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Sustainable Cooperation between Schools, Enterprises, and Government: An Evolutionary Game Theory Analysis

Chao Liu [1], Hexin Wang [1] and Yu Dai [2,3,*]

[1] College of Education, Zhejiang University, Hangzhou 310058, China; charlouisdas@zju.edu.cn (C.L.); 12003006@zju.edu.cn (H.W.)
[2] Education Science Research Center, Tianjin University, Tianjin 300350, China
[3] School of Education, Tianjin University, Tianjin 300350, China
* Correspondence: yu.dai@tju.edu.cn

Abstract: Promoting close and sustainable cooperation between schools, enterprises, and government has become an important concern in many countries. However, the factors that influence the cooperation between schools, enterprises, and government have not been sufficiently explored in previous studies. Therefore, based on evolutionary game theory, in this paper, we construct a tripartite evolutionary game model of schools, enterprises, and government in order to analyze the strategies of different players and their influencing factors. The results show that the main factor that influences the stability of the strategies of schools and enterprises is the reward for positive cooperation from sources other than the government, and the main factor that influences the stability of the strategy of the government is the benefits from a positive cooperation strategy under the scenario where schools cooperate with enterprises. Some suggestions to promote sustainable cooperation between schools, enterprises, and government are proposed at the end.

Keywords: sustainable cooperation; evolutionary game theory; school; enterprise; government

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1. Introduction

In many models of economic development, the development of the economy depends on human capital (talent). Schools can be viewed as the producers of such capital and enterprises as the consumers. Thus, strengthening the relationship between schools and enterprises is crucial to maintaining a dynamic balance between the supply and demand of talent and promoting the growth of the economy. In addition, the government plays an important role in facilitating the connection between schools and enterprises. For example, the German government has established a series of laws, regulations, and management systems to ensure that students can acquire theoretical knowledge in school and develop practical skills in enterprise [1]. The U.S. government has also passed the Strengthening Career and Technical Education (CTE) for the 21st Century Act to support partnerships among various schools and enterprises [2], and the Chinese government has enacted Several Opinions on Deepening the Integration of Industry and Education to promote the supply side structural reform of talent and improve the synergy of educational resources and regional industries [3]. Promoting close and sustainable cooperation between schools, enterprises, and government has clearly become an important concern in these countries.

However, the reality is that the cooperation between schools, enterprises, and government has not been very effective. This is due to the differences in goals and culture between schools and enterprises, as well as disputes over the ownership of intellectual property. The differences in organizational attributes and social functions of schools and enterprises lead to two types of social division of labor, which results in differences in the goals of both of these types of institutions [4–6]. The goals of schools include cultivation, education, and theoretical research, and the primary goal of enterprises is to maximize profits. These differences in goals also lead to differences in culture between schools and

enterprises, such as in organization and management, behavioral patterns, and approaches to schedules [7–9]. In addition, there are some differences regarding the ownership of intellectual property. For example, researchers at schools tend to publish research results in order to increase their influence and push the frontier of knowledge, but enterprises are incentivized to keep their core technology and know-how secret in order to monopolize the market [10]. All these factors can impede the cooperation between schools, enterprises, and government.

Therefore, this study set out to investigate the main factors that influence the strategies of schools, enterprises, and government and to provide some suggestions to improve the effectiveness of sustainable cooperation between them.

The rest of the paper is organized as follows: Section 2 reviews the relevant literature. Section 3 constructs the tripartite evolutionary game model. Section 4 analyzes the stability of different combinations of game strategies. Section 5 summarizes the main conclusions and provides some suggestions for sustainable cooperation between schools, enterprises, and government in the real world.

2. Literature Review

The cooperation between schools and enterprises has been explored extensively in the existing literature. Many scholars have already investigated various school–enterprise cooperation models, such as the Dual System, Cooperative Education, and Sandwich Courses.

The Dual System is considered to be the driving force of Germany's post-war economic recovery and has become an exemplary case of school–enterprise cooperation. Theuerkauf and Weiner summarized five major characteristics of the Dual System, including a broad basic education, combined technical training and theory, training directed at acquiring key qualifications, a standardized system, and a planned change from schools to the training system [11]. The Federal Ministry of Education and Research of Germany (BMBF) has also published a book to introduce the origins, features, and training processes of the Dual System in detail [12]. Pleshakova analyzed the genesis and development of the Dual System in Germany from a historical perspective [13]. Given the advantages of the Dual System, some scholars have discussed the practice of Dual System in countries other than Germany, such as Russia [14,15], Ukraine [16], and China [17–19]. However, there are also some weaknesses with the Dual System. Pritchard pointed out that the Dual System is permeated with tensions emanating from individuals, schools, firms, and various influential interest groups [20] that can limit competition in the labor market, delay adult status in the labor market, and fail to guarantee employment [21].

Compared to the German Dual System, in which the government and enterprises are deeply involved, American Cooperative Education and British Sandwich Courses are driven by schools, with little responsibility from government or enterprises [22]. Cooperative Education is a model of school–enterprise cooperation in America that refers to an educational program that combines classroom learning with work experience, and Younis and Pierrakos et al. argued that Cooperative Education is essential for both students and society [23,24]. Cooperative Education has also been found to have a positive impact on students' early career success and self-efficacy [25,26]. Students who enroll in Cooperative Education programs can learn professional knowledge and skills and gain practical on-the-job experience [27,28].

Sandwich Courses are a British model of school–enterprise cooperation that involve a pattern in which periods of school study alternate with periods of industrial training or experience [29]. Sandwich Courses have been recognized as an effective method for accumulating sustained, structured work experience and improving employment chances [30–32].

The motivations and factors of cooperation between schools and enterprises have also attracted the attention of scholars. Lee and Win (2004) summarized the motivations of schools in cooperating with enterprises, such as assessing the needs of the economy and developing talent accordingly, placing students in industry to connect classroom learning

with practical experience, conducting both fundamental and applied research, accessing protected markets, enhancing the business stature, improving the implementation of new technology, developing new products and patents, and saving production costs [33]. Arza (2010) divided the motivations of schools into economic motivation and research motivation [34]. Similarly, Lam (2011) argued that "gold", "ribbons", and "puzzles" are the motivators of researchers in schools for cooperating with enterprises and found that few academic researchers are driven by economic motivation [35]. Reducing transaction costs [36,37]; obtaining human capital, technology, education, and equipment [38]; and establishing a network of cooperation [39] have all been argued to be motivators of enterprises to cooperate with schools. Moreover, the factors influencing the cooperation between schools and enterprises, such as the scale of schools and enterprises [40,41], trust and mutual benefits between schools and enterprises [42,43], and culture differences [44], have also been widely explored in the literature.

However, the previous literature on models, motivations, and factors has focused on schools and enterprises. Although it has been realized that the government plays a crucial role in school–enterprises cooperation and a few scholars have proposed that the government should formulate some policies to facilitate cooperation between schools and enterprises [11,12], the government has not been considered as the main party in the cooperation between schools and enterprises. The influence of the government on the cooperation between schools and enterprises has been ignored.

In addition, evolutionary game theory is an effective tool for analyzing the strategic interactions between different parties [45], and has been used in various disciplines, including economics [46,47], public policy [48], and environmental science [49–51]. Some scholars have also introduced evolutionary game theory into education. For example, Zhu and Wang (2022) built an evolutionary game model involving government, universities, and students to explore the development of the choice between innovation and entrepreneurship in education [52], and Li and Wang (2022) discussed the management of primary and secondary school students' online learning during COVID-19 lockdowns by constructing two game models involving "schools and students" and "schools, students, and parents" [53]. Zhang and Zeng (2022) analyzed the manifestation of both the instrumental and human value of education for sustainable development, and proposed that a country's curriculum on sustainable development should start from concrete education issues that urgently need to be solved within the theory of sustainable development [54]. However, evolutionary game theory has rarely been used to research the cooperation between schools and enterprises.

To sum up, although the above research has provided some theoretical and methodological support for the study of cooperation between schools, enterprises, and government, there are still some shortcomings. (1) There are very limited studies that use evolutionary game theory to analyze the cooperation between schools and enterprises. (2) The role government plays in this cooperation has yet to be sufficiently revealed. To address these shortcomings, in this paper, we construct a tripartite evolutionary game model in which schools, enterprises, and the government are all considered as main game players. Based on stability strategy analysis, we then put forward some effective ways to promote cooperation between schools, enterprises, and government.

3. Methodology

In this section, a tripartite evolutionary game model of schools, enterprises, and government is established to investigate the evolution of cooperative behavior among these three stakeholders.

3.1. Model Assumptions

According to the evolutionary game theory, each player is an individual with limited rationality and has two alternative strategies (cooperation and defection) with different probabilities and payoff [55,56]. Each player updates their strategy based on their payoff [57]. Many scholars argue that when schools cooperate with enterprises (i.e., when both

schools and enterprises choose a cooperative strategy), they can get a lot of benefits, such as outstanding talent and advanced technology [33,36–39]. Moreover, the government will also promulgate policies to reward or punish schools and enterprises for their strategies of cooperation or defection [1–3]. Therefore, considering evolutionary game theory; previous research on the cooperation between schools, enterprises, and the government; and practical experience, we make the following assumptions.

Assumption 1. *There are three populations, schools, enterprises, and government, all of which have bounded rationality.*

Assumption 2. *Each population has two strategies: a positive cooperation strategy and a negative cooperation strategy. x, y, and z represent the probability of selecting the positive cooperation strategy for schools, enterprises, and government, respectively, and $1 - x$, $1 - y$, and $1 - z$ represent the probability of selecting the negative cooperation strategy of schools, enterprises, and government, respectively.*

Assumption 3. *We assume that schools can receive some benefits in terms of discipline construction, knowledge innovation, and talent cultivation, denoted by M, before cooperating with enterprises. When schools choose the positive cooperation strategy, some costs will be spent on the development of teachers and the adjustment of talent cultivation to meet the needs of enterprises, denoted by C_1. In return, schools obtain some rewards from the government such as political and financial support, denoted by G_1. Beyond that, if enterprises also choose the positive cooperation strategy, schools will produce more high-quality talent. This talent will not only bring direct economic benefits to schools, such as alumni donations, but will also bring indirect benefits, such as improving the social reputation of the schools. We use R_1 to denote the additional benefits to schools from cooperating with enterprises. However, when schools choose the negative cooperation strategy, they receive some punishment from the government, denoted by P_1. In order to reflect the binding force of punishment, we assume $P_1 > C_1 + G_1 + R_1$.*

Assumption 4. *We assume that enterprises can receive some benefits from the cooperation process, denoted by N, before cooperating with schools. When enterprises choose the positive cooperation strategy, some costs will be spent on providing internships and salaries for students, as well as training and managing students, denoted by C_2. In return, enterprises obtain some rewards from the government such as political and financial support, denoted by G_2. Beyond that, if schools choose the positive cooperation strategy, enterprises will have access to cheap labor and technical support from schools, which can improve their social reputation. We use R_2 to denote the additional benefits to enterprises from cooperating with schools. However, when enterprises choose the negative cooperation strategy, they receive some punishment from the government, denoted by P_2, and we assume $P_2 > C_2 + G_2 + R_2$.*

Assumption 5. *When the government chooses the positive cooperation strategy, some costs will be incurred on aligning the interests of various parties and issuing relevant policies to regulate and facilitate the cooperative behavior of schools and enterprises, denoted by C_3. In return, if both schools and enterprises choose the positive cooperation strategy, the government will gain more outstanding talent, better development of the economy, and a higher social reputation, denoted by B_1. Moreover, when the government chooses the negative cooperation strategy, and both schools and enterprises choose the positive cooperation strategy, the government will still receive the benefits of talent cultivation, economic development, and social reputation as a result of the cooperation between schools and enterprises, denoted by B_2. In order to reflect the effect of the government's support, we assume $B_1 > B_2$. However, when the government chooses the negative cooperation strategy, and at least one of schools or enterprises chooses the negative cooperation strategy, the government suffers losses in talent cultivation, economic development, and social reputation, denoted by P_3. Consistent with the previous assumption, we also stipulate $P_3 > C_3 + G_3 + R_3$.*

In order to understand the model assumptions clearly, we list the meanings of the aforementioned symbols in Table 1.

Table 1. Notation of symbols.

Symbol	Meaning
M	The benefit of schools before cooperating with enterprises.
N	The benefit of enterprises before cooperating with schools.
C_1	The cost of schools' positive cooperation strategy.
C_2	The cost of enterprises' positive cooperation strategy.
C_3	The cost of the government's positive cooperation strategy.
G_1	The reward for schools' positive cooperation strategy from the government.
G_2	The reward for enterprises' positive cooperation strategy from the government.
R_1	The additional rewards of schools' positive cooperation strategy from sources other than the government.
R_2	The additional rewards of enterprises' positive cooperation strategy from sources other than the government.
B_1	The benefits of the government's positive cooperation strategy.
B_2	The benefits of the government's negative cooperation strategy.
P_1	The punishment for schools' negative cooperation strategy from the government.
P_2	The punishment for enterprises' negative cooperation strategy from the government.
P_3	The punishment for the government's negative cooperation strategy.

3.2. Model Construction

Based on the above assumptions, we drew a tree diagram to show all the combinations of strategies among schools, enterprises, and government, shown in Figure 1.

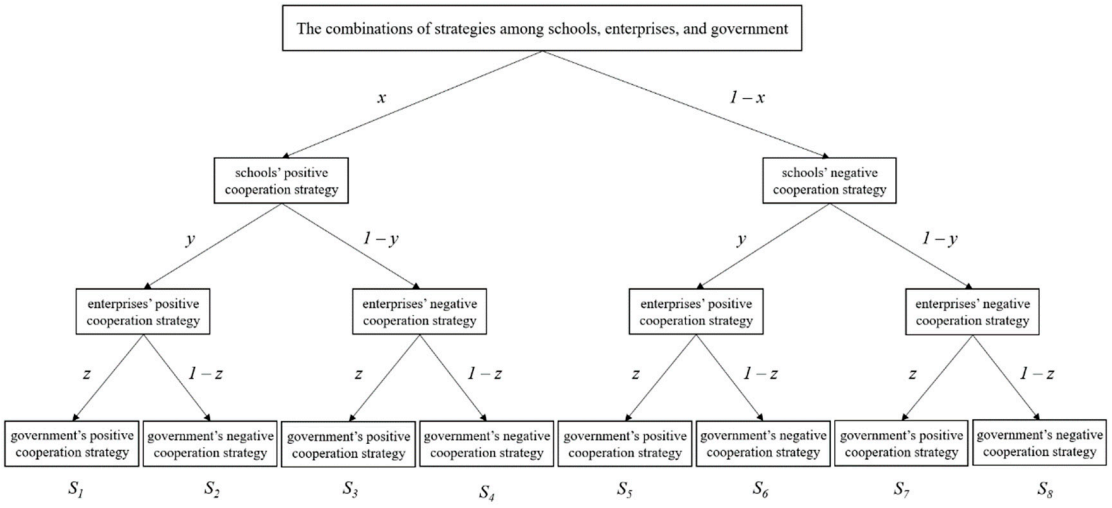

Figure 1. Tree diagram of the strategy combinations among schools, enterprises, and government.

As shown in Figure 1, there are eight strategy combinations, labeled as S_1 (schools' positive cooperation strategy, enterprises' positive cooperation strategy, government's positive cooperation strategy), S_2 (schools' positive cooperation strategy, enterprises' positive cooperation strategy, government's negative cooperation strategy), S_3 (schools' positive cooperation strategy, enterprises' negative cooperation strategy, government's positive cooperation strategy), S_4 (schools' positive cooperation strategy, enterprises' negative cooperation strategy, government's negative cooperation strategy), S_5 (schools' negative cooperation strategy, enterprises' positive cooperation strategy, government's positive cooperation strategy), S_6 (schools' negative cooperation strategy, enterprises' positive cooperation strategy, government's negative cooperation strategy), S_7 (schools' negative cooperation strategy, enterprises' negative cooperation strategy, government's positive cooperation strategy), and S_8 (schools' negative cooperation strategy, enterprises' negative cooperation strategy, government's negative cooperation strategy).

According to the previous assumptions and strategy combinations, we construct the tripartite evolutionary game payoff matrix of schools, enterprises, and government, as shown in Table 2.

Table 2. Payoff matrix of the tripartite evolutionary game between schools, enterprises, and government.

				Government	
				Positive Cooperation Strategy	**Negative Cooperation Strategy**
schools	positive cooperation strategy	enterprises	positive cooperation strategy	$M - C_1 + G_1 + R_1$, $N - C_2 + G_2 + R_2$, $-C_3 - G_1 - G_2 + B_1$	$M - C_1 + R_1$, $N - C_2 + R_2$, B_2
			negative cooperation strategy	$M - C_1 + G_1$, $N - P_2$, $-C_3 - G_1 + P_2$	$M - C_1$, N, $-P_3$
	negative cooperation strategy	enterprises	positive cooperation strategy	$M - P_1$, $N - C_2 + G_2$, $-C_3 - G_2 + P_1$	M, $N - C_2$, $-P_3$
			negative cooperation strategy	$M - P_1$, $N - P_2$, $-C_3 + P_1 + P_2$	M, N, $-P_3$

Each entry in Table 2 contains three values; the first represents the schools' payoff, the second represents the enterprises' payoff, and the last represents the government's payoff. We adopt a replicator dynamics equation, one of the most fundamental methods in evolutionary game theory, to indicate the evolution mechanism of cooperative behavior [58]. Here, we set U_{A1} and U_{A2} as the expected payoff of schools' positive and negative cooperation strategies, respectively. According to the tripartite evolutionary game payoff matrix and the probability of different strategies among schools, enterprises, and government, U_{A1} and U_{A2} can be calculated as follows:

$$U_{A1} = yz\,(M - C_1 + G_1 + R_1) + y(1-z)(M - C_1 + R_1) + (1-y)z(M - C_1 + G_1) + (1-y)(1-z)(M - C_1) \quad (1)$$

$$U_{A2} = yz\,(M - P_1) + y(1-z)M + (1–y)z(M - P_1) + (1-y)(1-z)M \quad (2)$$

$\overline{U_A}$ denotes the average expected payoff of schools, which can be simplified to:

$$\overline{U_A} = xU_{A1} + (1-x)U_{A2} \quad (3)$$

Similarly, we use U_{B1} and U_{B2} to represent the expected payoff of enterprises' positive and negative cooperation strategies, respectively, and use $\overline{U_B}$ to represent the average expected payoff of enterprises, which are simplified below.

$$U_{B1} = xz\,(N - C_2 + G_2 + R_2) + x(1-z)(N - C_2 + R_2) + (1-x)z(N - C_2 + G_2) + (1-x)(1-z)(N - C_2) \quad (4)$$

$$U_{B2} = xz\,(N - P_2) + x(1-z)N + (1-x)z(N - P_2) + (1-x)(1-z)N \quad (5)$$

$$\overline{U_B} = yU_{B1} + (1-y)U_{B2} \quad (6)$$

Finally, we use U_{C1} and U_{C2} in the same way to represent the expected payoff of the government's positive and negative cooperation strategies, respectively, and use $\overline{U_C}$ to represent the average expected payoff of the government:

$$U_{C1} = xy\ (-C_3 - G_1 - G_2 + B_1) + x(1-y)(-C_3 - G_1 + P_2) + (1-x)y(-C_3 - G_2 + P_1) + (1-x)(1-y)(-C_3 + P_1 + P_2) \quad (7)$$

$$U_{C2} = xyB_2 + x(1-y)(-P_3) + (1-x)y(-P_3) + (1-x)(1-y)(-P_3) \quad (8)$$

$$\overline{U_C} = zU_{C1} + (1-z)U_{C2} \quad (9)$$

Thus, the replicator dynamics equations of schools, enterprises, and government, which are denoted by $\frac{dx}{dt}$, $\frac{dy}{dt}$, and $\frac{dz}{dt}$, respectively, can be obtained as follows:

$$F(x) = \frac{dx}{dt} = x\left(U_{A1} - \overline{U_A}\right) = x(1-x)[yR_1 + z(G_1 + P_1) - C_1] \quad (10)$$

$$F(y) = \frac{dy}{dt} = y\left(U_{B1} - \overline{U_B}\right) = y(1-y)[xR_2 + z(G_2 + P_2) - C_2] \quad (11)$$

$$\begin{aligned} F(z) = \tfrac{dz}{dt} &= z\left(U_{C1} - \overline{U_C}\right) \\ &= z(1-z)[xy(B_1 - B_2 - P_3) + x(-G_1 - P_1) + y(-G_2 - P_2) - C_3 + P_1 \\ &\quad + P_2 + P_3] \end{aligned} \quad (12)$$

In the next section, we analyze the stability of the strategies of each population by solving the replicator dynamics equations, constructing a Jacobian matrix, and calculating the eigenvalues of the Jacobian matrix at different equilibrium points.

4. Strategy Stability Analysis

First of all, we let $F(x) = 0$, $F(y) = 0$, and $F(z) = 0$ and define the system of simultaneous equations as:

$$\begin{cases} F(x) = x(1-x)[yR_1 + z(G_1 + P_1) - C_1] = 0 \\ F(y) = y(1-y)[xR_2 + z(G_2 + P_2) - C_2] = 0 \\ F(z) = z(1-z)[xy(B_1 - B_2 - P_3) + x(-G_1 - P_1) + y(-G_2 - P_2) - C_3 + P_1 + P_2 + P_3] = 0 \end{cases} \quad (13)$$

By solving the equations in (13), 14 equilibrium points can be obtained: E_1 (0, 0, 0), E_2 (0, 0, 1), E_3 (0, 1, 0), E_4 (0, 1, 1), E_5 (1, 0, 0), E_6 (1, 0, 1), E_7 (1, 1, 0), E_8 (1, 1, 1), E_9 (0, $\frac{C_3-P_1-P_2-P_3}{-G_2-P_2}$, $\frac{C_2}{G_2+P_2}$), E_{10} (1, $\frac{G_1+C_3-P_2-P_3}{B_1-B_2-P_2-P_3-G_2}$, $\frac{C_2-R_2}{G_2+P_2}$), E_{11} ($\frac{C_3-P_1-P_2-P_3}{-G_1-P_1}$, 0, $\frac{C_1}{G_1+P_1}$), E_{12} ($\frac{G_2+C_3-P_1-P_3}{B_1-B_2-P_1-P_3-G_1}$, 1, $\frac{C_1-R_1}{G_1+P_1}$), E_{13} ($\frac{C_2}{R_2}$, $\frac{C_1}{R_1}$, 0), and E_{14} ($\frac{C_2-G_2-P_2}{R_2}$, $\frac{C_1-G_1-P_1}{R_1}$, 1). However, the solution of the replicator dynamics system in a multi-agent evolutionary game must be a strict Nash equilibrium solution [58]. Hence, we selected only the pure strategy combinations E_1, E_2, E_3, E_4, E_5, E_6, E_7, and E_8 (1, 1, 1) as the possible stable equilibrium points.

Next, we adopted Friedman's replication dynamics system stability analysis method [59] to construct a Jacobian matrix of the "schools–enterprises–government" tripartite game.

$$J = \begin{pmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{pmatrix} = \begin{pmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{pmatrix} \quad (14)$$

where

$$J_{11} = (1 - 2x)\ [y\ R_1 + z\ (G_1 + P_1) - C_1]$$

$$J_{12} = x\,(1 - x)\,R_1$$

$$J_{13} = x\,(1 - x)\,(G_1 + P_1)$$

$$J_{21} = y\,(1 - y)\,R_2$$

$$\mathrm{J_{22}} = (1 - 2\mathrm{y})\,[\mathrm{x\,R_2} + \mathrm{z}\,(\mathrm{G_2} + \mathrm{P_2}) - \mathrm{C_2}]$$

$$J_{23} = y\,(1 - y)\,(G_2 + P_2)$$

$$J_{31} = z\,(1 - z)\,[y\,(B_1 - B_2 - P_3) + (-\,G_1 - P_1)]$$

$$J_{32} = z\,(1 - z)\,[x\,(B_1 - B_2 - P_3) + (-\,G_2 - P_2)]$$

$$J_{33} = (1 - 2z)\,[x\,y\,(B_1 - B_2 - P_3) + x\,(-\,G_1 - P_1) + y\,(-\,G_2 - P_2) - C_3 + P_1 + P_2 + P_3]$$

According to Lyapunov stability theory, the stability at an equilibrium point can be judged by analyzing the eigenvalues of the Jacobian matrix [60]. Specifically, for any equilibrium point, if there are no positive eigenvalues, that point is stable. If there are any positive eigenvalues, the equilibrium point is unstable, and if the eigenvalues cannot be estimated, the equilibrium point is a saddle point. The results of substituting each of the eight equilibrium points into the Jacobian matrix and calculating the eigenvalues of the Jacobian matrix at different equilibrium points are shown in Table 3.

Table 3. Eigenvalues and stability of equilibrium points.

Equilibrium Point	λ_1	Symbol	λ_2	Symbol	λ_3	Symbol	State
E_1 (0, 0, 0)	$-C_1$	−	$-C_2$	−	$P_1 + P_2 + P_3 - C_3$	+	unstable
E_2 (0, 0, 1)	$G_1 + P_1 - C_1$	+	$G_2 + P_2 - C_2$	+	$C_3 - P_1 - P_2 - P_3$	−	unstable
E_3 (0, 1, 0)	$R_1 - C_1$	N	C_2	+	$P_1 + P_3 - G_2 - C_3$	+	unstable
E_4 (0, 1, 1)	$R_1 + G_1 + P_1 - C_1$	+	$C_2 - G_2 - P_2$	−	$G_2 + C_3 - P_1 - P_3$	N	unstable
E_5 (1, 0, 0)	C_1	+	$R_2 - C_2$	N	$P_2 + P_3 - G_1 - C_3$	N	unstable
E_6 (1, 0, 1)	$C_1 - G_1 - P_1$	−	$R_2 + G_2 + P_2 - C_2$	+	$G_1 + C_3 - P_2 - P_3$	N	unstable
E_7 (1, 1, 0)	$C_1 - R_1$	N	$C_2 - R_2$	N	$B_1 - B_2 - G_1 - G_2 - C_3$	N	saddle
E_8 (1, 1, 1)	$C_1 - R_1 - G_1 - P_1$	−	$C_2 - R_2 - G_2 - P_2$	−	$B_2 + G_1 + G_2 + C_3 - B_1$	N	saddle

In Table 3, "N" means that the sign of the eigenvalue cannot be determined, "+" means that the eigenvalue is positive, and "−" means that the eigenvalue is negative.

As can be seen from Table 3, there are two saddle points (E_7 and E_8) in the system. When the equilibrium point is E_7(1, 1, 0), when both schools and enterprises choose the positive cooperation strategy and the government chooses the negative cooperation strategy, the conditions for stability of the system are $R_1 > C_1$, $R_2 > C_2$ and $C_3 > B_1 - B_2 - G_1 - G_2$. When this occurs, the positive cooperation strategy rewards for both schools and enterprises received from sources other than the government are greater than their cost, and the cost of the government's positive cooperation strategy is greater than the difference between the benefit of the government's positive cooperation strategy, the benefit of the government's negative cooperation strategy, and the incentives given to schools and enterprises by the government.

When the equilibrium point is E_8(1, 1, 1), when all populations cooperate, the condition for stability of the system is $C_3 < B_1 - B_2 - G_1 - G_2$. When this occurs, the cost of the government's positive cooperation strategy is lower than the difference between the benefit of the government's positive cooperation strategy, the benefit of the government's

negative cooperation strategy, and the incentives given to schools and enterprises by the government. Comparing the two equilibrium points shows that the main factor that influences the stability of the strategies of schools and enterprises is the reward for the positive cooperation strategy from sources other than the government, and the main factor that influences the stability of the strategy of the government is the benefit from the positive cooperation strategy under the condition of schools cooperating with enterprises.

5. Conclusions

In this paper, we studied cooperation between schools, enterprises, and government from the perspective of evolutionary game theory by establishing a tripartite evolutionary game model. Based on our strategy stability analysis, we found several effective ways to promote the cooperation between schools, enterprises, and government, and reached the following conclusions.

(1) There are two equilibrium points, E_7 (1, 1, 0) and E_8 (1, 1, 1), at which the system can reach a stable state.

(2) The main factor that influences the stability of the strategies of schools and enterprises is the reward for positive cooperation from sources other than the government. When schools and enterprises receive enough rewards from sources other than the government, the system can reach a stable state regardless of whether the government chooses the positive or negative cooperation strategy. The nongovernmental effects of the cooperation between schools and enterprises are greater than the governmental effects. That is, the current influence of the government on school–enterprise cooperation is not obvious. Therefore, the government should focus on implementing more effective policies, such as increasing incentives and penalties, improving the mechanism for managing conflicts, ensuring the fairness of benefit distribution, and clarifying the responsibilities of different departments, in order to provide the best possible environment to facilitate the cooperation between schools and enterprises.

(3) The main factor that influences the stability of the strategy of the government is the benefit from the positive cooperation strategy under the condition of schools cooperating with enterprises. When the government receives enough benefits from the cooperation of schools and enterprises as a result of a positive cooperation strategy, the system can reach a stable state. Therefore, the effectiveness of schools cooperating with enterprises should be emphasized. Schools should focus on providing more practical curricula and programs for students, training high-quality teachers, and perfecting talent cultivation to meet the needs of enterprises. Similarly, enterprises should focus on providing job experiences for students and transforming the results of schools' teaching and theoretical research into practical productivity.

In summary, this study reveals the factors that influence the sustainable cooperation between schools, enterprises, and government, and emphasizes the critical role of the government in the connection between schools and enterprises, which is lacking in the existing literature. The tripartite evolutionary game model provides a new framework for analyzing the cooperation between schools, enterprises, and government, and the results deepen our understanding of sustainable cooperation between schools, enterprises, and government. Admittedly, the process by which different factors influence the strategy evolution of schools, enterprises, and government has not been explored in this study. How various parameters impact strategy selection and evolution deserves more attention. Therefore, a future study with numerical simulations is needed to investigate the strategy evolution mechanism of schools, enterprises, and government.

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References

1. Legal Framework and Financing. Available online: https://www.bibb.de/en/77214.php (accessed on 20 July 2023).
2. Strengthening Career and Technical Education for the 21st Century Act. Available online: https://careertech.org/Perkins (accessed on 20 July 2023).
3. Several Opinions on Deepening the Integration of Industry and Education. Available online: https://www.gov.cn/gongbao/content/2018/content_5254308.htm (accessed on 21 July 2023).
4. Cyert, R.M.; Goodman, P.S. Creating effective university-industry alliances: An organizational learning perspective. *Organ. Dyn.* **1997**, *25*, 45–57. [CrossRef]
5. Wright, M.; Clarysse, B.; Lockett, A.; Knockaert, M. Mid-range universities' linkages with industry: Knowledge types and the role of intermediaries. *Res. Policy* **2008**, *37*, 1205–1223. [CrossRef]
6. Bergman, E.M. Knowledge links between European universities and firms: A review. *Pap. Reg. Sci.* **2010**, *89*, 211–222. [CrossRef]
7. Harrison, R.; Leitch, C. Enterpreneurial learning: Researching the interface between learning and the entrepreneurial context. *Entrep. Theory Pract.* **2005**, *29*, 351–371. [CrossRef]
8. Plewa, C. Exploring organizational culture difference in relationship dyads. *Australas. Mark. J.* **2009**, *17*, 46–57. [CrossRef]
9. Galan, M.V.; Plewa, C. What drives and inhibits university-business cooperation in Europe? A comprehensive assessment. *R D Manag.* **2016**, *46*, 369–382.
10. Perkmann, M.; Tartari, V.; McKelvey, M.; Autio, E.; Broström, A.; D'este, P.; Fini, R.; Geuna, A.; Grimaldi, R.; Hughes, A.; et al. Academic engagement and commercialisation: A review of the literature on university-industry relations. *Res. Policy* **2013**, *43*, 423–442. [CrossRef]
11. Theuerkauf, W.E.; Weiner, A. The German Dual System of Vocational Education and Implications for Human Resource Development in America. *Oxf. Rev. Educ.* **2002**, *1*, 53–73.
12. BMBF. *Vocational Training in the Dual System in Germany*; Federal Ministry of Education, Science, Research and Technology, Public Relations Division: Bonn, Germany, 1997.
13. Pleshakova, A.Y. Dual System of Education in Germany: Historical Context. *Nauchnyi Dialog* **2018**, *10*, 301–312. [CrossRef]
14. Remington, T.F. Business-Government Cooperation in VET: A Russian Experiment with Dual Education. *Post-Sov. Aff.* **2017**, *33*, 313–333. [CrossRef]
15. Dudyrev, F.; Romanova, O.; Shabalin, A. Dual Education in Regions of Russia: Models, Best Practices, Growth Prospects. *Vopr. Obraz.-Educ. Stud. Mosc.* **2018**, *2*, 117–138. [CrossRef]
16. Pyliavets, M.; Protas, O.; Martinets, L.; Lyaskevich, A.; Babyshena, M.; Chumak, L.; Lazorko, O. A Comparative Analysis of Peculiarities of Vocational Education in Ukraine and Germany. *Rev. Rom. Pentru Educ. Multidimens.* **2020**, *12*, 200–212. [CrossRef]
17. Cai, Y. A Study on the Education Model of Dual System in Comprehensive Universities in Germany. *Stud. Foreign Educ.* **2010**, *37*, 80–85. (In Chinese)
18. Liang, L. Inspiration of German "Dual System" on the Cooperation with Enterprises in Application-oriented Universities. *Sci. Manag. Res.* **2014**, *32*, 128–131. (In Chinese)
19. Yang, R.; Sun, S. A Study and Reference of the Dual System of Education Governance in Germany: An Analysis Based on Cultural-Historical Activity Theory. *J. Beijing Adm. Inst.* **2021**, *4*, 99–107. (In Chinese)
20. Pritchard, R.M.O. The German Dual System: Educational Utopia? *Comp. Educ.* **1992**, *28*, 131–143. [CrossRef]
21. Shackleton, J.R. Training in Germany: A view from abroad. *Educ. Train.* **1997**, *39*, 303–308. [CrossRef]
22. Li, J.; Li, D. International Comparative Analysis of Industry-Education Integration in Vocational Education. *Res. High. Educ. Eng.* **2019**, *4*, 159–164.
23. Younis, N. Cooperative Education Impact on Enhancing Mechanical Engineering Curriculum. In Proceedings of the 2012 ASEE Annual Conference & Exposition, San Antonio, TX, USA, 10–13 June 2012.
24. Pierrakos, O.; Borrego, M.; Lo, J. Preliminary findings from a quantitative study: What are students learning during cooperative education experiences? In Proceedings of the 2008 Annual Conference & Exposition, Pittsburgh, PA, USA, 22–25 June 2008.
25. Schuurman, M.K.; Pangborn, R.N.; McClintic, R.D. Assessing the Impact of Engineering Undergraduate Work Experience: Factoring in Pre-work Academic Performance. *J. Eng. Educ.* **2008**, *97*, 207–212. [CrossRef]

26. Raelin, J.A.; Bailey, M.B.; Hamann, J.C.; Pendleton, L.K.; Raelin, J.; Reisberg, R.; Whitman, D. The Effect of Cooperative Education on Change in Self-Efficacy Among Undergraduate Students: Introducing Work Self-Efficacy. *J. Coop. Educ. Internsh.* **2011**, *45*, 17–35.
27. Rowe, P.M. Work Experience, the Scientist-Practitioner Model, and Cooperative Education. *Can. Psychol.-Psychol. Can.* **2018**, *59*, 144–150. [CrossRef]
28. Chopra, S.; Golab, L. Undergraduate engineering applicants' perceptions of cooperative education: A text mining approach. *Int. J. Work-Integr. Learn.* **2022**, *23*, 95–112.
29. Baldwin, C.T. Sandwich courses in the universities. *Phys. Bull.* **1969**, *20*, 486. [CrossRef]
30. Jones, B.; Healey, M.; Matthews, H. The thick sandwich: Still on the menu. *J. Geogr. High. Educ.* **1995**, *19*, 23. [CrossRef]
31. Santiago, A. Impact of Sandwich Course Design on First Job Experience. *Asia-Pac. Educ. Res.* **2009**, *18*, 205–217. [CrossRef]
32. Brooks, R.; Youngson, P.L. Undergraduate work placements: An analysis of the effects on career progression. *Stud. High. Educ.* **2016**, *41*, 1563–1578. [CrossRef]
33. Lee, J.; Win, H.N. Technology transfer between university research centers and industry in Singapore. *Technovation* **2004**, *24*, 433–442. [CrossRef]
34. Arza, V. Channels, benefits and risks of public—Private interactions for knowledge transfer: Conceptual framework inspired by Latin America. *Sci. Public Policy* **2010**, *37*, 473–484. [CrossRef]
35. Lam, A. What motivates academic scientists to engage in research commercialization: 'Gold', 'ribbon' or 'puzzle'? *Res. Policy* **2011**, *40*, 1354–1368. [CrossRef]
36. Mowery, D.C.; Sampat, B.N. The Bayh-Dole Act of 1980 and university-industry technology transfer: A model for other OECD government? *J. Technol. Transf.* **2004**, *30*, 115–127. [CrossRef]
37. Eom, B.Y.; Lee, K.D. Determinants of industry-academy linkages and their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. *Res. Policy* **2010**, *39*, 625–639. [CrossRef]
38. Santoro, M.D.; Chakrabarti, A.K. Firm size and technology centrality in industry-university interactions. *Res. Policy* **2002**, *31*, 1163–1180. [CrossRef]
39. Perkmann, M.; Neely, A.; Walsh, K. How should firms evaluate success in university-industry alliances? A performance measurement system. *R D Manag.* **2011**, *41*, 202–216. [CrossRef]
40. de Moraes Silva, D.R.; Furtado, A.T.; Vonortas, N.S. University-industry R&D cooperation in Brazil: A sectoral approach. *J. Technol. Transf.* **2018**, *43*, 285–315.
41. Laursen, K.; Reichstein, T.; Salter, A. Exploring the effect of geographical proximity and university quality on university-industry collaboration in the United Kingdom. *Reg. Stud.* **2011**, *45*, 507–523. [CrossRef]
42. Numprasertchai, S.; Igel, B. Managing knowledge through collaboration: Multiple case studies of managing research in university laboratories in Thailand. *Technovation* **2005**, *25*, 1173–1182. [CrossRef]
43. Rosendo-Rios, V.; Ghauri, P.N.; Zhang, Y. Empirical analysis of the key factors that can contribute to university-industry cooperational success from a relationship marketing approach. *Eur. J. Int. Manag.* **2016**, *10*, 647–677. [CrossRef]
44. Li, Z.; Wang, D.; Li, X. Status quo and influence factors of university industry collaboration: Evidence of Zhejiang Province. *Sci. Technol. Prog. Policy* **2012**, *29*, 150–154. (In Chinese)
45. Shan, H.; Yang, J. Sustainability of photovoltaic poverty alleviation in China: An evolutionary game between stakeholders. *Energy* **2019**, *181*, 264–280. [CrossRef]
46. Zhao, R.; Zhou, X.; Han, J.J.; Liu, C. For the sustainable performance of the carbon reduction labeling policies under an evolutionary game simulation. *Technol. Forecast. Soc. Chang.* **2016**, *112*, 262–274. [CrossRef]
47. Babu, S.; Mohan, U. An integrated approach to evaluating sustainability in supply chains using evolutionary game theory. *Comput. Oper. Res.* **2018**, *89*, 269–283. [CrossRef]
48. Congleton, R.D. Game theory and public policy—By Roger, A. *McCain. Public Adm.* **2013**, *91*, 248–250. [CrossRef]
49. Hui, E.; Bao, H. The logic behind conflicts in land acquisitions in contemporary China: A framework based upon game theory. *Land Use Policy* **2013**, *30*, 373–380. [CrossRef]
50. Estalaki, S.M.; Abed-Elmdoust, A.; Kerachian, R. Developing environmental penalty functions for river water quality management: Application of evolutionary game theory. *Environ. Earth Sci.* **2015**, *73*, 4201–4213. [CrossRef]
51. Wu, B.; Liu, P.; Xu, X. An evolutionary analysis of low-carbon strategies based on the government–enterprise game in the complex network context. *J. Clean. Prod.* **2017**, *141*, 168–179. [CrossRef]
52. Zhu, H.; Wang, Q. The Development Dilemma and Path Choice of Innovation and Entrepreneurship Education Based on Game Theory. *Adv. Multimed.* **2022**, *2022*, 2232253. [CrossRef]
53. Li, D.; Wang, W. Online Learning Management for Primary and Secondary Students during the COVID-19 Epidemic: An Evolutionary Game Theory Approach. *Sustainability* **2022**, *14*, 12416. [CrossRef]
54. Zhang, H.; Zeng, Y. The Education for Sustainable Development, Online Technology and Teleological Rationality: A Game between Instrumental Value and Humanistic Value. *Sustainability* **2022**, *14*, 2101. [CrossRef]
55. Axelrod, R.; Hamilton, W.D. The evolution of cooperation. *Science* **1981**, *211*, 1390–1396. [CrossRef]
56. Nowak, M.A.; May, R.M. Evolutionary games and spatial chaos. *Nature* **1992**, *359*, 826–829. [CrossRef]
57. Nowak, M.A. *Evolutionary Dynamics: Exploring the Equations of Life*; The Belknap Press of Harvard University Press: Cambridge, MA, USA, 2006.
58. Ritzberger, K.; Weibull, J.W. Evolutionary selection in normal form games. *Econometrica* **1995**, *63*, 1371–1399. [CrossRef]

59. Friedman, D. Evolutionary Games in Economics. *Econometrica* **1991**, *59*, 637–666. [CrossRef]
60. Lyapunov, A.M. The general problem of the stability of motion. *Int. J. Control* **1992**, *55*, 531–534. [CrossRef]