PUBLIC-PRIVATE PARTNERSHIPS FOR GREEN SKILLS: EVALUATION OF DIFFERENT STAKEHOLDERS UNDER THE SHADOW OF GAME THEORY MODEL

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Green skills development is central to achieving sustainability goals, but development of green skills is hindered by strategic triads of governments, private sector players, awareness campaigns, large data intermediary players. The aim of writing this research work is to develop a game theory framework for incentive and strategic decision in where the green skills are absorbed. Initially with a strategic game in which every player decides whether to invest in green skills L or H. Payoff functions have economic benefits, costs, and externalities that will arise because of other players choices. Thus, a Prisoner's Dilemma effects yielding low cooperation (L, L) exogenously, although it is socially optimal to invest, yielding (H, H). A Public Goods Game framework emphasizes the issue of free riding, in which actors receive the benefits of others' contributions without investing themselves. The study analyzes potential policy interventions to address the inefficiencies by exploring the implications of government subsidies (S_G), penalties for non-compliance, and public-private partnerships that help to realign incentives. This research work developed a framework with key green skill components to guide policymakers and businesses to optimize their green skill development strategies. Utilizing insights from game theory, stakeholders can create incentive-compatible mechanisms that ensure collaboration, productivity, and a workforce dedicated to innovation.

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1 Introduction

The path toward a sustainable, low-carbon economy depends critically on the development of green talents. It entails arming people and companies with the knowledge, resources, and skills required to promote environmentally responsible behavior, encourage innovation, and slow down global warming (OECD Cedefop, 2014). Reaching this shift, however, calls for group efforts among several stakeholders—including the government, the business sector, awareness campaigns, data-sharing systems, technological application and innovation. Though their activities are often intertwined and create a complicated ecosystem of cooperation and competition, each of these stakeholders has a vital role to contribute to promote green skills (Peloza & Falkenberg, 2009).

Here, game theory offers a helpful analytical framework for comprehending the strategic interactions among these parties (Pérez-Cirera, 2010). Modeling how these individuals could behave when their individual payoffs are affected by the actions of others. Game theory—a subfield of mathematics that investigates decision-making in circumstances when outcomes depend on the decisions of several agents. It helps applying game theory to green skills development allows us to investigate how various stakeholders might cooperate or free-ride on one other's investments in green projects as well as what systems might support best collaboration.

2 Literature review

How does green skills impact by Government (G) initiatives

Government programs play a crucial role in developing green skills, particularly in developing economies. These programs include green production incentives, environmental sustainability policies, and investments in education that aim to align the workforce's skills with the needs of a green economy. The impact of these programs in addressing the green skills gap continues to be a key research focus. In the Thailand context, the national skill-formation and education system has struggled to produce industry-ready employees with green skills. Napathorn (2022) highlights that universities and vocational colleges are unable to provide students with the appropriate green skills, leading to a shortage of skilled workers. To mitigate this, companies often rely on internal green human resource management (GHRM)

practices, such as on-the-job training and mentorship programs. While these internal initiatives help address the skill gaps, government intervention is essential to integrate green skills into national curricula and training schemes.

Governments can also create industry-academia partnerships. Napathorn (2022) proposes that additional university-industry partnerships would enable additional green knowledge transfer, less dependent on in-company training programs. Agrawal et al. (2023) also posit that government-funded training programs and public-private partnerships can enhance knowledge transfer and employee skill building.

In spite of these interventions, evidence reveals that government interventions are not necessarily enough to trigger mass green skills uptake. Agrawal et al. (2023) identified that government policies create the platform for green practices but have little direct impact in encouraging green skills unless complemented by social awareness campaigns. This suggests that government interventions are successful if they are accompanied by mass involvement in the wider society and education campaigns.

Additionally, other businesses are not ready to embrace green practice because of profitability issues. Agrawal et al. (2023) observe that while some businesses utilize green certification to increase brand value, other businesses consider the investments in sustainability as expensive and are not ready to embrace green technologies unless they are driven by stricter regulations or economic incentives. Governments should, therefore, supplement green skills policy with economic incentives like tax relief and subsidies to motivate businesses to embrace green technologies.

Private Sector Contribution to Green Skills Development

The private sector also has an important role to play in promoting green skills through embedding business strategy and sustainability objectives. Firms have a role to play in enhancing green skills via green human resource management (GHRM), investment in low-carbon technologies, and collaborative arrangements with academic institutions. Effectiveness of the contribution of the private sector is reliant on regulatory systems, fiscal policy incentives, and organizational dedication to sustainability.

Companies increasingly understand that they need to invest in green skills to remain competitive in the changing economy. Napathorn (2022) points out that in Thailand, companies have no choice but to create green skills internally since the national education system is incapable of producing graduates ready for industries. This investment is typically in the form of on-the-job training, mentorship schemes, and partnerships with universities to incorporate sustainability into curricula. Vaquero et al. (2021) also highlight that private sector investments in upskilling workers are essential to improve adaptability to green job standards and to overall economic resilience.

Aside from training, green innovations in the private sector have a critical influence on workforce skill development. The European Green Deal, for example, emphasizes that job creation and specialized green skills are stimulated by private investments in renewable energy, sustainable mobility, and waste prevention. In Spain, businesses have used EU recovery funds to adopt green strategies that reconcile profitability with environmental sustainability, developing a skilled workforce in clean energy and circular economies (Vaquero et al., 2021). There are various challenges that prevent the private sector from scaling green skills development. Vaquero et al. (2021) identify that there are companies that resist green training investments because they have cost concerns as well as uncertainty about the benefits. Furthermore, companies' announced sustainability pledges and actual workplace transformation, there can be a large gap because most green activities tend to be compliance-driven rather than development-oriented. To overcome these issues, increased public-private partnerships and specific incentives must be applied to persuade companies to focus on green skills development.

Effect of Awareness Campaigns on Green Competency Development

Public awareness campaigns are important for developing green competency because they enhance ecological awareness, behavior, and drive people towards adopting sustainable practices. Empirical evidence confirms the notion that awareness campaigns, if complemented by education and training, increase green motivation and ability, which, in turn, contributes to enhanced environmental performance.

Awareness campaigns like environmental education, outreach to communities, and media communication, enable individuals to understand the significance of sustainability and gain key green skills. Yafi et al. (2021) discovered that awareness-based training programs significantly improve the attitudes, knowledge, and skills of workers concerning sustainable practices. Also, properly structured awareness activities trigger spontaneous green actions, like conserving energy and reducing waste.

Green human resource management (GHRM) also incorporates environmental consciousness into organizational training, enhancing green competencies among workers. Yafi et al. (2021) added that individuals who are more environmentally aware are more likely to adopt sustainable workplace behavior. This is why awareness campaigns are important in bridging the knowledge-action gap when it comes to green skills.

Despite their promise, awareness campaigns simply can't drive short-term awareness into long-lasting green behaviors. Yafi et al. (2021) observes that although awareness campaigns may arouse preliminary interest, long-term behavioral change is made possible through training and reward mechanisms. Moreover, socioeconomic status, cultural orientations, and exposure to green education can determine the success of these campaigns in supporting green skill acquisition.

Effect of Data Sharing Platforms on Green Skills Development

Data-sharing platforms between governments and enterprises are central to promoting green skills development. Through the sharing of sustainability-related data, these platforms assist in upskilling workers, enforcing policies, and influencing technology development in the green sector.

Decision-making based on data is increasingly becoming vital in the green economy. Vaquero et al. (2021) highlight that data-sharing platforms between private organizations and government institutions facilitate the development of sophisticated green skills through the real-time access to such crucial metrics as energy efficiency indicators, carbon footprint, and regulatory compliance trends. Such online platforms also enable firms to coordinate their employees' training programs with changing sustainability standards.

In addition, data-sharing activities provide significant data insights on trends in the labor market and greener job prospects. In accord with OECD (2021), data-driven analytics facilitate mapping out the skills demand, thus equipping education and training institutions with the capacity to create programs oriented toward the adaptive needs of environmentally friendly industries. Through data sharing, the provision guarantees workers learn appropriate skills for inclusion in green businesses that are more environmentally friendly.

Though beneficial, data-sharing platforms are confronted with a number of challenges in promoting green skills development efficiently. Vaquero et al. (2021) observe that challenges like weak data governance, fragmentation, security threats, and interoperability among systems hamper the efficiency of the platforms. Moreover, firms will be reluctant to exchange proprietary sustainability information owing to competitive issues, which can impair the efficiency of data-exchange programs in creating green skills.

Effect of Technology Adoption and Innovation on Green Skills Development

Innovation and technology are central to the development of green skills in that they change the demands on the workforce, generate new employment opportunities, and lead to the shift to a sustainable economy. With the development of new green technologies, staff have to develop new competencies, technical skills, and problem-solving skills to meet the challenges of environmental sustainability.

Green technologies, including renewable energy, energy-efficient systems, and smart automation, are changing industries at a fast rate. Nikolajenko al. (2021) point out that transitioning to a greener economy hinge on getting the workforce ready with high-level green skills corresponding to these technological developments. They point out that new green industries need employees with technical, mechanical, and IT-related skills to enable sustainability-oriented sectors.

The International Labour Organization in 2018 estimates that green technological shifts may generate almost 24 million jobs worldwide and displace 6 million jobs in carbon-emitting sectors. This transition highlights the urgency to reskill and upskill employees to remain employable in changing green industries (ILO, 2018).

In spite of the increasing need for green skills, a number of challenges hamper their universal application. Viederytė et al. (2021) observe that new graduates lack the technical competencies necessary for green occupations, especially in areas like renewable energy, sustainable building, and environmental management. In addition, most organizations are unable to integrate green technology training into current workforce development programs because of financial limitations and a lack of institutional support.

3 Results

Green skills framework with multiplayers. In this framework, the model a strategic game involving five players: 1. government (α1)i; 2. private sector (α2)i; 3. awareness initiatives (α3)i; 4. data sharing platforms (α4)i; 5. technology usage & innovation (α5)i. Each player has the option to choose between two strategies:

- High push-initiatives (H): Invest in high green skills aggressively
- Low push-initiatives (L): Low interest in green skills

Strategy mechanism. Each player selects its strategy based on high-low mechanism. Therefore, each player [(α1)(H1,L1), (α2)(H2,L2), (α3)(H3,L3), (α4)(H4,L4), (α5)(H5,L5)]. The collective strategy will be written as, S= (α1+α2+α3+α4+α5).
Payoff Functions. Each player's payoff depends on several factors:

- Economic outcomes thus the gains achieved from the investment in green skills Ei (S)
- Costs appear be to the expenses incurred for implementing green initiatives Ci(S)
- External factors are the positive or negative spillover effects that occur due to the strategies chosen by others thus (any player) EFi (S)

The payoff function can be written as follow for the each player, Ui = Ei (S) - Ci(S)+ EFi (S). Where: Ei (S) is the economic benefits for player (α1…..α5), which increases when more players choose H due to positive network effects (i.e., the more players invest in green skills, the greater the overall benefit). Ci(S) is the costs incurred by player (α1…..α5)„ which are typically higher when H is chosen because implementing green skills is costly. EFi (S)is the externality or spillover effect from

other players' actions. For example, if the government invests in green policies, the private sector might benefit without direct cost (positive externality). In Table 1. shows the Payoff Matrix.

Table 1: Payoff Matrix

Player (Government – Private sector)	**High push-initiatives (H)**	**Low push-initiatives (L)**
High push-initiatives (H)	(Max, Max)	(Min, Max)
Low push-initiatives (L)	(Max, Min)	(Min, Min)

Source: own editing

Where *Max* = 1 … infinity and *Min* = -1 …, 0. *(Max, Max)* means that both the government and private sector invest in green skills. They both benefit equally, thus representing the maximum benefit when both cooperate. (Min, Max) is when the government invests, but the private sector free-rides (does not invest). The government incurs costs, while the private sector benefits from the government's investment. (Max, Min) means that the private sector invests, but the government free-rides. The private sector incurs costs, while the government benefits from the private sector's actions. (Min, Min) is when neither the government nor the private sector invests in green skills, leading to no benefits for either, and stagnation in green skills development.

Application of game theory. Considering the fact, several game theory models fit this framework to examine possible results and strategic interactions.

Prisoner's Dilemma:

A. Dominant Strategy: Low Effort (L)(Min). Players may choose the strategy that reduces their expenses (i.e., free-riding), thereby under investing in green talents, based on the payoff matrix.
B. The Nash Equilibrium happens at (L, L)(Min,Min) where both participants free-ride. Still, this is less than ideal since it results in stagnation in the evolution of green talents.
C. The socially ideal outcome is (H, H)(Max,Max), in which both participants invest to maximize the group payback.
D. Optimal Soluition: To get the best result, rules, incentives, or subsidies could be required to guarantee cooperation.

Public Goods Game:

Green skills and talents are a public benefit; and considering the fact free-riding is a risk. Role of Government: Subsidies (Gs) offered by the government can help the private sector to commit in green technologies. The payback for the private sector, for instance, might be changed as: Ui = Ei (S) - Ci(S)+ (Gs).

Evolutionary game:

Strategies and Techniques may change with time in long run. Early adoption that is, governments or businesses may inspire other participants to follow their approaches and move to High Effort (H) if they find great advantages from funding green technologies. Furthermore, because of positive externalities and economic growth, players that adopt High Effort (H) could gain more over time, hence promoting the dissemination of high-effort techniques.

4 Conclusions

The game theory framework for green skills development considers strategic interactions between key players (government, private sector, awareness initiatives, data sharing platforms, and technology usage). Based on the outcomes we have to take into account the following to reach best cooperation in the development of green skills. Taxes or penalties for participants who do not contribute – that is, companies not using green technologies – are known as penalty for free-riding. Government subsidies to change incentives will help to attract private sector and other actors to invest in green skills. Public-private partnerships allow the public and private sectors to help lower individual expenses and risks, thereby facilitating the investment in green talents. Platforms for data sharing and technology transfer help to lower adoption obstacles and optimize the network impacts of environmental projects. Government initiatives are critical to the development of green skills, with their impact stemming from policies that promote sustainable practices, educational reforms, and industry-academia collaborations. However, the success of these initiatives relies on effective implementation, alignment with industry needs, and collaboration with businesses.

The private sector is an important source of green skill development through green technology investments, training programs, and partnerships with learning institutions. Nevertheless, in order to have maximum impact, corporations need to shift beyond the stage of mere compliance and infuse long-term green skill initiatives into their day-to-day operations. Future research could investigate firm-level barriers to the adoption of green skills and the efficiency of incentive schemes as a means to encouraging private sector investment in sustainable training. Awareness campaigns play a crucial role in promoting the development of green skills through motivation, knowledge, and behavior. Yet, to enhance their effectiveness, awareness campaigns must be supported by formal training programs and organizational support systems. Future studies must investigate the long-term impacts of awareness campaigns on green workforce development in different industries.

Green skills development can be expedited through data-sharing platforms between the business and government by providing greater accessibility to key sustainability data and correlating workforce training with industry demands. To maximize their effectiveness, however, stakeholders need to confront data governance, privacy, and industry collaboration issues. Future research should be targeted at the long-term success of these platforms in green labor market formation and creation of a sustainable economy. Technology adoption and innovation are critical drivers of green skills creation by creating new sectoral demands and job opportunities for sustainable industries. Nonetheless, a seamless transition involves sector-specific training programs, robust industry-academic collaboration, and policy-friendly frameworks. Future studies must aim to assess the potency of technology-driven green training programs in imparting future-tight skills to workers.

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