Routledge
Taylor & Francis Group

Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

Firms' re-innovation after failure and institutional environment: an evolutionary game theoretical approach

Zhuang Xiong, Pengju Wang & Lingling Wang

To cite this article: Zhuang Xiong, Pengju Wang & Lingling Wang (2023) Firms' re-innovation after failure and institutional environment: an evolutionary game theoretical approach, Economic Research-Ekonomska Istraživanja, 36:1, 885-905, DOI: 10.1080/1331677X.2022.2080743

To link to this article: https://doi.org/10.1080/1331677X.2022.2080743

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2023, VOL. 36, NO. 1, 885–905
https://doi.org/10.1080/1331677X.2022.2080743

Routledge Taylor & Francis Group

OPEN ACCESS Check for updates

Firms' re-innovation after failure and institutional environment: an evolutionary game theoretical approach

Zhuang Xiong[a,b], Pengju Wang[c] and Lingling Wang[a]

[a]School of Business, Zhengzhou University of Aeronautics, Zhengzhou, China; [b]Business Administration Post-Doctoral Mobile Station, Henan University, Kaifeng, China; [c]School of Economics and Management, Zhongyuan University of Technology, Zhengzhou, China

ABSTRACT

Carrying out follow-up innovation activities is significant to encourage firms with failed innovation to improve their innovation quality and sustainable competitiveness. However, the existing studies lack discussion on how to stimulate firms' re-innovation after failure from the institutional level. To explore the relationship between institutional environment and the behavior choice of firms' re-innovation after failure, the behavior characteristics of firms' re-innovation after failure were discussed. A game model between government departments and firms with failed innovation was constructed by using the evolutionary game approach. The stable equilibrium strategies in the process of institutional environment optimization and firms' re-innovation decision-making after failure were analyzed. Meanwhile, the case of Zhengzhou in China was used to illustrate the theoretical model. Results show that the subjective perception of risk and benefit of re-innovation affects the behavior choice of firms' re-innovation after failure. The increase of re-innovation income promotes re-innovation behavior after failure and enhances firms' competitiveness. The improvement of intellectual property protection improves re-innovation income, but the reduction of re-innovation cost has a limited impact on the behavior choice of firms' re-innovation after failure. The increase of government social welfare benefits promotes the institutional environment construction and firms' willingness to re-innovate after failure.

ARTICLE HISTORY
Received 29 January 2022
Accepted 16 May 2022

KEYWORDS
Firms with failed innovation; re-innovation after failure; institutional environment; evolutionary game

JEL CLASSIFICATIONS
M13; O32; O33; O38

1. Introduction

The uncertainty and high risk of technological innovation determine the objective existence of innovation failure, but innovation failure does not always mean firm bankruptcy or closure (Ucbasaran et al., 2010). After failed innovation, firm decision-makers are faced with the choice of "flinch" or "restart" for subsequent innovation behavior, which affects firm competitiveness. Many theoretical and practical examples

CONTACT Pengju Wang wangpengju1986@zut.edu.cn

show that a failed innovation project possesses great value; hence, innovation failure is not treated negatively due to the nature of failure. For example, Pfizer has explored the potential value of innovation failure from the Viagra products' R&D; they successfully generated huge business value through subsequent innovation behavior and improved their market competitiveness (Dong & Zhang, 2019). Viagra's R&D and marketization process is a typical case of re-innovation from failure. After innovation failure, firms not only need to face financial repercussions but also incur emotional and social costs. In the face of failure cost, how to improve re-innovation intention, stimulate re-innovation behavior, and maintain the competitiveness of firms have become hot issues in the field of innovation management. To encourage firms' re-innovation behavior after failure will help improve the quality of firm innovation and drive economic and social values.

Existing literature has found that, after failed innovation, whether firms make re-innovation decisions is not only affected by internal factors but also by external environmental factors (Dana et al., 2021; Lu et al., 2019). On the one hand, considering that technology innovation consumes a large amount of a firm's resources, the firm needs to face the huge failure cost if innovation fails. Moreover, for managers and R&D staff, failure experience is a traumatic event, which brings negative emotions (Jenkins et al., 2014). Therefore, restricted by their resource constraints and the impact of negative emotions, firms with failed innovation should have the ability to re-allocate failed resources and manage emotions (Shepherd, 2009). Through the integration of failure resources and a positive view of failure experience, the willingness of firms' re-innovation after failure can be improved.

On the other hand, institutional factors play an important role in the process of firms' innovation (Guerrero & Espinoza-Benavides, 2021). Institutional environment is one of the factors that affect firms' innovation failure (Xiong et al., 2020), and firms with failed innovation are likely to attribute failure to external factors (Eggers & Song, 2015). Whether external factors can be improved or not may be an important basis for firms to re-innovate behavior after failure. As an important part of external factors, institutional environment may have an impact on firms' re-innovation decision-making after failure. Although the existing studies from the perspective of failure attribution and failure learning analyzed how to promote firms' re-innovation decision-making after failure through reflective learning, a research gap exists in understanding how to stimulate firms' re-innovation after failure and competitiveness from the institutional level. First, due to the large consumption of resources and limited resources, firms' re-innovation behavior needs support from external resources. Through the government's policy incentives and the financial market-oriented system, firms' shortage of resources can be solved. Second, a high level of intellectual property protection can effectively prevent the spillover of innovation achievements to improve firms' re-innovation confidence (Xiong et al., 2020). Therefore, clarifying the relationship between institutional environment and the behavior choice of a firm's re-innovation after failure is necessary.

Based on the above analysis, this study seeks to answer the following research questions. Can the optimization of institutional environment stimulate a firm's re-innovation behavior? What kind of institutional support measures are needed? Owing to the difficulty in obtaining the data of firms with failed innovation, according to the analysis of the characteristics of firms' re-innovation after failure, this study attempts to construct a game model between the institutional environment optimization agent (government departments) and firms with failed innovation by using the evolutionary game method and uses a case study to illustrate the theoretical model. The purpose is to discuss the stable equilibrium strategies of government departments and firms with failed innovation and analyze the internal relationship between institutional environment and the behavior choice of firms' re-innovation after failure.

The remainder of the study is structured as follows: Section 1 theoretically analyses the re-Innovation behavior characteristics of firms with failed innovation based on institutional theory. Section 2 describes the game model of institutional environment optimization and firms' re-innovation behavior after failure. Section 3 explores the results of the game model and empirically illustrates the results with a case study. Section 4 summarizes the conclusions, theoretical contributions, and research limitations.

2. Literature review

2.1. Institutional theory and firms' re-innovation behavior after failure

In the definition of the innovation concept, Schumpeter's innovation theory pointed out that whether or not the expected revenue is achieved is the main indicator of the success or failure of technological innovation (Block et al., 2017). With the deepening understanding of innovation in theoretical circles, the examination of "whether to achieve the expected goal of innovation" (failure criteria) is diversified (Wang et al., 2014). The discussion of failure criteria needs comprehensive judgment from the degree dimension, level dimension, and time dimension, combined with the specific context of technological innovation process (Jenson et al., 2016). Regardless of the degree dimension, the level dimension, or the time dimension, the core criterion for judging the success or failure of innovation lies in whether it meets the expected requirements of the above dimensions. Therefore, this study defines technological innovation failure as follows. Innovation failure refers to whether a firm's innovation activities have achieved the expected goal in the aspects of degree dimension, level dimension, and time dimension. In the process of firm innovation, due to external environmental factors such as technical resources, market and internal organizational factors, technological innovation is terminated or canceled because the innovation achievements do not reach the expected innovation value.

Institutional theory is an important perspective in exploring the innovation behavior of firms. According to institutional theory, firms' innovation activities should not only conform to the technical external environment of efficiency principle but also the institutional external environment of rationality principle (Van Wijk et al., 2019). Therefore, the institutional environment is an important external factor affecting firms' innovation activities, which can stimulate firms' innovation behavior (Ghazali et al., 2021).

Institutional economics theory holds that institutional environment is an important factor in determining the efficiency of organizational economics, and institutional change affects the allocation efficiency of production factor resources (Acs et al., 2018). The government's R&D subsidies, tax incentives, and other innovation incentive policies can reduce the cost of firm innovation to a certain extent (Fu et al., 2016). A high degree of financial marketization can reduce the financing cost of firms. A good level of legal environment can enable firms to obtain corresponding innovation benefits in a fair competition environment (Wu, 2013). The lack of financial development and legal environment to support firms' innovation activities, and the government's lack of effective incentive intervention for firms' innovation activities will increase the uncertainty of firm innovation and increase the risk of innovation failure. Moreover, previous failure results will bring heavy failure costs to firms (McGrath, 1999), and their resource constraints increase the difficulty of re-innovation from failure. Therefore, good institutional support can effectively promote firms' re-innovation decision-making after failure.

2.2. Behavior characteristics of firms with failed innovation

2.2.1. Decision-making process

Firms' innovation decision-making is influenced by market environment, innovation system, innovation tendency of decision-makers, leadership quality of decision-makers, and the relationship between risk and benefit of technological innovation. A comprehensive evaluation of various influencing factors is part of the decision-making process of firms. Owing to the influence of previous failure, the re-innovation decision-making process of firms with failed innovation is often complex (Cheng & Shiu, 2008). On the one hand, the attribution of innovation failure will affect decision-makers' re-innovation decision (Lin, 2016). Mantere et al. (2013) believed that the main basis for firms to make re-innovation decisions is the subjective attribution of innovation failure. The attribution of failure includes the internal causes of firms' ability and effort, as well as the external causes of the difficulty of innovation. The differentiated attribution results in innovation failure, which will lead to excessive amplification of re-innovation risk and pessimistic expectation of follow-up innovation. On the other hand, a re-innovation decision is a pre-judgment based on previous failure results. Firms with failed innovation need to further consider the impact of the degree of innovation loss, innovation ability, re-innovation cost, innovation failure stage, and other factors, which increase the uncertainty of re-innovation after failure. Compared with the general situation, firms with failed innovation will give greater weight to the risk and benefit of re-innovation in the process of decision-making.

Firms' re-innovation behavior after failure is a comprehensive embodiment of the judgment and selection of influencing factors under uncertain conditions, which is not only constrained by interests but also influenced by the differences of individual characteristics of decision-makers (Chen et al., 2021). This difference leads to different failure attribution of decision-makers, resulting in different strategic choices that show the characteristics of limited rationality. Prospect theory in behavioral economics can accurately describe the actual state of decision-makers facing the results of previous innovation failure, making the re-innovation decision-making process more in line with the behavior pattern of bounded rational person (Dooley, 2018).

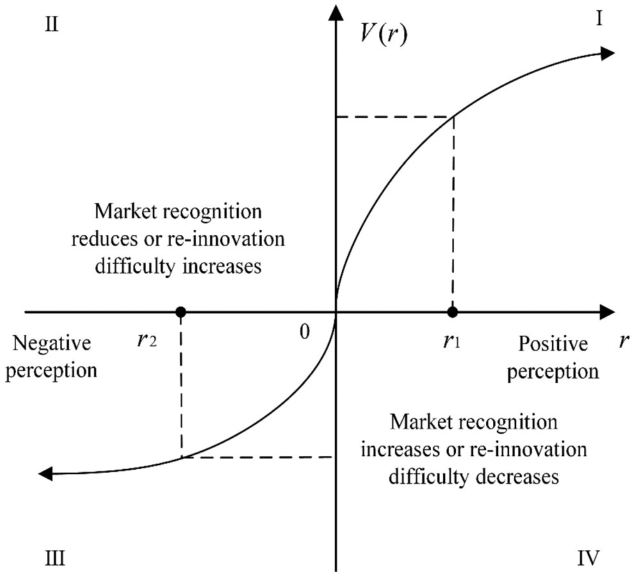

Figure 1. Prospect utility function of re-innovation after failure.
Source: compiled by authors.

Therefore, prospect theory can effectively explain the re-innovation behavior characteristics of firms with failed innovation under uncertain conditions.

In summary, relative difference r between the expected market recognition of the re-innovation products and the re-innovation difficulty is selected to measure the relationship between risk and benefit in the re-innovation decision-making process of firms with failed innovation. Among them, the expected market recognition of re-innovation products can reflect the future incomes of re-innovation activities (He et al., 2020). The difficulty of re-innovation is the comprehensive perception of uncertainty and risk in the process of firms' re-innovation after failure according to the loss degree of previous failure, self-innovation ability, re-innovation cost, and other factors (Wang, 2016). The relative difference between the expected market recognition and the difficulty of re-innovation is taken as the reference point for the re-innovation decision of firms with failed innovation. When $r>0$, firms with failed innovation think that the prospect of re-innovation is better and the utility is positive. When $r<0$, firms with failed innovation think that the prospect of re-innovation is poor and the utility is negative.

2.2.2. Prospect utility of re-innovation after failure

Figure 1 shows the prospect utility function $V(r)$ of re-innovation after failure. The concave function in the first quadrant (I Quadrant) shows that when $r>0$, firms with failed innovation have a positive perception of the re-innovation prospect. With the increase of the future market recognition of the re-innovation products or the reduction of the re-innovation difficulty, relative difference r increases, and the re-innovation prospect utility of firms with failed innovation will also increase correspondingly. However, affected by the scale of firms, the market structure and the level of competition, the utility of re-innovation shows a law of marginal decline, that is, the sensitivity of firms with failed innovation to the positive perception of re-innovation prospects gradually decreases. However, from the convex function in the third quadrant (III Quadrant), when $r<0$, firms with failed innovation show a negative perception of the re-innovation prospects. Given that decision-makers hold pessimistic views on the future market of the re-innovation products or excessively enlarge the difficulty of re-innovation, relative difference r gradually decreases, and the re-innovation prospect utility of firms with failed innovation is negative and constantly decreasing.

Figure 1 shows that firms' re-innovation behavior after failure is closely related to the future market recognition of innovative products and re-innovation difficulty. Particularly, the change of the relative difference between the two values will affect firms' subjective perception of the prospect utility of re-innovation behavior. Therefore, in the process of re-innovation decision-making after failure, the focus of firms with failed innovation is not only the absolute value of the future market recognition of re-innovation products and re-innovation difficulty but also the change of the reference point of the relative difference between the two values. The change of relative difference leads to the difference between the positive perception and negative perception of the re-innovation prospect utility of firms with failed innovation, which affects re-innovation behavior choice after failure.

In reality, the judgment of the future market recognition of re-innovation products and re-innovation difficulty of firms with failed innovation is not only affected by their internal factors such as their capabilities but also by the support of external environmental resources. Especially in the context of uncertain economic policies, whether the institutional environment and the innovation process adapt to each other affects firms' re-innovation decision-making after failure (Peng & Luo, 2000). Previous studies have found that market structure (Song & Wang, 2018), intellectual property protection (Brem et al., 2017), and government intervention strategies (Zuo et al., 2016) have a significant impact on firm innovation, whereas institutional environment affects firms' financing decisions and resource allocation (Dorobantu et al., 2017). Institutional environment also plays an important role in the process of firms' re-innovation decision-making after failure, which affects decision-makers' subjective perception of the future market recognition of re-innovation products and re-innovation difficulty. Therefore, the optimization of institutional environment can create an external environment that is conducive to re-innovation after failure, thus reducing the excessive pessimism of decision-makers on re-innovation activities. However, determining how to co-evolve between firms' re-innovation behavior after failure and institutional environment optimization, and how to form the behavior choice of stable strategy, the evolution conditions between the two agents need to be systematically revealed through evolutionary game theory. Furthermore, the mechanism of firms' re-innovation after failure should be optimized from the institutional perspective.

3. Methodology

3.1. Model hypothesis

Hypothesis 1: According to the theory of institutional change, the government is regarded as the main agent of institutional environment optimization. Therefore, in the process of re-innovation decision-making of firms with failed innovation, both sides of the game include government departments and firms with failed innovation. The strategy set of government departments is either optimizing the institutional environment or not optimizing the institutional environment. Whereas the strategy set of firms with failed innovation is either re-innovation after failure or using old technology. Besides, both sides of the game are bounded rationality. The government departments take the maximization of social welfare as the principle, that is, the main consideration of government departments in decision-making is whether the optimization of institutional environment promotes the growth of social welfare through firms' re-innovation after failure. However, firms with failed innovation follow the principle of maximizing economic benefits; the core problem of its re-innovation decision-making is the relative difference between the future market recognition of re-innovation products and re-innovation difficulty. Moreover, the information on the two sides of the game is not completely symmetrical; hence, they need to adjust their behaviors according to each other's strategies. The game process is repeated and dynamic until it reaches the equilibrium state of both sides' strategies.

Hypothesis 2: No matter whether or not firms with failed innovation carry out re-innovation, they will bear the loss of previous innovation failure I. When firms with failed innovation choose a re-innovation strategy, the cost of the re-innovation activity is Ce. Through re-innovation after failure, benefit $Re1$ brought by the innovative product can be obtained. However, if firms with failed innovation continue to use the old technology and do not carry out re-innovation activities, then they can only gain profits $Re2$ from the original products. That is, $Re1>Re2$, and $Re1-Re2$ is the revenue increase of re-innovation after failure. Government departments need to invest cost Cg to optimize the institutional environment, and when firms with failed innovation carry out re-innovation activities, due to the positive externality of technological innovation, government departments can obtain social welfare benefits $Rg1$. Moreover, due to the synergistic effect of firm innovation and institutional environment optimization (Leydesdorff & Ivanova, 2016), the government departments can obtain additional income W brought by more taxes due to the increase of re-innovation income of firms with failed innovation. However, when firms do not carry out re-innovation activities and continue to use the old technology, the social welfare benefit obtained by the government departments is $Rg2$, that is $Rg1>Rg2$.

Hypothesis 3: According to Cai and Wan (2012), government departments mainly optimize the institutional environment from three aspects: financial market, legal environment, and government intervention. The optimization of institutional environment can effectively reduce the re-innovation difficulty of firms with failed innovation and enhance the future market recognition of re-innovation products. The specific performance is as follows: the optimization of institutional environment improves the marketization level of financial institutions and reduces the financing cost of firms with failed innovation, that is, re-innovation cost Ce is reduced. If the coefficient of financial market development level is β $(0<\beta<1)$, then the cost of re-innovation after failure is βCe. The optimization of institutional environment also promotes the improvement of intellectual property protection, which improves the market competitiveness of innovative products, and then increases the profits of firms'

Table 1. Game income matrix.

Firms with failed innovation	Government departments: Institutional environment is optimized (y)	Government departments: Institutional environment is not optimized ($1-y$)
Re-innovation after failure (x)	$\varepsilon Re1-\beta Ce-I+\alpha I$; $Rg1-Cg+W$	$Re1-Ce-I$; $Rg1$
Using old technology ($1-x$)	$Re2-I$; $Rg2-Cg$	$Re2-I$; $Rg2$

Source: compiled by authors.

re-innovation after failure. If the coefficient of intellectual property protection is $\varepsilon(\varepsilon>1)$, then government departments optimize the institutional environment, and the profit of firms' re-innovation after failure is $\varepsilon Re1$. Referring to the findings of Sheng (2008), innovation subsidy is an important incentive mode for the government to guide firm innovation to measure the level of government intervention. If the coefficient of government innovation subsidy is $\alpha(0<\alpha<1)$, combined with the innovation risk subsidy method in practice (Liu et al., 2019), then the subsidy intensity is closely related to failure loss I, and the subsidy intensity of firms with failed innovation is αI.

Hypothesis 4: The probability of firms' re-innovation behavior after failure is $x(0\le x\le 1)$, whereas the probability of using old technology for production is $1-x$. The probability of government departments choosing institutional environment optimization strategy is $y(0\le y\le 1)$, whereas the probability of not optimizing institutional environment is $1-y$. Besides, x and y are functions of time t.

3.2. Evolutionary game model

Based on the above hypothesis analysis, the game income matrix between firms with failed innovation and government departments is established, as shown in Table 1.

According to the revenue matrix of firms with failed innovation and government departments in Table 1, the expected benefits $\overline{Ue}$ of firms with failed innovation and expected benefits $\overline{Ug}$ of government departments are solved.

Expected benefits $Ue1$ of firms with failed innovation when they choose "re-innovation after failure" is:

$$Ue1=(y\varepsilon+1-y)Re1+\left[(1-\beta)y-1\right]Ce+(\alpha y-1)I \tag{1}$$

Expected benefits $Ue2$ of firms with failed innovation when they choose "using old technology" is:

$$Ue2=Re2-I \tag{2}$$

Average expected benefits $\overline{Ue}$ of firms with failed innovation is:

$$\overline{Ue}=(y\varepsilon+1-y)xRe1+(1-x)Re2+\left[(1-\beta)y-1\right]xCe+(\alpha xy-1)I \tag{3}$$

Expected benefits $Ug1$ of government departments when they choose the strategy "institutional environment is optimized" is:

$$Ug1 = x(Rg1 - Rg2 + W) + Rg2 - Cg \tag{4}$$

Expected benefits $Ug2$ of government departments when they choose the strategy "institutional environment is not optimized" is:

$$Ug2 = x(Rg1 - Rg2) + Rg2 \tag{5}$$

Similarly, average expected benefits $\overline{Ug}$ of government departments is:

$$\overline{Ug} = x(Rg1 - Rg2) + Rg2 - yCg + xyW \tag{6}$$

According to replicator dynamics theory (Rosnitschek et al., 2020), replicator dynamic equations of firms with failed innovation and government departments are respectively:

$$\begin{cases} \dfrac{dx}{dt} = x(1-x)\{y[(\varepsilon - 1)Re1 + (1 - \beta)Ce + \alpha I] + Re1 - Re2 - Ce\} \\ \dfrac{dy}{dt} = y(1-y)[xW - Cg] \end{cases} \tag{7}$$

If $\frac{dx}{dt} = 0$ and $\frac{dy}{dt} = 0$, then five stable points in the replicator dynamics equation can be obtained, which are $E1(0,0)$, $E2(0,1)$, $E3(1,0)$, $E4(1,1)$, and $E5(x^*, y^*)$, where $x^* = \frac{Cg}{W}$ and $y^* = \frac{-(Re1-Re2-Ce)}{(\varepsilon-1)Re1+(1-\beta)Ce+\alpha I}$.

According to the method of Fridernan (1991), the local stability of five stable points in the replicator dynamics equation is theoretically analyzed by using the Jacobi matrix. Jacobi matrix J can be obtained by using $\frac{dx}{dt}$ and $\frac{dy}{dt}$ in formula (7) to obtain partial derivative of x and y:

$$J = \begin{bmatrix} (1-2x)\{y[(\varepsilon-1)Re1 + (1-\beta)Ce + \alpha I] + Re1 - Re2 - Ce\} & x(1-x)[(\varepsilon-1)Re1 + (1-\beta)Ce + \alpha I] \\ Wy(1-y) & (1-2y)(Wx - Cg) \end{bmatrix} \tag{8}$$

Following the local stability criterion of Jacobi matrix (Glamsch et al., 2019), and using the values of points x and y, the values of Cg and W, as well as the positive and negative of $Re1 - Re2 - Ce$, are used to determine the evolutionarily stable strategy (ESS) between firms with failed innovation and government departments in different situations.

4. Results

4.1. Evolutionarily stable strategy analysis

4.1.1. Situation 1

When $Re1 - Re2 - Ce > 0$ and $W - Cg > 0$, the revenue increase of the re-innovation behavior of firms with failed innovation is greater than the cost of re-innovation. Moreover, the additional benefits obtained by the government departments due to the synergy effect of institutional environment optimization and firm innovation are

Table 2. Local stability of situation 1.

Stable point	det(J)	tr(J)	Result
$E1(0,0)$	<0	Indeterminacy	Unstable
$E2(0,1)$	>0	>0	Unstable
$E3(1,0)$	<0	Indeterminacy	Unstable
$E4(1,1)$	>0	<0	ESS

Source: compiled by authors.

greater than the cost of institutional environment optimization. Table 2 shows the local stability of Jacobi matrix J under this scenario.

Table 2 indicates that $E_4(1,1)$ is the evolutionary stable point of the system in this situation because the revenue increase of re-innovation behavior of firms with failed innovation is large enough ($R_{e1}-R_{e2}>C_e$). From the perspective of prospect perception, firms with failed innovation believe that their re-innovation products can receive better market recognition, and economic benefits make firms choose re-innovation behavior after failure. For government departments, the additional benefits W generated by synergy effect are greater than the cost C_g of institutional environment optimization. Owing to the increase of social benefits, government departments choose the strategy of institutional environment optimization. In addition, $E_2(0,1)$ is an unstable point, and a slight disturbance leads to the steady-state imbalance of the system. Even if firms choose to use old technology strategy, firms' decision-making will still change into re-innovation behavior due to the influence of the revenue increase $R_{e1}-R_{e2}>C_e$ of re-innovation after failure. However, if firms continue to use old technology for production and even if government departments choose to optimize the institutional environment, government departments will not generate additional social welfare and will forego the choice of institutional environment optimization strategy. With the influence of economic benefits, the choice of firms' re-innovation behavior will change, and when $W>C_g$, the strategic choice of government departments will change. Finally, the game between the two sides will evolve into stable point $E_4(1,1)$. Figure 2 shows the dynamic evolution diagram.

4.1.2. Situation 2

When $Re1-Re2-Ce>0$ and $W-Cg<0$, the revenue increase of the re-innovation behavior of firms with failed innovation is greater than the cost of re-innovation. Moreover, the additional benefits obtained by the government departments due to the synergy effect of institutional environment optimization and firm innovation are less than the cost of institutional environment optimization. Table 3 shows the local stability of Jacobi matrix J under this scenario.

Table 3 indicates that $E3(1,0)$ is the evolutionary stable point of the system in this situation. The revenue increase of re-innovation can offset the input cost of re-innovation, and the optimal decision of firms with failed innovation is re-innovation after failure. However, additional benefits W obtained by the government departments due to the synergy effect of institutional environment optimization and firm innovation cannot make up for the input cost Cg. Hence, instead of optimizing the institutional environment, government departments can obtain social benefits $Rg1$. In addition, the system stability achieved by the stability point $E3(1,0)$ can be understood as the "ideal state" of firms' choice of re-innovation behavior. That is, when the institutional

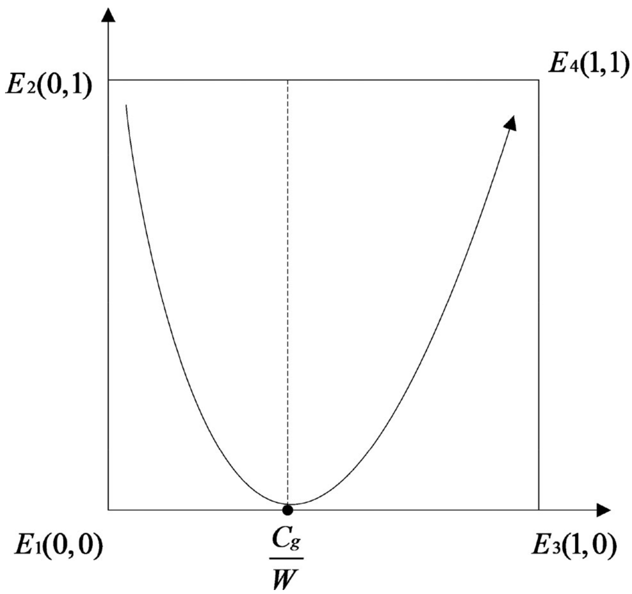

Figure 2. Dynamic evolution diagram of situation 1.
Source: compiled by authors.

Table 3. Local stability of situation 2.

Stable point	det(*J*)	*tr*(*J*)	Result
$E1(0,0)$	<0	Indeterminacy	Unstable
$E2(0,1)$	>0	>0	Unstable
$E3(1,0)$	>0	<0	ESS
$E4(1,1)$	<0	Indeterminacy	Unstable

Source: compiled by authors.

environment is in the optimal situation, firms with failed innovation will choose re-innovation behavior spontaneously without the guidance of government departments. However, due to the high cost of institutional environment optimization Cg, this state is difficult to achieve in terms of the current innovation environment. Figure 3 shows the dynamic evolution diagram.

4.1.3. Situation 3

When $Re1-Re2-Ce<0$ and $W-Cg<0$, the revenue increase of the re-innovation behavior of firms with failed innovation is less than the cost of re-innovation, and the additional benefits obtained by the government departments due to the synergy effect of institutional environment optimization and firm innovation are less than the cost of institutional environment optimization. Table 4 shows the local stability of Jacobi matrix J under this scenario.

Table 4 indicates that $E1(0,0)$ is the stable point of system evolution in the game process, and it is a negative state of institutional environment that is not conducive to stimulating firms' re-innovation behavior. From the perspective of firms with failed innovation, on the one hand, the pessimistic outlook formed by the failure experience makes firms reduce the value perception of the revenue increase ($Re1-Re2$) of the re-innovation behavior. On the other hand, firms' fear of failure magnifies the

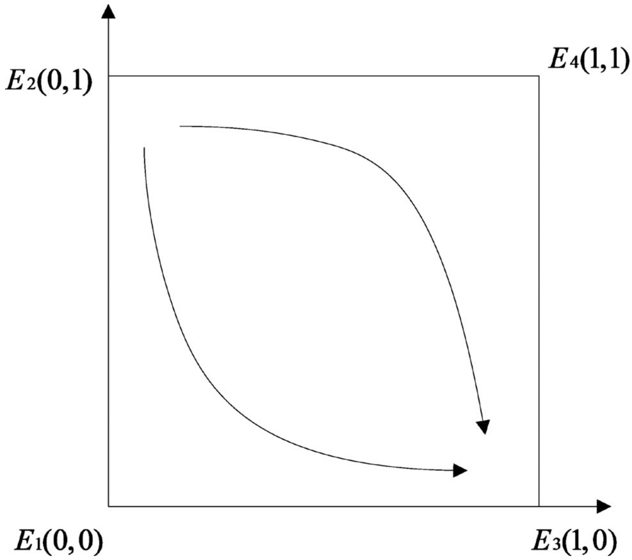

Figure 3. Dynamic evolution diagram of situation 2.
Source: compiled by authors.

Table 4. Local stability of situation 3.

Stable point	det(J)	tr(J)	Result
$E1(0,0)$	>0	<0	ESS
$E2(0,1)$	Indeterminacy	Indeterminacy	Unstable
$E3(1,0)$	<0	Indeterminacy	Unstable
$E4(1,1)$	Indeterminacy	Indeterminacy	Unstable

Source: compiled by authors.

estimation of the innovation risk, resulting in the excessive cost of re-innovation Ce, which makes the revenue increase of the re-innovation behavior less than that of re-innovation cost Ce. Owing to the survival pressure of the market environment, firms with failed innovation will choose to use the old technology for production. From the perspective of government departments, even if firms choose re-innovation after failure, the social welfare benefits do not show the promotion effect because input Cg of institutional environment optimization is greater than additional income W generated by the synergy effect. Given the lack of driving force of institutional environment optimization, government departments will still choose the strategy of institutional environment optimization. Figure 4 shows the dynamic evolution diagram.

4.1.4. Situation 4

When $Re1-Re2-Ce<0$ and $W-Cg>0$, the revenue increase of the re-innovation behavior of firms with failed innovation is less than the cost of re-innovation. Moreover, the additional benefits obtained by the government departments due to the synergy effect of institutional environment optimization and firm innovation are greater than the cost of institutional environment optimization. Table 5 shows the local stability of Jacobi matrix J under this scenario.

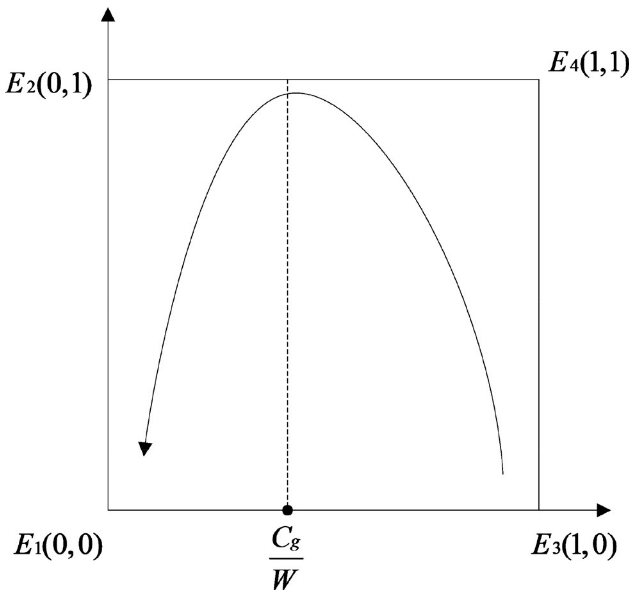

Figure 4. Dynamic evolution diagram of situation 3.
Source: compiled by authors.

Table 5. Local stability of situation 4.

Stable point	det(J)	tr(J)	Result
$E1(0,0)$	>0	<0	ESS
$E2(0,1)$	Indeterminacy	Indeterminacy	Unstable
$E3(1,0)$	>0	>0	Unstable
$E4(1,1)$	Indeterminacy	Indeterminacy	Unstable

Source: compiled by authors.

The results in Table 5 show that $E1(0,0)$ is still the stable point of the evolutionary system, whereas $E3(1,0)$ is the unstable equilibrium point of the evolutionary system. The reason is that even if firms choose re-innovation behavior after failure, they will change their behavior choice because the revenue increase of re-innovation activities cannot make up for the re-innovation cost. Moreover, when firms choose re-innovation behavior after failure, government departments find that the additional benefits W generated by the synergy effect of institutional environment optimization and firms innovation are greater than the optimization cost Cg. The subtle system disturbance will break the transient equilibrium phenomenon of evolutionary system at point $E3(1,0)$, and government departments will change their strategic choice to optimize the institutional environment. However, as a growing number of firms with failed innovation choose to use the old technology for production, the additional benefits obtained by the government departments are decreasing. When the additional benefits are less than the optimal cost Cg of the institutional environment, the non-optimization of the institutional environment will become the optimal strategy of the government departments at this time. Hence, the stability of the evolutionary system will be achieved. Figure 5 shows the dynamic evolution diagram.

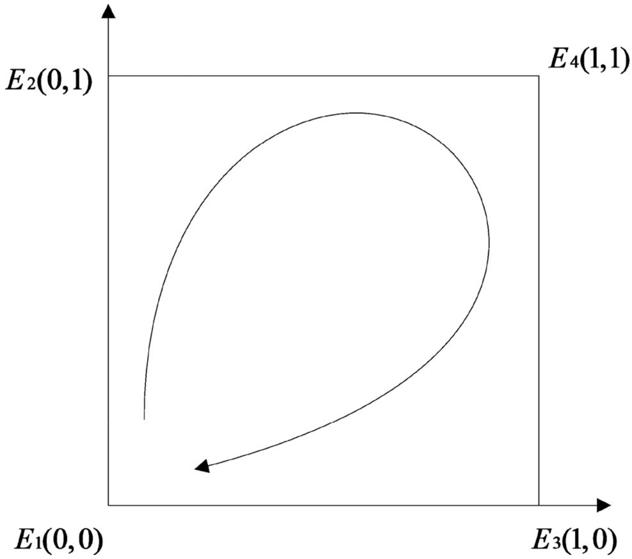

Figure 5. Dynamic evolution diagram of situation 4.
Source: compiled by authors.

4.2. Parametric analysis

The above analysis results show that the stable point $E4(1,1)$ of the evolutionary system in situation 1 is the most reasonable state between firms with failed innovation and government departments at this stage, that is, under the constraint conditions of $Re1-Re2-Ce>0$ and $W-Cg>0$, firms choose re-innovation behavior after failure and government departments optimize the institutional environment. In addition, according to the dynamic evolution diagram in Figure 1, $x* = Cg/W$ is the inflection point of system evolution curve. When $x<x*$, $y = 0$ is a stable strategy; when $x>x*$, $y = 1$ is a stable strategy. To make the system converge to the stable point $E4(1,1)$ quickly, $x*$ strain is small, that is, the evolution time of the system to $y = 0$ strategy is reduced, and the process of the system to $y = 1$ strategy is expanded. On this basis, the following corollary can be obtained:

> Corollary 1: Increasing the revenue increase and reducing the re-innovation cost can promote the re-innovation behavior of firms with failed innovation.

> Corollary 2: Increasing the government departments' additional benefits due to re-innovation and reducing the input cost of institutional environment optimization can promote the government departments to invest more resources in institutional environment construction.

However, given that firms' re-innovation is based on previous failure results, the evolutionary system may have difficulty converging to the stable point due to the anti-failure bias (McGrath, 1999). On the one hand, from the perspective of prospect utility function, relative difference between the expected market recognition and the re-innovation difficulty of firms with failed innovation easily produces cognitive bias. According to cognitive psychology, decision-makers tend to feel more sensitive to losses than gains (Song et al., 2020). Especially for firms with failed innovation, previous failure experiences may lead to fear of re-innovation, over-amplify the re-innovation difficulty, and create a pessimistic view on the prospect of re-innovation (Wyrwich et al., 2019). In addition, due to the uncertainty and complexity of the process of re-innovation after failure, decision-makers easily overestimate the re-innovation cost and prudently predict the revenue increase of re-innovation. As a result, the perceived cost of re-innovation is greater than the actual cost of re-innovation, and the predicted revenue increase from re-innovation is less than the actual revenue increase.

4.3. Empirical illustration

In recent years, to optimize the innovation environment in this region, Zhengzhou of China, through the promulgation of relevant policies from the aspects of financial subsidies, financial support, personnel training, business environment and so on, is changing the rigidity of the original innovation environment and solving the problem of insufficient support for innovative firms. The prominent part of the reform is that it changed the original focus on innovation success while ignoring innovation failure in the policy design, and put more emphasis on the improvement of innovation fault-tolerance mechanism.

Take a high-tech firm engaged in pharmaceutical products R&D in Zhengzhou of China as an example. In 2016, the high-tech firm started a new drug R&D, invested huge resources in the R&D process, and obtained some innovation assistance from the aspects of capital, labor, financing and so on through the relevant innovation policy support of Zhengzhou city. Nevertheless, the uncertainty and risk of innovation process determine the objective existence of innovation failure. After three years, the new product did not achieve the expected goal, leading to R&D failure. However, the fault-tolerant mechanism does not pursue the firm's responsibility and recover the subsidy due to the innovation failure. On the contrary, a certain amount of post innovation subsidy was given to the firm according to the sustainability of R&D project. This firm still gets millions of policy subsidy funds, which share the cost of innovation failure, and encourage the firm to carry out re-innovation activities.

The innovation failure has brought an obvious negative impact on the firm of the case study. Although the government department's policy subsidies can make up for part of the loss of innovation failure, there is still a big gap compared with re-innovation investment. The capital loss of innovation failure and the challenge of R&D team on innovation ability have a real impact on the re-innovation decision-making of firm. However, through the comprehensive evaluation of product market, intellectual property protection, financing environment, and innovation failure support, this firm still considers that its new products have strong market competitiveness. As can be seen from Figure 6, to promote the re-innovation behavior of this firm, increasing the revenue increase of re-innovation is better than reducing the innovation failure cost. Thus, through failure learning, this firm integrates failure resources and carries out re-innovation activities based on previous innovation failure, which confirms Corollary 1.

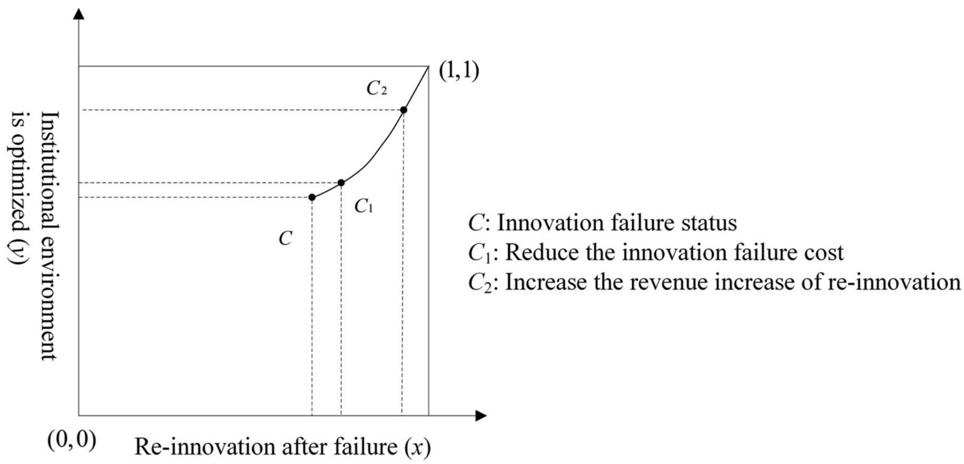

Figure 6. Change of re-innovation behavior after failure of case firm.
Source: compiled by authors.

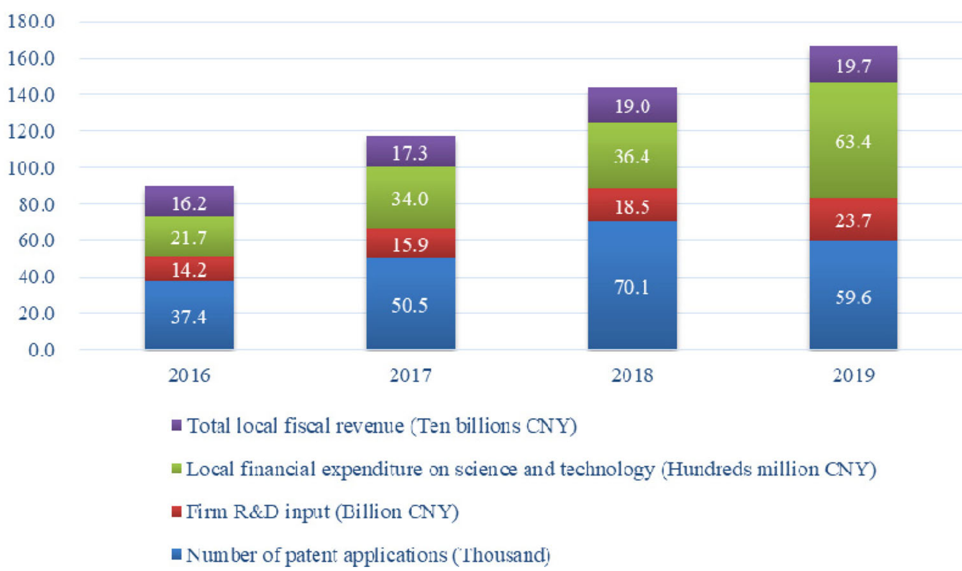

Figure 7. Optimization effect of Zhengzhou on innovation environment.
Source: compiled by authors.

In addition, the optimization effect of Zhengzhou on innovation environment is also significant. As can be seen from the results in Figure 7, the number of patent applications increased from 37.4 thousands in 2016 to 59.6 thousands in 2019. The firm R&D input increased from 14.2 billion CNY in 2016 to 23.7 billion CNY in 2019. The total local fiscal revenue increased from 16.2 ten billions CNY in 2016 to 19.7 ten billions CNY in 2019. With the growth of financial revenue, the investment in institutional environment optimization is also growing. For example, the local financial expenditure on science and technology of Zhengzhou in 2019 is 63.4 hundreds million CNY, an increase of 192.2% compared with 21.7 hundreds million CNY in 2016. This is also a verification of Corollary 2.

5. Discussion

From the perspective of case firm, the reduction of re-innovation cost can promote its choice of re-innovation behavior from failure, but this effect may be limited. In the current innovation environment, firms with failed innovation focus on future benefits of re-innovation activities. The increase of re-innovation income can not only enhance firms' competitiveness but also significantly enhance the willingness of firms to re-innovation after failure. Firms' re-innovation behavior further drives the enhancement of social welfare to promote government departments to invest more resources in the construction of institutional environment. Although affected by anti-failure bias, firms tend to exaggerate the difficulty of re-innovation after failure, resulting in fear of innovation and prudence in predicting the re-innovation income. However, the market competition environment will also affect re-innovation income. The improvement of the protection level coefficient of intellectual property rights will especially increase the success probability of re-innovation after failure. Good intellectual property protection can help enterprises improve the market sales volume of re-innovative products in a fair market competition environment and ensure the sustainable competitiveness of firms (Xiong et al., 2020). Perfect intellectual property system can alleviate the pessimistic view on firms' re-innovation behavior to promote the re-innovation behavior of firms with failed innovation.

From the perspective of government management, the improvement of institutional environment can promote the evolution of firms with failed innovation and government departments to stable strategies (re-innovation after failure and optimized institutional environment). Government departments can significantly improve re-innovation intention and promote re-innovation behavior while continuously optimizing the institutional environment. Moreover, when the revenue of government departments increases due to firms' re-innovation behavior, the construction level of institutional environment will be improved. When this revenue is insufficient, it not only restricts the optimization of the institutional environment but also prevents firms from receiving re-innovation resources (lack of innovation subsidies, market financing difficulties, etc.). Therefore, the optimization of institutional environment and firms' re-innovation behavior need to form a good synergy effect.

For example, the government can promote the development of circular economy to strengthen the innovation of institutional environment (Kyriakopoulos et al., 2019), clarify the relationship between firms and environment, reconstruct the production mechanism and cost formation mechanism of firms, and reduce the cost of firms' re-innovation. Meantime, the government promotes the choice of re-innovation behavior by improving the level of institutional environment (e.g. the improvement of the financial and credit incentive system (Liu et al., 2022)). Firms obtain market income through re-innovation after failure, the overall social welfare benefits also will be improved and government departments have sufficient resources to optimize the institutional environment (Hartley et al., 2013; Orazalin, 2019). In addition, the cost reduction will reduce the difficulty of institutional environment optimization by government departments and enhance their willingness to optimize the institutional environment. When the cost of optimizing the institutional environment is too high, government departments' revenue is insufficient, which will lead the institutional environment to hover at a low level, resulting in a negative and malignant state of social innovation environment. Therefore, government departments should enhance the transparency and efficiency of relevant policies and reduce the cost of institutional environment optimization.

6. Conclusions and future research orientations

To explore the relationship between firms' re-innovation after failure and institutional environment, this study analyzes the behavior characteristics of firms' re-innovation, establishes the evolutionary game model of firms with failed innovation and government departments, and uses a case study to illustrate the theoretical model. The following conclusions are obtained: (1) the optimization of institutional environment can promote the re-innovation behavior of firms with failed innovation and enhance the competitiveness of firms. However, the subjective perception of re-innovation risks and benefits of firms with failed innovation will affect their behavior choice of re-innovation after failure. (2) Improving the level of intellectual property protection in the institutional environment can reduce the risk perception of firms' re-innovation after failure, ensure the re-innovation income of firms, and alleviate the pessimistic view of firms on re-innovation. However, the reduction of re-innovation cost has a limited impact on the behavior choice of firms' re-innovation. (3) The increase of social welfare benefits promotes the improvement of institutional environment construction, promotes the improvement of firms' willingness to re-innovation after failure, and creates a good synergy between institutional environment optimization and firms' re-innovation behavior.

The theoretical contributions of this study are as follows. Most of the existing studies focus on the behavior incentive of re-innovation after failure from the perspective of firms' internal environment but ignore the influence of external environmental factors. The findings of this study reveal the relationship between firms' re-innovation behavior after failure and institutional environment, enrich the research boundary of the relationship between innovation failure and subsequent innovation behavior, and expand the research ideas of firms' re-innovation decision-making. In addition, this study reveals important insights into the role of institutional environment in firms' re-innovation activities. Government departments should guide the public to understand that technological innovation is long-term, arduous, and uncertain. The government should correct the anti-failure bias that is widespread in innovation, be less questioning and critical, and patient and tolerant when innovation fails.

Certainly, this study has shortcomings that are recognized. It only theoretically deduces the re-innovation behavior of firms with failed innovation and institutional environment optimization from the perspective of evolutionary game. The conclusions lack the empirical test support, which may have an impact on the robustness of the results. In the following study, it can be considered obtaining relevant cases and data of firms with failed innovation for empirically testing the findings of this study. Meanwhile, the characteristic behavior of firms' re-innovation should be explored from the perspective of informal institutions.

Disclosure statement

No potential conflict of interest was reported by the authors.

This study is supported by the National Natural Science Foundation of China (No. 72002206); Humanities and Social Sciences Research Project of the Ministry of Education of China (No. 20YJC630171); National Social Science Fund of China (No. 18CJL006) and Science and Technology Innovation Talent Support Plan in Colleges and Universities of Henan in China (Humanities and Social Sciences) (No. 2020-cx-019).

References

Acs, Z. J., Estrin, S., Mickiewicz, T., & Szerb, L. (2018). Entrepreneurship, institutional economics, and economic growth: An ecosystem perspective. *Small Business Economics*, *51*(2), 501–514. https://doi.org/10.1007/s11187-018-0013-9

Block, J. H., Fisch, C. O., & Van Praag, M. (2017). The Schumpeterian entrepreneur: A review of the empirical evidence on the antecedents, behaviour and consequences of innovative entrepreneurship. *Industry and Innovation*, *24*(1), 61–95. https://doi.org/10.1080/13662716.2016.1216397

Brem, A., Nylund, P. A., & Hitchen, E. L. (2017). Open innovation and intellectual property rights. *Management Decision*, *55*(6), 1285–1306. https://doi.org/10.1108/MD-04-2016-0223

Cai, D., & Wan, D. F. (2012). Do institutional environments matter for firm's R&D investment? *Science of Science and Management of S.&.T*, *33*(4), 121–128.

Chen, W., Han, C., Wang, L., Ieromonachou, P., & Lu, X. (2021). Recognition of entrepreneur's social ties and firm innovation in emerging markets: Explanation from the industrial institutional environment and survival pressure. *Asia Pacific Journal of Management*, *38*(2), 491–518. https://doi.org/10.1007/s10490-019-09680-2

Cheng, C. J., & Shiu, E. C. (2008). Re-innovation: The construct, measurement, and validation. *Technovation*, *28*(10), 658–666. https://doi.org/10.1016/j.technovation.2007.08.002

Dana, L. P., Gurău, C., Hoy, F., Ramadani, V., & Alexander, T. (2021). Success factors and challenges of grassroots innovations: Learning from failure. *Technological Forecasting and Social Change*, *164*, 119600. https://doi.org/10.1016/j.techfore.2019.03.009

Dong, X. D., & Zhang, P. F. (2019). The typical characteristics and management inspiration of "scientists" in the failed technological innovation based on biopharmaceutical industry. *Forum on Science and Technology in China*, (11), 10–20. https://doi.org/10.13580/j.cnki.fstc.2019.11.002

Dooley, K. (2018). Routine rigidity and environmental sustainability: Why rational innovations are regularly ignored. *Business Strategy and the Environment*, *27*(1), 70–81. https://doi.org/10.1002/bse.1984

Dorobantu, S., Kaul, A., & Zelner, B. (2017). Nonmarket strategy research through the lens of new institutional economics: An integrative review and future directions. *Strategic Management Journal*, *38*(1), 114–140. https://doi.org/10.1002/smj.2590

Eggers, J. P., & Song, L. (2015). Dealing with failure: Serial entrepreneurs and the costs of changing industries between ventures. *Academy of Management Journal*, *58*(6), 1785–1803. https://doi.org/10.5465/amj.2014.0050

Fridernan, D. (1991). Evolutionary games in economics. *Econometrica*, *59*(3), 637–666. https://doi.org/10.2307/2938222

Fu, X., Woo, W. T., & Hou, J. (2016). Technological innovation policy in China: The lessons, and the necessary changes ahead. *Economic Change and Restructuring*, *49*(2-3), 139–157. https://doi.org/10.1007/s10644-016-9186-x

Ghazali, E. M., Mutum, D. S., & Javadi, H. H. (2021). The impact of the institutional environment and experience on social entrepreneurship: A multi-group analysis. *International Journal of Entrepreneurial Behavior & Research*, *27*(5), 1329–1350. https://doi.org/10.1108/IJEBR-05-2020-0332

Glamsch, J., Deese, K., & Rieg, F. (2019). Methods for increased efficiency of FEM-based topology optimization. *International Journal of Simulation Modelling*, *18*(3), 453–463. https://doi.org/10.2507/IJSIMM18(3)482

Guerrero, M., & Espinoza-Benavides, J. (2021). Does entrepreneurship ecosystem influence business re-entries after failure? *International Entrepreneurship and Management Journal*, *17*(1), 211–227. https://doi.org/10.1007/s11365-020-00694-7

Hartley, J., Sørensen, E., & Torfing, J. (2013). Collaborative innovation: A viable alternative to market competition and organizational entrepreneurship. *Public Administration Review*, *73*(6), 821–830. https://doi.org/10.1111/puar.12136

He, Y., Peng, X., & Xu, H. (2020). Overeducation, market recognition, and effective labour supply. *China Economic Review*, *59*, 101384. https://doi.org/10.1016/j.chieco.2019.101384

Jenkins, A. S., Wiklund, J., & Brundin, E. (2014). Individual responses to firm failure: Appraisals, grief, and the influence of prior failure experience. *Journal of Business Venturing*, *29*(1), 17–33. https://doi.org/10.1016/j.jbusvent.2012.10.006

Jenson, I., Leith, P., Doyle, R., West, J., & Miles, M. P. (2016). Innovation system problems: Causal configurations of innovation failure. *Journal of Business Research*, *69*(11), 5408–5412. https://doi.org/10.1016/j.jbusres.2016.04.146

Kyriakopoulos, G. L., Kapsalis, V. C., Aravossis, K. G., Zamparas, M., & Mitsikas, A. (2019). Evaluating circular economy under a multi-parametric approach: A technological review. *Sustainability*, *11*(21), 6139. https://doi.org/10.3390/su11216139

Leydesdorff, L., & Ivanova, I. (2016). "Open innovation" and "triple helix" models of innovation: Can synergy in innovation systems be measured? *Journal of Open Innovation: Technology, Market, and Complexity*, *2*(1), 11. https://doi.org/10.1186/s40852-016-0039-7

Lin, S. (2016). Review on entrepreneurial failure: Tradition research, newly developing topics and opportunities in the future. *Science of Science and Management of S.&.T*, *37*(8), 58–67.

Liu, D., Chen, T., Liu, X., & Yu, Y. (2019). Do more subsidies promote greater innovation? Evidence from the Chinese electronic manufacturing industry. *Economic Modelling*, *80*, 441–452. https://doi.org/10.1016/j.econmod.2018.11.027

Liu, Y., Kim, C. Y., Lee, E. H., & Yoo, J. W. (2022). Relationship between sustainable management activities and financial performance: Mediating effects of non-financial performance and moderating effects of institutional environment. *Sustainability*, *14*(3), 1168. https://doi.org/10.3390/su14031168

Lu, J., Ren, L., Qiao, J., Lin, W., & He, Y. (2019). Female executives and corporate social responsibility performance: A dual perspective of differences in institutional environment and heterogeneity of foreign experience. *Transformations in Business & Economics*, *18*(2), 174–196.

Mantere, S., Aula, P., Schildt, H., & Vaara, E. (2013). Narrative attributions of entrepreneurial failure. *Journal of Business Venturing*, *28*(4), 459–473. https://doi.org/10.1016/j.jbusvent.2012.12.001

McGrath, R. G. (1999). Falling forward: Real options reasoning and entrepreneurial failure. *Academy of Management Review*, *24*(1), 13–30. https://doi.org/10.5465/amr.1999.1580438

Orazalin, N. (2019). Corporate governance and corporate social responsibility (CSR) disclosure in an emerging economy: Evidence from commercial banks of Kazakhstan. *Corporate Governance: The International Journal of Business in Society*, *19*(3), 490–507. https://doi.org/10.1108/CG-09-2018-0290

Peng, M. W., & Luo, Y. (2000). Managerial ties and firm performance in a transition economy: The nature of a micro-macro link. *Academy of Management Journal*, *43*(3), 486–501. https://doi.org/10.5465/1556406

Rosnitschek, T., Hueter, F., & Alber-Laukant, B. (2020). FEM-based modelling of elastic properties and anisotropic sinter shrikage of metal EAM. *International Journal of Simulation Modelling*, *19*(2), 197–208. https://doi.org/10.2507/IJSIMM19-2-509

Sheng, Y. C. (2008). Innovation subsidies or product subsidies: The government strategy choice of technical alliance. *Chinese Journal of Management Science*, *16*(6), 184–192. https://doi.org/10.16381/j.cnki.issn1003-207x.2008.06.019

Shepherd, D. A. (2009). Grief recovery from the loss of a family business: A multi-and meso-level theory. *Journal of Business Venturing*, *24*(1), 81–97. https://doi.org/10.1016/j.jbusvent.2007.09.003

Song, M., & Wang, S. (2018). Market competition, green technology progress and comparative advantages in China. *Management Decision*, *56*(1), 188–203. https://doi.org/10.1108/MD-04-2017-0375

Song, Y., Li, G., & Ergu, D. (2020). Recommending products by fusing online product scores and objective information based on prospect theory. *IEEE Access*, *8*, 58995–59006. https://doi.org/10.1109/ACCESS.2020.2982933

Ucbasaran, D., Westhead, P., Wright, M., & Flores, M. (2010). The nature of entrepreneurial experience, business failure and comparative optimism. *Journal of Business Venturing*, *25*(6), 541–555. https://doi.org/10.1016/j.jbusvent.2009.04.001

Van Wijk, J., Zietsma, C., Dorado, S., De Bakker, F. G., & Marti, I. (2019). Social innovation: Integrating micro, meso, and macro level insights from institutional theory. *Business & Society*, *58*(5), 887–918. https://doi.org/10.1177/0007650318789104

Wang, P. J. (2016). The object selection of government compensation enterprises' science and technology innovation failure project. *Enterprise Economy*, (4): 175–178. https://doi.org/10.13529/j.cnki.enterprise.economy.2016.04.034

Wang, P. J., Ye, J. M., & Luo, J. (2014). Mechanism of government financial compensation on science and technology innovation failed projects. *Science of Science and Management of S.&.T*, *35*(1), 3–8.

Wu, J. (2013). Diverse institutional environments and product innovation of emerging market firms. *Management International Review*, *53*(1), 39–59. https://doi.org/10.1007/s11575-012-0162-z

Wyrwich, M., Sternberg, R., & Stuetzer, M. (2019). Failing role models and the formation of fear of entrepreneurial failure: A study of regional peer effects in German regions. *Journal of Economic Geography*, *19*(3), 567–588. https://doi.org/10.1093/jeg/lby023

Xiong, Z., Wang, P. J., & Zhao, Y. (2020). Re-Innovation from failure, institutional environmental differences, and firm performance: Evidence from China. *Amfiteatru Economic*, *22*(53), 197–219. https://doi.org/10.24818/EA/2019/53/197

Zuo, J. J., Tang, Y. J., & Ji, Z. C. (2016). Government intervention, marketization reform and corporate R&D innovation. *R&D Management*, *28*(6), 80–90. https://doi.org/10.13581/j.cnki.rdm.20161021.001