0.00
2002	0.99	0.74	0.59	0.52	0.53	0.39	0.23	0.21	0.28	0.11	0.23	0.23	0.27	0.00
2003	0.97	0.64	0.52	0.43	0.43	0.34	0.21	0.21	0.32	0.13	0.15	0.29	0.2	0.00
2004	0.98	0.48	0.47	0.39	0.34	0.27	0.17	0.24	0.25	0.13	0.12	0.19	0.18	0.00
2005	0.99	0.62	0.48	0.46	0.46	0.33	0.17	0.24	0.35	0.13	0.15	0.21	0.19	0.00
2006	1.00	0.63	0.49	0.49	0.37	0.29	0.16	0.26	0.2	0.08	0.16	0.18	0.19	0.00
2007	1.00	0.60	0.45	0.44	0.46	0.34	0.2	0.23	0.29	0.15	0.20	0.19	0.18	0.00
2008	1.00	0.62	0.51	0.44	0.40	0.40	0.24	0.25	0.41	0.13	0.20	0.18	0.17	0.00
2009	1.00	0.51	0.44	0.38	0.38	0.46	0.21	0.24	0.33	0.08	0.18	0.15	0.17	0.06
2010	1.00	0.55	0.42	0.36	0.36	0.41	0.2	0.22	0.33	0.05	0.18	0.12	0.13	0.00
2011	1.00	0.48	0.43	0.33	0.38	0.39	0.2	0.21	0.32	0.06	0.21	0.15	0.13	0.00
2012	1.00	0.48	0.4	0.31	0.48	0.37	0.21	0.24	0.29	0.05	0.21	0.13	0.14	0.00
AVG	0.99	0.59	0.48	0.42	0.43	0.37	0.21	0.23	0.31	0.11	0.18	0.20	0.18	0.01

4 main coupling coordination types are summarized according to table 2's calculation results and the classification standard introduced above. Meanwhile, based on the comparison results of figure 1, essential reasons why the coupling coordination degrees are different are analyzed. Conclusions are:

Coupling coordination degree of Changsha and is in the range of 0.8 to 1. It belongs to good coordinated development and is the most ideal state in which Sci-tech innovations continue to emerge, Sci-tech finance continue to expand, their spiral development situation promote regional knowledge economy rapid development. Changsha is always superior to other cities in coupling coordination degree during the study period. Its development is relatively stable and coordinate value of the variation is very small. By the comprehensive evaluation index, Changsha belongs to Sci-tech innovation and Sci-tech finance synchronous City, and gives full play to their mutual promotion, improve the coordination level.

(2) Coupling coordination degree of Zhuzhou, Xiangtan and Hengyang is ranged 0.4-0.6. They belong to the type of basic coordinated development. At this time they Sci-tech innovation and Sci-tech finance are still at the stage of running-in. Their structures, scales and some other aspects still need to be matched in a better way. Coupling coordination degree of these cities declined in the study period, among them Zhuzhou city has the largest decline (-0.25), the smallest is Yueyang city (-0.08). By the comprehensive evaluation index, Xiangtan belongs to Sci-tech innovation and Sci-tech finance synchronous type city. The other 3 cities belongs to Sci-tech finance hysteretic type. The low level of financial development in a certain extent hindered the development of science and technology innovation, and hinders the coordination degree improvement of the two.

(3) Changde, Yiyang, Chenzhou and Loudi have the coupling coordination degree between 0.2-0.4, which belongs to moderate recession type. In this type of cities, except Chenzhou,the the coupling coordination degree decreased. Changde and Loudi have the largest decline (-0.07) and Yiyang keep the lowest (-0.05), while Chenzhou makes an increase (0.03). In figure 1, all the 4 cities belong to Sci-tech innovation and Sci-tech finance jointly lose type. Based on this, the government departments should actively promote the development of Sci-tech innovation and Sci-tech finance integration policy; promote the coordinated development between the two to narrow the gap between these cities and the others.

(4) The coordination degrees of Shaoyang, Zhangjiajie, Yongzhou, Huaihua and West-Hunan are all below 0.2, which belongs to the serious recession type. During the study period, coupling coordination degrees of Yongzhou, Huaihua and Zhangjiajie decreased by 0.2, 0.12 and 0.14 respectively. Shaoyang increased by 0.08.Zhangjiajie remained in the lowest state. From the comprehensive evaluation index, all these cities belongs to Sci-tech innovation and Sci-tech finance jointly lose type, and comprehensive evaluation index of these 5 cities' Sci-tech innovation and Sci-tech finance are down on the list in the province.

3.2 Spatial coupling analysis

This paper calculated the classification results of coupling coordinated levels in 14 cities of Hunan in three economic circles, tenth Five Year Plan, eleventh Five Year Plan, and twelfth Five Year Plan. With the use of reclassification tool, ArcGIS10.1, the distribution map of coupling coordination degree between Sci-tech innovation and Sci-tech finance in Hunan is drawn (see Figure 2). Specific attributes are:

(1) Changsha-Zhuzhou-Xiangtan region: in the study period, Changsha and Xiangtan were in good coordination state and basic coordination state respectively. Zhuzhou fell from moderate coordination state to basic coordination. In general, the economic sector of the region is at high coordination level, and the advantage against other area is gradually expanding. (2) Dongting Lake region: Yiyang and Changde has been in a moderate imbalanced state, Yueyang experienced from the basic coordination to moderate disorders and again back to basic coordination. The overall coordination level of the economic region is low. Trend changes and internal differences are small during the research period. (3) Xiangnan region: Loudi and Chenzhou have moderate imbalanced state, Hengyang fell from basic coordination state to moderate disorder state, and Yongzhou fell from moderate disorders to serious imbalance state. (4) West-Hunan region: Zhangjiajie and Xiangxi autonomous prefecture has always been in a serious imbalance, while Huaihua is form moderate recession to serious imbalance, Shaoyang developed from serious imbalance to moderate disorders. This region has the lowest coupling coordination degree in the four economic regions, and the development speed is also the slowest. Meanwhile, comprehensive evaluation index of the 4 West-Hunan cities' Sci-tech innovation and Sci-tech finance ranks in the rear, lack of inter city interaction effect.

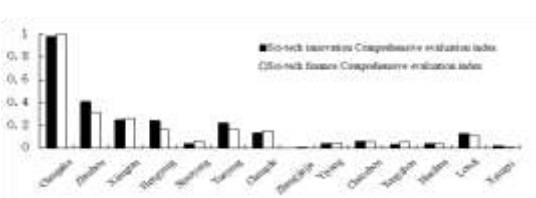

Figure 1: Comprehensive evaluation index of Sci-tech innovation and Sci-tech finance in Hunan cities

Figure 2: The spatial difference between Sci-tec innovation and Sci-tech finance coupling coordination degree in Hunan

4. Conclusions

This paper used coupling coordination model to conduct an empirical study to the coupling coordinated development of Sci-tech innovation and Sci-tech finance in 14 cities in Hunan during 2001 to 2012. Conclusions are: (1) from the time perspective, the 14 Hunan cities' Sci-tech innovation and Sci-tech finance coordination degree have polarized trend. For example, Changsha has been in a good state of coordination, while Zhangjiajie has been in a state of serious imbalance. Their coupling coordination degree has considerable numerical difference. (2) From the comprehensive evaluation index, Zhuzhou, Hengyang and Yueyang are Sci-tech finance hysteretic type, Changsha and Xiangtan are synchronous type cities and the others belong to jointly lose type. (3) From the perspective of space, the coupling coordination degree has obvious regional imbalance. Changsha-Zhuzhou-Xiangtan region's coupling coordination degree is at the highest level, Xiangnan region and Dongting Lake region take the second place in coupling coordination degree while West-Hunan region has both the lowest coupling coordination degree and the slowest development speed. (4) From the view of economic growth, the higher the level of economic development, the better the coupling coordination degree between Sci-tech innovation and Sci-tech finance, such as Changsha and Zhuzhou. Low level of economic and Sci-tech development leads to a low coupling coordination level, such as Zhangjiajie and West-Hunan Autonomous Prefecture, et al.

Acknowledgments

The authors would like to thank the referee for his helpful advice and comments. This is a Project Supported by Soft Science Program of Hunan Provincial Science & Technology Department (Research on the Mechanism, evaluation and countermeasures of the integrative development of science & technology and finance in Hunan Province, 2014ZK3024), Philosophy Social Science Fund of Hunan Province (13YBB088) and Scientific Research Fund of Hunan Provincial Education Department (13B022).

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