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Article

Modeling risky portfolios with guaranteed maximize returns under a patent race

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Abstract: This paper studies the patent race problem of communication enterprises investing in communication technologies, and constructs a portfolio optimization model which considers the expected returns, investment risks, and replacement costs, in order to achieve the dual goals of maximizing the net investment income of backward enterprises and minimizing the expected investment risk. Through numerical experimental analysis, the optimal investment portfolio strategy under different risk levels and the impact of different risk levels on the net income of lagging company are obtained. The research results show that due to the backward research in the first stage of the backward enterprises, when their own investment decision-making power is relatively high, they can focus on the development of self-interested key technology areas in order to achieve the victory of the patent race.

Keywords: patent race; R&D; lagging firm; communication technology; portfolio strategy

1. Introduction

Under the background of further development in the world, economic integration and science and technology enterprises are inevitably faced with the competition from the same industry abroad, which makes enterprise decision makers pay more attention to the core of enterprise performance—the growth of competitive advantages. Subsequently, the dimension of competition is gradually changing from economic competition to technological competition when entering the 1970s. Therefore, in order to get a leading position in the fierce market competition environment, gain competitive advantages, and strive to achieve sustainable growth and operation, enterprises usually reduce production costs and develop new products by increasing research and development (R&D) investment to invent advanced technologies (Kabongo, 2019). Technological innovation has become one of the necessary means for enterprises to win competitive advantages in the new era, and thus triggered fierce R&D competition between enterprises. When an innovation is protected by a patent, the first successful company will gain monopoly profits while the others will gain nothing. Therefore, the R&D competition between companies is mainly manifested as a competition to obtain patent rights, that is, a patent race. In the patent race, the strategy of the company is crucial. As the competition progresses, participants must continually adjust their R&D portfolio strategies based on their relative position in the competition in order to win the patent race.

Patent literally refers to the exclusive right, and from the perspective of market competition, it is a tool for enterprises to seek benefits, that is, the patentee uses the exclusive right of the patent to carry out patent encirclement, and through the patent encirclement movement, obtains the competitive advantage in the market, and then wins lucrative profits for the right holder, which is the value of the patent. With the development of world economic integration, the trade competition among countries has become more and more intense. In the context of building an innovative country, the intellectual property system including patents plays an increasingly important role in promoting economic development, scientific and technological progress and cultural prosperity. In particular, patent race has become an important part of economic competition day by day. If a trademark is the business card of an enterprise, then a patent is the most powerful "weapon" for an enterprise to compete with the outside world. In today's world, the competition among enterprises is reflected in the competition of independent innovation and core technology, and accordingly in the competition of patents. Many multinational enterprises have used the patent system to establish layers of technical barriers and trade barriers, and launched round after round of patent wars around the world. Chinese enterprises must face this new feature of global economic integration, and only if they are fully familiar with and make good use of the patent system as the rules of the game in the market competition, they can be invincible in the cruel market competition. Patent, as a form of intellectual property, represents the result of scientific and technological research and development, which has the characteristics of heterogeneity and irreplaceability. In fact, with the TRIPS agreement, as far as the national level is concerned, intellectual property is no longer just a simple national issue. Actually, it has developed into a new stage of international trade and national competitiveness. Then, for enterprises, if the technological innovation results are protected by patents, the first successful innovation enterprise will obtain the patent right of this patent and apply the innovative technology or improve the old technology to make new products, to obtain a higher voice in the market.

Relevant data show that by the end of the first half of 2022, China has become the world's largest source of communication equipment manufacturing technology, and the number of communication equipment manufacturing patent applications accounts for 73.77% of the total number of global communications equipment manufacturing patent applications, see **Figure 1**. The United States followed with 15.81 percent of applications, while Japan and South Korea ranked third and fourth, with 4.74 percent and 1.33 percent, respectively (Prospective Industry Research Institute). In addition, from the perspective of patent application trend, since 2010, China's communication equipment manufacturing industry has been far ahead in terms of the number of patent applications. However, after 2021, the number of patent applications for China's communication equipment manufacturing decreased significantly, with a year-to-year decrease of 19.65%. Relevant scholars have pointed out that there is a bubble phenomenon in Chinese patents, and the rapidly increasing number of patents has not been truly transformed into high national innovation capability. In 2022, facing a complex and volatile macroeconomic environment, China's communications industry developed in a healthy and orderly manner with stable revenue growth, and it is expected that the communications industry will still maintain a good development trend in 2023. From the macro environment, the triple pressure of demand contraction, supply shock and expected weakening in China is still high, and the foundation of economic recovery is still not solid, but the fundamentals of China's economy with strong resilience, high potential, full vitality and long-term positive will not change. From the policy environment, the digital economy for the communications industry to bring development opportunities, communications industry norms management will be more refined to protect the orderly and safe production of the communications industry; under the influence of this, 5G development will drive the industry into the fast lane, Internet construction to accelerate the popularity of emerging business will continue to become the main growth point of the communications industry revenue. Specifically, the research background of this paper is based on the field of communication technology, and we note that enterprises in the communication technology industry will shift their attention from the field of technological competition to the R&D and patent race of independent innovation technologies at the present stage. Accordingly, the quantity, quality and breadth of the patent layout of communication enterprises are often an important embodiment of their technical creativity, influence and core competitiveness.

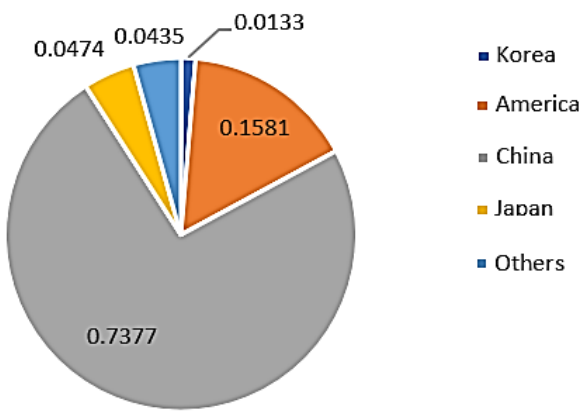

Figure 1. Number of patent applications for communication technologies in different countries.

In reality, patent race occurs when multiple telecommunications companies compete to produce a new invention and apply for a patent first. Thompson and Kuhn (2020) emphasize the ubiquity of patent races in information technology. Specifically, as a special competition of technological innovation, patent race refers to the competition behavior of competing for the first place among enterprises for the final goal of patent authorization (Gao et al., 2005). When the result of technological innovation is protected by patent, the first enterprise with successful technological innovation will get the patent right of the technology and can put the technology into the production of new products to seize the market share, to obtain monopoly profits and change the market pattern. On the contrary, the loser of technological innovation or the market latecomer will get nothing. The theory of patent race, which is used to guide the innovation activities of enterprises and the theory of technological competition, is the product of the combination of the theory of technological innovation and the theory of industrial organization. With the rise of the second upsurge of the theory of industrial organization in the 1970s, the theory of patent race has been rapidly developed. In the traditional theory of patent race, the participators of patent race are divided into leaders and laggards. Among them, the leading enterprises occupy a dominant position in the process of acquiring technology patents, while the backward enterprises are in an inferior position in the industry due to the lack of independent innovation capability and independent intellectual property rights. For backward enterprises, if they cannot effectively achieve "overtaking at the curve" in the process of competition, they will be eliminated in the patent race and lose market opportunities.

Spillover is a very common phenomenon in the process of patent race. How to effectively use spillover requires patent race participants to make strategic spillover in the process of patent race, which not only can avoid the core patents of the enterprise being used without compensation, but also can mislead competition rivals to invest and make the patent position of competitors unprotected. Enterprises should choose strategic spillover behavior to change their lagging position in the patent race. Although disclosure of information about patented technologies may not only undermine their own possibilities of obtaining patents, but also undermine competitors' ability to apply for patents, disclosure of information means that the party in the patent race that is a follower can close the gap with the leader or undermine the leader's current filing advantage. The patent race leader takes strategic spillovers to protect its existing position. This strategic spillover not only reduces the possibility of a follower "leapfrogging" over the leader to obtain a patent, but also reduces the benefits to the follower. On the other hand, strategic spillovers by the leader can reduce the eventual return on patent investment, thus reducing the R&D incentives of the followers. Disclosure of important information related to the competitor effectively undermines the competitor's position in the patent race. The spiller can disclose important information related to the competitor's core patents, products and services at the periphery of the competitor, making it difficult for the competitor to extend its product line, and with this means it can weaken the competitor's position in the patent race. By strategically disclosing information related to the final patent, it can not only help patent investors to cut R&D costs, but also to solve the problems in the R&D process with the help of common strength. Hiding information that is useful for patent development and spilling "useless" or "unfavorable" information may effectively slow down or mislead competitors' research and development. Companies usually propose different solutions to a problem, and eventually choose the most core technology to apply for a patent. For the secondary core and additional new technologies, companies adopt strategic spillovers to disclose these non-patentable technologies so that competitors in the patent race cannot apply for patents. Through active technology spillover to upstream and downstream enterprises to achieve the purpose of expanding the long-term demand for the enterprise's products. By actively spilling such information, suppliers and downstream enterprises can be prompted to make complementary innovations related to them, and upstream and downstream enterprises develop new related technologies, not only to induce suppliers and potential buyers, but also to attract suppliers to make technological innovations or changes, thus further expanding the market for the technology or opening up a new market.

Since the development of domestic patents is later than that of foreign countries, the environment is constantly changing, especially with the increasing improvement of intellectual property protection policies, patents are inseparable. Some ways of using patents to invest are subject to more policy constraints. On the one hand, it takes a long time from new application to authorization, and if it cannot be authorized, it is often impossible to transfer for profit, therefore, the way of examination and the provision of documents need to be gate-checked. On the other hand, some investments are made for local government subsidies, and once the subsidy policy changes, there will be unreliable losses. There are also some investors who use the enterprise subsidy policy to cooperate with the enterprise, but after getting the subsidy, they have conflicts with the enterprise and even go to court. In addition, if the purchase method is used for trading investment, there can be market price fluctuations, or demand fluctuations, and the problem of unrecoverable investment. Therefore, when acquiring a patent, it is necessary to examine the market value of the patent itself. This is for bulk acquisitions, most of which are experienced, under the banner of bulk acquisitions, in essence in selecting the right patents, acquiring them and then selling them at a high price. This kind of investment is relatively quicker in recovering funds compared with the uncertainty of long authorization time for new applications, but then there is also the problem of information asymmetry and market variability. Especially, as intangible assets, patents will be useful in listing, capital operation, technology trading, financing pledge, etc. We believe that with the improvement of the policy and environment, more and more institutions or capital will appear with patent technology as the profit point. Patent investment, especially patent investment with technology, is often lucrative despite the risks involved. It is often reported on the Internet that a certain technology patent has been transferred or licensed to obtain hundreds of millions of dollars or capitals. There are also many practitioners who are working hard in patent trading and making a lot of money. There are risks in the industry, but as long as appropriate ways are used to avoid them, profits and even windfall profits are possible. In addition, as a patent innovation activity with high uncertainty and long cycle, the patent needs a market environment with greater risk preference and higher tolerance for failure. At the same time, it is also necessary to screen and find R&D investment enterprises with the ability to diversify innovation risk.

For a company, it is always necessary to consider the investment portfolio and risk diversification. We consider the semi-absolute deviation method to measure risk, which meets the requirements of risk-averse investors, can effectively control investment risk. The semi-absolute deviation is the absolute value of the actual return of the portfolio below the desired return, i.e., the lower semi-absolute deviation. Risk measurement is accurately expressed as not taking unnecessary risks and reasonably controlling risks. When a company invests in risky assets, it will bear risks. But it can still withstand smaller losses. While winning the patent race can bring greater benefits to a company, the outcome of a company's investment is more than just a patent package, and the return on investment needs to be carefully evaluated before making a decision, so as to effectively reduce losses and maximize benefits. In fact, due to the influence of internal and external uncertain factors, enterprises are always faced with the risk of losing patent competitive advantages and failing to achieve patent goals. Therefore, when making patent R&D and investment decisions, the preference of decision makers is considered, that is, the psychological attitude of decision makers towards risk, and then the different behavior of decision makers under different risk preferences is analyzed, to provide theoretical support for improving the technological innovation ability and enhancing the competitive advantage of both sides of patent race game.

In the patent race in the field of communications technology, it is important to explore which R&D portfolio strategies the laggards adopt to turn the tide. The main innovations in this paper are as follows:

- Combining with the technical background of mobile communication network and theoretical knowledge such as patent race and investment portfolio, this paper establishes a mathematical model to simulate the R&D investment process of backward enterprises in the process of patent race, to maximize the net investment return and minimize the expected investment risk.
- Numerical experiments are conducted to obtain the optimal portfolio results of lagging enterprises under different risk levels, which can intuitively obtain the investment situation of lagging enterprises in each key technology field, and explore the changes in the net income of lagging enterprises under different risk levels.

The remainder of this paper is organized as follows. After reviewing the relevant literature in Section 2, Section 3 describes the research question, proposes the portfolio model and transforms the model. In Section 4, we simulate the portfolio models of lagging company in key technology areas in the field of communication through numerical experiments, and obtain the optimal portfolio strategy. Section 5 summarizes our research by showing research highlights, and gives management implications and future research directions.

2. Literature review

2.1. Patent race

Today, the global patent race has changed from a competition of patent quantity to a competition of the patent industry. The patent race has changed from the competition of patent quantity to the competition of patent quality, from the competition of single patent race to patent portfolio competition, and from natural competition to strategic competition. Patent race refers to the possession and comprehensive use of patent rights as the main purpose. The acquisition and operation of patent rights have become a competitive tool in global high-tech. The acquisition and operation of patent rights has become a competitive tool for a country/region/industry/enterprise to win in the global high-tech competition. The ability of enterprises to win in the patent race depends on their ability to use patents strategically and their management level (Wang et al., 2018). Al-Fazari and Teng (2020) thought in the patent race, The contestants are competing in a patent race, and at the same time, they are both providing an industry collective good for the enhancement of the prize of the patent race. The model finds out that innovation effort peaks when the contestants have equal research and development cost efficiency. Furthermore, greater returns to scale in innovation increase innovation efforts when contestants are about equal in their innovation cost efficiency and decrease innovation efforts when contestants are very unequal in their innovation cost efficiency. Neil and Jeffrey (2020) provided the first broad-based view of them in the real world. It reveals that patent races are common, particularly in information-technology fields. They then analyzed the effect of winning a patent race, showing that patent race winners do significantly more follow-on innovation, and their follow-on research is more similar to what was covered by the patent.

Wu (2022) believed that China's communication technology has stepped into a whole new era, people use high-tech means to advance modern communication technology to realize information exchange. From a theoretical perspective, Liang (1998) discussed the enlightenment of the Verdmog model on China's technological innovation phenomenon. Mao and Li (2021) believed that, in the context of the increasing number of mobile terminals, it is no small challenge for the development of wireless communication network technology. This requires that wireless communication network technology must be transformed in order to better meet the requirements of the development of the times. According to Ren (2022), with the continuous development of science and technology, computer information and communication technology are widely used in the field of artificial intelligence. Through the analysis and comprehensive organization of data, it was able to develop artificial intelligence technology. In the era of artificial intelligence, the communication technology of computers is given full play to further improve the ability of deep learning of artificial intelligence. Therefore, it is necessary to develop modern computer communication technology. Moreover, various companies are paying more and more attention to the development of communication technology. Yuan and Hou (2024) found that patent portfolio competition, technological complexity, and technological accumulation are at least three factors that promote the formation of patent jungle.

The two-stage patent race is developed based on a one-time dynamic game model. Considering that the invention and creation process consists of two stages, in the first stage, each enterprise must carry out basic research work, that is, the basic invention stage; subsequently, the second stage refers to the patent development of the enterprise, that is, the patent development stage. In addition, the end of the two phases is marked by the first inventor receiving the patent. Among them, the two-stage model is represented by the Verdmog model two-stage patent race model, in which the influence of first-mover advantage in the patent race is considered and has been fully applied. Gilbert and Newbery (1982) also considered the dynamic nature and phasing of the patent race. Then, based on this two-stage model, scholars conduct optimization research on patent race. Scotchmer (1996) argued that forward protection in the first stage will compress or even eliminate the R&D and production space for second-stage entrants. Denicolo (2000) focused on the optimal "forward patent protection", considers competition in innovation and R&D, and incorporates time into the patent race, assuming that there is a patent race at each stage. Feng et al. (2002) established a two-stage patent race model in the research competition stage and the development competition stage, and assumed that the patent race occurred before the achievement of the research stage. After the followers fully acquired the research results, there would be a secondary competition to study the R&D investment strategy of the enterprise. The results showed that in the two-stage patent race, the leading firms always invest more aggressively than the lagging ones. Kim and Koo (2012) proposed an optimal patent design system based on the two-stage patent race model. The results show that only granting patents with mandatory contingent licensing fees to the first innovator can avoid problems such as loss of control and duplication of R&D efforts. Green and Scotchmer (1995) considered the forward projection of the innovator in the first stage of the model. Parell (2015) assumed the existence of a two-stage R&D race and embedded informal intellectual property rights (IPR) and secrecy in a Schumpeterian growth model of constant size to study the long-run effects of enhanced secrecy protection. Research results show that strengthening confidentiality protection can improve enterprise welfare. Leung and Kwok (2012) studied preferential patenting behavior in a two-stage real options game in which incumbents and potential entrants compete for patents on alternative products in product markets with uncertain profit flows. Dong (2018) thought that high-value patents can not only improve the core competitiveness of enterprises to avoid homogeneous competition but also form a protective layer for the innovation achievements of enterprises and continuously provide the impetus for their innovation. Tang (2023) believed that a patent layout that starts with business and proper strategy, with clear objectives and effective mining methods, can help enterprises quickly build a high-value patent portfolio that matches their development stage. A clear and effective mining method can help enterprises quickly build a high-value patent portfolio that matches the development stage of the enterprise.

With the increasing strategic use of patents, patenting activities are increasingly motivated by the strategic goals of firms, rather than just patent protection goals (Agrawal et al., 2024; Harhoff et al., 2007). The strategic use of enterprise patents is a full-chain strategic management process to maximize the value of portfolio patents (Yang et al., 2016), and is increasingly based on the patent acquisition and its effective management, strengthening the integrated operation of patent activities such as patent research and development, application, maintenance, and licensing and implementation becomes an inevitable choice for enterprises to enhance their competitiveness in the global patent race, and also becomes the focus of strategic use and management of enterprise patents. It has also become the focus of strategic patent application and management. Wang et al. (2018) showed that in the future, attention should be paid to systematic research on the management of the strategic use of patents by enterprises, the design of a patent analysis and decision-making method for enterprises based on patent race, while focusing on the management of conventional activities such as patent research and development, application, maintenance, and implementation, as well as strengthening the management of strategically oriented patent activities such as patent licensing, patent affiliation, patent infringement litigation, and litigation response, focusing on the integration of patent resources and Patent Activities Collaborative management of patent activities. Yang and Fan (2023) believed that the higher the quality of authorized patents of strategic emerging enterprises, the more advanced the technology of the enterprises, the greater the depth of protection of the technology, and the greater the advantage of patent rights.

2.2. Portfolio risks

As early as the 1970s, scholars have been studying patent R&D investment. With the increasing complexity of the market environment, scholars began to evaluate the economic uncertainty. Some scholars believe that patent investment, there is in a broad sense, there is a narrow sense; investment for profit, there are short-term, there are long-term; there are visible and invisible. There are low-level and high-level ways to make profits. Because of the difference in awareness and policies of domestic and foreign intellectual property rights, especially patents, domestic patent investment also reflects different ways and risks. In the process of patent investment, we need to choose the appropriate way according to our actual situation, and if necessary, we need to cooperate with familiar people to contribute money and work together. Some use of patents to invest in the way, subject to policy constraints situation more, on the one hand, the new application to authorize a long time, if not authorized, often cannot be transferred for profit, therefore, the city checks the way and the provision of documents need to be gate-keeping; on the other hand, some investment is rushing to the local government subsidies, once the subsidy policy changes, there will be unreliable losses. There are also some investments in green using enterprise subsidy policy and enterprise cooperation, after getting subsidies, but conflicts with the enterprise, and even in court. Furthermore, relevant scholars incorporated risk preference into mathematical models and discussed the investment decisions of enterprises under the influence of risk preference. Risk refers to the decision makers' psychological attitude to risk, due to differences in policy makers' psychological characteristics, in the face of the same object, different decision-makers can produce different psychological reactions, and make a different behavior, namely hold different risk preferences of decision-maker in the face of the same investment will be based on different angles, to produce different decision-making results. Zhong (2019) believed that patent investment refers to the investment made by the patentee with the patent rights of his inventions for a price. In the existing literature, the research related to the risks faced in the process of patent R&D and investment is mostly focused on exploring the impact of risk factors on decision variables such as investment portfolio, while relatively few literature consider the risk preferences of both sides in the process of patent race. Garleanu et al. (2012) emphasized on innovation introduces a "displacement" wind that cannot be ignored. Hsu and Huang (2010) constructed a technical risk factor to explain the variation in French portfolio returns. Banerjee and Sengupta (2019) focused on the lower systematic risk coefficient of innovation leaders compared with laggards, established a winner-takes-all patent race model, and analyzed the impact of strategic interaction between innovative competitive enterprises on risk and expected reporting.

Lee et al. (2022) studied the optimal patent R&D decisions and investment portfolios under different market conditions and risk assumptions by considering the risk preferences of target enterprises. Beauchene (2019) hypothesized that the two firms compete in both the R&D and product markets, and explores the outcomes of R&D investment and the possible effects of the two firms' aversion to the risk of ambiguous product market outcomes. Research results showed that ambiguity aversion intensifies the competitive threat, while risk aversion reduces the profit motive of investment. Yuan (2013) believed that the investment strategies of the two companies interact with each other during the patent race of each other. In addition to investing in patent research and development, a strong company can choose to gradually invest or acquire a weak in addition to investing in patent research and development, the stronger company can also choose to gradually invest in or acquire weaker company to ensure the maximization of its revenue. However, being a leader in the patent race does not mean that the company remains in the It will change dynamically depending on the investment strategies of both competitors. This will change dynamically depending on the investment strategies of both competitors. Yuan (2013) believed that the process of patent race is accompanied by numerous uncertainties and that companies must position themselves in the process. This is because no matter how complex the R&D projects a company engages in and how unpredictable the competitive environment is, companies will always find relevant information that will help them formulate their investment strategies when making decisions. Different positioning requires different strategic actions. Therefore, companies need to clearly define their state based on industry and technology trends and their characteristics. Clearly define the state of the race to decide which investment strategy to choose. Li and Wu (2019) believed that against the background of the rapid growth in the number of patent applications in China, the relevant government authorities need not only to strengthen the supervision of patent quality but also to provide SMEs with practical and effective guidance on patent strategy and intellectual property management.

2.3. Research gap and contribution

We provide **Table 1** here to highlight the contribution of this study and to further clarify research gaps with existing studies. Through the combing of the above-mentioned relevant literature, it can be seen that patent competition has become an important research field widely concerned by intellectual property scholars. However, most literature considers patent competitions between firms in equal competitive positions. However, we have observed that in the patent race in the communications industry, laggards usually do not voluntarily withdraw from a promising technology field because of a temporary lag in R&D.

Table 1. Summary of the literature review most related to this study.

Reference	Patent race	Portfolio risks	Semi-absolute deviation method	Modeling
Feng et al. (2002)	✓			✓
Beauchene (2019)	✓	✓		✓
Zhong (2019)	✓	✓		✓
Al-Fazari and Teng (2020)	✓			✓
Lee et al. (2022)	✓	✓		✓
Tang (2023)	✓			
Agrawal et al. (2024)	✓			✓
Yuan and Hou (2024)	✓			
This paper	✓	✓	✓	✓

In the context of the development of the new era of communication network technology transformation, considering the rapidly changing market environment, this paper is more realistic to incorporate investment risks into the bi-objective model of investment portfolios in the field of communication technology. In this paper, the portfolio problem of lagging company in the process of communication technology patent race is studied, and a bi-objective planning model is constructed to maximize the net return of the lagging company' portfolio and minimize the risk function of semi-absolute deviation. On this basis, through the analysis of the nature of the model and the sensitivity analysis of the corresponding parameters through numerical experiments, it provides specific investment strategy enlightenment for backward enterprises in the process of patent race. The findings in this paper support the ultimate success of R&D activities if the right R&D investment decisions are made in the next stage, regardless of the investment decisions of laggards in the current R&D.

3. Problem description and model formulation

3.1. Problem description

This paper studies the patent race of communication technology invested by enterprises in the field of communication. We define the most outstanding companies in the field of communication technology as leading companies. The most competitive enterprises among other SMEs can be represented and defined as lagging company. As a result, this article sets out a scenario in which there is only one leading company with a competitive advantage and one lagging company. For the leading company, the environment is relatively stable, and the goal of the leading company is to maintain its competitive advantage and establish a balance. Obviously, the lagging company has the best chance of catching up with the leaders in the patent race. Therefore, the horizontal competition of multiple enterprises can be reduced to the competition between a leading company and a lagging enterprise. Leading and laggard companies act as independent stakeholders who make independent decisions in the communications patent market at the same time.

We assume that there are investment risks in the technology fields in which enterprises invest, which is risky investment. The significance of venture capital is that it can promote technological innovation and the transformation of high-tech achievements, which is conducive to improving the industrial structure and cultivating the competitiveness of enterprises. We assume that when the investment portfolio meets certain liquidity conditions, after deducting the withdrawal and entry costs of various assets, the enterprise pursues the maximization of net investment returns and the minimization of expected investment risks. When the leading enterprise has completed the first stage (Research), based on the successful practice that the leading enterprise has completed the first stage, it can greatly stimulate the enthusiasm of the backward enterprise in the process of patent race, and complete the current stage as soon as possible by increasing the investment intensity to enter the next stage (Development). The research framework is shown in **Figure 2**.

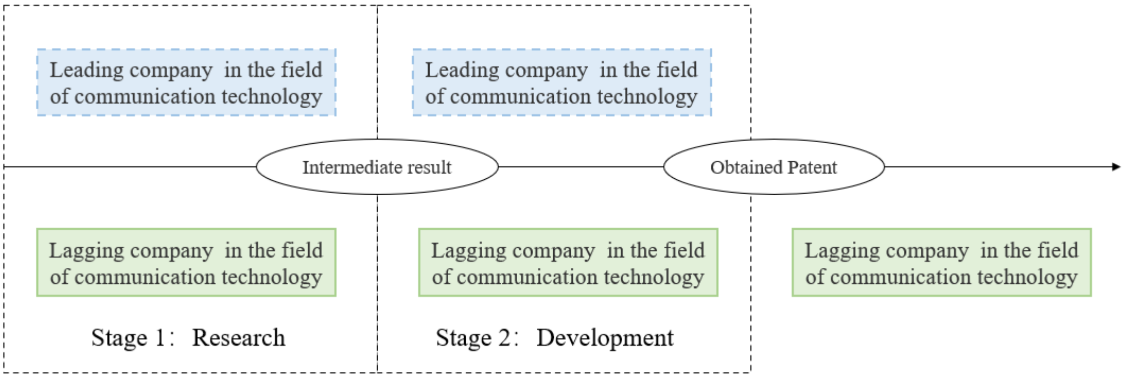

Figure 2. The patent race process of communication enterprises.

Based on the above problem description, the decision variable and parameters involved in this paper are described in **Table 2**.

Table 2. Notation.

Decision variable	**Definition**
x_{it}	The proportion of investment in technology field $i$in period t, $i = 1,2,\ldots,n$ and $t = 1,2,\ldots,T$
Parameter	**Definition**
r_{it}	The expected revenue of the technology sector in period t
t	The period of patent investment (R&D), $t = 1,2,\ldots,T$
α_i	Percentage of lagging company that has invested in technology i
w_{it}	The risk of venture capital$i$in period t, $i = 1,2,\ldots,n$
β_i	Risk benchmark of venture capital$i$, $i = 1,2,\ldots,n$
k_i	The cost of replacement (input or withdrawal) of technology i, $i = 1,2,\ldots,n$
u_{it}	An upper bound on the proportion of investment in technology i in period, $i = 1,2,\ldots,n$

3.2. Model formulation

We establish a mathematical model to simulate the R&D investment process of lagging enterprises in the process of patent competition, so as to achieve the dual goals of maximizing net investment return and minimizing expected investment risk. Since the above two objectives are in conflict, it is not possible to combine the two objectives into a unified goal to resolve them. Therefore, this paper provides the optimal portfolio strategy for lagging communication enterprises in the patent competition process in key technology fields, and establishes a dual-objective planning model.

In the process of investing in the research and development of key technologies, it is normal to withdraw from the process due to uncertain factors. However, the resulting expense and the cost of time spent are called exit expense. In the process of patent race, the total expenditure of the withdrawal expense is expressed as

$$K = \sum_{i=1}^{n} k_i \left| \sum_{t=1}^{T} x_{it} - \alpha_i \right|$$

And the expected return of the portfolio of investment assets invested by the backward enterprise in each key technology field are, respectively, expressed as:

$$R = \sum_{i=1}^{n} \sum_{t=1}^{T} r_{it} x_{it},$$

where $\left|\sum_{t=1}^{T} x_{it} - \alpha_i\right|$represents the difference between the total proportion invested in the technology field and the proportion invested in the three periods. The income from investment in R&D in communication technology refers to the net income from profits and other income obtained from investment in communication technology minus investment losses. Therefore, the portfolio net return function of backward enterprises is as below:

$$f(x) = R - K = \sum_{i=1}^{n} (\sum_{t=1}^{T} r_{it} x_{it} - k_i \left|\sum_{t=1}^{T} x_{it} - \alpha_i\right|) \tag{1}$$

We consider the semi-absolute deviation method to measure risk, which meets the requirements of risk-averse investors, can effectively control investment risk. The semi-absolute deviation is the absolute value of the actual return of the portfolio below the desired return, i.e., the lower semi-absolute deviation. For portfolio $x_i = (x_{i1}, x_{i2}, \ldots, x_{it})'$, its semi-absolute deviation risk function can be expressed as

$$g(x) = \sum_{t=1}^{T} |min\{0, \sum_{i=1}^{n} (w_{it} - \beta_i) x_{it}\}| \tag{2}$$

The main problem addressed in this article is how to diversify investments to maximize returns while minimizing risk. The main purpose of a portfolio strategy is to achieve an expected return target at a certain point in the future and control the volatility of assets within the tolerable range of the enterprise. We introduce mathematical statistical methods (semi-absolute deviation risk functions) into portfolio theory to solve the proportion of optimal investment allocation. The specific bi-objective programming model (P_0) can be constructed as follows.

$$max\, f\,(x), min\, g\,(x)$$

$$\text{s.} t. \sum_{t=1}^{T} \sum_{i=1}^{n} x_{it} = 1, 0 \le x_{it} \le u_{it}.$$

3.3. Model conversion

In the process of patent race in the field of communication, enterprises participating in research and development have uncertainty and different intensity of investment risk. Conservative companies have minimum standards for investment returns f_0, then the original dual objective model (P_0) is transformed into the following single objective model (P_{1-1}).

$$min\, g\,(x) = \sum_{t=1}^{T} |min\{0, \sum_{i=1}^{n} (w_{it} - \beta_i) x_{it}\}|$$

$$s.t. \sum_{t=1}^{T} \sum_{i=1}^{n} x_{it} = 1, \tag{3a}$$

$$0 \le x_{it} \le u_{it}, \tag{3b}$$

$$f(x) = \sum_{i=1}^{n} (\sum_{t=1}^{T} r_{it} x_{it} - k_i \left|\sum_{t=1}^{T} x_{it} - \alpha_i\right|) \ge f_0, \tag{4}$$

We introduce the new variable z satisfying

$$\sum_{i=1}^{n} k_i \left|\sum_{t=1}^{T} x_{it} - \alpha_i\right| \le z, \tag{5a}$$

Then constraint (4) is equivalent to

$$\sum_{i=1}^{n}\sum_{t=1}^{T} r_{it}x_{it} - z \geq f_0 \tag{5b}$$

The single objective model (P_{1-1}) can be transformed into

$$min\, g\,(x) = \sum_{t=1}^{T}\left|min\left\{0, \sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}\right\}\right|$$

$s.t.$ (3a) (3b) (5a) (5b).

Furthermore, we use the ascending method to transform the model (P_{1-1}). The idea of the ascending method is that it can transform highly abstract problems into concrete problems that are easy to describe and demonstrate, and easy to solve. That is, the contradictory goal that lacks association is extended to a type of problem, and the simpler goal is solved first, and then the law and experience are promoted, and then the dual-goal problem of minimizing risk and maximizing benefits is solved. Specifically, by introducing new variables e_i^+ and e_i^-

$$e_i^+ = \frac{\left|\sum_{t=1}^{T} x_{it}-\alpha_i\right|+\left(\sum_{t=1}^{T} x_{it}-\alpha_i\right)}{2},\ e_i^- = \frac{\left|\sum_{t=1}^{T} x_{it}-\alpha_i\right|-\left(\sum_{t=1}^{T} x_{it}-\alpha_i\right)}{2},$$

The constraint condition (5a) is equivalently transformed into

$$\sum_{i=1}^{n} k_i(e_i^+ + e_i^-) \leq z, \tag{6a}$$

$$e_i^+ - e_i^- = \sum_{t=1}^{T} x_{it} - \alpha_i, \tag{6b}$$

$$e_i^+ \cdot e_i^- = 0, \tag{6c}$$

$$e_i^+ \geq 0, e_i^- \geq 0. \tag{6d}$$

For the objective function in the above single-objective model,

$$\left|min\left\{0, \sum_{j=1}^{n}(w_{it}-\beta_i)x_{it}\right\}\right| = max\left\{0, -\sum_{j=1}^{n}(w_{it}-\beta_i)x_{it}\right\} = \frac{\left|\sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}\right|-\sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}}{2}.$$

Similarly, we use the ascending method to introduce new variables l_i^+ and l_i^-

$$l_t^+ = \frac{\left|\sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}\right|+\sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}}{2},\ l_t^- = \frac{\left|\sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}\right|-\sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}}{2}.$$

Based on the above equations, we can convert to the following system

$$l_t^+ - l_t^- = \sum_{i=1}^{n}(w_{it}-\beta_i)x_{it}, \tag{7a}$$

$$l_t^+ \cdot l_t^- = 0, \tag{7b}$$

$$l_t^+ \geq 0, l_t^- \geq 0. \tag{7c}$$

We use an important mathematical idea, the equivalent transformation method. Due to the difficulty of solving the original model, the original problem is equivalently transformed, and this process reflects the solution strategy of reducing the problem of unknown solutions to solvable within the scope of existing knowledge. According to the above analysis, the original model is transformed into the following model:

$$(P_1)\ min\,\overline{g(x)} = \sum_{t=1}^{T} l_t^-$$

$s.t.$ (3a) (3b) (5b) (6a) (6b) (6c) (6d) (7a) (7b) (7c).

The objective function $\overline{g(x)}$ in the model(P_1) is the semi-absolute deviation risk function of the portfolio of backward enterprises after the model transformation. The constraint condition (3a) is the enterprise's investment capital budget constraint on communication technology, that is, the sum of the investment proportion of each key technology is 1. The constraint condition (3b) means that the proportion of investment has certain upper and lower bounds, that is, the upper and lower bounds of the proportion of investment in the technology i in the period t are respectively denoted as u_{it} and 0. The constraints (5b) represents that the first constraint says that the expected return of the investor has a minimum standard, that is, there is some minimum return that the investor can be accepted f_0. The constraint condition (6a)–(6d) is the transformed Equation (5a), indicating that there is an upper bound on the total expenditure of the replacement cost of the assets invested by the backward enterprise in various technological fields. The constraint condition (7a)–(7c) is the constraint condition after transforming the absolute value part of the objective function. To deal with complementary constraints (6c) and (7b), the large M method is used to convert them into the following constraints:

$$\begin{cases} e_i^+ \le M(1 - v_{e_i}) \\ e_i^- \le M v_{e_i} \end{cases} \text{and} \begin{cases} l_t^+ \le M\left(1 - v_{l_t}\right) \\ l_t^- \le M v_{l_t} \end{cases}.$$

Among which $v_{ei}, v_{lt} \in \{0,1\}$, $M = +inf$. In a word, the economic implication of the model (P_1) refers to how backward enterprises should allocate various assets to invest in key technologies of communication under the precondition of meeting the above constraints, to minimize the semi-absolute deviation risk of their portfolio and maximize the net return of their portfolio.

3.4. Stackelberg game model with lagging company as leaders

As described in Subsection 3.2, similar to the portfolio model of lagging company, we give the leading company's portfolio net return function is as below:

$$d(y) = \sum_{i=1}^{n} (\sum_{t=1}^{T} r_{it} y_{it} - k_i \left| \sum_{t=1}^{T} y_{it} - \delta_i \right|)$$

where y_{it} represents the proportion of investment in technology field $i$in period t ($i = 1,2,\ldots,n$ and $t = 1,2,\ldots,T$), δ_i represents the percentage of leading company that has invested in technology i . For portfolio $y_i = (y_{i1}, y_{i2}, \ldots, y_{it})'$, the leading company's semi-absolute deviation risk function can be expressed as

$$h(y) = \sum_{t=1}^{T} |min\{0, \sum_{i=1}^{n} (w_{it} - \beta_i) y_{it}\}|.$$

For investors, when investing in a certain technical field, it is necessary to master the balance between risk control and the pursuit of profit. For lagging company and leading companies in the field of communications, there is also the problem of how to reconcile increasing investment to expand scale and reducing investment to differentiate operations in order to maximize profits. In order to discuss the game process between lagging company and leading company under the patent race, the game theory is combined with the portfolio model to construct a bi-objective Stackelberg model. Stackelberg Game is a two-stage fully informational dynamic game. The main idea is that both parties choose their own strategy according to the other party's possible strategy to ensure that their interests under the other party's strategy are maximized, so as to achieve Nash equilibrium. In this game model, the party that makes the decision first is called the leader, and after the leader, the remaining players make decisions according to the leader's decision, which is called the follower, and then the leader adjusts its own decision according to the follower's decision, and so on until the Nash equilibrium is reached. In order to help lagging company makes optimal decision, we construct a Stackelberg game model with lagging company as leader and leading company as follower:

$$(P_3)\ max\, f\,(x), min\, g\,(x)$$

$$s.t. \sum_{t=1}^{T}\sum_{i=1}^{n} x_{it} = 1, 0 \le x_{it} \le u_{it},$$

$$f(x) \ge d(y),$$

$$max\, d\,(y), min\, \hbar(y)$$

$$s.t. \sum_{t=1}^{T}\sum_{i=1}^{n} y_{it} = 1, 0 \le y_{it} \le m_{it},$$

where m_{it} represents an upper bound on the proportion of investment in technology i in period. $f(x) \ge d(y)$ in the upper-level constraints of model (P_3) indicates that the lagging company pursues the goal of higher profits than the leading company within the appropriate risk tolerance.

Similar to the model transformation method in Subsection 3.3, we introduce new variables ε, p_i^+, p_i^-, q_t^+, q_t^-, and leading company have minimum standards for investment returns d_0. We also use the equivalent transformation method to perform equivalent transformation of the original problem, and use the large M method to deal with complementary constraints. Therefore, we can transform model (P_3) into (P_4) as follows:

$$(P_4)\ min\,\overline{g(x)} = \sum_{t=1}^{T} l_t^-$$

$$s.t. \sum_{t=1}^{T}\sum_{i=1}^{n} x_{it} = 1,$$

$$0 \le x_{it} \le u_{it},$$

$$\sum_{i=1}^{n}\sum_{t=1}^{T} r_{it}x_{it} - z \ge k(y^*)\,,$$

$$\sum_{i=1}^{n} k_i(e_i^+ + e_i^-) \leq z,$$

$$e_i^+ - e_i^- = \sum_{t=1}^{T} x_{it} - \alpha_i,$$

$$e_i^+ \leq M(1 - v_{e_i}),$$

$$e_i^- \leq M v_{e_i},$$

$$e_i^+ \geq 0, \qquad e_i^- \geq 0,$$

$$l_t^+ - l_t^- = \sum_{i=1}^{n} (w_{it} - \beta_i) x_{it},$$

$$l_t^+ \leq M\left(1 - v_{l_t}\right),$$

$$l_t^- \leq M v_{l_t},$$

$$l_t^+ \geq 0, \qquad l_t^- \geq 0,$$

$$min\ \overline{\hbar(y)} = \sum_{t=1}^{T} q_t^-$$

$$s.t. \sum_{t=1}^{T} \sum_{i=1}^{n} y_{it} = 1,$$

$$0 \leq y_{it} \leq m_{it},$$

$$\sum_{i=1}^{n} \sum_{t=1}^{T} r_{it} y_{it} - \varepsilon \geq d_0,$$

$$\sum_{i=1}^{n} k_i(p_i^+ + p_i^-) \leq \varepsilon,$$

$$p_i^+ - p_i^- = \sum_{t=1}^{T} y_{it} - \delta_i,$$

$$p_i^+ \leq M(1 - v_{p_i}),$$

$$p_i^- \leq M v_{p_i},$$

$$p_i^+ \geq 0, \qquad p_i^- \geq 0,$$

$$q_t^+ - q_t^- = \sum_{i=1}^{n} (w_{it} - \beta_i) y_{it}$$

$$q_t^+ \leq M\left(1 - v_{q_t}\right),$$

$$q_t^- \leq M v_{q_t},$$

$$q_t^+ \geq 0, q_t^- \geq 0.$$

4. Numerical analysis

The process of patent race is always full of uncertainties, and it is exceptionally important for laggard firms to clarify the positioning of this uncertain patent race. In this paper, we study what optimal pursuit strategy should be adopted by the lagging company when the leading companies have completed the first stage and the lagging company are still in the first stage of research. This section takes communication key technologies as an example and focuses on six key technological fields: large-scale antennas, multi-connectivity technology, distributed cloud architecture, flexible subframe configuration, new airports, and new spectrum.

In the previous section, the net portfolio return model of the lagging firm was constructed by means of theoretical analysis, but since the relationship between the parameters is expressed in the form of a function. Therefore, this section will analyze the relationship between the decision variables and the objective function and the corresponding parameters through numerical simulation to obtain the optimal portfolio strategy in the field of communication technology. The transformed problem is modeled by MATLAB software, and the model is further solved by using CPLEX mathematical optimization technique. The specific parameter assignments are shown in **Table 3**.

Table 3. Model parameter values.

Symbols	Value
r_{i1}	300,190,300,180,120,350 (million dollars)
r_{i2}	180,180,200,100,280,300 (million dollars)
r_{i3}	280,250, 250,190,120,350 (million dollars)
β_i	Risk benchmarks for technological field$i$,50,200,500,200,150,300
k_i	Removal (input or withdrawal) costs for technological field i, 5, 3, 6, 1, 1, 8 (million dollars)

Below we give the program coding process of the upper problem as in Algorithm 1, and the lower problem can be obtained similarly:

Algorithm 1 The algorithm for solving the portfolio return model

```
g_min =[zeros(1,N*T+1+N+N+T),ones(1,T),zeros(1,N+T)]
M=inf;
B1=[ones(1,N*T),zeros(1,1+N+N+T+T+N+T)];b1 =1;
A_temp={};
for i=1:N
A_temp{1,i}=ones(1,T);
end
B2 = [blkdiag(A_temp{:}),zeros(N,1),-eye(N,N),eye(N,N),sparse(N,T+T+N+T)];
b2 = alpha_i';
A_temp=[];
for i=1:N
A_temp1=[];
for t=1:T
A_temp1=[A_temp1,(omega_i(t,i)-beta_i(i))];
end
A_temp=[A_temp,sparse(1:T,1:T,A_temp1)];
end
B3 = [A_temp,zeros(T,1),sparse(T,2*N),-eye(T,T),eye(T,T),sparse(T,N+T)];
```

Algorithm 1 (*Continued*)

```
b3 = zeros(T,1);
B = [B1;B2;B3]; b = [b1;b2;b3];
A1=[eye(N*T,N*T),zeros(N*T,1+N+N+T+T+N+T)];c1 =u_i;
A2 = [zeros(1,N*T),-1,k_i,k_i,zeros(1,T+T+N+T)];c2 =0;
A3_1 =[zeros(N,N*T+1),eye(N),zeros(N, N+T+T),M*eye(N),zeros(N,T)];
c3_1 =M*ones(N,1);
A3_2 =[zeros(N,N*T+1),zeros(N,N),eye(N),zeros(N, T+T),-M*eye(N),zeros(N,T)];
c3_2 =zeros(N,1);
A3 = [A3_1;A3_2];c3 =[c3_1;c3_2];
A4 =[-r_i',1,zeros(1,N+N+T+T+N+T)];c4 = -f0;
A5_1 =[ones(T, N*T+1+N+N),eye(T,T),zeros(T, T+N ),M*eye(T)];
c5_1 =M*ones(T,1);
A5_2 =[zeros(T, N*T+1+N+N+T),eye(T,T),zeros(T, N ),-M*eye(T)];
c5_2 =zeros(T,1);
A5 =[A5_1;A5_2];c5 =[c5_1;c5_2];
A = [A1;A2;A3;A4;A5];c = [c1;c2;c3;c4;c5];
low_x=[zeros(N*T,1);0;zeros(N+N+T+T,1);zeros(N+T,1)];
up_x =[ones(N*T,1);10000;10000*ones(N+N+T+T,1);ones(N+T,1)];
ctype_ascii_milp = [67*ones(1, N*T+1+N+N+T+T), 66*ones(1,N+T)];
ctype = char(ctype_ascii_milp);
options = cplexoptimset;
options.ExportModel='model.lp';
[x,fval,exitflag,output]=cplexmilp(g_min,A,c,B,b,[ ],[ ],[ ],low_x,up_x,ctype,[ ],options)
```

4.1. Optimal portfolio strategies for different risk levels

Some companies expect to commercialize their investments in key technologies and generate further revenue from their commercial activities, while others expect to sell their investments in R&D technologies for profit and then convert the proceeds into capital for a new R&D phase and a new round of technology investment. Regardless of the business purpose, companies usually focus on the R&D process of key communication technologies on a benchmark of investment risk, and then quickly pull back their investments once the prospects of a key technological field become poor. In short, during the patent race, the investment objective of communication companies is to determine the optimal communication key technology portfolio strategy.

When the investor in the lagging firm has a minimum requirement for net income and the investment risk is taken randomly, the optimal portfolio of the lagging firm is shown in **Figure 3**, where the risk of each key technological field in each period is taken randomly as follows：

$$w_{i1} = [200,100,400,300,200,300],$$
$$w_{i2} = [200,100,400,300,200,300],$$
$$w_{i3} = [200,100,400,300,200,300].$$

When laggard investors have a minimum requirement for net income and the investment risk is high (That is, when the risk in each key technological field at each period $w_{it} \geq 600$), The optimal portfolio of lagging firms is always shown in **Figure 4**. The results of the study show that the portfolio strategy for optimal communication technologies should be laid out for each key technological field based on a comprehensive consideration of minimum expected returns, investment risk, and withdrawal costs. In particular, the distributed cloud architecture technological field can be a key R&D area for laggards to catch up with the leading companies. For the laggards in the communication field, conducting independent R&D may be the most powerful tool to attack the leading companies, and only then can the laggards achieve the dual goals of maximizing net investment returns and minimizing expected investment risks.

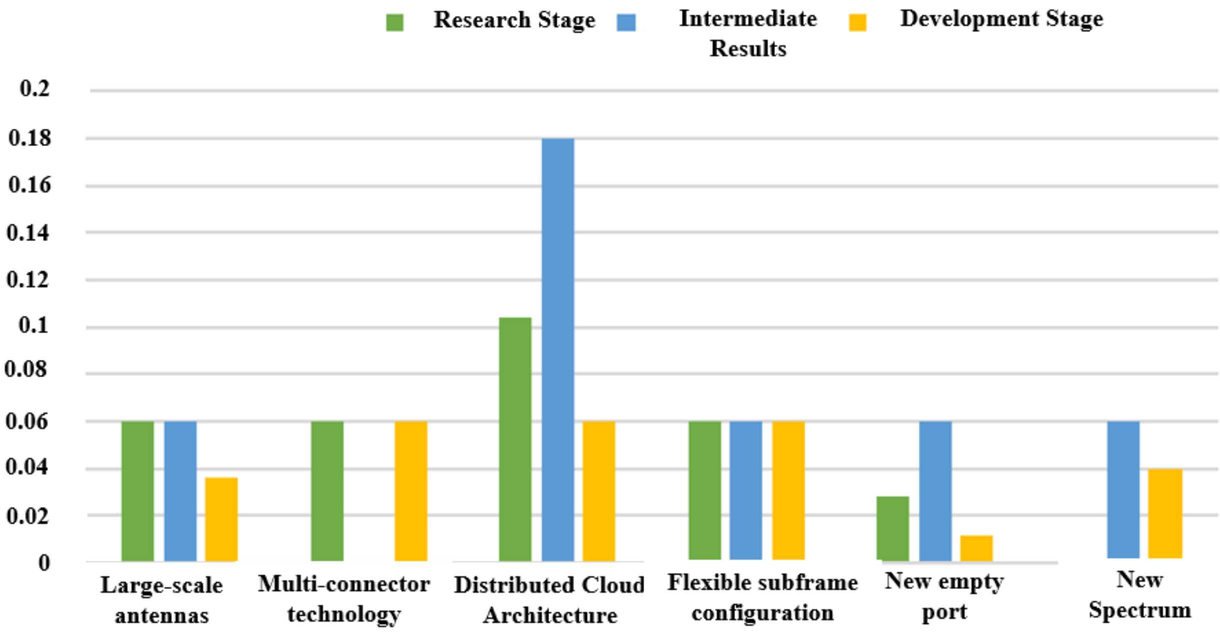

Figure 3. Optimal portfolio strategy for communication technology when w_{it} is random.

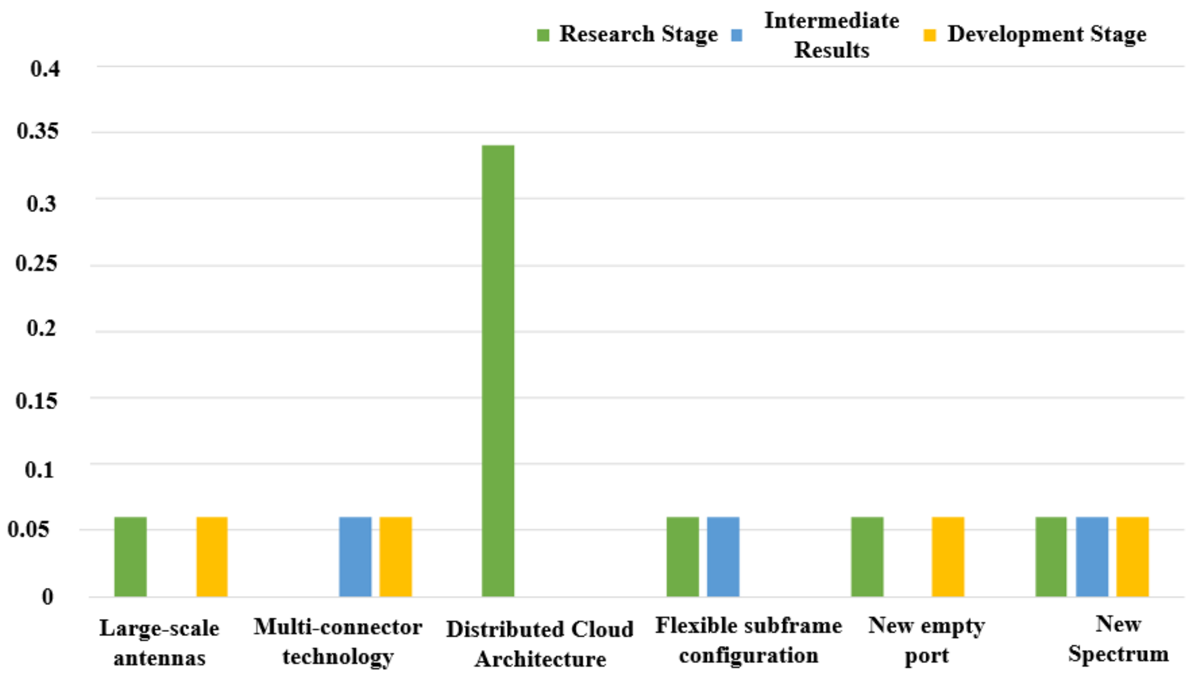

Figure 4. Communication technology optimal portfolio strategy when w_{it} is high.

4.2. Change in net portfolio returns of lagging firms

Studying the patent race process of communication firms in communication key technologies is not only a key technology portfolio problem in the communication field, but also a management problem and economic control problem with theoretical significance. Therefore, this section focuses on the changes of net portfolio returns of lagging firms under different risk levels, and the results are shown in **Figure 5**.

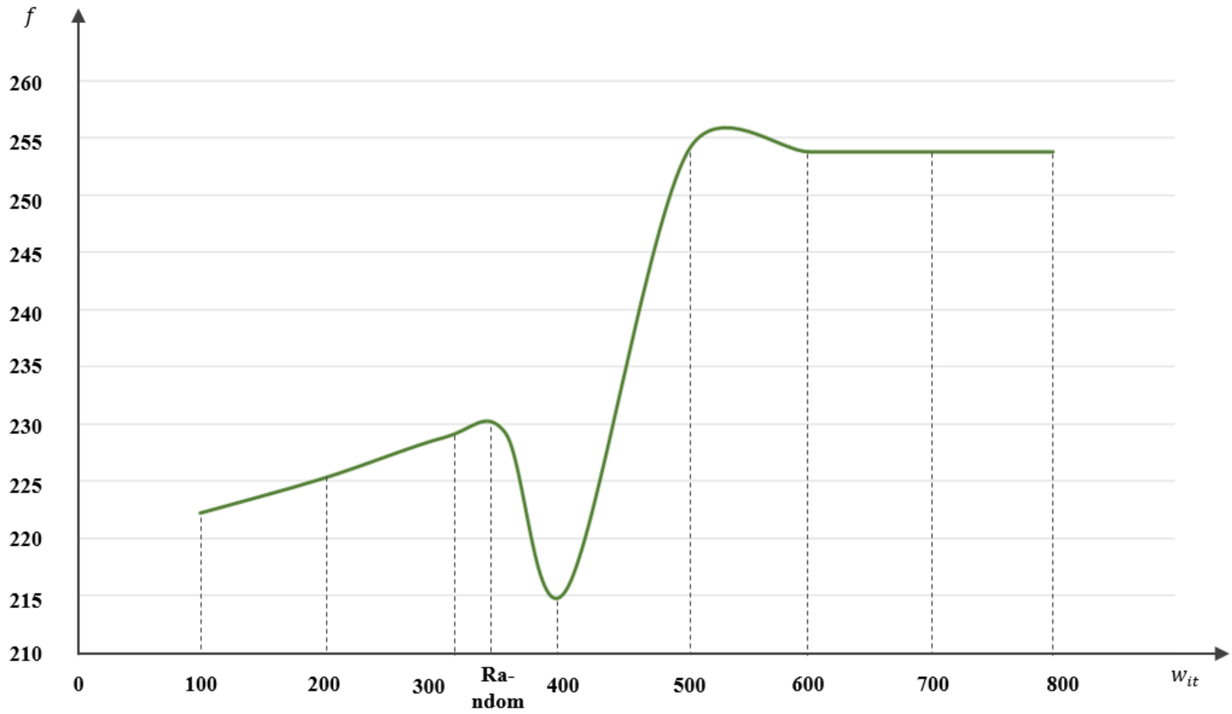

Figure 5. Changes in net portfolio returns for lagging firms at different w_{it}.

According to **Figure 5**, the changes in net portfolio returns of the backward companies show that the superiority of the optimal portfolio strategy lies in the integration of investment uncertainty in the key communication technologies, i.e., by classifying the key communication technologies to that the uncertainty of their R&D process becomes a measurable risk. **Figure 2** reveals an important management insight: risk is not the same as profit, and companies need to set the right attitude towards investment and not have a false sense of "high risk and high reward". In terms of the overall R&D investment process, most of these investment risks are related to the decision making of enterprise managers. As long as the experts in the communication field complete the measurement of expected returns in each key technological field, and then quantify the investment risks in each key technological field in each investment period, the conversion of uncertainty to certainty in the key technological field of communication is completed.

5. Conclusion

Portfolio and risk diversification are always something to consider for a company. When a company invests in risky assets, it assumes the risk. But it can still withstand smaller losses. While winning a patent race can bring greater benefits to a business, the outcome of a company's investment is more than just a patent package, and the return on investment needs to be carefully evaluated before making a decision, so as to effectively reduce losses and maximize benefits. Portfolio is an effective way to diversify investment risks. Therefore, through the portfolio model of communication technology proposed in this paper, the optimal portfolio model of lagging enterprises in patent race under different risk situations is analyzed. And we give a portfolio model of lagging company under the Stackelberg game. The findings reveal that by rationally classifying key communication technologies, the dual-objective planning model established in this paper can often transform the uncertainty risk of their R&D process into measurable risk, thereby helping managers make optimal portfolio decisions. Moreover, the results of this article remind investors that risk does not equal profit, and enterprises need to establish a correct investment attitude and not have the misconception of "high risk and high return". The next work is to extend the results of this paper to other competitive markets and consider the effects of multidimensional random changes brought about by market volatility on portfolio strategies.

The ability of enterprises to win in the patent race depends on their strategic application ability and management level of patents. At a time when the strategic use of patents has become a normal practice, the strategic use of patents has become the norm. In the global patent race where the strategic use of patents has become a norm, realized patent value and gained competitive advantage is the ultimate goal of the patent race, and strengthening the strategic use and the only way to realize the value of patents is to strengthen the strategic application and management of patents, which is the only way for China to catch up and win in the global patent race. It is the inevitable choice for China to achieve catch-up and win competitive advantages in the global patent race.

6. Managerial and policy implications

The portfolio model proposed in this study is designed to provide management insights to lagging firms. Through the model, these firms can more accurately assess their investment risks and make investment decisions in communication technologies accordingly, thus realizing "frog jump" breakthroughs in R&D competition. The findings provide a theoretical basis for laggard firms to take strategic actions to effectively pursue and win patent competition. In the process of communication technology patent race, for the temporarily lagging communication enterprises, they should actively seek reasonable and effective patent race strategies to catch up with the leading enterprises, to finally obtain the patent rights of relevant key technologies in the communication field. In addition, since uncertainty is an inherent characteristic of patent race, it is important not to have the mentality of "high risk and high reward". On the one hand, in practice, decision makers should seek a more competitive post risk return through a reasonable diversified patent layout, by diversifying investment risks and making careful choices when investing in each key technological field. On the other hand, the strategic positioning of enterprises has an important guiding significance in selecting specific portfolio strategies for patent race. Only in this way can lagging company catch up with leading companies in the patent race and make healthy, sound and long-term investments in the field of communication technologies.

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