Assessment of Effects of Science Popularization Activities from the Perspective of Attractor: A Theory Model Thinking

Peixiao Qi

qipeixiao@foxmail.com

China Research Institute for Science Popularization, 100081 Beijing, China

Abstract. Assessment of effects of science popularization activities plays an irreplaceable role in impelling science popularization modernization. This paper firstly reviewed some published literature and summarized the research status and characteristics of the assessment of effects of science popularization activities. Based on above which, the paper proposed the mathematical assessment model on the effects of science popularization activities including “attractor” in demand and investment perspective by applying some knowledge and theories on economics and systems science. The results show the effectiveness of science popularization activities under demand attraction is positively correlated with regional demand for science popularization activities, per capita income, and the final consumption of science popularization activities. However, it is inversely correlated with the cost of organizing science popularization activities and the number of personnel engaged in science popularization activities. The effectiveness of science popularization activities under investment attraction is positively correlated with the amount of investment that science popularization activities can attract. However, it is important to note that it is inversely correlated with the potential profits that may be obtained from organizing science popularization activities.

Keywords: Science Popularization Activity, Effect Assessment, Attractor, Mathematical Model.

1 Introduction

Assessment is a social science measurement method that requires the application of multidisciplinary knowledge for systematic analysis of the object under evaluation. Generally, science popularization activity assessment is similar to evaluations of economy activities, education activities, etc. However, in comparison, the assessment of science popularization activities places greater emphasis on future effects. Additionally, evaluating the effects of science popularization activities is the most important aspect of conducting science popularization assessments. The evaluation of science popularization activity effects encompasses various aspects such as society, economy, culture, and scientific education, making it highly empirical characteristic.

The evaluation of the effects of science popularization activities is very significant importance to science popularization work. It plays an irreplaceable role in promoting the modernization of science popularization work [1]. With the continuous development of science and information

EIMT 2024, March 29-31, Wuhan, People's Republic of China

DOI 10.4108/eai.29-3-2024.2347701

technology, society has become increasingly modernized. Modern society is an era of information explosion, and the development of science popularization is synchronized with the development of society. Science popularization activities now place greater emphasis on public demand and interactive engagement. Strengthening the evaluation of science popularization activity effects is benefit for the healthy cycle of the entire science popularization system. Science popularization activities serve as a practical platform for the effective implementation of science popularization work. Through effect evaluation, timely and effective feedback can be obtained to identify problems, thereby enabling more rational allocation of science popularization resources in future work. Furthermore, evaluating the effects of science popularization activities also helps improve relevant theories in the field of science popularization research. Theoretical frameworks are the supports and foundations, but evaluation practices can also contribute to the continuous enrichment and refinement of theories.

It should be noted that the effects of science popularization activities are most directly related to individuals. Therefore, the preferences of different individuals towards science popularization activities will exhibit economic preferences. Additionally, adequate financial support is indispensable for the better implementation of science popularization activities. From an economic perspective, investing in a project is done to generate returns, especially economic returns. Therefore, the level of effectiveness of science popularization activities directly affects the probability of obtaining investment. Furthermore, science popularization activities are closely related to economic activities. The direct manifestation of economic development lies in the continuous progress of individuals, who are the core of economic activities, and the ultimate purpose of science popularization activities is to improve the scientific literacy of citizens. As the scientific literacy of individuals improves, they can better serve production and stimulate the economy. On the other hand, the prosperous development of economic activities increases the urgency of citizens' demand for science popularization activities, which further drives the continuous development and diversification of science popularization activities. Moreover, science popularization activities are essentially a form of consumption. A science popularization activity with a clear theme can mobilize a large number of consumer groups and generate certain economic income. The increase in economic income can attract a substantial amount of investment, thus creating a virtuous cycle. Figure 1 shows the relationship between science popularization activities and economic activities. Therefore, conducting an analysis of the effects of science popularization activities using relevant economic theories is feasible.

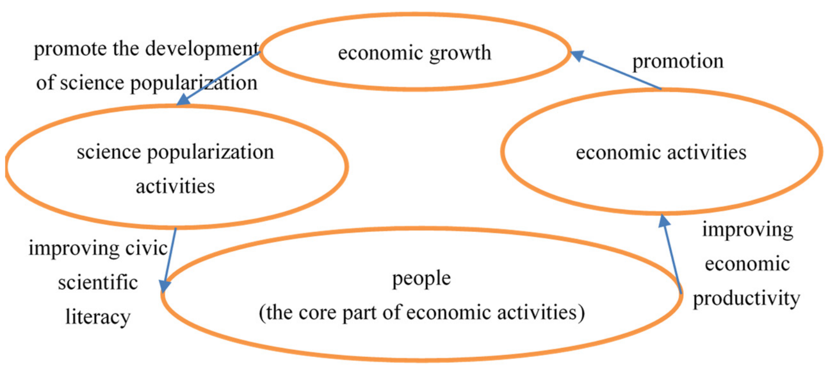

Figure. 1. The relationship between science popularization activities and economic activities

2 Literatures

Based on the currently available literature, there are relatively few studies on the evaluation of science popularization activities in China, especially in academic literature. From the classification of science popularization evaluation, it can be broadly divided into three categories: firstly, the assessment of public scientific literacy; secondly, the evaluation of the effectiveness of science popularization activities; thirdly, the evaluation of the overall implementation effect of science popularization. Among them, the evaluation of science popularization activities refers to the evaluation of one or more science popularization activities, which reflects the economic and social value in these activities. Therefore, science popularization activities should be evaluated in order to understand their actual effectiveness and determine the necessity of continued implementation [2].

Currently, the overall efficiency of China's science popularization activities is relatively high, but researches on the evaluation of science popularization activities, especially large-scale activities with complex organization and high resource consumption, is still lacking, particularly in academic research [3]. The main purpose of holding science popularization activities is to promote the dissemination and popularization of science and technology. Conducting investigations and evaluations of science popularization activities is an important way to measure their effectiveness. The effectiveness of science popularization activities is not only a concern for the organizers, but also a hot topic for science popularization researchers [4]. The evaluation of the effectiveness of science popularization activities is an important part of the science popularization evaluation system. By systematically summarizing and analyzing the experiences of the holded science popularization activities, timely and effective feedback can be obtained, and accumulated experiences and lessons can be provided for future science popularization activities or plans [5]. The British Science Festival has the most professional evaluation strategy among all science festivals. The British Science Association attaches great importance to the evaluation of the festival's effectiveness and conducts comprehensive evaluations from various perspectives and using various methods [6]. Chinese scholars Liu Yanjun and Wu Chensheng (2010) also conducted a detailed analysis of the evaluation objectives, content, and methods of the 2008 British National Science and Engineering Week activities, and provided several enlightenments for the evaluation of major science popularization activities in China [7].

Regarding the evaluation research on science popularization activities of China, Tan Chao (2011) used the promotion of the Beijing main event of the National Science Popularization Day in 2010 as an example to explore the significance of pre-promotion evaluation for improving performance and ensuring sustainable operation of large-scale science popularization activities [8]. Zhang and Ren (2012) conducted an effectiveness evaluation of popular science activities with the theme of "water resource conservation and protection", they pointed out that efforts should be made to promote the integration of school scientific education and social popular science activity resources, expand the benefits of activities, and optimize the design of popular science activities to promote the social educational value and role of popular science activities [9]. In addition to evaluating the effectiveness of specific popular science activities, Zhang and Zheng (2013) elaborated on the indicator system and construction methods for the evaluation of large-scale popular science activities, and tested the evaluation framework through the evaluation practice of large-scale popular science activities [10]. Tan Chao, Yan Jun, and Liu

Kun (2014) also pointed out that during the evaluation stage of popular science activities, new media such as micro-blog can be used to collect activity data and feedback information [11].

Additional, Hu Xinchuan (2012) also suggests establishing a “three document” evaluation system of “planning document”-“task document”-“evaluation document” for the management of popular science activity effects. This system should be applied in the process of planning, implementing, and summarizing popular science activities, as well as strengthening the monitoring and evaluation of the effectiveness of popular science venues in organizing various activities [12]. In fact, whether a large-scale popular science activity achieves its intended goals and whether it is recognized by the public are important basis for continuously improving and enhancing the quality of popular science activities. This requires timely monitoring and evaluation to be realized. Therefore, how to conduct evaluation work scientifically and pursue maximum effectiveness is an important issue to be addressed in future work [13].

In conclusion, as far as the evaluation field is concerned, the effectiveness evaluation of popular science activities belongs to a relatively novel research direction. In terms of the attributes of the evaluation of popular science activities, it falls into the category of “soft evaluation”, which means that different evaluation methods, approaches, and objectives may lead to different evaluation results. From the current state of literature research, there is a lack of research on the effectiveness evaluation of popular science activities from an economic perspective and in combination with relevant knowledge from systems science. Therefore, this paper focuses on using an economic perspective as a starting point and utilizing relevant knowledge from systems science, specifically the concept of “attractor”, to construct a mathematical model for the effectiveness evaluation of popular science activities from the perspectives of demand attraction and investment attraction.

3 What is an attractor

It is important to clarify that the effectiveness of popular science activities referred to in this paper is a broad concept encompassing the evaluation of popular science activities.

Popular science activities can be as a “complex system” [14], [15], [16]. Ludwig von Bertalanffy defined this concept from the perspective of basic science: a system is a comprehensive entity of interconnected and interacting elements [14]. The two mathematical theory models constructed in this section regarding the effectiveness of popular science activities are linked to the field of economics through the concept of “attractors” in the system. This paper mainly discusses two “attracting” entities: the consumer group and the investment group for popular science activities. The unique endowments of different regions can influence or even change the behavior of attracting entities in a region-specific manner, constituting a dynamic behavior of the popular science activity system. The following sections will build relevant mathematical models and analyze the effectiveness of popular science activities from the perspectives of supply and demand, as well as investment.

Anything in the real world exists and operates in a systematic way, and there is no such thing that cannot be seen as a system [14]. When studying complex system problems, especially large-scale systems such as living and social systems, the concept of purposefulness must be emphasized and is essential. The research on systems science has found that purposefulness is a dynamic characteristic of a system, which can be accurately described by the concept of "attractor" [14]. From the perspective of phase space, the ultimate purpose of system evolution is manifested as a certain set of points, representing the ultimate state of evolution, and is therefore also called the "purpose state", which has three distinct characteristics: ultimacy, stability, and attractiveness. Generally speaking, a set of points in the phase space that satisfies these three conditions of ultimacy, stability, and attractiveness is called an attractor of this system [14], [17]. Specifically, the behavior of a system in phase space usually exhibits two situations: convergence or divergence. Among them, if, in a given phase space, regardless of where the initial value is located, the state of the system gradually approaches a point (or several points, or a certain finite region) in that phase space, this phenomenon is called "convergence", and the point (one, several, or a finite region) is the attractor of the phase space, which is also called the attractor of the system [18], for example, Simeon and Zaslavski analysed that attracting mappings in Banach and Hyperbolic spaces [19], Chen Zeling and Zhao Hong studied self-similar attractor sets of the Lorenz model in parameter space [20]. It should be noted that an attractor is a concept that represents the overall characteristics of a system and cannot be divided into multiple subsets, nor can multiple attractors be combined into one attractor.

4 A mathematical theory model: assessment of effects of science popularization activities

4.1 The mathematical assessment model: attractor perspectives on demand

In recent years, the importance of evaluating science popularization activities has been strengthened, indirectly indicating an increasing focus on the actual demands of the public for these activities. Similar to other economic activities, science popularization activities are also driven by the demands of the public. When there is demand, there will be supply. As the demand behavior continuously changes, the science popularization activities system also undergoes changes. The changing demands become the internal factors that cause changes in the science popularization activities system. The demand side and the supply side, especially the demand side, are the main user groups of science popularization activities. From an individual behavior perspective, these two groups consist of individuals with different behavioral factors and preferences, and each individual also has incomplete information. Therefore, from an economic perspective, the demands of different individuals for science popularization activities have different distribution patterns. In other words, this "different distribution" is caused by the attractor of demand. Thus, the term "attractor perspectives on demand" can be used to represent the behavioral preferences toward a specific (or a certain category of) science popularization activities among multiple choices.

According to the above analysis, a mathematical expression for the demand attractiveness of science popularization activity k in location L_1 to the demanders in location L_2 is given as follows:

$$DA_{L_1,L_2}^{k} = e^{[-\eta(C_{L_1}^{k} + F_{L_1,L_2}^{k})]} \tag{1}$$

of which, e is the natural logarithm, $e=\lim_{n\to\infty}(1+\frac{1}{n})^n$; η is a coefficient; $C_{L_1}^k$ represents the cost of organizing a science popularization activity k in region L_1; F_{L_1,L_2}^k represents the fee that a demander in region L_2 has to pay to participate in science popularization activity k.

Therefore, the total demand attractiveness of all science popularization activities for region L_2 can be represented as:

$$TDA_{L_2}^k=\sum_{L_1}DA_{L_1,L_2}^k \tag{2}$$

From the perspective of region L_2, the relative attractiveness of science popularization activity k in region L_1 can be represented as:

$$RA_{L_1}^k=\frac{DA_{L_1,L_2}^k}{TDA_{L_2}^k}=\frac{DA_{L_1,L_2}^k}{\sum_{L_1}DA_{L_1,L_2}^k} \tag{3}$$

Furthermore, viewing science popularization activity as a special type of "commodity", from an economic perspective, the effectiveness of science popularization activities can be perceived as the ratio between the consumption of these activities and the benefits obtained, allowing for further analysis from an input-output standpoint. Input refers to the consumption involved in engaging in an economic activity, while output refers to the results derived from engaging in that activity. This method is suitable for analyzing the national (regional) economy, a specific sector (enterprise), or a particular production activity, among others, and is widely applicable. Of course, this method remains applicable in the analysis of science popularization activities.

Therefore, from an input-output perspective, it is to calculate a local demand function for science popularization activity k:

$$LD_{L_1,L_2}^k=RA_{L_1}^k\cdot[ID_{L_2}^k\cdot(C_{L_1}^k+F_{L_1,L_2}^k)+\frac{G_1^k}{\sum_{\tilde{k}}G_1^{\tilde{k}}}\cdot PCI_{L_2}+\frac{G_2^k}{\sum_{\tilde{k}}G_2^{\tilde{k}}}\cdot IV_{L_2}] \tag{4}$$

It makes $\Delta^k=ID_{L_2}^k\cdot(C_{L_1}^k+F_{L_1,L_2}^k)+\frac{G_1^k}{\sum_{\tilde{k}}G_1^{\tilde{k}}}\cdot PCI_{L_2}+\frac{G_2^k}{\sum_{\tilde{k}}G_2^{\tilde{k}}}\cdot IV_{L_2}$, so, $LD_{L_1,L_2}^k=RA_{L_1}^k\cdot\Delta^k$.

The explanation for Δ^k is as follows: $ID_{L_2}^k$ represents the internal demand of region L_2 for science popularization activities; $G_1^{\tilde{k}}$ represents the per capita income consumption structure function of region L_2; PCI_{L_2} represents the per capita income of region L_2; $G_2^{\tilde{k}}$ represents the demand function for science popularization activities generated by investment in region L_2; IV_{L_2} represents the investment in science popularization activities in region L_2.

So, $ID_{L_2}^k \cdot (C_{L_1}^k + F_{L_1,L_2}^k)$ represents intermediate consumption, which refers to internal consumption; $\frac{G_1^k}{\sum_{\tilde{k}} G_1^{\tilde{k}}} \cdot PCI_{L_2}$ represents the final consumption demand for science popularization activities; $\frac{G_2^k}{\sum_{\tilde{k}} G_2^{\tilde{k}}} \cdot IV_{L_2}$ represents the demand for science popularization activities generated by investment accumulation.

Based on the above analysis, the aggregate demand and aggregate supply of region L_1 for science popularization activity k are as following:

$AD_{L_1}^k = \sum_{L_2} LD_{L_1,L_2}^k$ and $AS_{L_1}^k = C_{L_1}^k \cdot S_{L_1}^k \cdot E_{L_1}^k$

$S_{L_1}^k$ represents the number of staff engaged in science popularization activity k in region L_1; $E_{L_1}^k$ represents the effectiveness of science popularization activity k in region L_1.

Therefore, the balanced effectiveness of science popularization activity k in region L_1 under the perspective of demand attraction analysis is expressed by the following equation:

$$E_{L_1}^k = \frac{\sum_{L_2} LD_{L_1,L_2}^k}{C_{L_1}^k \cdot S_{L_1}^k} = \frac{\sum_{L_2} (RA_{L_1}^k \cdot \Delta^k)}{C_{L_1}^k \cdot S_{L_1}^k} \tag{5}$$

4.2 The mathematical assessment model: attractor perspectives on investment

Science popularization activities are important ways and approaches for popularizing science. However, organizing and implementing these activities require sufficient financial support. With the rapid development of the Chinese economy, there has been an increasing demand for science popularization activities, characterized by diversification, specialization, and in-depth content. Therefore, obtaining more investment to support the smooth implementation of science popularization activities is crucial. More and more investment serves as a significant driving force for expanding economic production, and the successful implementation of science popularization activities also relies on strong financial support. In the following, we will analyze the relationship between the effectiveness of science popularization activities and investment from the perspective of investment attraction by constructing mathematical models.

First, it presents a mathematical expression include investment attractiveness as follows. To simplify the analysis, we consider only two main indicators in defining investment attractiveness: the required space for organizing scientific popularization activities, represented by the square of the venue, and the profit obtained from conducting scientific popularization activities. Therefore, the investment attractiveness of organizing scientific popularization activity k in a region l can be expressed as follows:

$$IA_l^k = e^{\alpha \cdot \frac{Square_l^k}{TS}} + \beta \cdot Profit_l^k \tag{6}$$

of which, α and β are the parameters; $Square_l^k$ indicates the space square required for holding science popularization activity k in region l; TS represents the total square of the venue required for holding the entire science popularization activity; $\frac{Square_l^k}{TS}$ represents the venue occupancy rate during holding the science popularization activity k in region l; $Profit_l^k$ represents the potential profit that can be obtained when the region l holds science popularization activity k.

Furthermore, the investment attractiveness of region l holding a series of science popularization activities is $IA_l = \sum_k IA_l^k$. The total investment attractiveness of organizing a series of science popularization activities in regions other than l is $TIA = \sum_{L \neq l} IA_l = \sum_{L \neq l} \sum_k IA_l^k$. Therefore, the relative investment attractiveness of science popularization activity k in region l is $RIA_l = \frac{IA_l^k}{IA_l} = \frac{IA_l^k}{\sum_k IA_l^k}$, the total relative investment attractiveness of science popularization activity k in region l, compared to other regions, is $TRIA_l = \frac{IA_l^k}{TIA} = \frac{IA_l^k}{\sum_{L \neq l} \sum_k IA_l^k}$.

Based on the above analysis, the investment attracted by science popularization activity k in region l is $IV_{attrac} = E_l^k \cdot (IV_l \cdot RIA_l + IV_{L \neq l} \cdot TRIA_l)$. Of which, E_l^k represents the effectiveness of science popularization activity k in region l, IV_l represents the regional investment in area l, $IV_{L \neq l}$ represents the total investment in all other regions except area l.

Finally, it further leads to the conclusion that the effectiveness of science popularization activity k in area l can be obtained through investment attraction analysis framework:

$$E_l^k = \frac{IV_{attrac}}{IV_l \cdot RIA_l + IV_{L \neq l} \cdot TRIA_l} \tag{7}$$

5 Conclusion

The effect of science popularization activities has an accumulative characteristic, and this effect accumulation ultimately manifests as the accumulation of human capital. In other words, the accumulation of the effect of science popularization activities is also the process of human capital accumulation. The effect of science popularization activities directly affects the improvement of the overall scientific literacy of the public. Evaluation, on the other hand, is the process in which the social system detects, adjusts, and receives feedback on itself. Therefore, evaluating the effect of science popularization activities is great practical significance.

Based on a review of existing research literature, this study applies relevant knowledge from economics and systems science to the field of evaluating science popularization activities. By using the concept of "attractor", the economic concepts of demand and supply as well as investment and return are introduced into the evaluation system to get the mathematical model for evaluating the effect of science popularization activities under demand attraction and investment attraction, respectively. This study focuses on the derivation and solution of mathematical models, and it serves as an exploration of introducing new variables into the field of evaluating the effect of science popularization activities. Further empirical analysis of data is needed to further refine the theoretical model and conduct in-depth analysis based on a more complete theoretical model in future research.

References

[1] China research institute of science popularization: Study on effect of science popularization in China team: effect assessment of science popularization. Beijing: Theories and Methods Social Sciences Documentation Publishing House. (2003) (in Chinese)

[2] Jing, J., Wei, Q., Ma, S. and Liao, J. P.: Scientific education activities: planning and implementation. Wuhan: Huazhong University of Science and Technology Press. (2011) (in Chinese)

[3] Huang, X. Y.: Research on the method for evaluating large science popularization activities. Harbin: Harbin Institute of Technology. (2006) (in Chinese)

[4] Hu, J. P.: Study on the organizers and services evaluation of large-scale science popularization activity: based on the evaluation of the participant organizations of 2012 Beijing science festival. Vol. 22, No. 2, pp. 143-146. Journal of Architectural Education in Institutions of Higher Learning, (2013)

[5] Zhang, F. F. and Li, D. S.: Analysis on assessment system of science popularization. No. 10, pp. 12-17. Science & Technology Association Forum, (2005)

[6] Liu, Y. J., Wu, C. S., Dong, X. Q. and Li, X. Y.: Analysis and consideration on the pattern of British Science Festival Summative Evaluation. Vol. 5, No. 2, pp. 60-65. Studies on Science Popularization, (2010)

[7] Liu, Y. J. and Wu, C. S.: 2008 British National Science and Engineering Week evaluation case analysis, problems and enlightenment. Pp. 5768-5771. International Conference on Engineering and Business Management Proceedings, (2010)

[8] Tan, C.: Research on the evaluation of effectiveness science popularization events: an example of national science day outreach activities in Beijing. Vol. 6, No. 3, pp. 80-83. Studies on Science Popularization, (2011)

[9] Zhang, Z. M. and Ren, F. J.: Role of science communication in social education: a case study of the impact of a science communication event on education. No. Z1, pp. 98-102. Science & Technology Review, (2012)

[10] Zhang, Z. M. and Zheng, N.: Evaluation framework of impact of large-scale science communication events. No. 24, pp. 48-52. Science and Technology Management Research, (2013)

[11] Tan, C., Yan, J. and Liu, K.: The application of microblog in large-scale popular science activity: take official microblog operation of 2013 National Popular Science Day for example. pp. 329-333. Theory and Practice on Chinese Science Popularization-The 21st National Seminar on Science Popularization Theory Proceedings, (2014)

[12] Hu, X. C.: The management of science education performance. pp. 336-342. The 19th National Seminar on Science Popularization Theory and 2012 International Forum on Science & Technology Communication in Asia-Pacific Proceeding, (2012)
[13] Zhang, Z. M.: Studies on the effectiveness of science communication events in China. Vol. 4, No. 4, pp. 41-44. Studies on Science Popularization, (2009)
[14] Miao, D. S.: Essentials of systems science. 3rd Edn. Beijing: Renmin University of China Press, (2010) (in Chinese)
[15] Li, D. Y. and Mu, Y.: Neuromodulatory system in network science: comment on "Structure and Function in Artificial, Zebrafish and Human Neural Networks" by Peng Ji et al. Vol. 46, pp. 155-157. Physics of Life Reviews, (2023)
[16] Henderson, K. H., Hammond, R. A. and Homer, J. B.: Complex adaptive systems simulation modeling to address cardiovascular disparities: complex science for a complex problem. Vol. 148, No. 3, pp. 201-203. Circulation, (2023)
[17] Naik, M. K., Baishya, C. and Veeresha, P.: A chaos control strategy for the fractional 3D lotka–volterra like attractor. Vol. 211, pp. 1-22. Mathematics and Computers in Simulation, (2023)
[18] Reveal and explain the mysteries of the human brain thinking in a complex dynamical system perspective, http://blog.sina.com.cn/s/blog_5ffe8e5701013we1.html, (2022)
[19] Simeon, R. and Alexander, J. Z.: Attracting mappings in Banach and Hyperbolic Spaces. Vol. 253, No. 1, pp. 250-268. Journal of Mathematical Analysis and Applications, (2001)
[20] Chen, Z. L. and Zhao, H.: Self-similar attractor sets of the Lorenz Model in parameter space chaos. Vol. 173, pp. 113651. Solitons and Fractals, (2023)