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A Game Analysis of Family Participation in Shadow Education

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Abstract

Shadow education is a common social phenomenon in the world. The prosperity of shadow education will increase students' learning pressure, aggravate educational involution, and produce educational anxiety. Looking further, due to differences in urban and rural development levels and social capital, shadow education poses a great challenge to the implementation of educational equity policies. This paper studies shadow education in primary schools in China from the perspective of game theory, and uses the prisoner's dilemma model to explore the impact of competition mechanism on cooperation, in order to reduce the phenomenon of educational involution and promote educational equity. This paper draws the main conclusions: The educational competition mechanism reduces the reciprocal behavior of cooperation in the competitive environment to a certain extent, and the cooperation of the shadow education demanders will promote education fairness and increase the overall social welfare.

Keywords

Shadow education; Prisoner's dilemma model; Competition mechanism; Cooperation.

1. Introduction

The concept of shadow education originates from Marimuthu, Singh, Stevenson and Baker' metaphor for extra school education. The term shadow education has been applied to the study of educational phenomena since the UNESCO report by Mark Bray [1]. They believe that extra-curricular supplementary tutoring is an educational phenomenon that exists with the existence of the mainstream education system, and its scale and model change with the mainstream system, so it is a "shadow education" that exists with the education system [2]. Over the past two decades, various off-campus training institutions have rapidly expanded around the world. Shadow education makes up for the lack of school education to a certain extent, and strengthens subject learning through small classes or one-to-one teaching. However, it also generates problems such as educational anxiety, students' heavy schoolwork burden and educational ecological imbalance. The current student participation rate in shadow education varies from 20% to 80% in various countries. Due to different market demands, shadow education in the world can be roughly divided into high-intensity regions such as China and Japan, medium-intensity regions such as Europe and Africa, and low-intensity regions such as the United States, Canada etc. In order to better manage shadow education and achieve an educational ecological balance, it is necessary to deeply understand and analyze the motivations and behaviors of shadow education demanders.

This paper takes shadow education in primary schools in China as the research object. At present, the government work report of the 19th National Congress of the Communist Party of China has made key requirements for reducing the extracurricular academic burden of students. Shadow education has become an "accomplice" of exam-oriented education, hindering the promotion of quality education and burden reduction policies, and has become the focus of the government and scholars [3]. There are multiple motivations for families to participate in the shadow education game in basic education, especially in primary education. Therefore, it has important practical and social significance to clarify the internal mechanism of family

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participation in the shadow education game. On the one hand, this research can reduce the resistance of the government to manage off-campus training institutions, and better achieve the goal of reducing the heavy burden of students' extracurricular studies during the compulsory education stage. On the other hand, the use of research results can guide families to rationally consume shadow education, achieve win-win cooperation among shadow education demanders, reduce the impact of shadow education on the allocation of educational resources and educational equity, and thus increase social welfare.

This paper will use the prisoner's dilemma model to analyze the motivation of families to participate in extracurricular training from the perspective of game theory, study the internal mechanism that affects the market demand of shadow education, point out the drawbacks that excessive competition will cause education involution, and clarify cooperation between demanders of shadow education is of great significance to the healthy development of compulsory education and the realization of educational equity.

The paper is divided into six sections: Section I briefly introduces the background of the research. Section II introduces the importance and significance of studying the influence of competition mechanism on cooperation under shadow education from the perspective of game theory, sorts out the viewpoints of the existing literature on related topics, and points out the contribution of the paper to the existing research; Section III establishes the experimental model; Section IV gives the experimental design; Section V includes hypothesis and discussions about the research; Section VI makes conclusions and provides relevant suggestions .

2. Literature Review

The concept of "shadow education" is first proposed by Stevenson, D., & Baker, D. when they study the phenomenon of after-school tutoring of Japanese high school students [4]. They believe that shadow education is a kind of non-mainstream education activity that takes place outside the mainstream education in order to improve students' academic performance and achieve educational goals. Wang Yousheng is the first to conduct research on shadow education in China [5]. He analyzes the characteristics, causes and influences of shadow education and believes that school education is the mainstream and shadow education has a negative impact on educational decision-making and management, which should attract social attention. Xiao Ling uses the prisoner's dilemma and benefit maximization theory to analyze the game strategies between demanders and suppliers, and between demanders and demanders in the shadow education field [6]. She analyzes the policy governance relationship between stakeholders and puts forward policy suggestions to improve the quality of school education. S.r. Lucas 's "Effective Maintenance of Inequality Theory" (EMI) explains the reasons for the emergence of shadow education from the perspective of educational competition [7]. EMI theory believes that after the popularization of compulsory education, the unbalanced development of compulsory education between urban and rural areas and between schools leads to education competition centering on quality. When the government takes measures to control the education quality gap between urban and rural areas and between schools, in order to effectively maintain the education inequality, the core of family education competition has shifted from school education to shadow education.

The two-sided effects of competition mechanism on cooperation have been proved in a large number of literatures. On the one hand, the incentive effect of competition mechanism can be traced back to relative performance evaluation in incentive theory. When other uncertainties are completely the same, relative performance evaluation is a sufficient statistic of agents' efforts [8], and it will form a competitive relationship between agents, resulting in inefficient behaviors such as unfair competition. Loch et al. found that in order to improve the survival probability in the environment with limited resources, individuals would reduce their

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willingness to cooperate [9]. Carpenter and Yermack find that although increasing the reward gap between winners and losers has a certain incentive effect [10], the strong winner-take-all competition mechanism may reduce the cooperative behavior between competitors and sabotage even occurs [11].

The existing literatures generally study the causes, impacts and costs of shadow education from an empirical perspective, while few discuss it from the perspective of game theory. In addition, teachers, students and the government are the main subjects of analysis. The innovation of this paper lies in the use of game theory as the basis of the analysis method, taking the family as the main subject of research, to study the relationship between educational competition and cooperation under the background of shadow education.

3. Theoretical Model

This paper assumes that the information is complete, and the participants' input and their utility functions are public information. With game theory as the basic analysis method, it is assumed that participants choose their own strategies under the premise of complete rationality to pursue the maximization of their own interests. Players, strategy and payoff are the three basic elements of game theory. In this paper, the family is regarded as a player, and "participation" or "non-participation" is the strategy of the game, and the benefits of the game are the benefits obtained by choosing "participation" or "non-participation". Specifically, participants, action strategies and utility functions of shadow education are as follows:

1) Players: The shadow education game mainly occurs between multiple families, so the participants are set as families with different economic backgrounds. Let $N=\{1, 2, 3, 4, \ldots, n\}$ denotes the set of all the participants.

2) Action strategy: The game strategy selection set of each player in the shadow education game is $m_i=[0, M_i]$. "0" means that the family has no investment in shadow education, which means that participants do not participate in shadow education. "M_i" means the total income of family i, which means that participants fully participate in shadow education.

3) Utility function: when the combination of strategies selected by players in the shadow education game is $(m_1, m_2, \ldots, m_n)$, the utility value of participant i is $f_i(m_1, m_2, \ldots, m_n) = u_i(m_i) - c_i(m_1, m_2, \ldots, m_n)$.

u_i represents the income gained by player i for entering key schools or classes in the absence of competition; c_i represents the influence of other players' participation in shadow education on player i's utility.

Specifically, U(i)=[positive effect of shadow education]×[negative effect of shadow education] $= (1+m_i) *(a_i-\beta\cdot m_i)$. a_i ($i = 1,2$. $1<a_i<2$) represents the individual learning ability of students, m_i represents the strategy selection of players in shadow education $m_i \in [0, M_i]$. In this case, the number "1" is added to explain that when the family shadow education expenditure is "0", the probability of students entering key schools or classes depends on students' ability and psychological pressure caused by external objective environment changes. β is the negative influence coefficient of shadow education on the independent utility of player i without participation and $\beta\in[0,1]$. $(a_i-\beta\cdot m_i)$ represents the negative utility of shadow education caused by the existence of competitive pressure.

4. Experimental Design

While education is currently being promoted to reduce the burden of education, shadow education is in fact always present. The scarcity of educational resources, increasing number of students and the intense pressure of the competitive environment have led to a “violent involution” in education, where students actively engage in shadow education to improve their

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own performance. The existence of "involution" reduces the benefits of cooperation, which in turn increases competition and reduces overall social welfare. So why do students and their families choose the shadow education when it seems to be a detriment to whole welfare? We therefore want to investigate whether the choice to participate in shadow education is a universal choice and whether it is optimal. An experimental design will use to investigate the prisoner's dilemma to investigate the participation attitude in shadow education and to consider the impact of student ability, family condition and the intensity of competition on it.

In the experiment, subjects are divided into 10 groups according to the symmetrical and asymmetrical conditions, and the setting of the competition mechanism. The specific group settings are described later.

Firstly, the factor of competition intensity is measured by the specific operational control of the competition mechanism settings. That is, the effect of different competition mechanism settings on subjects' behavior can be modelled to show the effect of environmental competition intensity on the choice of whether to participate in shadow education in a realistic situation. Secondly, for the two factors of students' individual ability and family conditions, then the initial endowment is assigned through the first stage of the test, which in turn explores the effects on behavior under different conditions. Overall we will use the Prisoner's Dilemma game model for hypothesis testing.

Throughout the experiment Subjects interact anonymously via a computer terminal, and their final payout consists of both an appearance fee and an experimental payout proportional to the number of points earned during the experiment, thus ensuring that subjects are motivated to actively increase their earnings.

4.1. Experimental Phases

The experiment will be divided into two phases. In the first phase subjects will be assigned an initial ability endowment through a same set of test questions, which will later influence the subsequent phases of the game. This corresponds to the initial differences in individual learning ability in a realistic environment. After this, the initial conditional endowment is assigned through a random number selection design mechanism, which corresponds to realistic differences in family conditions, and which later becomes the condition that influences subsequent choices either. In this test, a same number of people in each group of conditions was guaranteed. The first 50% of subjects in each of the two tests will receive 500 points, while the second 50% will receive 400 points each. These points will be evenly distributed across the ten rounds of the second phase of the test as the subject's base endowment for the round in order to be a prerequisite for choices. In the second stage subjects will be invited to participate in ten rounds of a rotating match between two players and a description of the competitive mechanism will be given prior to the game.

4.2. Experimental Design

4.2.1. Matching Mechanism

In order to avoid possible contagion effect and other exogenous interference between different repeated games, a rotating matching mechanism was therefore adopted. Subjects are not matched with each other in more than one game, and choices made in one game do not otherwise affect their own or other subjects' other choices.

4.2.2. Competition Mechanism Setting

A total of two different competition mechanisms were set up in the second phase of the experiment. The first was a general competition mechanism, where subjects would receive a 20:1 ratio of points to final payout. The second is a head-tail competition mechanism, whereby the top 20% of subjects will receive an additional 40:1 final payout of points, while the bottom

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20% will lose their 40:1 final payout of points. This condition will be operationalized in subsequent modelling as a representation of the intensity of competition factor.

4.2.3. Group Setting

The subjects were first divided into broad categories of symmetric and asymmetric groups according to the initial endowment results of the first round of the experiment. The symmetrical group implies that the subjects have the same background, like the same degree of individual learning ability and family conditions on both players of the game. Under this condition, they are then differentiated into 2 groups through a dissimilar competitive mechanism. The asymmetrical group means that the subjects have different backgrounds and that both parties involved do not match same level of their own abilities and family conditions. In the asymmetrical group, in comparison, "good-weak" means that one of the parties has relatively good family condition and relatively weak individual ability, while another has relatively poor family condition and relatively strong individual ability and is regarded as "poor-strong". "good-strong" means that one of the parties has relatively good family condition and relatively strong individual ability, while another has relatively poor family condition and relatively weak individual ability and is regarded as "poor-weak".

On the basis of this, different competition mechanisms were developed. In general, the groups were divided into 6 groups, each with 20 eligible subjects, and each group was randomly matched 10 times internally according to a rotating matching mechanism.

The specific experimental groups were set up as shown in Table 1.

Table 1. Description of group settings

Case No.		Competition mechanism	Initial endowments
1		General competition mechanism	Symmetrical
		Head-tail competition mechanism	Symmetrical
2	A	General competition mechanism	Asymmetrical (good-weak; poor-strong）
	B	Head-tail competition mechanism	Asymmetrical (good-weak; poor-strong)
3	A	General competition mechanism	Asymmetrical (good-strong; poor-weak)
	B	Head-tail competition mechanism	Asymmetrical (good-strong; poor-weak)

4.2.4. Stage Game Design

In the second phase of the experiment, each participant was given the choice between 'participating' in shadow education and 'not participating' in each round of the game, and their choice was not interfered with by others. Before participating in the game, subjects receive information about the set competition mechanism. The specific game payoff matrix is discussed in more detail in the subsequent hypothesis analysis.

Then the following section will specifically discuss the hypothesis of the experimental cases and analyze it accordingly. And in the subsequent discussion, separate hypothesis setting and game analysis will be carried out for symmetric and asymmetric situations respectively, and the asymmetric situations part will discuss the four types of players optimal strategies further.

5. Hypothesis and Discussion

Hypothesis 1: When other conditions are the same, both families get the greatest benefit when they do not participate in shadow education.

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The same other conditions mean that families participating in the shadow education game have the same economic background, students have the same ability, and individuals face the same degree of intense competition in the external environment. In this symmetric scenario, players have the same strategy choice and payoff. We can analyze it using a payoff matrix similar to the Prisoner's dilemma. Table 2 shows the game payoff matrix of family A and family B in the symmetric scenario.

Table 2. Payoff matrix

	Participate	Not participate
Participate	(P*U-c, (1-P) *U-c)	(P*U-c, 0)
Not participate	(0， P*U-c)	(P*U, (1-P)*U)

In order to simplify the processing, "U" is the total number of points that players finally get, and represents the direct income of families choosing to participate in shadow education to upgrade to key schools or classes. "C" is the investment amount of players, which is reflected in the cost of families participating in shadow education in reality, and the range is [0, C]. "P" is the probability of winning the game, which is reflected in reality as the probability of a family being promoted to a key school or class. "EU" represents the expected income of family participation in shadow education; β is the negative influence coefficient of competitive pressure on participants' learning effectiveness under the shadow education, and (a-β·c) represents the negative effect of shadow education caused by the existence of competitive pressure. The EU = PU+(1-P)·0-c=P(1+mi)(a-β·c)-c.

If a household chooses the "non-participation" strategy, its expenditure is zero; If the other family chooses the "participation" strategy, its expenditure is c, and the probability of the latter entering the key school or class is "1". If both families choose the strategy of "participation" or "non-participation", i.e. their expenditure is both "c" or "0", they have the same probability of entering the key school or the key class and P=1/2.

When U＞2c, both families choose the "participation" strategy as the dominant strategy, but it is not a perfect Nash equilibrium. In this case, the expected benefits of households choosing to "participate" exceed the costs, so every household chooses to "participate". However, in terms of the choice of cost input C, it is assumed that the cost of family A's investment in shadow education is c1 (c1∈[0, C]), and family B will invest c2 (C≥c2＞c1) based on the fear of being surpassed. At this time, family A will invest in c3 (C≥c3＞c2) to participate in shadow education. Following this vicious cycle, the investment of both families will eventually reach the payment limit C, so the expenditure of both families on shadow education will eventually be "C". At this point, A Nash equilibrium has been achieved. This Nash equilibrium is not perfect because if both families choose to spend "0", the probability of both family A and family B being promoted to A key school or A key class will be 1/2. The direct income obtained is the same as the expenditure "C" for both choices, but the overall utility is greater than the utility of both choices "c".

When U = 2c, the expected benefits of "participating" or "not participating" are the same for the two families, so there is no pure dominant strategy. In this case, no matter what kind of strategic choice one family makes, the other family's strategic choice is mainly based on the family's educational preference and students' own will.

When U < 2c, the expected income of the family is lower than the cost, and "non-participation" becomes the dominant strategic choice of the two families. At this point, the expenditure on shadow education of both family A and family B is "0", and the income of both family A and

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family B reaches the maximum, forming A perfect Nash equilibrium of family shadow education game.

Hypothesis 2: In the case of asymmetric family economic background, the expenditure of family shadow education is not determined by family background or individual ability, but by the strategic choice of another family.

According to family conditions and students' personal ability, there are four game scenarios:

Case 1: the family condition is poor, and the student's individual ability is weak;

Case 2: the family condition is poor, and the student's individual ability is strong;

Case 3: the family condition is good, and the student's individual ability is weak;

Case 4: the family condition is good, and the student's individual ability is strong.

In this asymmetric situation, the income of family participation in shadow education can be expressed as (1+mi) *(ai-β·mi). Only when the income of one family is greater than that of the other family will it choose to "participate" in shadow education. If students have the same ability and shadow education expenditure, the probability of them entering key schools or classes is P = 1 / 2.

The utility functions of the two families are as follows:

$$U1(m1, m2) = \begin{cases} -\beta m_1, & (1+\beta m_1)a_1 < (1+\beta m_2)a_2 \\ \frac{u1}{2} - \beta m_1, & (1+\beta m_1)\, a_1 = (1+\beta m_2)a_2 \\ u_1 - \beta m_1, & (1+\beta m_1)a_1 > (1+\beta m_2)a_2 \end{cases}$$

$$U2(m1, m2) = \begin{cases} -\beta m_2, & (1+\beta m_2)a_2 < (1+\beta m_1)a_1 \\ \frac{u2}{2} - \beta m_2, & (1+\beta m_2)\, a_2 = (1+\beta m_1)a_1 \\ u_2 - \beta m_2, & (1+\beta m_2)a_2 > (1+\beta m_1)a_1 \end{cases}$$

The expected utility function of the two families can be expressed as:

$$EU1 = \frac{1}{(1+\beta m_2)}\{(u_1a_1 - 1 - \beta m_2)\beta m_1 + u_1(a_1 - (1+\beta m_2))\}$$

$$EU2 = \frac{1}{(1+\beta m_1)}\{(u_2a_2 - 1 - \beta m_1)\beta m_1 + u_2(a_2 - (1+\beta m_1))\}$$

Let m1* represent the optimal strategy for family 1, and m2* represent the optimal strategy for family 2. Every family is rational and seeks to maximize utility. Therefore, the optimal strategy combination of family 1 and family 2 is:

$$m1^* = \begin{cases} 0, & \text{if } u_1a_1 < 1+\beta m_2 \\ \beta m \in [0, M_1], & \text{if } u_1a_1 = 1+\beta m_2 \\ M_1, & \text{if } u_1a_1 > 1+\beta m_2 \end{cases}$$

$$m2^* = \begin{cases} 0, & \text{if } u_2a_2 < 1+\beta m_1 \\ \beta m \in [0, M_2], & \text{if } u_2a_2 = 1+\beta m_1 \\ M_2, & \text{if } u_2a_2 > 1+\beta m_1 \end{cases}$$

[Case 1] indicates the situation where the income level of both families is above the threshold. When the income of family 1 is higher than $\frac{u2 \cdot a2 - 1}{\beta}$ and that of family 2 is higher than $\frac{u1 \cdot a1 - 1}{\beta}$, $\left(\frac{u2 \cdot a2 - 1}{\beta}, \frac{u1 \cdot a1 - 1}{\beta}\right)$ is the achievable equilibrium point. This point indicates that both households are spending a portion of their income level on shadow education, but this spending is influenced by the investment strategies of other households. This strategy tends to lead to blindness and disorder in family competition. That is, when a family has a student with strong ability to participate in shadow education, other families will increase their input in shadow education to narrow the gap, thus increasing the economic burden of low-income families.

Hypothesis 3: The higher the family income or the individual ability of the participants, the greater the demand for shadow education.

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In [Case 2] and [Case 3], (0,M2) and (M1,0) are Nash equilibrium points. The former shows that students have strong personal ability, but families with low economic level will invest all their disposable income in shadow education. However, after repeated games, such families will eventually quit the game due to the limitation of income level, and they will have certain economic burden in the game of shadow education. The latter shows that if the family has good economic conditions and the student's personal level is low, the family will also spend all its income on shadow education. However, shadow education costs a lot and yields are not high because students from such families have weak personal ability.

[Case 4] shows that students' personal ability and family economic conditions are very high. In this case, a Nash equilibrium (M1,M2) is formed, where both families devote all of their income to shadow education. However, according to the above "Prisoner's dilemma" model of family participation in shadow education game, when all families choose not to participate in the shadow education game, the income is greater than that of all families choosing to participate in the shadow education game. Therefore, although such families invest a lot in shadow education, their income is relatively low. This family class occupies the leading position of shadow education. Therefore, the guidance and governance of shadow education should start from the stratum with good family economic background.

Hypothesis 4: The higher the intensity of competition, the lower the utility for shadow education.

In addition, β reflects the intensity of external competition.

In the symmetrical scenarios, the equation of utility EU and the negative effect of shadow education (a-β·c) show that β will influence the real utility of players while it might not chance the game strategy. Similarly, in the symmetrical scenarios, the equation of utility EU1 and EU2 and equilibrium points ($\frac{u2 \cdot a2 - 1}{\beta}$, $\frac{u1 \cdot a1 - 1}{\beta}$) show that β has an effect on the utility of participating households and shows a negative correlation. While the intensity of external competition has no significant difference in family choice, but with the increase of external competition, the utility of family participation in shadow education gradually decreases.

6. Conclusions and Recommendations

This paper uses the Prisoner's Dilemma model to analyze the influence of competition mechanism and information disclosure degree on cooperative behavior under the background of shadow education one by one. In general, we find the following conclusions: (i) The degree of competition does not have a significant impact on the market demand and choice of shadow education, but as the degree of competition increases, the rewards for participating in shadow education will gradually decrease; (ii) When the economic background of the shadow education demanders and the learning ability of the students are the same, the players who do not participate in the shadow education will get the highest income, which is a perfect Nash equilibrium; (iii) When the economic background of shadow education demanders is asymmetric, whether a player participates in shadow education competition is not determined by family background or personal ability, but is affected by the actions of other players; (iv) The higher the player's personal ability, the greater the demand for shadow education.

Under the circumstance of limited educational resources that can be allocated, the phenomenon of "involution" of shadow education is commonplace in the current society, which will not only reduce the efficiency of organizational operation, but also reduce the behavior of reciprocity such as cooperation. The scope of competition in traditional competition mechanism design is limited to individuals within a group or between different groups within a group, and the competition is mostly based on the level of individual contribution to the team (Fehr & Gächter， 2000; Cárdenas & Mantilla， 2015) . However, the “involution” environment is more

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of an individual as a unit, competing with others in the group on the basis of their own performance, which involves different research content. This paper takes shadow education as the background to study the influence of education "involution" competition on cooperative behavior under different information disclosure levels, which is an attempt in this theme direction.

The implications of our research conclusions for motivating individuals to improve their cooperation willingness in reality are at least as follows: In societies with incomplete information disclosure and different social capital backgrounds, individuals will always be subject to competition from each other or from social competition mechanisms' invisible pressure (such as further education and promotion), thereby reducing the willingness to cooperate, resulting in the consumption of more resources and excessive competition and aggravation of social and ecological imbalances. In the context of shadow education, it is necessary for the government and society to guide urban and rural families and families with different social capital backgrounds (especially the high income class) to view and rationally choose extracurricular tutoring, reduce educational introversion and anxiety, and avoid prisoners' dilemma and excessive consumption of resources from all parties, thus improving social welfare.

Of course, there are still some directions along which the study could be extended. For example, we can also explore the differences in the influence of competition mechanism and information disclosure on the cooperative behavior of individuals with heterogeneous social preferences, and give more specific incentive designs to be more realistic. In addition, this paper only studies the impact of educational involution on cooperation, a behavior with a reciprocal attribute. We can also study the impact of "involution" competition in different environments on other social behaviors such as individual trust and altruism, so as to obtain more comprehensive and more realistic conclusions.

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