Research on the Training Mechanism of Dual-Supervisor System for Postgraduate Students from the Perspective of Game Theory

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Abstract. With the rapid development of postgraduate education in China, the dual-supervisor system (academic supervisor from university and practical supervisor from industry) has gained increasing prominence. However, the implementation of this dual-supervisor system is often characterized by perfunctory collaboration, accompanied by practical challenges such as inefficient university-enterprise coordination and conflicting objectives between supervisors. This study employs a game theory analytical framework to deconstruct the tripartite interaction mechanisms among academic supervisors, practical supervisors and postgraduate students, conducting systematic analysis of game participants and scenario modeling. By establishing payoff functions for supervisors and students, this paper conducts rigorous cost-benefit analyses under varying levels of engagement from both supervisors and students. The research aims to enhance collaborative supervision efficiency and provide theoretical foundations with practical implementation pathways for reforming the dual-supervisor postgraduate training system.

Keywords: Game Theory, Dual-Supervisor System, Postgraduate Student

1 Introduction

The reform initiatives in Chinese postgraduate education have significantly enhanced both the quality and scale of professional master's programs. China's professional degree postgraduate education commenced with an initial enrollment cohort of 219,000 students in 2013. The Ministry of Education officially released the "Development Plan for Professional Degree Postgraduate Education (2020-2025)" in September 2020. According to this strategic blueprint, professional master's programs are projected to constitute nearly 67% of total postgraduate enrollments by 2025 [1]. This target reflects a 300% growth rate relative to the baseline established in 2013. As a pivotal mechanism in postgraduate education, the dual-supervisor system bridges university-based academic knowledge with industry-specific practical expertise, facil-

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itating integrated talent development. However, operational challenges emerge as the system frequently reduced to symbolic cooperation due to fundamental divergences in academic-industrial alignment across educational objectives, curricular design and expectation frameworks. These systemic inconsistencies critically undermine postgraduate education quality.

In higher education, particularly within professional master's programs, student development transcends traditional classroom instruction through integrating intensive research training with professional competency development, thereby positioning the dual-supervisor system as an essential pedagogical framework. The framework operationalizes collaborative guidance from academic supervisors and industry supervisors, who specialize in theoretical and applied domains respectively. Although designed to foster university-industry collaboration and holistic competency development, practical implementation reveals systemic challenges including coordination inefficiencies, role ambiguity, and student role conflicts [2].

Within the dual-supervisor framework, three key stakeholders (academic supervisors, industry supervisors, and students) maintain divergent priority structures. Academic supervisors prioritize scholarly outputs, while industry supervisors focus on applied competencies. This value incongruence engenders ceremonial collaboration patterns in pedagogical implementation [4]. To resolve this coordination dilemma and enhance supervisory synergy, this paper develops an analytical game-theoretic framework with scenario modeling and stakeholder-specific utility functions. Through scenario-based modeling, this paper conducts systematic analysis of equilibrium outcomes under varying engagement levels, providing operational insights for academic guidance resource allocation. This optimization protocol synchronizes supervisory incentives with student development trajectories, ultimately enhancing the integrative capacity of dual supervision.

2 Game Theory and Its Applications in Educational Practice

Game theory provides a formal analytical framework that examines complex social interactions through the lens of strategic decision-making, offering systematic solutions for coordinating multi-agent interest conflicts [3]. Departing from unilateral optimization paradigms, this discipline identifies equilibrium solutions that characterize optimal strategy profiles and payoff allocations among rational actors. Rooted in mathematical axiomatization, game theory has generated diverse formalisms demonstrating theoretical robustness in complex systems, achieving growing analytical traction in educational research. Educational interactions constitute dynamic information-exchange processes, wherein all stakeholders iteratively adapt their strategies based on observed behavioral patterns. This paradigm enables rigorous examination of strategic decision-making dynamics spanning classroom participation, assignment completion, and feedback loops. The methodology optimizes educational engagements through data-driven pedagogical interventions, while reinforcing classroom management protocols and compliance frameworks. Moreover, it informs evidence-based instructional designs that maximize resource utilization, thereby elevating the overall efficacy of educational systems [5-6].

In higher education, particularly within professional master's programs, the systemic challenge originates from tripartite strategic conflicts: academic supervisors prioritize research engagement for scholarly outputs, industry supervisors emphasize corporate project involvement for operational competencies. The students strategically navigate between these demands to maximize personal utility (encompassing graduation quality, career prospects, and temporal investment) [7]. This multi-agent scenario characterized by divergent interests, information asymmetry, and inadequate coordination mechanisms constitutes a quintessential case for game-theoretic resolution. The application of game-theoretic analytical frameworks therefore offers both theoretical substantiation and operational guidance for optimizing the dual-supervisor system.

In conclusion, game theory provides systematic analytical tools and conceptual frameworks for educational research, revealing its significant theoretical value and practical relevance when addressing complex multi-agent challenges within graduate education systems. Through applying game-theoretic modeling to map tripartite strategic interactions within the dual-supervisor system, the methodology not only identifies systemic barriers to collaboration breakdowns but also establishes evidence-based frameworks for optimizing graduate training mechanisms, ultimately advancing holistic quality improvement of postgraduate education outcomes.

3 Game-Theoretic Player Analysis and Scenario Modeling in Dual-Supervisor System

This paper examines the application of game theory in dual-supervisor postgraduate training through a prototypical case analysis. Consider a postgraduate student L jointly supervised by two mentors: supervisor A (academic) and supervisor B (industry). Supervisor A (academic) prioritizes research engagement to produce scholarly outputs (high level publication, etc.), he allocates X hours/week to academic guidance. Supervisor B (industry) emphasizes corporate project involvement to develop practical competencies (employment quality, project completion efficiency, etc.), he provides Y hours/week of project supervision.

The strategic conflict manifests in competing priorities: supervisor A requires academic output, while supervisor B demands corporate collaboration deliverables. Student L maintains Z weekly dedicated research hours. The optimal allocation of these hours between dual-supervisor forms the primary strategic variable in the game-theoretic model. The secondary strategic parameter entails optimizing time investments (X, Y) from each supervisor for mentoring effectiveness maximization.

3.1 Strategy Space of the Players

All game players (supervisor A, supervisor B, student L) make strategic decisions based on their self-interest maximization, information sets, and expected payoffs. In this study, both supervisors face binary strategy choices: high-commitment engagement or low-commitment engagement. High-commitment engagement for supervisor A entails providing additional academic advising. For supervisor B, it involves granting extended enterprise data access through increased mentoring time. Although high-commitment strategies enhance supervisors' payoff gains and student outcomes, they incur additional cost burdens. In contrast, low-commitment strategies yield minimum viable returns without addition costs. The student's strategy space comprises three time-allocation strategies: academic-oriented (α>0.5), industry-oriented (α<0.5), and balanced allocation (α=0.5).

3.2 Ayoff Function of the Players

The payoff function of supervisors

In this paper, each supervisor's payoff is positively correlated with the student's time allocation ratio to their respective research tasks. Formally, the student's exclusive time dedication (α=1) to a single supervisor maximizes the payoff gains for the corresponding supervisor. Therefore, the payoff function of the supervisors is:

The payoff function of supervisor A (academic): U_{in}

$$U_{in} = \theta_{in} \times V_{in} + \alpha_{in} \times B_{in} - (1 + \gamma_{in}) \times D_{in} \tag{1}$$

The payoff function of supervisor B (industry): U_{out}

$$U_{out} = \theta_{out} \times V_{out} + \alpha_{in} \times B_{out} - (1 + \gamma_{in}) \times D_{out} \tag{2}$$

θ_{in}: Percentage of the time students allocate to supervisor A (academic) ($0 \leq \theta_{in} \leq 1$).

θ_{out}: Percentage of the time students allocate to supervisor B (industry), $\theta_{out}=1-\theta_{in}$.

V_{in}: The maximal payoff of supervisor A (academic) .

V_{out}: The maximal payoff of supervisor B (industry).

α_{in}: The factor of the extra payoff of high-commitment engagement of the supervisor.

B_{in}: The maximal payoff of high-commitment engagement of supervisor A (academic).

B_{out}: The maximal payoff of high-commitment engagement supervisor B (industry).

γ_{in}: The factor of the extra cost of high-commitment engagement of the supervisor.γ_{in}=Max(θ_{in},θ_{out}) and $\gamma = \begin{cases} 2(\gamma_{in} - 0.5) & \gamma_{in} \geq 0.5 \\ 0 & \gamma_{in} < 0.5 \end{cases}$

D_{in}: The cost of high-commitment engagement of supervisor A (academic).

D_{out}: The cost of high-commitment engagement supervisor B (industry).

The payoff function of student

The student's payoff derives from the weighted sum of academic gains (thesis outputs, theoretical competency) from the academic supervisor and practical gains (industry resources, project deliverables) from the industry supervisor. However, the student's cost structure incorporates a time allocation equilibrium constraint. Highly disproportionate allocations (e.g., α=1 or α=0) trigger dissatisfaction penalties from the neglected supervisor, imposing additional costs.

Therefore, the student's payoff function is:

$$U_S = \theta_{in} \times U_{in} + \theta_{out} \times U_{out} - \delta \times C \tag{3}$$

θ_{in}: Percentage of the time students allocate to supervisor A (academic) ($0 \le \theta_{in} \le 1$).
θ_{out}: Percentage of the time students allocate to supervisor B (industry).
U_{in}: Payoff from supervisor A (academic).
U_{out}: Payoff from supervisor supervisor B (industry).
δ: The factor of the extra cost of highly disproportionate allocations of the student.
$\delta = \mathrm{Max}(\theta_{in}, \theta_{out})$ and $\delta = \begin{cases} 2(\delta - 0.5) & \delta \ge 0.5 \\ 0 & \delta < 0.5 \end{cases}$
C: Costs paid by students.

4 Practical Case Studies

The following section analyzes the impact of supervisor's decision and student's time allocation on supervisor's payoffs and student's payoffs. To simplify the practical case, this study assumes $\alpha_{in}=0.5$, $B_{in}=B_{out}=30$, $D_{in}=D_{out}=10$ (high-commitment engagement), $D_{in}=D_{out}=0$ (low-commitment engagement), C=10.

Case A: The maximal payoff of supervisor A is greater than the maximal payoff of supervisor B ($V_{In}=30$,$V_{out}=20$) . The student allocates more research time to supervisor A ($\theta_{in}=0.7, \theta_{out}=0.3$).

(a) Both supervisors are low-commitment engagement:

Payoff of supervisor A:

$$U_{in}=0.7\times30=21$$

Payoff of supervisor B:

$$U_{out}=0.3\times20=6$$

Payoff of Student:

$$U_S=0.7\times21+0.3\times6-0.4\times10=12.5$$

(b) Both supervisors are high-commitment engagement:

Payoff of supervisor A:

$$U_{in}=0.7\times30+0.5\times30-[1+2(0.7-0.5)]\times10=22$$

Payoff of supervisor B:

$$U_{out}=0.3\times20+0.5\times30-1\times10=11$$

Payoff of Student:

$$U_S=0.7\times21+0.3\times6-0.4\times10-0.4\times10=14.7$$

Table 1 shows the payoff matrix of supervisor A , supervisor B , student L for case A.

Table 1. The payoff matrix of supervisor A , supervisor B and student for case A

Payoff (A,B,Student)	supervisor B (high-commitment)	supervisor B (low-commitment)
supervisor A (high-commitment)	(22,11,14.7)	(22,6,13.2)
supervisor A (low-commitment)	(21,11,14)	(21,6,12.5)

Case B: The maximal payoff of supervisor A is greater than the maximal payoff of supervisor B (V_{In}=30 ,V_{out}=20). The student allocates research time equally to both supervisors (θ_{in}=0.5,θ_{out}=0.5).

If both supervisors are low-commitment engagement, the payoffs of supervisor A is 15, the payoffs of supervisor B is 10, and the payoffs of student is 12.5.

If both supervisors are high-commitment engagement, the payoffs of supervisor A is 20, the payoffs of supervisor B is 15, and the payoffs of student is 17.5.

Table 2 shows the payoff matrix of supervisor A , supervisor B , student L for case B.

Table 2. The payoff matrix of supervisor A , supervisor B and student for case B

Payoff (A,B,Student)	supervisor B (high-commitment)	supervisor B (low-commitment)
supervisor A (high-commitment)	(20,15,17.5)	(20,10,15)
supervisor A (low-commitment)	(15,15,15)	(15,10,12.5)

Case C: The both supervisors give the same maximum payoffs to the student (V_{In}=20 ,V_{out}=20). The student allocates more research time to supervisor A (θ_{in}=0.7,θ_{out}=0.3).

If both supervisors are low-commitment engagement, the payoffs of supervisor A is 14, the payoffs of supervisor B is 6, and the payoffs of student is 7.6.

If both supervisors are high-commitment engagement, the payoffs of supervisor A is 15, the payoffs of supervisor B is 11, and the payoffs of student is 9.8.

Table 3 shows the payoff matrix of supervisor A , supervisor B , student Li for case C.

Table 3. The payoff matrix of supervisor A , supervisor B and student for case C

Payoff (A,B,Student)	supervisor B (high-commitment)	supervisor B (low-commitment)
supervisor A (high-commitment)	(15,11,9.8)	(15,6,8.3)
supervisor A (low-commitment)	(14,11,9.1)	(14,6,7.6)

Case D: The both supervisors give the same maximum payoffs to the student (V_{In}=20 ,V_{out}=20). The student allocates research time equally to both supervisors (θ_{in}=0.5,θ_{out}=0.5).

If both supervisors are low-commitment engagement, the payoffs of supervisor A is 10, the payoffs of supervisor B is 10, and the payoffs of student is 10.

If both supervisors are high-commitment engagement, the payoffs of supervisor A is 15, the payoffs of supervisor B is 15, and the payoffs of student is 15.

Table 4 shows the payoff matrix of supervisor A , supervisor B , student L for case D.

Table 4. The payoff matrix of supervisor A , supervisor B and student for case D

Payoff (A,B,Student)	supervisor B (high-commitment)	supervisor B (low-commitment)
supervisor A (high-commitment)	(15,15,15)	(15,10,12.5)
supervisor A (low-commitment)	(10,15,12.5)	(10,10,10)

By analyzing the all the payoff matrix, the following conclusions can be drawn:

(1)Supervisors' "high-commitment engagement" yields superior payoffs compared to "low-commitment engagement" strategies. For the supervisors, unilateral reduction of the engagement would diminish their own payoffs, as high commitment simultaneously enhances academic productivity, scholarly reputation, and student training quality.

(2)Students achieve higher payoffs through balanced time allocation (α=0.5) than through skewed distributions. Over-emphasis on one supervisor reduces the engagement from the other supervisor, thereby depressing overall gains.

(3)The Pareto-optimal outcome emerges when both supervisors maintain "high-commitment engagement" and the student adopts "balanced time allocation".

5 Summary

This paper investigates practical challenges in postgraduate education under the dual-supervisor system. Through employing a game-theoretic analytical framework, this paper deconstructs the tripartite interaction mechanisms among academic supervisors, industry supervisors, and students.

For the supervisors, the "high-commitment engagement" not only facilitates academic advancement and career progression, but also elevates pedagogical quality through enhanced training outcomes. For students, appropriately balancing academic pursuits, practical engagements, and personal life facilitates holistic development, enhances comprehensive capabilities, and mitigates the weakness caused by excessive focus on a single area. Therefore, the supervisors' "high-commitment engagement" and the student's "balanced time allocation" collectively establish a more efficient and sustainable cultivation mechanism for master's students, which better promotes their holistic development and sustainable growth.

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