Path Refactoring of Chinese New Research and Development Institutes

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Abstract. Chinese new Research and Development institutions are of crucial importance for innovation-driven development strategy. This research employs the Grey Model to statistically analyze the development trend of these institutes and figures out their operation modes drawing on empirical investigation from four new R&D institutions in Guangdong Province. Prediction results and investigations demonstrate that: 1) The number of new R&D institutes are going through a recovery from fluctuations; 2) There are mainly three nature types of new R&D institutes, namely the public institutes, enterprises, and private non-enterprise unit; 3) They have three common ways of production-education-research cooperation, including entrusted cooperations, construction of platforms or training bases, and enterprise incubation; 4) Different from traditional university institutions, new R&D institutions are under the cross influence of internal and external environments, which causes path dependence in their construction, such as administrative intervention, deficiency of self-sufficient capacity and institutional homogeneity. In this regard, this research proposes to reconstruct new R&D institutions in terms of reshaping the university-government cooperation model, improving institutes' self-sufficient capacity, and conducting mechanism innovation in manner of the interoperability mechanism, evaluation criterion and incentives mechanism.

Keywords: new Research and Development institutes · Grey Model · production-education-research · path refactoring

1 Introduction

The public interest of new R&D institutes has increased remarkably since 1996 when the first new R&D institute, Research Institute of Tsinghua University in Shenzhen was built. In 1995, there were studies on the functional orientation and career prospects of researchers and managers in research institutes, development direction, construction planning, institutional reform [1–5]. Research on Chinese new R&D institutes could be classified into three parts.

The first is the evaluation system. The evaluation system should be combined with functions of the parent university, adhere to the construction of Double-First Class universities and the principle of integrity and innovation [6]. From aspects of scientific

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investment, innovation output, achievement transformation, contribution, talent gathering, a three-level multi-index evaluation system is constructed [7]. Regarding performance problems such as uncertain performance evaluation, correlations between indicators and unknown weights of indicator sets, a performance evaluation method based on Choquet points can be adopted [8].

The second is the reform of mechanism. New R&D institutes confront four main problems: 1) The guiding role of market demand on innovation has not been fully exerted; 2) There are still obstacles in the interdisciplinary innovation; 3) Reform is badly needed in the governance structure and mechanism; 4) The sustainable development capacity needs to be improved [9, 10]. It is necessary to integrate talents, technologies and management resources in order to realize the connection of project, market, talent and capital [11, 12].

The third is the integrated development of production-education-research. The primary factor for the low transformation rate is the immaturity of achievements. Therefore, advancement in maturity of achievements is the prerequisite for transformation [13]. The production-education-research cooperation of new R&D institutes can be divided into four modes: technology shareholding, joint construction, project incubation and talent exchange [14–16].

Nevertheless, new R&D institutes in China generally are out of balance and dragged in to mire of sluggish growth due to three reasons: 1) Governments and the parent university, as the constructors of institutes, are in void connection; 2) Institutes rely on governmental funding significantly and few of them could achieve self-supporting; 3) Institutes' rigid mechanism might result in obstacles in innovation [7, 17, 18].

This paper attempts to contribute to the literature in several manners. First, most of the existing studies related to new R&D institutes focus on their development at macro-level, but there are few researches indicating the development tendency of new R&D institutes at micro-level. This research filles in gaps in this domain based on the Grey Model. Second, the paucity of empirical research has always constrained research on new R&D institutes in China. It is stated in this research that how Chinese new R&D institutes operate by empirical investigation. Third, the research manages to find out the reasons why these institutes could not achieve their goals from the perspectives of operation modes and provides a better understanding of their mechanism for policy makers. Finally, this paper may facilitate with directions for further research on new R&D institutes. Therefore, it contributes to theoretical research, as well as empirical studies.

2 Methodology

In this research, data are analyzed and predicted using the Grey Model, the theory of which was first proposed by Julong Deng in 1982. After the development of decades, the model has been upgraded for several time and is used by scholars to make precise predictions of data which is of a very small sample size [19]. This model can be applied to social science [20, 21]. Also, the model is widely used in natural science [22, 23]. The advantage of the Grey Model is that it does not require large sample data support and can be used for short or medium forecasting with a high prediction accuracy. This

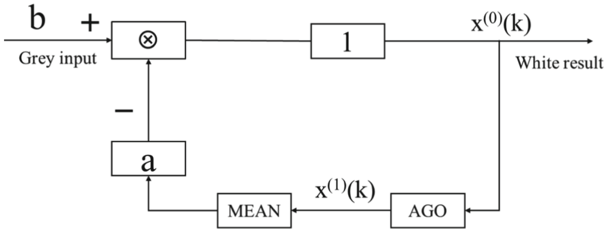

Fig. 1. Univariate grey model input and output diagram [24]

research takes the numbers of new R&D institutes authorized by Guangdong Province from 2015 to 2020 and uses the Grey model to indicate its development trend.

The research of Zeng, Li and Meng in 2020 shows that GM(1,1) is the main model for Grey System prediction [24]. In this study, we employed the mindsets of Zeng, Li and Meng and they depicted the relationship between the input parameter b and the system output $x^{(0)}(k)$ (the system characteristic variables) of GM(1,1) with one functional block diagram (see Fig. 1) [24].

Based on the studies of Zeng, Li and Meng [24], set the series $X^{(0)} = (x^{(0)}(1), x^{(0)}(2) \ldots, x^{(0)}(n))$, in which $x^{(0)}(k) \geq 0$, $k = 1, 2\ldots, n$, then the generate sequences in one accumulation of $X^{(0)}$ is $X^{(1)} = (x^{(1)}(1), x^{(1)}(2) \ldots, x^{(1)}(n))$, $x^{(1)}(k)=\sum_{i=1}^{k} x^{(0)}(k)$, $k = 1,2\ldots,n$.

$Z^{(1)}$ is the immediately adjacent to the mean generating sequence of $X^{(1)}$, $Z^{(1)}(k) = 0.5 \times [x^{(1)}(k) + x^{(1)}(k-1)]$, $k = 2, 3\ldots, n$.

Therefore, $x^{(0)}(k) + az^{(1)}(k) = b$ is the basic form of GM(1,1), the parameter column is $\hat{a} = (a,b)^T$.

$$\mathbf{Y} = \begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{pmatrix}, \mathbf{B} = \begin{pmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{pmatrix}$$

The columns of least squares estimated parameters of GM (1,1) ($x^{(0)}(k) + az^{(1)}(k) = b$) is $\hat{a} = (B^TB)^{-1}B^TY$. The temporal response function of GM(1,1) is

$$x^{(1)}(t) = \left(x^{(1)}(1) - \frac{b}{a}\right)e^{-a(t-1)} + \frac{b}{a}.$$

The final form of GM (1,1) is a chi-square exponential function [24]:

$$\begin{aligned} \hat{x}^{(0)}(k+1) &= \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \\ &= \left(1 - e^{a}\right)\left(x^{(0)}(1) - \frac{b}{a}\right)e^{-ak},\ k = 1, 2\ldots,\ n. \end{aligned}$$

Set the original series $X^{(0)}$ to be:

$$X^{(0)} = \left(x^{(0)}(1),\ x^{(0)}(2)\ldots, x^{(0)}(n), x^{(0)}(n+1)\ldots, x^{(0)}(n+t)\right).$$

Establish the grey prediction model of the former n elements in $X^{(0)}$. Then the corresponding simulation sequence of it is $\widehat{S}^{(0)} = (\hat{x}^{(0)}(1), \hat{x}^{(0)}(2),\ldots, \hat{x}^{(0)}(n))$ [24].

The prediction series $\widehat{F}^{(0)}$ containing the subsequent t elements based on this grey prediction model is [24]:

$$\hat{F}^{(0)} = (\hat{x}^{(0)}(n+1), \hat{x}^{(0)}(n+2)\ldots, \hat{x}^{(0)}(n+t)).$$

Then, we carried out our case study at four new R&D institutes in Guangdong Province in 2021. These institutes, which were related to this research were Foshan Nanhai Guangdong Technology University CNC Equipment Cooperative Innovation Institute, Zhuhai Fudan Innovation Institute, South China University of Technology Zhuhai Institute of Modern Industrial Innovation and Tsinghua Innovation Center in Zhuhai. We undertook semi-structured interviews containing a set of open-ended questions 10–15 staff and managers at each institute and used a multiple-case studies approach to explore the research questions under study through the use of a replication strategy i.e. seeking patterns of similar results across four institutes to produce substantial support for the development of themes [25, 26]. Thematic analysis was the main research method in this part, in which way the extraction of meanings and concepts from data and includes examining and recording patterns or themes [27].

3 Results and Discussion

3.1 Results

The numbers of institutes authorized by Guangdong Province from 2015 to 2019 were input into the Grey model in the statistics software R and the predicted number of 2020 is supposed to be 32, but in fact the number is 43, which is 34% larger than the predicted. And the annual growth rate is also lager than the model's prediction (see Table1, Fig. 2 and Fig. 3). This means that although the development of new R&D institutes has gone through fluctuations in the past few years, its recovery is better than we thought. Such a strong recovery development may be the result of implementation of the innovation-driven development strategy launched these years.

3.2 Operation Modes

All of four institutes aim to serve local industries, focusing on core technologies in key or strategic industries. Institute A has set several innovation platforms covering various fields such as energy utilization, biotechnology, intelligent manufacturing and food health. These research directions are in line with local priority industries which are strongly supported by the government (Table 2). Institute B takes industrial robotics, intelligent equipment, 3D printing and semiconductor equipment as its core research, which keeps in step with the governmental goal of building an innovation engine of advanced equipment manufacturing industry.

There are mainly 3 nature types of new R&D institutes in China: public institutes, enterprises and private non-enterprise units. The majority are public institutes. In terms of modes, institutes mostly work under governments' funding, the parent university's

Table 1. Institutes authorized by Guangdong Province (2015–2020)

Year	*Real numbers*	*Predicted number*	*Annual Growth Rate*	
2015	42		*Real*	*Predicted*
2016	71		0.69	
2017	67		-0.06	
2018	25		-0.63	
2019	53		1.12	
2020	43	32	-0.19	-0.40

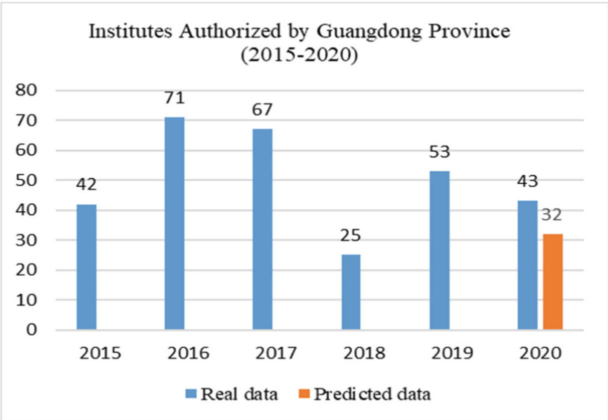

Fig. 2. Institutes authorized by Guangdong Province (2015–2020).

guidance. Their management structures employ the dean responsibility system under the leadership of the council. The de-administrative actions launched by governments grant new R&D institutes more autonomy. Leaders of innovation and transformation departments from the parent university and governments compose the council in four institutes. The nature and responsible system of four institutes are shown in Table 3.

The initial fund of four institutes were governments' investment. Guangdong Province has launched a dedicated fund of 150 million yuan in support of institutes with a one-time 5 million yuan as construction funds on the basis of competitive selection. New R&D institutes are also given corresponding subsidies in the purchase of instruments, equipment and other aspects related. In addition to the preparatory-period funds, four institutes receive continuous funds in the way of one discussion over each

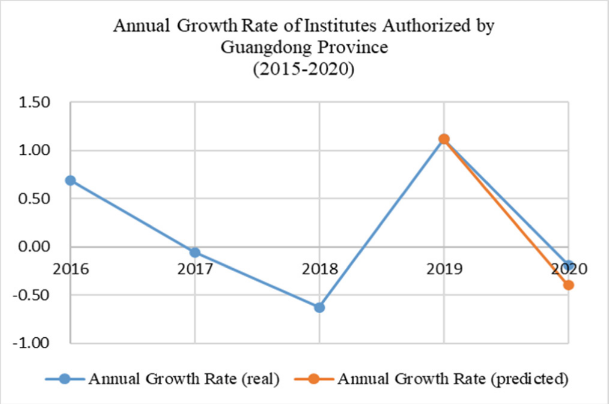

Fig. 3. Annual growth rate of institutes authorized by Guangdong Province (2015–2020).

Table 2. Platforms of Institute A

Platforms	***Field of local industries***
Energy utilization	New energy
Nano-biotechnology	New material
Big data intelligent recognition system	Artificial intelligence and smart manufacturing
Intelligent control system and equipment	Internet of things
Food nutrition and health	Big health

Table 3. Nature and System

Platforms	***Nature***	***System***
A	Public institute	Dean responsibility system
B	Public institute	Dean responsibility system
C	Public institute	Dean responsibility system
D	Public institute	Committee responsibility system

project. For example, the province will give a maximum of 10 million yuan to provincial new R&D institutes with excellent evaluation. Government funds account for 30% to 50% to maintain the normal operation of four institutes. The 50%–70% remaining are filled by institutes themselves. The sources of income to fill the gap include public service charges, investment returns, housing rent, research funding, technology transfer, and business profits.

There are three common ways of production-education-research cooperation showed in the four institutes: entrusted cooperations, construction of platforms or training bases, and enterprise incubation. The first type is entrusted cooperations. Institutes, governments and enterprises dock their needs and establish short-term cooperation relationships by signing commission contracts. The traditional entrusted cooperations are small-scale and have low-level research sustainability, with limited input and output. It is difficult to generate scale benefits in this way due to the influence of information asymmetry. However, with the empowerment of intelligent platform, a single entrusted cooperation may evolve into integrated cooperations. The online intelligent manufacturing platform established of Institute B can release various goods and services, such as technological achievements, technical services, testing services and instrument sharing. The second type is to jointly build platforms or training bases. Institutes, universities and companies carry out joint research, or declare joint laboratories, engineering technology research centers and training bases. Institute A and Qingdao Beer Co., Ltd. Jointly established an undergraduate practice base. The third type is enterprise incubation. Institute A has established a wholly-owned subsidiary, which sets up a venture capital fund to provide professional services such as registration, consultation of finance and legislation, or provide venture capital for entrepreneurs.

3.3 Path Dependence

a) Administrative intervention.

Excessive intervention from governments is one significant reason for institutes slipping to hetero-organizing paradigm. Being charge of public institutes, managers of four institutes are limited in decision making and resource allocation. They accept the guidance or regulation from the government actively or passively. Although enterprises and private non-enterprise units receive less administrative intervention, it is more difficult for them to apply for government funds.

Collaborative innovation activities enable new R&D institutes to evolve as self-organizing systems. Institutes hardly turn into a higher orderly organization if lack of innovation incentives. The mighty administrative intervention leads to a low level of collaborative innovation since short-term projects and economic indicators are preferred by investors. In this way, the intangible benefits of scientific innovation and technology breakthroughs generated in the long process might be ignored by governors. Governors' short sightedness gives rise to the situations that managers of new R&D institutes give up those time-consuming projects with unclear output expectations, which could be key to the whole economic society. Exploring how to overcome the deadlock of cooperations among interested parties is urgent for institutes as self-organizing systems.

b) Self-sufficient capacity.

Four institutes are not profit-oriented. Government funds accounts for a large proportion in their income resource that further strengthens their reliance on governments. The local government invested them at initiation stage and provide preferential policies to help them with operation. Later, governments will have to decide whether to follow up with the next round of funds according to the annual assessment results of institutes. Under the dual effect of strong administrative interference and tough targets, managers have to make economic benefits as their main goal. This pressure and influence penetrate into research activities in institutes sooner or later and the inner drive of innovation could be held hostage by external sponsors. New R&D institutes lose the core feature of self-organizing systems, namely the self-driven power and orderly development.

Based on the investigation of four institutes, governments gradually reduce their funds after 5–10 years. Even if managers of institutes neglect the problem of driving force hostage, they still need to find their own living way under the pressure of survival. Dealing with the unstable output and unclear economic expectations is a realistic problem for each new R&D institute.

c) Institutional homogeneity.

New R&D institutes are prone to be trapped in institutional homogeneity. They directly copying the existing institutional designs in order to pursue external institutional legitimacy. According to the new institutional sociology, one system is a superimposed network of internal technical environment and external institutional environment [28]. The internal technical environment pays attention to the optimal solution of efficiency, while the external institutional environment pursues the legitimacy of survival. In order to maintain survival, instead of innovation, systems tend to increase its compliance by adopting strategies that have been accepted by the society [29]. As thus, institutes might sacrifice the option of endogenous optimization.

One of the manifestations of institutional homogeneity is institutes' utilitarian assessment mechanism. Unconsciously influenced by governments' performance management, new R&D institutes similarly attach much importance to economic benefits when designing their assessment mechanism. Some institutes even choose to sign contracts with research teams directly to assign tasks to them, including the number of incubated enterprises, tax contribution, patents, transformation benefits, etc. Scientific advancement and accumulation are neglected or not paid adequate attention in assessment.

Another manifestation of institutional homogeneity is to duplicate the incentive mechanism from the parent university. Managers of four institutes design their incentive mechanism by referring to that of their parent university for institutional legitimacy and rationality reason. This kind of imitative homomorphism mainly comes from managers' response to the ambiguous orientation of institutes. Different from universities, new R&D institutes are to serve industrial development by innovation. Managers who duplicate mechanically and applying the exiting standards to institutes indiscriminately will seriously influence their productivity efficiency.

4 Path Reconfiguration

4.1 University-Government Cooperation Model

The cooperation model between institutes, the parent university and governments should not only enable three parties with different endowments to do their best, but also place a high value on possible contradictions between different stakeholders. On one hand, relying on the parent university's solid foundation of basic research, diversified achievements, rich talent reserve and facilities, new R&D institutes can carry out projects, transformation and consulting services more conveniently. On the other hand, institutes build efficient innovation and transformation platforms to provide the parent university with the conditions of transformation and incubation. The profit brought by the transformation of achievements and incubation of enterprises can feed back to the development of the parent university. For governments, a new R&D institute in good operation could attract high-level talents, promote project incubation, provide public services and incubate enterprises. Also, a well-run institute should receive more government funds. Normally this shall create a virtuous cycle.

In order to cooperate with the parent university and governments, institutes should find the balance of interests between three sides [17]. The dean system under the leadership of the council is adopted. The members of the council are appointed by the parent university and governments. The dean is then recruited by the university and appointed by the council. The managers under the leadership of the dean are divided into two parts, one is for operation and the other one is for research. Managers are responsible for formulating annual plans, drawing up management systems, requesting the appointment or dismissal of staff, and reporting regularly to the council. The council deliberates and decides on important issues submitted by managers, such as annual plans, system proposals and personnel hiring plans. Such a structure ensures scientific decision-making, efficient operation, and effective supervision. The structure is characterized by clear power and responsibility. More important, it can eliminate the potential pitfalls of dominance in decision-making and management, and protect new R&D institutes from excessive penetration of governments and the parent university.

4.2 Self-sufficient Capacity

To realize self-sufficient, institutes need to determine its research domains with discretion. Firstly, research domains should be considered in the context of local industrial clusters. For example, the Nano-biotechnology Innovation Platform of Institute A, the Energy and Industrial Intelligence Technology Platform of Institute C and the Financial Innovation Platform of Institute D are all in line with the development of local key industries. Secondly, institutes could take advantage of the parent university's preponderant disciplines, research accumulation and talent distribution into account, to facilitate the importation of resources in the later stage. For example, the Robotics and Autonomous Driving Research Platform of Institute C and the Robotics Technology R&D Center of Institute B are both headed by professors or alumni of their parent universities.

There are 3 main ways for new R&D institutes to gain a profit. The first way is research innovation. Research innovation is a vital way of survival in the early stage, mainly through the distribution of income from transformation, extraction of project management fee. Institutes select and hire principal investigators according to the fitness, maturity and prospect of their projects. After the team is stationed into the institute, the team and the institute jointly determine the projects. For new products, technologies and projects generated in institutes, institutes can enjoy the profits at an agreed ratio and extract management fees.

The second way is to incubate enterprises. Institutes provide technical docking channels and incubation carriers for entrepreneurial teams. On one hand, institutes lead the teams to cooperate with universities, institutes, governments and companies. On the one hand, institutes provide facilities and instruction for them. In project stage, institutes provide various services regarding teams' needs, including intellectual property protection, project declaration, high-tech breakthroughs, as well as support in business registration, financial consulting and team recruitment. In experimental production stage, institutes help teams analyze the whole industry and market trend. In mass production stage, institutes offer specific training for teams' managers in marketing promotion, brand operation, team upgrading, tax planning, relevant laws and regulations. At last, in the stage of enterprise incubation, institutes assess the status of the enterprise and choose whether to finance it or not. When enterprises incubated goes public, institutes could choose to gain their profits by initial public offerings exit. In the process of incubation, in addition to charging training, service and management fees, institutes can also enjoy the growth proceeds of incubated enterprises in the form of investment and shareholding.

The third way is to provide public services. Institutes tend to build public service platforms, rent out instruments or facilities at a relative low price, provide consulting services and personnel training. It is popular because local enterprises have large demand for professional support in research, testing, processing and other production processes [7]. Some new R&D institutes also charge venue fees by hosting large meetings and exhibitions to activate the effectiveness of venues and equipment.

4.3 Organizational Mechanism Innovation

a) Interoperability mechanism.

New R&D institutes and their parent university are complementary if they establish the circulation of resources [17]. Taking effective measures to break the barriers between them is crucial for institutes. But many new R&D institutes and their parent university are not in the same city. The physical distance brings considerable obstacles to connect institutes with the parent university. Without attractive conditions, the talent of the parent university would not choose to leave the university and work in the institute.

In order to solve the problems mentioned above, institutes could set up the talent and resource interoperability mechanism. In practice, institutes and their parent university found one base respectively at the same time. The university base filters out innovation teams from the university to meet the industrial needs; the institute base undertakes tasks of transferring and transforming the achievements of innovation teams selected by the university base. Such a dual-base model keeps institutes and their parent university in close touch to avoid vacuum. One problem of this model is that the double-employed personnel might worry about their achievements obtained based on institutes, including academic paper, projects, patents, monographs, software, databases, awards and other intellectual property rights, are not confirmed by their university. This could affect the evaluation of their titles and other welfares. Institutes and their parent university may negotiate to add a mutual approval regulation of research achievements to the interoperability mechanism.

b) Assessment mechanism.

The assessment of researchers in institutes are supposed to follow the rule of target-oriented and the concept of refinement. A classification and phased assessment mechanism is needed that complies with the logic of innovation-transformation-output. For teams whose main goal is scientific and technological innovation, the assessment emphasis is related to the contribution of scientific research, such as the approval of research projects, publication of high-level journal papers and publication of books; for teams whose main goal is transformation of achievements, the assessment emphasis is the contribution to industrialization, such as patents, technology transfer, scientific reward and public services; for teams whose main goal is economic profits, it is necessary to establish a market-oriented assessment criteria, taking enterprise incubation, business operation of enterprises, revenues and tax contribution into account.

c) Incentives mechanism.

The reform of incentive mechanism lies in the ownership and disposal right of achievements. Instead of ownership and disposal rights, researchers usually are rewarded with money for their great contribution traditionally [30]. Regarding the right to use, dispose and benefit of achievements as the core of reform, a more reasonable incentive mechanism breaks through the ownership restriction, and requires institutes to set up a scientific procedure to confirm ownership and rights. In case some institutes retain the ownership while being inactive in transformation, the power of independent transformation should be able to be transferred to researchers regardless of ownership, so as to reduce the waste of resources caused by missing good industrialization opportunities.

According to the theory of Mahen Tampoe on motivating knowledge workers, a four-dimensional incentive mechanism is proposed. It contains four key points: self-improvement, work autonomy, attainments, and wealth [31]. Self-improvement remands for the respect of the growth law of researchers, focusing on the cultivation and support of young personnel and reducing their pressure generated from quantitative assessment. Work autonomy asks institutes to keep scientific activities independent from administrative interference and confirm the subject status of researchers in scientific activities. The concept of attainments in incentive mechanism stresses the importance of research accumulation rather than results and implement a value-added-oriented distribution policy. At last, the incentive mechanism perceives that researchers could be motivated significantly by introducing a market-oriented operation model to enhance their basic treatment.

5 Conclusions

This research first predicts the development trend of new R&D institutions in Guangdong Province using the Grey Model. The results show that the real number of new R&D institutions authorized exceeds the expected number, which means that the importance of new R&D institutions as a platform for technology innovation and the integration of production-education-research is attached to more importance. Besides, its advantages in industrial orientation, diversification of nature and variety of funding sources are gradually highlighted as well. Nevertheless, empirical research also reveals that the existing new R&D institutions have path dependence, including significant administrative intervention, inadequate self-sufficient capacity and critical institutional homogeneity. In order to, the research suggests to solve the problems with innovation of university-government cooperation model and improvement of self-sufficient capacity with an upgraded mechanism system. This research is based on a small sample and needs to be further validated using qualitative analysis models and quantitative sampling methods. Therefore, the use of explanatory structural modeling and structural equation analysis techniques to test the findings of this research should be done in the future.

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