A Study on the Evolutionary Game of Digital Collaborative Innovation Between Industry, Academia and Research in Small and Medium-sized Manufacturing Enterprises

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Abstract. Small and medium-sized manufacturing enterprises, as the main body of China's manufacturing industry, bear the important task of building a manufacturing power, network power, its sustained and rapid development can not be separated from the scientific innovation model, combined with today's emerging technology innovation and the market economy environment changes, digitalization and digital synergy has become a factor to promote the rapid development of the national economy in the new economic era, and to promote the formation of small and medium-sized digital resources for core competitiveness of the new mode of collaborative innovation, to achieve the integration of development is an inevitable trend. To promote the formation of digital resources as the core competitiveness of small and medium-sized manufacturing enterprises, industry-university-research collaborative innovation new model, to achieve the integration of the development of the leap is an inevitable trend. Therefore, with the help of digital means, the article tries to take the digital collaborative innovation of industry-university-research institutes as the research object, establishes the evolution game of digital collaborative innovation of industry-university-research institutes of small and medium-sized manufacturing enterprises, and carries out simulation on the results of the model to analyze the changes of each parameter and its role in the results under the finite rationality. The results show that the direct benefit of digital collaborative innovation, the coefficient of benefit distribution, government support and other factors have the effect of improving the innovation efficacy of digital collaborative innovation of industry-university-research by enhancing the profit of enterprises. Finally, based on the results, countermeasure suggestions to enhance the independent innovation ability of China's small and medium-sized manufacturing enterprises are proposed from the perspective of digital industry-university-research fusion development.

Keywords: Small and Medium-sized Manufacturing Enterprises; Industry-University-Research Collaboration; Digitization; Evolutionary Games; Innovation

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1 Introduction

General Secretary Xi's 19th National Congress report proposes to accelerate the construction of an innovative country, especially to increase support for innovation of small and medium-sized enterprises (SMEs) and promote the transformation of scientific and technological achievements. According to the statistics of the Ministry of Industry and Information Technology, the main body of China's manufacturing industry is "small and medium-sized enterprises", accounting for more than 90%. Therefore, the digital transformation and upgrading of small and medium-sized manufacturing enterprises is the foundation for building a strong manufacturing country and a strong network country. At present, domestic research on the digital transformation of small and medium-sized manufacturing enterprises is very rich, Wang Yu [9]and other research pointed out that the current digital transformation of small and medium-sized enterprises in the digital transformation of the problems that exist: digital technology in small and medium-sized enterprises in the application of the breadth and depth of the need to improve the digital ecosystem of the need to strengthen the support of high-end elements, facing the demand to join the collaborative innovation system to enhance their own level of development. It can be seen that small and medium-sized manufacturing enterprises lack the ability of digital technology innovation. In order to reach scientific research and innovation resources faster, enterprises often tend to cooperate with universities and scientific research units with high innovation capability, creating a new technology innovation ecology of industry-university-research collaboration [6]. However, there are still problems of poor internal and external environmental drivers in development investment, technological innovation activities, and the application of innovation results, which are mainly due to the obstacles of digital knowledge sharing, irrational industrial structure, low conversion rate of innovation results, and limited governmental support [11]. Therefore, there is an urgent need for small and medium-sized manufacturing enterprises to improve the internal and external driving force of the industry and form a new type of science and technology innovation system. Combined with the innovation of today's emerging technologies and changes in the general environment of the market economy[3], digitalization and digital collaboration have become a factor to promote the rapid development of the national economy in the new economic era, and it is an inevitable trend to promote the formation of a new model of industry-university-research collaborative innovation in small and medium-sized manufacturing enterprises with digital resources as the core competitiveness, and to realize the leaping and integrative development.

Therefore, this paper takes industry-university-research digital coordination and innovation as a way to enhance the development of small and medium-sized manufacturing enterprises, takes the digital integration development mode as an opportunity, introduces the game model, takes the small and medium-sized manufacturing enterprises and the research institutions as the two sides of the game, and regards the game behavior of the two sides as that of the finite rational subject under incomplete information. And the government's support is quantitatively included in the study of the relationship between small and medium-sized manufacturing enterprises, industry, academia and research institutes of digital collaborative innovation, through the gov-

ernment guidance to promote the flow of external funds and internal funds, and promote industrial agglomeration. The digital platform is used to construct a platform ecology of close collaborative innovation between the two sides, obtain financial support for digital innovation, optimize the information barrier between the links from original innovation to the transformation of results with the help of digital factors, alleviate the problems of information asymmetry and resource asymmetry, increase the dynamics of the innovation and development of small and medium-sized manufacturing enterprises, and realize the supportive nature of the "digital-physical" fusion economy. The supportive effect of the "digital-physical" fusion economy and the leading role of digitization.

2 Evolutionary Game Theory Analysis

2.1 Theoretical analysis

In the process of digital collaborative innovation between industry, academia and research, small and medium-sized manufacturing enterprises and academic and research institutions, etc. are faced with factors such as uncertainty and risk, and they make strategic choices between the traditional operation mode as well as the digital collaborative innovation mode, which is consistent with the theoretical characteristics of the evolutionary game. Among them, the traditional operation mode refers to the process of value creation of small and medium-sized manufacturing enterprises through a unidirectional channel [5]. The digital co-innovation mode refers to the integration and optimization of small and medium-sized manufacturing enterprises to form a fusion and interaction mode of digitalization, informatization and ecology by integrating and optimizing their comprehensive analytical ability, connectivity, and intellectual ability. Therefore, it is reasonable to construct an evolutionary game model to study the choice of digital co-innovation of industry-university-research in equipment small and medium-sized manufacturing enterprises.

2.2 Model assumptions

In this paper, the following basic assumptions will be made based on the principle of finite rationality, combined with the theories of system evolution theory and game theory:

Assumption 1: In the "natural" state, small and medium-sized manufacturing enterprises and academic and research institutions as the main body of digital collaborative innovation, the two subjects are recognized as "limited rationality" because of their unique resources and information. Both parties will start from the perspective of their own common interests and choose the cooperation strategy that is favorable to their common development. Therefore, the game between small and medium-sized manufacturing enterprises and academic and research institutions are represented by the following symbols, academic and research institutions for A, small and medium-sized manufacturing enterprises for B, A, B have two strategy sets of choice, respectively, the "digital collaborative innovation mode" or "traditional operation mode

A and B have two strategy sets to choose from, which are "digital collaborative innovation model" or "traditional operation model" strategy.

Hypothesis 2: The University-Industry-Research model forms an interactive effect through technological innovation cooperation, whereby enterprises provide innovation funds, give universities and other scientific research institutions as well as strong human and material support for technological innovation, and at the same time utilize the technological and knowledge innovation results developed by the universities and other scientific research institutions to help themselves make profits, so that all parties can gain benefits through innovation. However, due to the inconsistency of interests and information asymmetry between the two parties, it is very likely to lead to "free-riding" and opportunistic behaviors. Therefore, the action strategies of each innovation subject are constantly changing. Therefore, if one of the small and medium-sized manufacturing enterprises and research institutions choose to carry out digital collaborative innovation, and the other chooses the traditional mode of operation, the subject who chooses the digital system of innovation will have an increase in profit Ri (i=a,b), and the subject who chooses the traditional mode of operation will have a decrease in profit Ri.

Hypothesis 3: Considering the obvious uncertainty of decision-making between the subjects of digital collaborative innovation of both sides, although the subjects of digital collaborative innovation are to realize the common goal of forming a community, but the process of digital collaborative innovation of industry-university-research institutes may be due to the interests of the interests of the other aspects of the conflict of time, resources, etc., and the phenomenon of "betrayal" may occur. However, in the process of digital collaborative innovation, there may be "betrayal in the middle" because of conflicts in interests, time, resources, etc. Under this condition, small and medium-sized manufacturing enterprises and academic and research institutions continue to operate according to the previous "traditional mode of operation", and can only get the normal income, academic and research institutions A to obtain the investment income of Ia, small and medium-sized manufacturing enterprises B to obtain the investment income of Ib.

Assumption 4: If the small and medium-sized manufacturing enterprises choose the strategy of "digital collaborative innovation mode" and the academic and research institutions choose the strategy of "traditional operation mode", then the small and medium-sized manufacturing enterprises must independently upgrade and transform their existing production lines, hardware equipment, software facilities, etc., according to the requirements in the process of technological innovation. If the academic and research institutions choose the "digital collaborative innovation mode" strategy, while the small and medium-sized manufacturing enterprises choose the "traditional operation mode" strategy, the academic and research institutions need to invest a certain amount of cost to obtain technical support, or to invest in the industry with influence, etc. The SMEs choose the "traditional operation mode" strategy, because the academic and research institutions need to invest certain costs to obtain technical support, or invest in the industry with influence and other business. Suppose the original cost is Ci(i=a,b). If both parties work closely together through digitalization to realize personalized service customization, SMEs significantly improve the quality

and universality of their products, and the academic and research institutions also hold a sincere attitude of positive cooperation and develop high-quality results to improve the level of the industry, the benefits of both parties will be increased. Therefore, the benefit coefficient for SMEs and research institutions through digital collaborative innovation is set to α (α>1).

Hypothesis 5: The relationship between lower and middle manufacturing enterprises and academic and research institutions is one of interdependence and close association, and both parties effectively utilize and complement each other's resources and technological advantages to a certain extent. If the academic and research institutions A and small and medium-sized manufacturing enterprises B are selected "digital collaborative innovation model" strategy, small and medium-sized manufacturing enterprises in the factors of production and other aspects of innovation, the academic and research institutions of technical support, then the role of technological cooperation and innovation between enterprises will produce a reduction in the cost of inputs, the cost of this time became Ti (i = a, b). And it brings additional benefits N. The distribution coefficient of the academic and research institutions is g, and the benefit distribution coefficient of the small and medium-sized manufacturing enterprises is 1-g.

Hypothesis 6: It is not enough to rely solely on the support and participation of enterprises, institutions of higher education, research units and other personnel in the digital collaborative innovation of industry-university-research, and the government's management and supervision of industry-university-research collaboration is impossible to be ignored. If the government's support and participation is greater, it will increase the investment of special funds to promote the collaborative innovation of industry-university-research, and reduce the cost of expenditure by government subsidies. Therefore, let the government support strength be β, β between [0,1], and the subsidy cost obtained by the subject is βCi(i=a,i=b).

Assumption 7: In the whole process of cooperation between academic and research institutions and SMEs, the probability of choosing "digital co-innovation" between A and B is x and y, respectively, and the probability of choosing the traditional mode of operation is 1- x, 1- y, x, y ∈ [0,1], respectively, which are all functions of time T. The probability of choosing "digital co-innovation" between A and B is 1- x, 1- y, x, y ∈ [0,1], respectively.

3 Game Evolution Mode

3.1 Build the model

Based on the above assumptions, the benefit payment matrix of digital co-innovation between academic and research institutions and SMEs is constructed, as shown in Table 1.

Table 1. Matrix of payments for digital co-innovation benefits between academic and research institutions and SMEs

		small or medium sized manufacturing enterprise (SME)	
		Digital Collaborative Innovation Model	Traditional mode of operation
academia	Digital Collaborative Innovation Model	Ia+αIa+gN+βCa-Ta	Ia+ Ra+αIa+βCa-Ca
		Ib+αIb+(1-g)N+βCa-Tb	Ib-Rb
	Traditional mode of operation	Ia-Ra	Ia
		Ib+Rb+αIb+βCb-Cb	Ib

3.2 Evolutionary game model analysis

Due to the matrix of benefit payments, it can be seen that under the "traditional mode of operation" strategy adopted by the academic and research institutions, Rb+αIb+βCb-Cb is difference in investment returns between two different strategies for small and medium-sized manufacturing firms ;Under the strategy of "Digital Collaborative Innovation Mode", Rb+αIb+(1-g)N+βCa-Tb is the difference of investment returns between two different strategies chosen by SMEs; under the strategy of "Traditional Operation Mode", Ra+αIa+βCa-Ca is the difference of investment returns between two different strategies chosen by academic research institutions. Under the strategy of "traditional operation mode", Ra+αIa+βCa-Ca is the investment return difference between the two different strategies chosen by the academic and research institutions; under the strategy of "digital collaborative innovation mode" adopted by small and medium-sized manufacturing enterprises, Ra+αIa+gN+βCa-Ta is the investment return difference between the two different strategies chosen by the academic and research institutions. The following inferences are drawn from this group of approaches:

(1) When Ib-Rb-αIb-βCb ≦ (1-g) N+Cb-Tb and Ca-Ra-αIa-βCa≦gN+Ca-Ta, (0,0) is the local stabilization point in the development and evolution of the whole system. This state will become the least favorable digital collaborative innovation between SMEs and research institutes, that is, SMEs and research institutes are not willing to collaborate on innovation, the return on investment of both is less than 0, and the R&D cost of industry-university-research collaborative technological innovation is too high, which is higher than the return on investment of both sides under the strategy of "Digital Collaborative Innovation", so both sides take into consideration the "Digital Collaborative Innovation". Therefore, considering the impact of economic costs, both parties will choose to adopt the "traditional operation mode" strategy to carry out technological innovation alone, and the final result will evolve into a stable state of (traditional operation mode, traditional operation mode). The above analysis shows that small and medium-sized manufacturing enterprises in the innovation chain and the industrial chain between the small and medium-sized manufacturing enterprises to reflect the lack of technological innovation ability, in the digital frontier, product iteration is increasingly fast, the product life cycle is gradually shortened, the small and medium-sized manufacturing enterprises in every link of the choice and

decision-making are facing greater risks, relying solely on the knowledge transfer capacity of the academic and research institutions, the pressure on the academic and research institutions is too much, the industry-academia-research innovation performance is generally poor. The overall performance is poor.

(2) When $Ra+\alpha Ia+\beta Ca-Ca \geqq 0$ and $Rb+\alpha Ib+(1-g)\ N+\beta Ca-Tb \leqq 0$, (1,0) is the local stabilization point of the whole system development and evolution process. In this stable state, academic and research institutions are more willing to cooperate with small and medium-sized manufacturing enterprises (SMEs) to carry out research and development of digital technology innovation, while SMEs choose the "traditional operation mode" strategy. The above analysis shows that: after the digital collaborative innovation by industry, academia and research, the knowledge transfer from academic and research institutions promotes the industrialization of knowledge, but only through the relatively long time of cooperation between industry, academia and research can slowly promote the innovation performance as well as the improvement of the innovation performance of the equipment manufacturing industry. In this process, the academic and research institutions have improved their own knowledge transformation ability, but the return on investment is slower for small and medium-sized manufacturing enterprises, which need to rapidly improve the integration ability of resources and information in the ever-changing development due to the uncertainty of disruptive technologies and market demand. Therefore, when the return on investment through digital co-innovation is low, small and medium-sized manufacturing enterprises will be less willing to participate in digital co-innovation, and will ultimately choose the "traditional mode of operation" strategy.

(3) At $Ra+\alpha Ia+gN+\beta Ca-Ta \geqq 0$ and $Rb+\alpha Ib+\beta Cb-Cb$, (0,1) is the local stabilization point in the development and evolution of the whole system. Small and medium-sized manufacturing enterprises are more willing to cooperate in digital collaborative innovation and research and development, while academic and research institutions choose the "traditional operation mode" strategy. For small and medium-sized manufacturing enterprises, the research and investment required through the digital collaborative innovation strategy is much lower than the investment and benefit under the "traditional operation mode" strategy, while for academic and research institutions, under the "digital collaborative innovation mode" strategy, the digital collaborative innovation mode is much lower than the investment and benefit under the "traditional operation mode" strategy. For the academic and research institutions, in the small and medium-sized manufacturing enterprises to adopt the "digital co-innovation model" strategy, the digital co-innovation of the investment return is reduced, the role of government subsidies and technological level and so on to reduce their R&D costs, independently engaged in the technological revolution. After many iterations, the system is stabilized to (digital collaborative innovation mode, traditional operation mode) this state. The above analysis shows that: after the digital collaborative innovation of industry-university-research institutes, small and medium-sized manufacturing enterprises have to grasp both innovation and market with one hand, so that the digital technology research and development can truly realize the integration of industry-oriented basic research and applied research under the dual drive of industrial demand and technological innovation. Among them, the academic and research insti-

tutions as a "wisdom aid" is the science and technology innovation goals can be implemented as the basis and guarantee, can be a good solution to its innovation difficulties.

(4) When $Ra + \alpha Ia + gN + \beta Ca\text{-}Ta \geqq 0$ and $Rb + \alpha Ib + (1 - g)N + \beta Ca\text{-}Tb \geqq 0$, (1, 1) is the stabilization point of the whole system in the process of development and evolution. This state is considered to be the most ideal state. Both sides of the industry-university-research are willing to digitize technology innovation and product development, and for small and medium-sized manufacturing enterprises and academic and research institutions, the investment returns obtained from digital collaborative innovation plus the investment returns created by the digital platform capabilities are greater than the total R&D costs due to the government subsidies as well as the reduction of the role of technological enhancement. Therefore, in this case, both parties are willing to digital co-innovation to obtain a greater return on investment, the system will gradually evolve to the ideal state (digital co-innovation model, digital co-innovation model). The above analysis shows that: after the digital co-innovation of industry-university-research institutes, the research institutes develop rapidly on the basis of the original technology by industrialization of the market demand, the small and medium-sized manufacturing enterprises also realize the significant improvement of the innovation ability and the promotion of the performance of the digital co-innovation, both sides of the game in the digital change to improve the adaptive ability to the innovation environment through the merger of the departments, optimization of the enterprise system, and personnel turnover adjust the internal management, improve the R & D process and scientific research results. management, and improve the level of internal collaboration in the R&D process and scientific research results.

3.3 Simulation analysis

In order to better analyze the impact of each parameter on the digital collaborative innovation of industry-university-research institutes, this paper adopts the method of simulation to simulate the changes of small and medium-sized manufacturing enterprises and academic and research institutes in the choice of digital collaborative innovation mode strategy, and quantitatively analyze the impact of each factor on collaborative innovation. In terms of literature and real cases, the parameter value setting refers to the rules for determining the parameter value in the existing literature as well as real cases [1][2][4][7][8][10].

(1) Impact of α on digital collaborative innovation between industry, academia and researchers

With other factors unchanged, the Figure 1 shows the impact on digital collaborative innovation of small and medium-sized manufacturing enterprises (SMEs) and academic and research institutions (ARIs) when the direct benefit coefficient takes the values of 1, 1.5, 2, and 2.5, respectively. α as the value increases gradually, the probability of digital collaborative innovation of industry-academia-research institutes evolves toward being 1. It can be seen that the direct benefit coefficient has a positive driving effect. Industry-university-research digital collaborative innovation mode and

digital close integration to promote the development of China's small and medium-sized manufacturing enterprises industry, is to promote the innovation drive to the direction of the greater market demand for the transformation of the guarantee. Promote the deep integration of the "Internet +" digital era and the traditional real economy, realize the integration and development of digital modern technology means based on mobile Internet technology, open up the innovation chain, industrial chain, capital chain between small and medium-sized manufacturing enterprises and other institutions, realize the interconnection and interoperability between enterprises, and continuously improve the efficiency of innovation, and ultimately build the innovation process information sharing, interoperability and interoperability, and continuously improve the efficiency of innovation. Eventually build a digital collaborative innovation system with information sharing in the whole process of innovation and efficient collaboration of resources and business. The change curve shows that the higher the direct benefit coefficient is, the more significant the change trend is, the more indirect investment both parties in the game get, and the higher the probability of digital collaborative innovation.

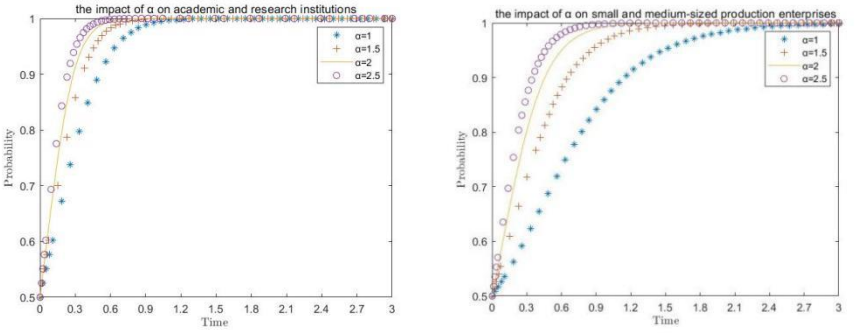

Fig. 1. Impact of α on academic and research institutions and small and medium-sized manufacturing enterprises (SMEs)

(2) Impact of N on digital co-innovation between industry, academia and researchers

As can be seen in Figure 2, the benefits can promote academic and research institutions and small and medium-sized manufacturing enterprises to choose the strategy of digital collaborative innovation. The greater the synergistic gains from the synergistic effects generated when both sides of the game choose to implement digital collaborative innovation, the more likely both sides of the game will choose to implement digital collaborative innovation. It can also be seen through Figure 2, when N takes the value of 1, 1.5, 2, 2.5, the curve to the probability of 1 evolution speed gap is not large, Thus it can be seen that the gap is not large synergistic gain on small and medium-sized manufacturing enterprises and academic and research institutions to carry out the digital collaborative innovation mode of incentive effect is not very obvious. In summary, the synergy gain has a positive promotion effect on the choice of digital collaborative innovation of small and medium-sized manufacturing enterprises, and the larger the synergy gain, the more small and medium-sized manufacturing enter-

prises are inclined to carry out the digital collaborative innovation of industry-university-research institutes.

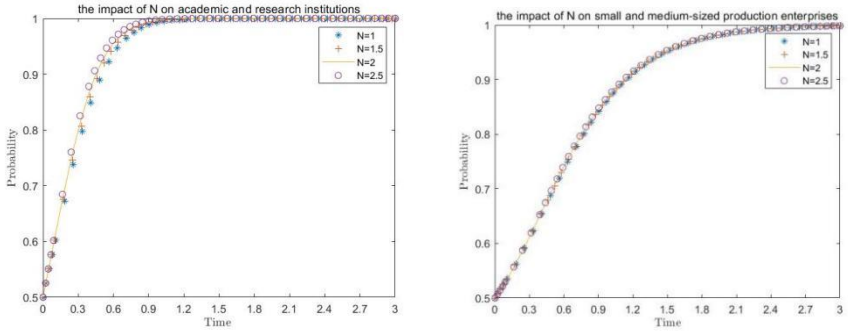

Fig. 2. N Impact on academic and research institutions and small and medium-sized manufacturing de-enterprises

(3) Impact of g on digital co-innovation between industry, universities and researchers.

According to (2), it can be concluded that the benefits brought by digital co-innovation have a positive promotion effect on the choice of digital co-innovation by small and medium-sized manufacturing enterprises (SMEs) and academic and research institutions (ARIs), and the impact of the simulation benefit distribution coefficient g on the strategies of SMEs and ARIs on digital co-innovation is simulated while other elements remain unchanged. As can be seen in Figure 3, the curve evolves toward probability g when g takes 0.2, 0.4, 0.5, and 0.8 respectively. This indicates that digital collaborative innovation brings benefits, and with the increase of the benefit distribution coefficient, the probability that academic and research institutions and small and medium-sized manufacturing enterprises choose digital collaborative innovation tends to be close to 1. However, since the gap between the curve evolution speeds is not large, it can be seen that the benefit distribution coefficients with a small gap do not have a very obvious incentive effect on small and medium-sized manufacturing enterprises and academic and research institutions to carry out the digital collaborative innovation mode. In summary, the synergy gain has a positive promotion effect on small and medium-sized manufacturing enterprises to choose digital co-innovation, at the same time, the larger the gain coefficient means the larger the gain, then both parties are more willing to choose the digital co-innovation of industry, academia and research.

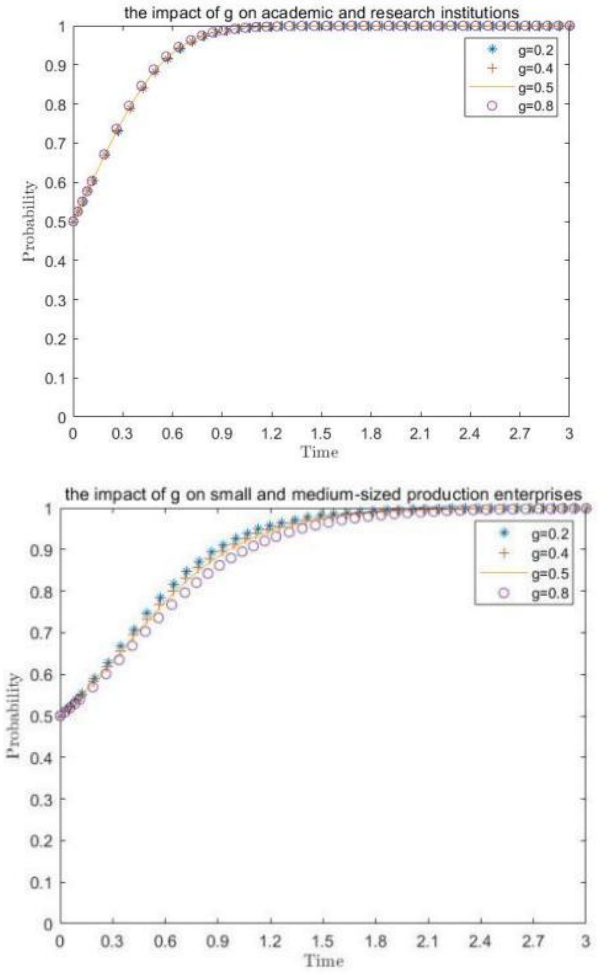

Fig. 3. Impact of g on academic and research institutions and small and medium-sized manufacturing go-betweens

(4) Impact of β on digital co-innovation between industry, universities and research institutes.

When other elements are unchanged, the impact of government subsidy β on the implementation of digital transformation of manufacturing enterprises is simulated. As can be seen in Figure 4, β takes the values of 0.2, 0.4, 0.5, 0.8. When β takes the value of 0.2, the curve tends to the direction of 0, indicating that at this point in time, academic and research institutes and small and medium-sized manufacturing enterprises tend to the traditional mode of operation, do not carry out digital co-innovation; when β takes the values of 0.4, 0.5, 0.8, the curve begins to change to tend to 1, and the slope is getting bigger and bigger, tend to choose digital co-innovation faster and faster. When β takes the value of 0.4, 0.5, 0.8, the curve begins to change to tend to 1,

and the slope is getting bigger and bigger, tends to choose the trend of digital collaborative innovation faster and faster. This shows that government subsidies have a positive promotion of small and medium-sized manufacturing enterprises, industry, academia and research digital co-innovation, when the greater the government subsidies, the more conducive to promote small and medium-sized manufacturing enterprises and academic and research institutions to choose digital co-innovation. This fully demonstrates that in digital technological innovation, for small and medium-sized manufacturing enterprises, the government promotes the flow of internal and external funds through guidance and promotes industrial agglomeration. The use of digital platforms to construct a platform ecology for collaborative innovation between the two sides, incorporating national and provincial science and technology plans, empowering innovation organizationally and data-wise, and promoting digital co-innovation to rapidly enhance China's regional technological and innovation capabilities; for academic and research institutes, through the government-industry-academia-research cooperation, the government gives financial support, provides policy support to promote enterprise development, and understands their needs so as to strive for more resources. Further, with the increase of government support, the willingness of both sides of the game to participate in digital co-innovation gradually increases. However, not as long as the government opportunity cost subsidies can motivate enterprises and institutions to carry out digital collaborative innovation, when the government's subsidy is too small, small and medium-sized manufacturing enterprises will not choose the digital collaborative innovation of industry, academia and research, when the government's subsidy does not motivate enterprises and institutions to carry out digital collaborative innovation.

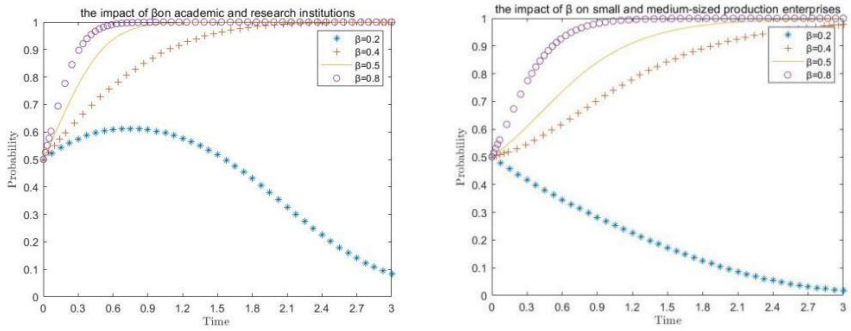

Fig. 4. Impact of β on academic and research institutions and small and medium-sized manufacturing de-enterprises

In summary, whether or not industry-university-research in small and medium-sized manufacturing enterprises engage in digital co-innovation shows a stable evolutionary state depends on a variety of factors. The benefits of digital co-innovation and the strength of government support on the direction of the influence of digital co-innovation of industry-university-research varies with the size of the degree of transformation.

4 Conclusion

(1) The choice of digital co-innovation mode, or traditional operation mode, by SMEs and academic and research institutions is the result of a combination of factors. Four strategies may be chosen (traditional operation mode, traditional operation mode), (digital co-innovation mode, traditional operation mode), (traditional operation mode, digital co-innovation mode), and (digital co-innovation mode, digital co-innovation mode), and which state the model is stabilized in is the result of a combination of factors.

(2) For small and medium-sized manufacturing enterprises and academic and research institutions, the profit output generated through digital collaborative innovation has an important impact on both sides of the game. Mainly in the dependence on the digital platform, digital resource integration after the formation of digital platform to absorb other industry resources, the two sides of the game strategy selection due to changes in profit changes, the increase in profit output to increase the willingness to participate in the two sides of the digital collaborative innovation.

(3) Numerical simulation shows that government support plays an important role in the decision-making of industry-university-research digital collaborative innovation. The strength of government support has the positive effect of promoting small and medium-sized manufacturing enterprises to carry out industry-university-research digital collaborative innovation. The greater the government support, the more conducive to promoting SMEs to carry out University-Industry-Research Digital Collaborative Innovation, and when the government support is very low, the government subsidies can't motivate the enterprises to carry out University-Industry-Research Digital Collaborative Innovation.

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