The Influence of Collaborative Innovation Among Technology, Institution and Finance on China's Economic Growth

LI TING[1] , CHEN QIU XIN[2], YE QIAN QIAN[3]
School of Internet Economics and Business[1]; College of Strait Rural Development[2]; Planning Department[3]
FuJian University of Technology[1]; Fujian Agriculture and Forestry University[2]; Fujian Provincial Technology Transfer & Industrialization Service Co.,Ltd.[3]
No.999, Dongsanhuan Road, Jin'an District, Fuzhou, Fujian[1]; No.15, Shangxiadian Road, Cangshan District, Fuzhou, Fujian[2]; Building C, Zhaobiao Building, 68 Hongshanyuan Road, Gulou District, Fuzhou, Fujian[3]
CHINA；CHINA；CHINA

Abstract: - This paper constructs a model of collaborative innovation among technology, institution and finance to measure the synergy degree of 29 provinces and cities. Official provincial-level panel data from 2011-2017 for 29 provinces are utilized. We find that there is a great difference in the synergy degree among different regions because of the uneven distribution of financial resources in the region. Then the synergy degree of 29 provinces and cities in China is regarded as an important variable in the fixed-effects model. The primary finding is that the degree of collaborative innovation among technology, institution and finance can positively affect China's economic growth. If the degree of collaborative innovation increase by 1%, and the GDP per capita will also increase by about 0.009%-0.016%. However, the domestic loan index of real estate enterprises has a negative impact on the per capita GDP. Then we get the conclusion that collaborative innovation will be effective for China's high-quality economic growth and suggest that government should use macro control to reduce capital's preference for real estate investment especially by strengthening direct financial innovation to support technological innovation.

Key-Words: Technology innovation, Institutional innovation, Financial innovation, Collaborative Innovation, China's high-quality economic growth

Received: April 23, 2020. Revised: August 11, 2020. Accepted: August 31, 2020.
Published: September 4, 2020.

1 Introduction

In the process of economic growth, China also needs to face the problem of changing economic growth from high-speed to medium-high speed. In the context of supply-side reform, China is changing the model of factor-driven and investment-driven, and steadily improving the quality of China's economy through innovation-driven. Many scholars focus on the dynamic evolution mechanism of technological and institutional collaborative innovation. They put forward the influence of technological and institutional collaborative innovation on the motive force of economic growth from the perspective of the unification of productivity and production relations.

In the framework of classical and neoclassical economics, social capital and other financial factors had not been included, because of their limited impact on the real economy. However, with the increasingly complex relationship between finance and technological and institutional collaborative innovation, financial innovation plays an important and catalytic role in technological and institutional collaborative innovation. In fact, it accelerates the hatching of emerging industries and promotes the transformation of technological innovation achievements. But how to measure the synergy degree of collaborative innovation among technology, institution and finance? What's the real effectiveness of collaborative innovation on China's economic growth? Is it significant positive? In the second part, this paper puts forward the viewpoints of the three collaborative innovation through literature review, calculates the synergy

degree of three system in the third part, and conducts empirical analysis in the fourth part, then proposes corresponding suggestions based on the empirical analysis results.

2 Literature Review

Researchers have always been interested in understanding the evolutionary theorising on collaborative innovation of technology and institution, including the following experts. Nelson (1994) and Murmann (2003) try to introduce institutional factors into the economic analysis framework[1][2]. They believe that co-evolution of institution and technology is regarded as the main driving force behind economic growth and industrial evolution, implying causal interdependencies between the two. In Marxist political economics theory, technological innovation is categorized as productivity, and institutional innovation is categorized as production relations. ”

For example, some experts focus on technological side of collaborative innovation. Wang Xu and Gao Shuang(2018) Use the algorithm of C-D production function and Solow residual value, and then the contribution rate of scientific and technological progress of collaborative innovation to the economic growth of construction industry is calculated. The result indicates that the Northeast construction industry is in a small scale growth in China[3]. Based on DEA-BCC model and Malmquist index model, Cui Zhixin and Chen Yao(2019) measured the efficiency of technological collaborative innovation and its evolution trend in Beijing-Tianjin-Hebei region and Yangtze River Delta region from 2006 to 2016, and made a comparative analysis[4]. However, some experts concern institutional factors more. From the perspective of institutional fairness and human capital, Wang Xuelong and Yuan Yiming (2015) propose that the decline in social equity largely offsets the positive effects of technological progress. Therefore, technological innovation is important, but institutional innovation is more important, because it will push the Chinese economy to a high level of equilibrium[5]. Phung T D , Van V T T , Thuong T T H , et al(2019) show that innovation, together with national openness, foreign direct investment inflows, and government expenditure on education, have directly and positively influenced economic growth. In addition, the study finds a positive intermediate role for institutional quality and the spillover effect of foreign direct investment in promoting the relationship between innovation and economic growth[6].

Obviously, regardless of scholars' emphasis on technological innovation or institutional innovation in collaborative innovation, the factor of financial innovation has been ignored. Since finance has become more and more important, economists have paid increasing attention to the relationship between financial development and economic growth. They mainly focus on technological innovation as an important factor increasing economic growth from the perspective of financial support.

Levin (1997) suggests that in financial system, financial functions can have a significant influence on economic growth under the way of technological innovation and capital accumulation[7]. Beck, Levine and Loayza (2004) discovered that financial sector development has positive effect on technological innovation[8]. Saviotti and Pyka (2009) analysed the co-evolution of technologies and financial institutions. They propose that the synergistic relationship between the two will appear in the integration of financial capital and emerging industry sectors[9]. As the emerging industry sectors create more value, financial capitals tends to play an important role in contributing to economic growth. At the same time, economic growth contributes to the growth of the financial sector. Cheng Yu, Zhou Xiaoliang and Chen Xiaofang (2016) point out that China's financial system need to improve for technological innovation in many areas based on the perspective of technological innovation[10]. Liu Xiangyun and Wu Wenyang (2018) establish the "Technological Finance-Industry-Environment" complex system dynamic evolution model to study the co-evolution mechanism of technological finance and high-tech industry from two perspectives of inter-system and intra-system[11]. The relaxation in financial regulations encouraged financial institutions to create optimized structure, and ultimately becomes a powerful driving force in technological innovation.

On the other hand, most scholars believe that financial innovation is a part of institutional innovation. Institutional innovation is the foundation of financial innovation.

Ba Shusong and Zhang Ning (2004) suggest that different kinds of realistic financial innovations have various driving forces for innovation[12]. The key is to establish the interaction between financial innovation and institutional perfection. In order to improve the system, we need to discover systemic deficiencies by enhancing financial innovation. Meanwhile, the improvement of the system also provides the better environment for standardized

financial innovation. From the perspective of property right system reform of finance, Ma Yunquan (2011) encourages financial institutions with greater innovation capability and building core competition power of joint-stock, foreign-owned, joint ventures, and improve the overall innovation ability in China's financial industry[13]. Jiang Yuting and Shi Yanze (2016) suggest the function of financial supervision system should not be limited to constraint function, but should have incentive function[14]. Sun Jing (2018) proposed that the comparative advantage of a market-oriented financial system not only depends on market development itself, but also on a better economic foundation, credit foundation and institutional foundation. On the road of developing direct financing and improving the capital market, Chinese government must pay attention to institutional factors[15]. Therefore, the incentive and restraint effect of institutional innovation on financial innovation is a pair of contradiction. Through improving the synergistic effects between financial innovation and institutional innovation, institutional innovation could meet the demand of financial innovation and accelerate economic growth.

Above all, financial innovation is closely related to technological innovation and institutional innovation. Therefore, this study proposes that financial innovation should not be regarded as a part of institutional innovation only. It could be considered as an independent innovation system. Then we put forward that financial innovation must be combined with institutional innovation independently in the process of financial support for technology innovation. A new collaborative innovation mechanism including technology, institution and finance must be established to fire all types of market participants and determinative factors with new vigor for development. The new collaborative innovation model is an open complex system. The cooperation-competition pattern allows technology, institution and finance to share information and learn from each other, gradually establishes a feedback compound mechanism, and eventually becomes a community of shared interests. Collaborative innovation of the three continues to follow a spiral-ascending growth way and becomes a motive force for economy sustainable development.

3 Measurement of Synergy Degree

3.1 Theoretical Framework

Based on the theories above, this study further analyzes the evolution trend of technological innovation, institutional innovation and financial innovation, and gradually figure out the mechanism of their interaction and the theoretical framework of three systems' collaborative innovation. Financial Innovation is the important link for technological and institutional collaborative innovation.

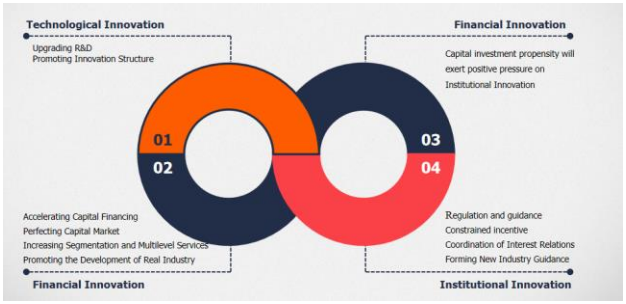


Fig.1 Three Theoretical Framework of Collaborative Innovation

Technological innovation could upgrade the industrial structure and promote the development of economy. Institutional innovation concerns with government's policy by coordinating interest relations and regulating macroeconomic policies. Financial innovation is the important bond to promote the incubation and landing of technological innovation projects which also needs government's new industry guidance and constrained incentive as shown in the Fig. 1.

In this three collaborative innovation mechanism, three innovation systems respectively reflect their functions. Technological innovation has become the core driving force of collaborative innovation and continuously improves independent innovation capabilities. Institutional innovation has become the traction driving force, which plays the role of "guide" and "regulator". Financial innovation has become a catalytic driver, accelerating the incubation of emerging industries, promoting entrepreneurship and employment, and stimulating market vitality.

In the initial stage of industrial development, government's innovation power is the guiding force for industrial development. In this period, technological innovation system is the main driving force, and financial innovation system is the pushing force. In the growing period of the industry, the government's innovation power is transformed into a pushing force for industrial development, and financial innovation plays the main driving force. In

the mature period of the industry, financial innovation promotes and upgrades rapid transformation of the industry, but technological innovation system is the main driving force to promote next round of technological innovation again at this period. Generally, this three systems continue to drive sustainable economic growth.

3.2 The Synergy Degree of 29 provinces and cities in China

3.2.1 Synergetic degree of single system

On the basis of the above theory, this study divides technological innovation, institutional innovation and financial innovation into three independent systems. In order to describe the mechanism of co-evolution among them more clearly, we learns from Meng and Han (2000) about the study of synergetic degree model of composite system, and then constructs a model of synergy degree of collaborative innovation among technology, institution and finance[16].

The total contribution of order parameters to the orderliness of subsystems can be achieved by a set. For a single system $S_j, j \in [1,k]$, it is assumed that the order parameter variables in the development process are $e_j = (e_{j1}, e_{j2}, \ldots, e_{jn})$. Under the condition of $n \geq 1$ $\beta_{ji} \leq e_{ji} \leq \alpha_{ji}, i \in [1,n]$, α, β are the upper and lower limits of the order parameter e_{ji} under the steady state of the system. Assume that the larger the value of $e_{j1}, e_{j2}, \ldots, e_{jm}$, the higher the order of the system, the smaller the value of $e_{j1}, e_{j2}, \ldots, e_{jm}$, the lower the order of the system; the greater the value of $e_{jm+1}, e_{jm+2}, \ldots, e_{jn}$, the lower the order of the system, the smaller the value of $e_{jm+1}, e_{jm+2}, \ldots, e_{jn}$, the higher the order of the system. We define the following formula (1) as the single system synergy degree of the system S_j and order parameter component e_{ji}:

$$U_j(e_{ji}) = \begin{cases} \dfrac{e_{ji} - \beta_{ji}}{\alpha_{ji} - \beta_{ji}}, i \in [1,m] \\ \dfrac{\alpha_{ji} - e_{ji}}{\alpha_{ji} - \beta_{ji}}, i \in [m+1,n] \end{cases} \quad (1)$$

Among them, the larger the value of $U_j(e_{ji}) \in [0,1]$, the greater the orderly contribution of e_{ji} to the subsystem S_j. In actual systems, e_{ji} will have various values. Therefore, the total contribution of the order e_j parameter to the order degree of subsystem S_j can be realized by the set of $U_j(e_{ji})$.

3.2.2 Synergetic degree of composite system

The composite system synergy degree model assumes that the initial moment is t_0, and the order degree of each subsystem order parameter is $U_j^0(e_j), j = 1,2,\ldots,k$. When the overall composite system evolves to time t_1, and the order degree of each subsystem order parameter is $U_j^1(e_j), j = 1,2,\ldots,k$, the time period is defined $t_1 - t_0$. The overall synergy of the composite system is the following formula (2) :

$$D(S) = \theta \sqrt[k]{\left| \prod_{j=1}^{k} \left[U_j^1(e_j) - U_j^0(e_j) \right] \right|}$$

$$\theta = \begin{cases} 1 & \min\left[U_j^1(e_j) - U_j^0(e_j)\right] \\ -1 & \left|\min\left[U_j^1(e_j) - U_j^0(e_j)\right]\right| \end{cases}, \begin{matrix} \min\left[U_j^1(e_j) - U_j^0(e_j)\right] > 0 \\ \min\left[U_j^1(e_j) - U_j^0(e_j)\right] < 0 \end{matrix}, j = 1,2,\ldots,k$$

$$\min\left[U_j^1(e_j) - U_j^0(e_j)\right] \neq 0 \quad (2)$$

The greater the overall coordination degree $D(S)=[-1,1]$ of the composite system, the higher the coordination development degree of the composite system. Otherwise, the lower the coordination degree. The role of the parameter θ is that the composite system has a positive degree of coordination only if $U_j^1(e_j) - U_j^0(e_j) > 0, \ \forall j \in [1,k]$. When $D(S) \in [-1,0]$ indicates that the entire system is uncoordinated, the order degree of some subsystems increase greatly, while the order degree of some subsystems increase little or even decrease. The trends and characteristics of the coordination degree of the composite system are measured relative to the base period of the survey. Generally, the larger the value, the higher the coordinated development degree of the composite system.

In this study, the technical innovation subsystem includes five indicators as the order parameters of the system: number of scientific and technical personnel, R&D expenditure, number of scientific and technological projects, number of patents, technology market turnover .

The institutional innovation subsystem includes five indicators as the order parameters of the system: de-nationalization rate, marketization index, degree

of opening to the outside world, system fairness, and degree of attracting talent as the order parameters of the system.

The financial innovation subsystem includes five indicators as the order parameters of the system: the number of employees in the financial industry, the output value of the financial industry, the proportion of fixed investment, the financial social contribution rate, and the degree of marketization of the financial financing structure.

3.3 The result of Synergetic degree

In the process of data verification, we use data from 2011 to 2017. Due to lack of some variable data of Chongqing and Tibet provinces, and the data of other special areas outside mainland of China are not easy to obtain, so we only use the panel data of 29 provinces and cities in China for 7 years. 29 provinces and cities are Beijin, Tianjin, Hebei, Shanxi, Neimenggu, Liaoning, Jili, Heilongjiang, Shanghai, Suzhou, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

Official provincial-level panel data from 2011-2017 for 29 provinces and cities are utilized. We measure the synergy degree of 29 provinces and cities respectively. This approach is often found in other papers. Therefore, In terms of the capacity and representativeness of the sample, the results are not affected by losing these two provincial data. Therefore, the results are reliable.

Table 1 The Mean Value of Provincial-Municipal Synergetic Degree

Province & Cities	2011	2012	2013	2014	2015	2016	2017	Mean Value	Ranking
Beijin	0.0000	0.0804	0.2604	0.3928	0.7626	0.8114	0.8291	0.4481	1
Fujian	0.0000	0.0659	0.1750	0.2756	0.4891	0.6329	0.8530	0.3559	2
Zhejiang	0.0000	0.1689	0.2993	0.3254	0.5996	0.5097	0.5045	0.3439	3
Jiangxi	0.0000	0.2071	0.2752	0.3602	0.5936	0.3266	0.5365	0.3285	4
Jilin	0.0000	0.0230	0.1485	0.2509	0.2459	0.6914	0.6771	0.2910	5
Guangdong	0.0000	0.1044	0.0708	0.2338	0.5545	0.6684	0.3853	0.2882	6
Jiangsu	0.0000	0.0801	0.1790	0.2556	0.3643	0.6044	0.5089	0.2846	7
Shandong	0.0000	0.0336	0.0947	0.1472	0.5336	0.6210	0.5395	0.2814	8
Shaanxi	0.0000	0.2991	0.3144	0.3008	0.2900	0.2483	0.4854	0.2769	9
Qinghai	0.0000	0.1401	0.2890	0.3085	0.3931	0.4756	0.3296	0.2765	10
Yunnan	0.0000	0.2046	0.2255	0.1004	0.4380	0.5947	0.3646	0.2754	11
Shanxi	0.0000	0.1168	0.2530	0.3402	0.3029	0.4857	0.4230	0.2745	12
Shanghai	0.0000	0.1527	0.2506	0.1356	0.3479	0.3844	0.5004	0.2531	13
Hebei	0.0000	0.1062	0.1672	0.0960	0.3133	0.6119	0.4759	0.2529	14
Hainan	0.0000	0.1955	0.1877	0.1548	0.2951	0.3936	0.4865	0.2447	15
Hubei	0.0000	0.1224	0.3351	0.3969	0.3896	0.1533	0.3013	0.2427	16
Liaoning	0.0000	0.1624	0.0590	0.2185	0.2407	0.5244	0.4918	0.2424	17
Anhui	0.0000	0.1536	0.1457	0.0904	0.1540	0.6326	0.4901	0.2381	18
Tianjin	0.0000	0.0837	0.1758	0.2999	0.3165	0.2395	0.4305	0.2208	19
Heilongjiang	0.0000	0.1539	0.0488	0.1486	0.1930	0.5053	0.4395	0.2127	20
Xinjiang	0.0000	0.1484	0.1326	0.1944	0.2701	0.4275	0.2677	0.2058	21
Neimenggu	0.0000	0.2300	0.2150	0.1433	0.2564	0.1775	0.4101	0.2046	22
Henan	0.0000	0.0964	0.2189	0.2059	0.1168	0.3617	0.4227	0.2032	23
Sichuan	0.0000	0.1292	0.1566	0.2060	0.2392	0.3299	0.2383	0.1856	24
Gansu	0.0000	0.1010	0.2441	0.0158	0.1036	0.2751	0.3555	0.1564	25
Hunan	0.0000	0.0965	0.1001	0.2077	0.1309	0.2972	0.2455	0.1540	26
Ningxia	0.0000	0.1152	0.1350	0.2123	0.1370	0.2202	0.2013	0.1459	27
Guizhou	0.0000	0.0756	0.1394	0.1658	0.2549	0.1637	0.1909	0.1415	28
Guangxi	0.0000	0.0563	0.1149	0.1777	0.3703	0.1825	0.0348	0.1338	29

Four provinces and municipalities with an average degree of synergy exceeding 0.3 include Zhejiang and Jiangxi, in addition to Beijing and Fujian. According to the relevant research, Fujian ranks second becasue Fujian Development and Reform Commission has built the 6.18 Collaborative Innovation Institute model and established more than 20 industrial and technological branches, including 7 under construction. Fujian government is speeding up the construction of two cooperative development zones in northeast Fujian and southwest Fujian. The institutional innovation may be the reason for Fujian's high ranking of synergetic degree.

The results of provincial-municipal synergetic degree of three innovation systems is analyzed through average annual growth rate.

Table 2 The Average Annual Growth Rate of Provincial-Municipal Synergetic Degree

Provinces & Citie	2011	2012	2013	2014	2015	2016	2017	Average Annual Growth Rate	Ranking
Gansu	0.0000	0.1010	0.2441	0.0158	0.1036	0.2751	0.3555	1.5974	1
Jilin	0.0000	0.0230	0.1485	0.2509	0.2459	0.6914	0.6771	1.5822	2
Shandong	0.0000	0.0336	0.0947	0.1472	0.5336	0.6210	0.5395	1.0069	3
Beijing	0.0000	0.0804	0.2604	0.3928	0.7626	0.8114	0.8291	0.7552	4
Fujian	0.0000	0.0659	0.1750	0.2756	0.4891	0.6329	0.8530	0.7295	5
Liaoning	0.0000	0.1624	0.0590	0.2185	0.2407	0.5244	0.4918	0.6573	6
Anhui	0.0000	0.1536	0.1457	0.0904	0.1540	0.6326	0.4901	0.6308	7
Heilongjiang	0.0000	0.1539	0.0488	0.1486	0.1930	0.5053	0.4395	0.6301	8
Hebei	0.0000	0.1062	0.1672	0.0960	0.3133	0.6119	0.4759	0.6286	9
Guangdong	0.0000	0.1044	0.0708	0.2338	0.5545	0.6684	0.3853	0.6266	10
Henan	0.0000	0.0964	0.2189	0.2059	0.1168	0.3617	0.4227	0.6092	11
Yunnan	0.0000	0.2046	0.2255	0.1004	0.4380	0.5947	0.3646	0.5760	12
Jiangsu	0.0000	0.0801	0.1790	0.2556	0.3643	0.6044	0.5089	0.5176	13
Tianjin	0.0000	0.0837	0.1758	0.2999	0.3165	0.2395	0.4305	0.4833	14

Hubei	0. 0000	0. 1224	0. 3351	0. 3969	0. 3896	0. 1533	0. 3013	0. 4525	15
Shanghai	0. 0000	0. 1527	0. 2506	0. 1356	0. 3479	0. 3844	0. 5004	0. 4309	16
Shanxi	0. 0000	0. 1168	0. 2530	0. 3402	0. 3029	0. 4857	0. 4230	0. 3751	17
Hunan	0. 0000	0. 0965	0. 1001	0. 2077	0. 1309	0. 2972	0. 2455	0. 3678	18
Zhejiang	0. 0000	0. 1689	0. 2993	0. 3254	0. 5996	0. 5097	0. 5045	0. 3084	19
Jiangxi	0. 0000	0. 2071	0. 2752	0. 3602	0. 5936	0. 3266	0. 5365	0. 2957	20
Neimenggu	0. 0000	0. 2300	0. 2150	0. 1433	0. 2564	0. 1775	0. 4101	0. 2787	21
Guizhou	0. 0000	0. 0756	0. 1394	0. 1658	0. 2549	0. 1637	0. 1909	0. 2759	22
Guangxi	0. 0000	0. 0563	0. 1149	0. 1777	0. 3703	0. 1825	0. 0348	0. 2710	23
Qinghai	0. 0000	0. 1401	0. 2890	0. 3085	0. 3931	0. 4756	0. 3296	0. 2616	24
Hainan	0. 0000	0. 1955	0. 1877	0. 1548	0. 2951	0. 3936	0. 4865	0. 2521	25
Xinjiang	0. 0000	0. 1484	0. 1326	0. 1944	0. 2701	0. 4275	0. 2677	0. 1916	26
Ningxia	0. 0000	0. 1152	0. 1350	0. 2123	0. 1370	0. 2202	0. 2013	0. 1822	27
Sichuan	0. 0000	0. 1292	0. 1566	0. 2060	0. 2392	0. 3299	0. 2383	0. 1580	28
Shaanxi	0. 0000	0. 2991	0. 3144	0. 3008	0. 2900	0. 2483	0. 4854	0. 1566	29

The average annual growth rate of Gansu, Jilin and Shandong are more than 1, mainly because of the large annual fluctuation. In terms of the index of finance system, these three provinces account for a large proportion of local financial supervision expenditure compared with other province. The synergetic degree of average annual growth rate of Beijing and Fujian are still more than 0.7, which is consistent with the above mean value ranking of provincial-municipal synergetic degree. Fujian has a strong momentum of development especially after being approved as the core area of the Maritime Silk Road. In general, the provinces and cities with higher degree of synergy because the collaborative innovation between financial system and institutional system is relatively close.

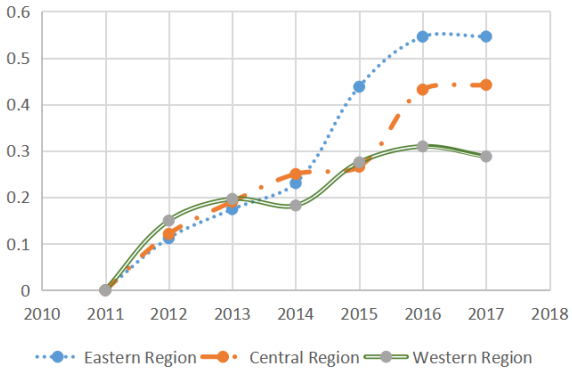
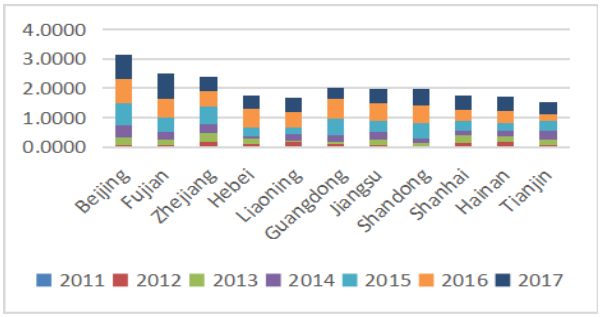


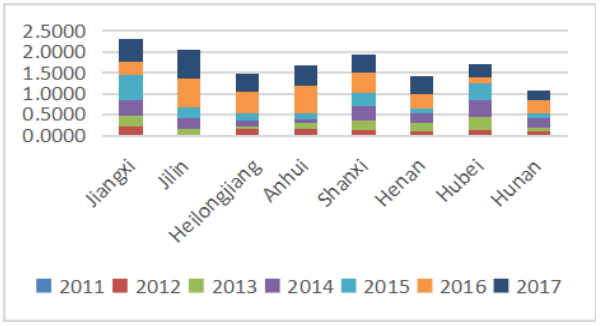
Fig.2 The Synergy Degree of Three Economic Zones

According to the China Statistical Yearbook, China is divided in eastern region, central region and western region. There are 11 provinces and cities in the eastern region, including Beijing, Fujian, Zhejiang etc..8 provinces and cities including Jiangxi, Anhui, Hubei, etc. in the central region. There are 12 provinces and cities in the western region, including Yunnan, Gansu, Qinghai, etc.. However, the following results do not include the two western provinces and cities of Chongqing and Tibet because of lacking some variable data. As shown in the Fig.2, the synergetic degree of three



regions is increasing year by year, but slight decline since 2017. The synergy degree of eastern region is highest including coastal cities most. The western region ranks the lowest. We could read more from the detailed histogram next.

Fig.3 The Total Synergy Degree of Eastern Region



As shown in the Fig.3, the total synergy degree of eastern provinces is above 1.5. Beijing, Fujian, Zhejiang rank top three. Provinces and cities with high synergetic degree are basically concentrated in the eastern region.

Fig.4 The Total Synergy Degree of Central Region

The total synergy degree of the provinces in the central region is between 1.5 -2 mostly, but three provinces are less than 1.5 including Heilongjiang, Henan, and Hunan. The innovation momentum of the central region is still inferior to that of the eastern region, but the growth rate is the largest in general.

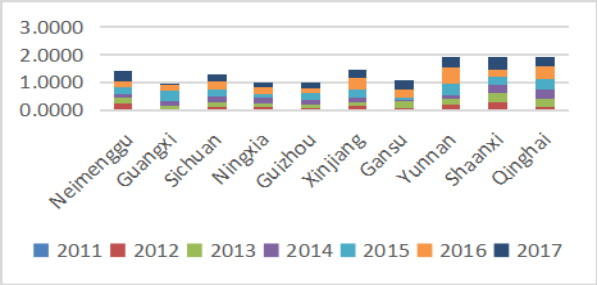


Fig.5 The Total Synergy Degree of Western Region

In the western region, the synergy degree of most provinces are less than 1.5. Only three provinces are between 1.5 -2. They are Yunnan, Shaanxi, Qinghai province because institutional innovation is lagging behind and few financial innovation factors included.

Therefore, we find that it exists a great difference in the synergy degree among different regions because of the uneven distribution of financial resources in the region. The degree of coordination in the eastern coastal region is higher. That in the central region is a little lower, but the degree of order is higher in single system. The average synergy degree in the western region is relatively low. The key reason is that the collaborative innovation between institution system and financial system is poor in the three system's collaborative innovation.

4 Empirical Results

4.1 Empirical model

Therefore, this study proposes the following two hypotheses in the case of China according to the aforementioned analysis.

Hypothesis 1: The synergetic degree of collaborative innovation has a positive impact on the economy in China.

Hypothesis 2: The domestic loans for real estate companies has a negative impact on the economy in China.

This study thus uses official panel data for 29 provinces and cities in China from 2010 to 2017 to verify this assertion. The empirical model adopted in this study is described as Equation (3).

$$lnPGDP_{i,t} = \omega_0 + \omega_1 ln(SYN_{i,t}) + \omega_2 ln(R\&D_{i,t}) + \omega_3 ln(URBAN_{i,t}) + \omega_4 ln(INV_{i,t}) + \omega_5 ln(OPEN_{i,t}) + \omega_6 ln(LIFE_{i,t}) + F_i + \nu_{i,t} \quad (3)$$

In equation (3), we use synergy degree as the main variable and others as the control variable, respectively, to empirically analyze the impact of three kinds of synergy degree on economic growth.

$$lnPGDP_{i,t} = \omega_0 + \omega_1 ln(SYN_{i,t}) + \omega_2 ln(R\&D_{i,t}) + \omega_3 ln(URBAN_{i,t}) + \omega_4 ln(INV_{i,t}) + \omega_5 ln(OPEN_{i,t}) + \omega_6 ln(LIFE_{i,t}) + \omega_7 ln(REALE_{i,t}) + F_i + \nu_{i,t} \quad (4)$$

In Equation (3) and (4), ω_0, F_i, and ν_{it} stand for the constant term, the fixed-effect or random-effect level of province i, and the random error term of province i in year t, respectively, where i=1, 2, …, 29 and t=2010, 2011, …, 2017. $PGDP_{i,t}$ stands for the real per capita gross domestic product (GDP) of province i in year t. $INV_{i,t}$ is the investment activity, $OPEN_{i,t}$ is the degree of openness, $LIFE_{i,t}$ is the life expectancy variable, $URBAN_{i,t}$ is the urbanization process, and $R\&D_{i,t}$ represents R&D activities. All variables are in logarithmic form to avoid high degrees of volatility and non-stationarity.

$SYN_{i,t}$ is the synergy degree of the collaborative innovation. SYN1 stands for the synergy degree of technological innovation and institutional innovation. SYN2 stands for the synergy degree of technological innovation and financial innovation. SYN3 stands for the synergy degree of three systems of technological innovation, institutional innovation and financial innovation.

We find that financial institutions' support for real estate will affect financial innovation, which will further negatively affect collaborative innovation. $REALE_{i,t}$ is the domestic loans for real estate companies. So we construct equation (4) model. The methods used to estimate Equation (3) and (4) are the fixed-effects model.

4.2 Analysis of Empirical Results

As for the problem of endogeneity, Durlauf *et al.* (2005) attached great importance to the endogeneity test of variables and even leveled the criticism sometimes made that the empirical convergence literature is based on a failure to account for the endogeneity of the explanatory regressors in the growth regression[17]. In order to avoid this potential endogeneity problem for some explanatory variables, these explanatory variables in Model 2 are their one-year lagged values.

Table3 Empirical Results of Fixed-Effects

Variables	Model 1			Model 2		
SYN1	0.0045			-.0001		
	(0.0056)			(0.0057)		
SYN2		0.0164***			0.0134***	
		(0.0045)			(0.0043)	
SYN3			0.0135**			0.0088
			(0.0054)			(0.0054)
INV	0..2058***	0.2068***	0.2064***	0.2061***	0.2056***	0.2050***
	(0.0261)	(0.0247)	(0.0254)	(0.0252)	(0.0243)	(0.0249)
OPEN	0.0042	0.0062	0.0118	0.0138	0.0180	0.0206
	(0.0182)	(0.017)	(0.018)	(0.0170)	(0.0160)	(0.0169)
LIFE	2.634***	2.5575***	2.4831***	3.2676***	3.2020***	3.1448***
	(0.6158)	(0.5588)	(0..584)	(0.5858)	(0.5499)	(0.5676)
URBAN	0.2262	0.1071	0.1786	0.2740**	0.2136	0.2710**
	(0.1554)	(0.1509)	(0.1528)	(0.1378)	(0.1345)	(0.1363)
R&D	0.2468***	0.2466***	0.2393***	0.2257***	0.2124***	0.2111***
	(0.0415)	(0.0383)	(0.040)	(0.0357)	(0.0332)	(0.0349)
Constant	-6.1612**	-5.9228**	-5.5496**	-8.7483***	-8.3571***	-8.1029***
	(2.6172)	(2.3346)	(2.4465)	(2.4475)	(2.2622)	(2.3454)
Obs.	145	145	145	174	174	174
F-statistic	216.75***	243.67 ***	228.89 ***	397.86***	426.75***	405.89***
	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
R-squared	0.9220	0.9300	0.9258	0.9450	0.9485	0.9460
Hausman Test	54.10	57.61	54.92	62.93	63.83	61.34
	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)

Prior to estimating equation (3), the Hausman test is adopted to determine which of the random-effects model and fixed-effects model is better in this study. In Table 3 and Table 4, the p-value of the cross-section random test is less than 0.001, implying that the Hausman test rejects the null hypothesis of the random-effects model. Therefore, the fixed-effects model is the better empirical model in this study.

In Table3, the coefficients of *INV*, *LIFE*, and *R&D* are all statistically and significantly positive implying that these three explanatory variables have a positive influence on China's economic growth. It means that both life expectancy and R&D can stimulate the economic growth of China due to the longer life expectancy contributing to capital accumulation and thus promoting economic growth. In addition, R&D is the factor of technological progress and further increases economic growth. The main coefficient of SYN2, SYN3 are statistically and significantly positive regardless of whether they are in Models 1 or 2, except SYN1. Then we continue to use equation (4).

The primary explanatory variables are SYN2, SYN3 and REALE in equation (4). The coefficients of SYN2 and SYN3 are statistically and significantly positive. This finding is also consistent with that in Table 3 and thus supports our first hypothesis that synergetic degree of collaborative innovation has a positive impact on the economy in China. The coefficient of REALE is statistically and significantly negative, and thus supports our second hypothesis that domestic loans for real estate companies has a negative impact on the economy in China.

Table4 Empirical Results of Fixed-Effects

Variables	Model 1		Model 2	
SYN2	0.0167***		0.0134***	
	(0.0044)		(0.0043)	
SYN3		0.0156***		0.0095*
		(0.0054)		(0.0054)
REALE	-0.0370*	-0.0440**	-0.0137	-0.0171
	(0.0191)	(0.0199)	(0.0170)	(0.0175)
INV	0.2314***	0.2355***	0.2164***	0.2184***
	(0.0275)	(0.0282)	(0.0278)	(0.0284)
OPEN	0.0128	0.0210	0.0204	0.0241
	(0.0172)	(0.0181)	(0.0163)	(0.0173)
LIFE	2.7357***	2.6554***	3.2824***	3.2359***
	(0.5596)	(0..5791)	(0.5596)	(0.5753)
URBAN	0.0613	0.1198	0.1869	0.2377*
	(0.1509)	(0.1525)	(0.1387)	(0.1405)
R&D	0.2493***	0.2404***	0.2145***	0.2127***
	(0.0378)	(0.0391)	(0.0334)	(0.0349)
Constant	-6.8904***	-6.5213***	-8.8170***	-8.2680***
	(2.3596)	(2.4440)	(2.3358)	(2.4067)
Obs.	145	145	174	174
F-statistic	214.61 ***	203.85 ***	364.96***	347.93***
	(<0.001)	(<0.001)	(<0.001)	(<0.001)
R-squared	0.9324	0.9290	0.9488	0.9464
Hausman Test	59.69	57.73	63.79	61.86
	(<0.001)	(<0.001)	(<0.001)	(<0.001)

It shows that if the collaborative innovation of technology and institution may not have a significant positive impact on economic growth to some extend. If finance factor is added as an important condition for collaborative innovation, the synergetic degree has a significant positive effect on economic growth.

The primary finding of empirical results is that the degree of collaborative innovation among technology, institution and finance can positively affect China's economic growth. If the synergy degree of collaborative innovation increases by 1%, and the GDP per capita will also increase by about 0.009%-0.016%.

However, the domestic loan index of real estate enterprises has a negative impact on the per capita GDP, in which the financial institution loan is the main source of financing for real estate development enterprises. Based on the factors of risk and rate of return, the higher the proportion of real estate loans, the higher the ratio of crowding-out effect on technological innovation caused by financial institutions' preference to loan to real estate. It means that financial support for real estate has a significant negative impact on economic growth, and will weaken the support for collaborative innovation and slow down the incubation of technological innovation achievements.

The coefficient of SYN3 is smaller than that of SYN2, which means that the main problem still lies in institutional innovation. Institutional innovation

lags behind the other two innovation system. It will be the system that needs to be adjusted in collaborative innovation in the future.

5 Conclusion and Discussion

Based on the theory above, this paper puts forward the view that it should build up three systems' collaborative innovation among technology, institution and finance. we measure the synergetic degree of 29 provinces and cities through synergetic degree model of composite system. Then official panel data for 29 provinces and cities in China from 2010 to 2017 are used to verify two hypotheses. The conclusions of this paper are as follows:

Firstly, the synergetic degree of three regions is increasing year by year, but slight decline since 2017. The eastern region ranks the highest but the western region gets the lowest. Beijing, Fujian and Zhejiang rank top three in the result of the mean value of provincial-municipal synergetic degree.

Secondly, from 2010 to 2017, synergetic degree of collaborative innovation has a positive impact on the economy in China. the synergy degree of collaborative innovation increases by 1%, and the GDP per capita will also increase by about 0.009%-0.016%.

Thridly, the coefficient of REALE is statistically and significantly negative. The higher the proportion of real estate loans, the higher the ratio of crowding-out effect on technological innovation. Financial support for real estate will weaken the support for collaborative innovation

We propose some relevant policy recommendations based on the conclusion above.

Firstly, from the perspective of the transformation of China's economic growth dynamics and the environmental requirements of green and sustainable growth, it is an effective mechanism to continuously improve the degree of collaborative innovation among technology, institution and finance to achieve high-quality economic growth in China.

Secondly, based on the obvious difference of regional efficiency in the synergy degree of collaborative innovation among provinces, supplementing the technical deficiency, streamlining administration and delegating power of government, or activating the capital market could be chosen and adopted by different provinces and cites according to the different stages of development of them.

Thirdly, government should think the role of institutional innovation among collaborative innovation and should vigorously develop multilevel capital market, reduce capital's preference for real estate investment, guide capital investment to innovation tendency, and optimize the ratio of capital investment between real economy and virtual economy. In terms of financing scale and structure, we should further develop the direct financial market, reduce the financing costs of small and medium-sized enterprises, and improve the investment environment to support independent innovation in China.

Acknowledgement

This research was financially supported by Fujian University of Technology Research Start-up Project under grant GY-S20008.

References:

[1] Nelson R R, The Co-evolution of Technology, Industrial Structure, and Supporting Institutions, *Industrial & Corporate Change*, Vol.3, No.1 1994, pp. 47-63.

[2] Murmann P J, *Knowledge and Competitive Advantage: The Co-evolution of Firms, Technology, and National Institutions*, Cambridge University Press, 2003.

[3] Wang X, Gao S, Contribution of Collaborative Innovation of Science and Technology Progress to Economic Growth about Northeast Construction Industry, *Science Technology and Industry*, Vol.18, No.5, 2018, pp. 44-47.

[4] Cui Z X, Chen Y, Study on the Efficiency Measurement and Evolution Characteristics of Regional Technological Collaborative Innovation——Take the Beijing-Tianjin-Hebei Region and the Yangtze River Delta Region as Examples, *Contemporary Economic Management*, Vol.41, No.3, 2019, pp. 61-66.

[5] Wang X L, Yuan Y M, How Could China Avoid the Middle Income Trap: Based on Institutional Equity and Human Capital Perspectives, *Economic Review*, No.6, 2015, pp. 3-16.

[6] Phung T D , Van V T T , Thuong T T H , et al, Innovation and Economic Growth: The Contribution of Institutional Quality and Foreign Direct Investment, *Asian Economic and Financial Review*, vol.9, No.11, 2019, pp.1266-1278.

[7] Levine R, Financial Development and Economic Growth: Views and Agenda, *Journal*

of Economic Literature, No.35, 1997, pp. 688-726.
[8] Beck T, Levine R, Loayza N, Finance and the sources of growth, *Journal of Financial Economics*, Vol.58, No.1, 2004, pp. 261-300.
[9] Saviotti P P, Pyka A, The Co-evolution of Technologies and Financial Institutions, *Chapters*, No.1, 2009, pp. 81-100.
[10] Chen Y, Zhou X L, Chen X F, Financial structure optimization and financial system reform from the perspective of technological innovation, *Journal of Fuzhou University (Philosophy and Social Sciences Edition)*, Vol.30, No.4, 2016, pp. 27-34.
[11] Liu X Y, Wu W Y, The Synergetic Evolution Mechanism and Empirical Test of Sci-Tec-Finance and High-tech Industry: Based on the Practice of Guangdong Province, *Journal of Guangdong University of Finance & Economics*, Vol.33, No.3 2018, pp. 22-34.
[12] Ba S S, Zhang N, Discussion on Financial Innovation and Supervision Based on System Defects, *Academic Monthly*, No.1, 2004, pp. 12-17.
[13] Ma Y Q, Research on Institutional Environment of Financial Innovation, *Contemporary Economic Management*, Vol.33, No.10, 2011, pp. 87-91.
[14] Jiang Y T, Shi Y Z, The Motive Force of Financial Innovation of my country's Commercial Banks and the Construction of Supervision, *Research on Financial and Economic Issues*, No.11, 2016, pp. 51-58.
[15] Su J, A Comparative Institutional Analysis of Financial Structure to Promote Technological Innovation—From the Perspective of Institutional Complementarity, *East China Economic Management*, Vol.32, No.12, 2018, pp. 152-163.
[16] Meng Q S, Hang W X, Research on Coordination Model of Compound System, *Journal of Tianjin University*, Vol.33, No.4, 2000, pp. 444-446.
[17] Durlauf, S N, Johnson P A, Temple J R W, Growth Econometrics, *Handbook of Economic Growth*, Vol.1A, 2005, pp. 556-663.