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STRATEGIC DECISION MAKING IN UNCERTAINTY BASED ON GAME THEORY

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ABSTRACT

This article presents a new mathematical model based on game theory about government policies in company planning. We present suggestions to the government on how to provide facilities to companies to implement energy improvement systems. This novel model helps companies and governments to make strategic decisions in times of uncertainty and to enhance management and planning in financing companies. Using game theory, we model the government and the company's performance and introduce some of the parameters affecting their performance. By examining the game between them, the solution of the game theory, which is the equilibrium, is calculated and suggestions to improve their performance are given. The results show that this model helps decision makers and planners to have a more appropriate strategic planning process and choose a more effective strategy under uncertainty conditions.

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1. INTRODUCTION

Today, unpredictable developments have eliminated many industries from the competition. In strategic planning, uncertainty and time play important roles. Various and unexpected changes have scuppered many plans. Organizations encounter new products, new markets, and new technologies, and the strategy chosen often does not meet their needs in this dynamic environment. Frenetic change has created a business environment where conventional organizational management

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methods cannot adapt enough. Experience is useful when changes are minor, but when strategic decisions lead to irreversible results, organizations may fail to make decisions based on intuitive and empirical judgments. Companies, however, can be prepared to deal with rapid change and this preparedness creates a competitive advantage.

Environmental instability and uncertainty have become important aspects of the strategic planning process. Organizations nimble enough to adapt to these changes can succeed. Experts in strategic planning do not see traditional methods succeeding in current conditions. This has led to emergence of tools such as scenario planning, stochastic planning, and game theory to help in planning for more efficient and effective management.

In this article, we use game theory tools to help companies and governments identify each other's behavior, align policies, and increase the favorable consequences. Game theory is a branch of mathematics that analyzes interactions related to strategic financial decision-making. These interactions are called games and the parties involved in this game are players who can be individuals or groups. In classical game theory, players are assumed to act logically. Rational players are those who decide on the basis of what is most profitable for them and choose the strategy (Jameson, 2014). Game theory is a mathematical tool for describing and analyzing situations of conflict, cooperation, and coordination. Game theory helps us understand situations where decision-makers interact. It provides a solution or a set of optimal decision-making strategies in a group; it is used in many fields, including economics, political science, biology, business, wireless networks, computer science, and many other sciences (Nie et al., 2014; Halpern, 2007).

A game means a competitive activity and a strategic situation where players interact with each other according to a series of rules. Game theory tries to model the mathematical behavior of a strategic situation. This situation arises when the success of one side of the game depends on the other side’s choice of strategy. The purpose of game theory and business applications is to show how game theory can be used to model and analyze business decisions. All of these programs include competitive decision settings. In company financial matters, game theory helps a lot in choosing the optimal decision. (Lashgari et al., 2022; Lashgari, Bahiraie, and Eshaghi Gordji, 2022; Bahiraie, Azhar, and Ibrahim, 2011). Game theory provides a compelling guide to analyzing business decisions and strategies

(Chatterjee and Samuelson, 2001). In a paper published in 2018 (Nagurney et al., 2018), a game theory model was developed, for transportation service providers to maximize their expected utility by competing for business by senders as well as investing in security. Senders reflect their preferences for shipping service providers through the prices they are willing to pay, depending on the quantities shipped and the security levels invested. In this study, Nash equilibrium is formulated as a guaranteed variable inequality problem. In 2017, an article on a game theory model for development strategy in uncertain market environment was published (Mednikov et al., 2017). In this paper, a game theory model for increasing market share under uncertainty was proposed and game theory was found to improve formation of organizational development strategy.

Making the right decision requires individuals or organizations to know what decisions their competitors are likely to make. Assuming their competitors are rational and self-interested, should organizations know how to respond to their actions? One important factor is that the optimal choices of competitors probably depend on what you will do. Their choice depends on their evaluation of your choice. This kind of thinking may make it seem as if the whole problem is completely unsolvable. But this is exactly where game theory is most useful (Brickley, Smith, and Zimmerman, 2000). In 1991, Garth Saloner who studied game theory and strategic management stated that by using game theory models in planning, we can realize the truth of game theory usefulness in strategic management (Saloner, 1991).

Today, economic organizations face fierce competition; only using traditional methods of decision-making in situations of risk, low confidence, and uncertainty cannot ensure the right decisions. Given that investing in developing countries is associated with many risks, many unknown variables, as well as multiple competitors, identifying a method such as game theory and using it to succeed is very helpful against competitors. Colombo (2015) examined the balance of pricing policy in dual monopolies. The question was, when a competitor uses price discrimination, should we also use the price discrimination method? The result showed that if customers were not forward-looking enough, it would be better to use the same pricing method instead of price discrimination (Bahiraie and Alipour, 2020).

Given the current state of market instability and uncertainty, the main aim is to answer the question of possibility to provide a model for improving performance of companies, organizations, and

institutions using game theory. Another objective is to present an optimal strategic planning process using game theory tools to help managers and planners identify environmental changes. Our study was based on companies such as Midhco, Daliran Pars, Sepahan Cement, and so forth.

2. MODEL

The basic principle of strategic management is that companies and institutions should seek to develop strategies that take advantage of effective external opportunities and minimize external threats or risks. SWOT Analysis is an important tool for identifying environmental conditions and organizational internal capabilities. The basis of this tool is strategic management and knowledge of the environment around the organization.

TABLE 1
The SWOT Matrix

	Strength	Weakness
Opportunity	Strategy $S-O$	Strategy $W-O$
Threat	Strategy $S-T$	Strategy $W-T$

- Strategy $S-O$ represents a strategy that seeks to seize opportunities, and these strategies are consistent with the company's ability.
- Strategy $W-O$ represents a strategy based on overcoming weaknesses to take advantage of opportunities.
- Strategy $S-T$ represents a strategy that seeks to identify and examine ways of reducing risk of threats to the company.
- Strategy $W-T$ represents a strategy that is purely defensive and prevents the company from being harmed by external threats because of its weaknesses.

We examine the game between a government and a company representing all companies. We consider a competitive game between these two players and do not introduce a monopoly in this game. Given that constant changes in the business environment necessitate changes in planning, it has led people to identify the tools for making such changes. An important tool is game theory, which we use to study the game between the government and the company. In this article, we

examine the granting of government facilities to companies implementing the energy efficiency plan. Given the impact of government executive policies on corporate planning, we consider the government as one of the market players. Changes in energy carrier tariffs in the industrial sector and payment of ancillary facilities cause changes in corporate planning, so we consider the game between the government and the company in a competitive environment to provide government facilities to companies implementing the energy efficiency plan.

This game is a dynamic game with complete information and a game with non-fixed sums. By definition, in a dynamic game, it is assumed that the government as a player implements economic or social policies and then companies react to the government strategy by formulating different strategies. On the other hand, because all players in the game are aware of each other's history, we consider the definition of this game with complete information. Also, because what the government loses does not necessarily profit the company, and vice versa, what the company loses does not necessarily profit the Government, we considered this game to be a game with a non-fixed sum.

Players' strategy is a mixed strategy because none of the players have a definite belief in their opponent's behavior and only have possibilities about how their opponent is performing. Companies consider long-term policies in their long-term or annual planning, but they do not say for sure when and how they will be implemented. That is, they do not have confidence in the choice of the other party, and that is why a mixed strategy is used.

When a government implements a particular program, the company responds to it and uses strategies with probabilities. The equilibrium that the company and the government achieve in playing this game is the Nash equilibrium of a mixed strategy. Nash equilibrium is the point at which none of the players can achieve a better outcome by changing their strategy, assuming that the other's play is consistent. In this game, at the equilibrium point, both the company and the government can choose the best point and plan based on it. The strategy resulting from this action plan is the best and most effective strategy for both players. In the event of changes in energy tariffs, the government provides facilities to encourage companies and provides these facilities to those companies that have implemented energy efficiency systems. The Government can control this process purposefully and effectively through a monitoring and evaluation

mechanism or to grant facilities without using such a monitoring and evaluation mechanism. Companies are also free to implement this system or not to implement it and can make a choice.

In this game, the government has the opportunity to provide facilities by examining and identifying the companies that have implemented such systems and have increased their organizational productivity. The government can also grant facilities without identifying whether the company is equipped with an improvement system. The company can also increase energy efficiency by doing this plan or not implement this plan.

We consider two players in the game as follows:

- First player: Company
- Second player: Government

The players' strategy is as follows:

- Company strategy: {Implement energy efficiency system (I), Non-implement energy efficiency system (NI)}.
- Government strategy: {Monitoring and evaluation of the company (M), Non-monitoring and non-evaluation of the company (NM)}.

Company strategies include “Implement energy efficiency system” and “Non-implement energy efficiency system”. Government strategies are “Monitoring and evaluation of the company” and “Non-monitoring and non-evaluation of the company”.

The government seeks to maximize its profits, that is, to minimize energy consumption, so government revenues and expenditures are defined accordingly. The company is also looking to achieve its maximum profit. A company that takes action to implement the energy efficiency system will receive a Government incentive, such as facilities, while if this plan is not implemented, the government will consider a punitive policy such as high taxes for the company. In the company-government interaction, we consider some parameters. Table 2, shows the symbols and parameters of the model.

In Table 2, Cc shows the cost of implementing energy efficiency systems for the company. If the company decides to implement this system, it will incur a cost of Cc and will benefit from the system implementation by Pc; for example, this profit can be a profit from reduced energy prices, increased product quality, and increased market share. The company will also receive A facilities

from the government if this plan is implemented, which is a kind of government incentive policy.

TABLE 2
Model Parameters

Symbol	Meaning
Cc	cost of implementing energy efficiency systems in the company
Pc	profit from implementing energy efficiency systems in the company
A	facilities received from the government for implementing the energy efficiency improvement system
B	penalty for non-implementation of energy efficiency system for the company
Cg	the cost of monitoring and evaluating companies for the government
$C'g$	costs due to non-implementation of energy efficiency improvement system for government

Cg is the cost to the government for monitoring and evaluating companies, which can include the cost of a working group to identify, develop a method, coordinate with financial institutions, and pay for facilities.

B represents the penalty for not implementing the energy efficiency improvement system for the company, which is a kind of punitive policy by the government. $C'g$ represents the cost to the government of not implementing an energy efficiency improvement system. These costs can be attributed to the lack of reduction in energy consumption in the country because energy production has many costs for the government and, as a result, reducing this cost can be considered as revenue for the government. The payoff matrix between company and government is shown in the following Table 3:

TABLE 3
The Payoff Matrix Between Company and Government

		Government	
		M	NM
Company	I	$-Cc+Pc+A, -Cg-A$	$-Cc+Pc, 0$
	NI	$-B, -Cg-C'g+B$	$0, -C'g$

The parameters of the table represent the profits of the company and the government when they choose their strategies.

3. ANALYSIS OF THE MODEL

In this study, reaching the equilibrium point is the goal of both sides of the game. To reach the solution of this game, we must get the equilibrium point. For example, the government can decide to what extent it should consider the size of its facilities to guide companies in implementing the plan. Also, given the volume of facilities provided and the costs of implementing the plan, companies can decide whether or not to implement such systems. Government facilities to companies can include large loans for companies to implement their activities and plans. As mentioned, this game has a non-fixed sum and the strategy used is mixed strategy. Therefore, we examine this game using the best response method.

In game theory, the best response is the strategy that gives the player the most benefit by constantly considering the strategy of the other players; in other words, in a two-player game, if the strategy of the first player is a and the strategy of the second player is b, and assuming that the function $U(s)$ is the first player's profit, in which case a is the best response to b if and only if for any a' of the first player strategies where $a \neq a'$ have:

(1) $U(a, b) \geq U(a', b)$

We examine the game from the perspective of both sides of the game. We first examine the game from a Government perspective. The Government does not know for sure whether the company is implementing or not implementing an energy efficiency improvement system. But the Government can consider the possibility of the company taking action. The Government assumes that the company is running the system with a probability of p and not with a probability of $1 - p$. Therefore, the government, according to its two strategies ("monitoring and evaluation of the company" and "non-monitoring and evaluation of the company") against the mixed strategy of the company, has consequences. We show the government payoff (expected payoff) obtained with $U(G)$.

When the government chooses a "monitoring and evaluation of the company" strategy (M), the payoff is as follows:

(2) $$U_G(p,M) = p(-Cg - A) + (1-p)(-Cg - C'g + B)$$
$$= p(-A + C'g - B) - (Cg + C'g - B)$$

When the government chooses a "non-monitoring and non-evaluation of the company" strategy (M), the payoff is as follows:

(3) $$U_G(p,NM) = p(0) + (1-p)(-C'g) = (p-1)(C'g)$$

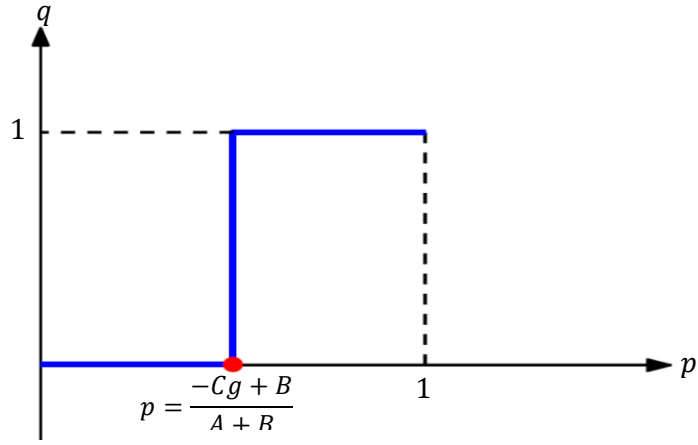
Given the consequences for the Government, we get the best response chart for the Government player that shows the most optimal probability for this game by the Government.

(4)
$$\frac{dU_G(p,M)}{d_p} = -A + C'g - B$$
$$\frac{dU_G(p,NM)}{d_p} = C'g$$

(5)
$$p < \frac{-Cg + B}{A + B} \rightarrow q = 0$$
$$p > \frac{-Cg + B}{A + B} \rightarrow q = 1$$
$$p = \frac{-Cg + B}{A + B} \rightarrow q = [0,1]$$

The chart of the best response for the Government is as follows:

FIGURE 1
Best Response for the Government



Therefore, when $p < \frac{-Cg + B}{A + B}$, the best response of the Government is to choose a strategy of "non-monitoring and evaluation of the company" of companies, i.e. $(q = 0)$, and when $p > \frac{-Cg + B}{A + B}$, the best response of the Government is to choose a "monitoring and evaluation of the company" of companies means $(q = 1)$. When $p = \frac{-Cg + B}{A + B}$, the Government's consequence of "monitoring and evaluation of the company" or "non-monitoring and evaluation of the company" the company is the same, that is, at this point the government's desirability of monitoring and evaluation of the company or non-monitoring and non-evaluation of the company is the same, in other words, the Government is indifferent at this point.

Now we will examine the game from the company's perspective. The company does not know for sure whether the Government monitors or evaluates the systems. But the company can consider the possibility of the Government taking action. The company assumes that the government is monitoring and evaluating the company with a probability of q and not with a probability of $1 - q$. Therefore, the company, according to its two strategies ("implement energy efficiency system" and "non-implement energy efficiency system") against the mixed strategy of the government, obtains

consequences. We show the company payoff (expected payoff) obtained with $U(C)$.

When the company chooses the "implement energy efficiency system" strategy (I), the payoff is as follows:

(6)
$$U_C(I,q) = q(-Cc - Pc + A) + (1-q)(-Cc - Pc) \\ = qA + Pc - C$$

When the company chooses the strategy of "non-implement energy efficiency system" (NI), the payoff is as follows:

(7)
$$U_C(NI,q) = q(-B) + (1-q)(0) = -qB$$

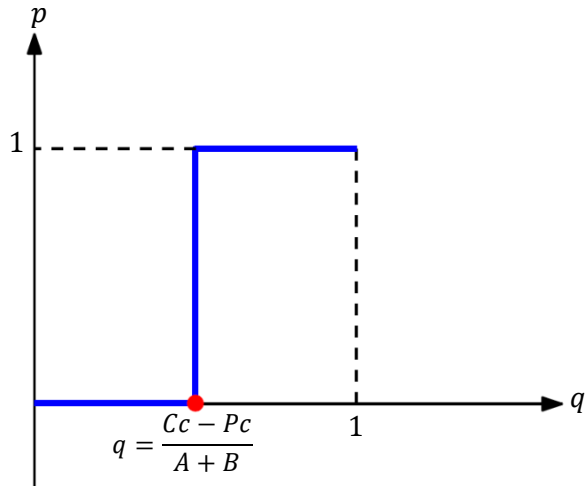
Considering the consequences for the company, we get the chart of the best response of the company that shows the most optimal probability for this game by the company.

(8)
$$\frac{dU_C(I,q)}{d_q} = A$$
$$\frac{dU_C(NI,q)}{d_q} = -B$$

(9)
$$q < \frac{Cc - Pc}{A + B} \rightarrow p = 0$$
$$q > \frac{Cc - Pc}{A + B} \rightarrow p = 1$$
$$q = \frac{Cc - Pc}{A + B} \rightarrow p = [0,1]$$

The chart of the best response for the company is as follows:

FIGURE 2
Best Response for the Company



So when $q < \frac{Cc-Pc}{A+B}$, the best response for the company is to choose a strategy of "non-implement energy efficiency system" i.e., $(p = 0)$, and when $q > \frac{Cc-Pc}{A+B}$, the best response is the Government choosing the strategy "implementing energy efficiency systems" i.e., $(p = 1)$. When $q = \frac{Cc-Pc}{A+B}$ the consequence of the company from the "implementation of the system" or "non-implement energy efficiency system" is the same, that is, at this point the "implement energy efficiency system" or "non-implement energy efficiency system" has the same benefit for the company and in other words, the company is indifferent at this point.

By definition, we know that equilibrium is a game where none of the players are willing to change their position, and the best result is the income of each player. So the equilibrium point of this game is $(p = \frac{-Cg + B}{A + B}, q = \frac{Cc-Pc}{A+B})$ and this point indicates exactly where both the government and the company get the best favor in this game and are indifferent to the choice of their opponent. In other words, neither side of the game changes their position, considering the choice of the opponent, this is their best decision.

4. DECISION MAKING

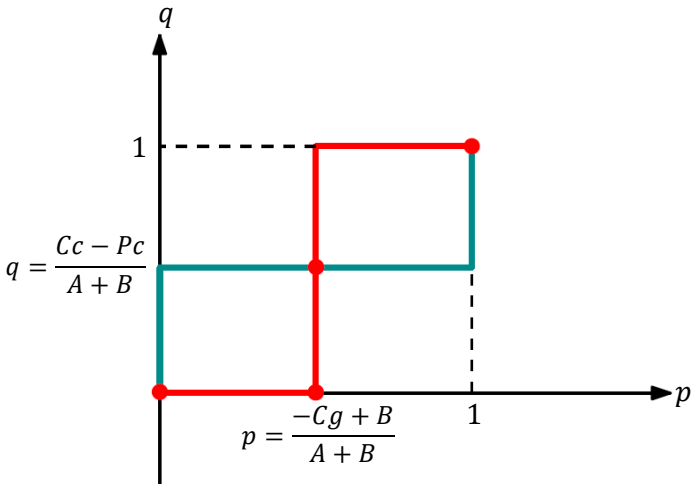
The best response diagram of the game the government and the company intersect at three points, which are as follows:

(10)

$$(p = 0, q = 0)$$
$$(\mathrm{p} = 1, \mathrm{q} = 1)$$
$$(p = \frac{-Cg + B}{A + B}, q = \frac{Cc - Pc}{A + B})$$

The chart of the best response for the government and the company is as follows:

FIGURE 3
Best Response for The Government and The Company



The point $(p = 0, q = 0)$ is a pure strategy equilibrium and states that the Government chooses the strategy of not monitoring and evaluating the company and the company chooses the strategy of not implementing the systems.

The point $(p = 1, q = 1)$ is also the equilibrium of the pure strategy, stating that the government chooses the strategy of monitoring and evaluating the company, and the company chooses the strategy of implementing the systems.

Point $(p = \frac{-Cg + B}{A + B}, q = \frac{Cc - Pc}{A + B})$ in a strategy equilibrium is mixed and states that if the government chooses the "monitoring and

evaluation of the company" strategy of the company with probability, then the company also chooses the strategy of "implement energy efficiency system" with probability. This is the point where none of the players are willing to change their position because this is where the government and the company get the most payoff.

The payoff of the government at the equilibrium point is as follows:

(11)

$$U_G(p,q) = qU_G(p,M) + (1-q)U_G(p,NM)$$
$$U_G(p,q) = \left(\frac{Cc - Pc}{A+B}\right)U_G(p,M) + \left(1 - \frac{Cc - Pc}{A+B}\right)U_G(p,NM)$$

The payoff of the company at the equilibrium point is as follows:

(12)

$$U_C(p,q) = pU_C(I,q) + (1-p)U_C(NI,q)$$
$$U_C(p,q) = \left(\frac{-Cg + B}{A+B}\right)U_C(I,q) + \left(1 - \frac{-Cg + B}{A+B}\right)U_C(NI,q)$$

Equilibrium point is where the best situation occurs and players are reluctant to change it, but in the area before and after the equilibrium point, the strategies no longer work with the same probabilities as before, and another solution must be found. In the chart, in the area before p, the Government is no longer indifferent to the choice of the company and prefers to grant the facility without monitoring and evaluation, i.e., it chooses $q = 0$. Also in the area after p, the government prefers to do monitoring and evaluation and then provide facilities, i.e., $q = 1$.

The company in the area before q is indifferent to the choice of the Government and prefers not implementing the energy efficiency system, ie it chooses $p = 0$. Also, in the area after q the company prefers to implement energy efficiency systems, i.e., it chooses $p = 1$.

5. CONCLUSIONS

In this study, the effective applications of game theory regarding the relationship between the Government and the company are

investigated. By using game theory, the problem between the government and the company regarding allocation of facilities to the companies implementing the energy optimization system has been examined. The results show that by using the obtained equilibrium for the government and the company, they reach their highest profit at the equilibrium point which is the game solution. By using the numerical values of the companies, the partners can use the balances obtained in this article and move toward the optimal strategy and maximize their expected utility. The Government can use the equilibrium point obtained to estimate the costs of implementing energy efficiency improvement systems in companies. It can also determine the value of facilities paid to the companies and the fines for non-implementation such that it can achieve maximum benefit.

Findings of this study help managers and planners to have a proper strategic planning process and choose a more effective strategy by using this model based on the theory of games under uncertainty conditions. The proposed model helps to improve company, organization and institution performance in a practical and effective way, while the balance obtained by using game theory enhances the executive programs in practice.

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