Interactive Innovation Balance Structure in Green Manufacturing

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Maturity and innovation degree of green manufacturing exploratory and exploitative innovation technologies can effectively measure the degree of innovation balance of the enterprise. Strengthening the scientific research layer to adopt green manufacturing technology innovation research and development for the enterprise and reducing the “conflict” will promote the enterprise to engage in exploratory innovation, which in turn will encourage the decision of enterprise interactive innovation balance. The support layer actively searches for information and supports the green manufacturing innovation ecosystem with information, funding, and other innovation resources, thus facilitating enterprises to engage in interactive innovation balance.

Keywords: green manufacturing ; innovation ecosystem ; innovation balance

1. Introduction

Green manufacturing is an advanced manufacturing model with the development of ecological civilization. Since 2016, China’s green manufacturing system has steadily advanced; green products, green factories, green parks, and green supply chains have developed in tandem, and the scale of the green manufacturing industry has gradually grown, effectively promoting the green and low-carbon transformation of industry and contributing to the realization of the vision of carbon peaking and carbon neutral goals [1]. With the accelerated evolution of the new “green” technological revolution, green manufacturing has become the key to high-quality economic development. Technological innovation is the driving force of the new revolution to generate new development momentum. In the new era of innovation-led development, where the competition for green manufacturing is becoming increasingly fierce, the demand for green manufacturing products and services in emerging markets is diversified. Sustainable research and development (R&D) of new technologies, products, and services is the inevitable path for enterprises to enhance their competitive advantages in green manufacturing. Under the current innovation environment, enterprises are no longer a single innovation subject but build and continuously optimize the innovation ecosystem to achieve access and utilization of cross-border resources [2]. The key to developing green manufacturing in enterprises lies in the sustainable innovation and application of major green vital technologies. Green manufacturing technology innovation requires a perfect and sound “ecosystem,” including the whole process of green manufacturing innovation from the source R&D to the transformation of scientific and technological achievements and the final marketization [3]. In reality, HP, BYD, and Gree and other enterprises have built a green manufacturing innovation ecosystem response to the enterprise collaboration with other innovative subjects for resource integration and technological innovation, and R&D to enhance green manufacturing competitiveness sustainably.

Suppose the enterprise continues to develop new green manufacturing technologies and products in collaboration with other innovation subjects, ignoring the optimization of existing green manufacturing skills, processes, and structures. In that case, it will likely result in an imbalance between exploratory and exploitative innovation. Excessive exploratory innovation will lead to large resource consumption, increased innovation cost, and the probability of failure, directly reducing the enterprise’s revenue. Extreme exploitative innovation will hinder the development of the enterprise’s cognitive ability in specific innovation areas, inhibit the enterprise’s ability to anticipate forward-looking technology, and miss the opportunity to seize the innovation highland. In an environment of increased competition in a globalized market, enterprises have been able to maximize the utility of resources and overcome the “innovation trap” by enhancing their position as the mainstay of the national innovation system and balancing exploratory and exploitative innovation [4]. Therefore, for the green manufacturing innovation ecosystem, when the external environment is stable and changing, the enterprise should focus on exploitative innovation; When the external environment changes in a revolutionary way, the enterprise should focus on exploratory innovation. This interactive balance of alternating exploratory and exploitative innovation slows down the consumption of innovation resources for the enterprise. It is an optimal approach for green manufacturing innovation ecosystems in the development stage.

2. Green Manufacturing Innovation Ecosystem

Green technology innovation, represented by clean production, environmental technology, and low-carbon technology, is a new engine for the manufacturing industry to promote sustainable economic development [5]. Compared with traditional technological innovation, the complexity and uncertainty of green manufacturing technological innovation are higher, and the development of exploratory innovation is hindered [6].

The institutional and environmental influences on green manufacturing innovation in the Chinese context have been researched from multiple perspectives. In terms of macro factors such as government guidance and subsidies, Cumming, Rui et al. selected data information on Chinese enterprises and found that inequality in political capital directly affects the ability of enterprises to obtain bank loans through political channels, which in turn affects their likelihood to invest in innovation [7]; Guo, Guo et al. used panel data of Chinese manufacturing enterprises from 1998–2007 to empirically analyze the impact of government R&D programs on enterprises' innovation industries [8]; Liu, Du et al. used data of Chinese listed enterprises from 2010–2016 to examine government R&D subsidies as a primary policy tool for market failure and concluded that ex ante incentives have a higher impact on enterprises' innovation performance than ex post incentives [9]; Zhao, Xu et al. used empirical data of Chinese provinces to examine the impact effect of the formulation and deployment of national R&D subsidy policies significantly advancing national technological progress [10]. In terms of the influence of market environment factors, Fang, Lerner, et al. used a DID model to empirically analyze the impact of knowledge industry protection on innovation in China before and after the privatization of SOEs, concluding that IPR protection enhances firms' incentives to innovate and that private firms are more sensitive to this than SOEs [11]; Rong, Wu et al. used patent data of Chinese listed firms from 2002–2011 found that the presence of institutional investors promotes firm innovation [12]; Tian, Kou, et al. argued that venture capital plays a crucial role in fostering enterprise technological innovation and dissects it from two perspectives: equity background and investment strategy [13]; Zhang, Mohnen investigated whether innovation in Chinese manufacturing firms prolongs survival time and found that both R&D and product innovation increases the chances of firm survival [14].

In addition, scholars have also conducted research on green manufacturing in general contexts, mainly from the perspectives of green manufacturing development level, influencing factors, realization paths, and technology applications. For instance, Mao and Wang et al. pointed out that the core technology for enterprises to achieve green manufacturing is artificial intelligence [15]. Song and Yu et al. proposed a green innovation strategy, which refers to manufacturing enterprises' efforts to obtain a sustainable competitive advantage by carrying out green technological innovation to meet stakeholders' expectations while making strategic decisions [16]. Song and Lin found that the R&D of green technology innovation in the manufacturing industry requires the support of production factors such as capital, labor, and knowledge, and financial agglomeration provides the basis for achieving this condition [17]. Ying and Li et al. argued that the internal and external drivers of green manufacturing are mainly the internal enterprise environment, market environment, and institutional environment [18].

The synergistic effect of institutional innovation and technological innovation has significantly promoted the development of green manufacturing [19], while the innovation ecosystem emphasizes inter-subjective collaborative innovation to achieve value co-creation, typically characterized by synergistic symbiosis [20]. The concept of an innovation ecosystem can be traced back to Moore's "enterprise innovation ecosystem" from a business perspective in 1993 [21], which was later defined by Ander [22]. Nowadays, enterprises are more concerned with the static institutional analysis of factor composition and resource allocation when conducting green manufacturing and emphasize the dynamic evolution of the mechanism of action among innovation subjects. Meng and Li et al. concluded that green innovation is a crucial path for manufacturing enterprises to build a resource-saving and environment-friendly oriented innovation ecosystem through a single case analysis of a traditional manufacturing company—Iceberg Group [23]. Zeng and Xue et al. studied the green innovation ecosystem and pointed out that the innovation subjects mainly include core enterprises, upstream and downstream enterprises in the green supply chain, competing enterprises, complementary enterprises, government, universities, research institutes, users, and information intermediaries, and the environmental elements mainly include market environment, policy environment, economic environment, cultural environment, scientific and technological environment, and natural environment, in which the innovation subjects and the innovation environment form a complex system of symbiotic competition and dynamic evolution through the flow of innovation elements [24]. Considering the limited rationality of enterprises and other innovation subjects in the cooperative innovation game, Su and Wei studied the stabilization strategy of tripartite participation of government, enterprise, and the public in green technology innovation through an evolutionary game model [25]; Lu and Cheng et al. studied the dynamic impact of government subsidies on manufacturers' green R&D through an evolutionary game model [26].

3. Exploratory and Exploitative Innovation

Exploratory innovation brings emerging market customer demand and future long-term revenue, while exploitative innovation brings stable short-term revenue [27]. Based on the organizational learning perspective, March first defined explorative learning and exploitative learning, emphasizing that exploration is an organizational activity characterized by search, change, experimentation, risk-taking, and experimentation, while exploitative organizational activity embodies optimization, selection, action, and efficiency [28]. On this basis, scholars have gradually combined exploration and exploitation with technological innovation and proposed exploratory and exploitative innovation [29]. Moreover, scholars have uncovered different clusters of research knowledge. For instance, Danneels argued that exploratory innovation is the act of developing new technologies to meet new customer needs, and exploitative innovation refers to the act of optimizing existing technologies to serve customers [30]; Wang further suggested that exploratory innovation is matching new customer and market needs to explore new market opportunities or new technological services for the organization, and exploitative innovation is to broaden the existing knowledge and skills of the organization and optimize the existing technology system to achieve production and service efficiency [31]. Regarding methods and contexts for the research of exploratory and exploitative innovation, Ngo and Bucic et al. empirically analyzed 150 Vietnamese enterprises as a sample, concluding that exploratory and exploitative innovation is the primary way in which technology perception and market perception enhance enterprise performance [32]. Duodu and Rowlinson explored the direct role of internal and external social capital on exploratory versus exploitative innovation and the indirect role of absorptive capacity based on a linkage and knowledge base perspective using a least squares approach [33].

4. Interactive Innovation Balance

Exploration and exploitation achieve innovative coexistence organically and coupled in the same subject to reach a state of balance and achieve matching efficiency and adaptation [34]. Interactive innovation balance reflects that exploratory and exploitative innovation are mutually reinforcing and dependent on each other. Zhang and Shen et al. argued that the balance strategy improves an enterprise’s buffering ability to cope with innovation uncertainty and facilitates the acquisition of a long-term competitive advantage [35]. Using individuals engaged in innovation development as subjects, Simon and Tellier distinguished innovation streams into developmental and exploratory projects, concluding that learning processes in the dual balance of innovation streams arise first within projects and then between projects [36]. Lawrence and Tworoger et al. empirically analyzed the balance between exploratory and exploitative innovation by enterprise leaders. They found that leaders could demonstrate flexibility in balance-switching behaviors, effectively enhancing enterprise innovation performance [37]. The optimal innovation balance model differs when enterprises are at different life cycle stages. Burgelman proposed the intermittent innovation balance model, emphasizing that enterprises interactively explore and exploit innovations at different stages and that both create ambivalence [38]. Rui and Luo studied the optimal innovation balance model for enterprises at different stages. They found that startup enterprises are suitable for interactive innovation balance, and when enterprises enter the growth stage, they need to change the innovation balance model to simultaneity equilibrium [39].

5. Gaps in the Current Literature

The research perspective of the current literature is usually a specific research field or a disciplinary perspective, which has been explored from local to overall, effectively promoting the development of exploratory and exploitative innovation theory of enterprises. However, the following gaps remain. First, the research subject is relatively single and needs a systematic perspective to track and analyze. Most of the literature focuses on enterprises alone but rarely incorporates the core innovation ecosystem of enterprises into the research scope and needs to include the influence of other innovation subjects on the balance of interactive innovation of enterprises. Second, it is more subjective and requires rigorous model arguments or mathematical derivations. The current literature on exploratory and exploitative innovation balance uses mainly qualitative methods such as questionnaires and case studies, ignoring the mathematical and theoretical connections between the two developments. Finally, most of them are based on static perspectives, and few pieces of literature have been sorted out from dynamic evolution and game perspectives, leading scholars to lack a dynamic and systematic understanding of the evolutionary process of the interactive innovation balance theory of exploratory and exploitative innovation.

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