A new balancing approach in Balanced Scorecard by applying cooperative game theory

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Abstract: Balance scorecard is a widely recognized tool to support manager in performance of work. Balance Score Card (BSC) has many advantages but it also suffers from some drawbacks. In this paper, we develop a new balancing approach based on game theory. We propose an interaction method among different strategic agents of scorecard as players providing a methodology for collaboration among different players to reduce any inconsistency. We implement four-person cooperative game theory to balancing in BSC.

Keywords: Balanced Scorecard (BSC), Balanced Scorecard (BSC), cooperative game theory.

1. Introduction

During the past few years, balanced scorecard (BSC) has been widely used among academicians and researchers involved in strategic management and managerial accounting. The BSC, designed by Kaplan and Norton [1], uses four perspectives which reflect firm value creation activities: Learning and growth perspective, internal/business process perspective, customer perspective, and finally financial perspective.

The BSC methodology creates an infrastructure for strategic management activities and introduces four new management processes contributing to linking long-term and short-term strategic objectives separately and simultaneously and use tools for doing balance in organization. BSC helps managers understand numerous interrelationships and causal effects in among perspectives [2]. This understanding can help managers transcend traditional notions regarding functional barriers and ultimately improve decision-making and problem solving. Strategy and execution reviews can help management teams review the strategic plans, the planning process, including BSC metrics and strategy maps [7, 8]. Although BSC has proven a powerful tool for strategic planning and communicating strategy that assists in strategy implementation but there are some limitations on using this method. One basic issue to be surmounted is the difficulty of determining Balancing among different

BSC perspective. In this article, We use cooperative evolutionary game theory to make predictions about four-person coorporation games.

The rest of this article is organized as follows. In the following section, we provide an introduction to balance score card and the cooperative evolutionary game theory and the model. In Section 3, we present coalition formation. In Section 4 one balancing system defined by the use of game theory and Finally, the conclusion remarks are given in section 5 to summarize the contribution of the paper.

2 Literature review

2.1 Literature on the balanced scorecard (BSC)

First devised by Kaplan and Norton, the balanced scorecard approach comprises four perspectives: learning and growth perspective, internal process perspective, customer perspective, and financial perspective [1, 8, 9] which seeks to offer managers a system that would help them turn strategy into action. This system arranges the vision of organization into themes that are disaggregated and detailed top-down in strategic maps. Presently, a large number of organizations are currently successful using BSC. In fact, Niven [14] mentions that recent estimates suggest that 50% of the 1000 largest Fortune Organizations use BSC. There is considerable evidence that organizations are increasingly adopting BSC in their strategic process and that methodological scope does exist to using it, with case study descriptions showing that its application calls for a degree of innovation in order for BSC ideas to be really beneficial to the organization.

The BSC is just a few numbers or performance indicators need to be checked. Also it serves as a bridge between different fields (financial and non-financial fields), but it must be noted that there are some limitations :

1. *Undirectional causality too simplistic*: The use of causal-loops alone is seen as problematic because these loops do not capture the notion of strategic factors accumulating and depleting [17].
2. *Does not separate cause and effect in time*: The time dimension is not part of the BSC, because in some cause-and-effect relationships a time lag exists between cause and effect [17,18].
3. *No mechanisms for validation* : The BSC concept provides no mechanism for maintaining the relevance of defined measures [18,19].
4. *Insufficient links between strategy and operations*: State that the BSC fails to identify performance measurement as a two-way process [17, 18,19].
5. *Too internally focused* : A BSC may be too narrowly defined [18,19].

2.2 Background of the evolutionary game and the model

Game theory is often described as a branch of applied mathematics and economics that studies situations where multiple players make decisions in an attempt to maximize their returns. Generally, the publication of the Theory of Games and Economic Behavior by Morgenstern and Von Neumann in 1944 symbolizes the foundation of Game Theory system [20]. But the modern Game Theory has little relationship with this book. The modern Game Theory developed from 1950s- 1960s, and in 1970s the modern Game Theory became popular economic theory [21]. The basic concept of game theory includes: player, action, strategy, information, income, equilibrium. Player can be individual or groups such as manufacturer, government, and nation.

The basic model of formal game theory [22]:

σ_1, σ_2 Are the actions of player1 and player2; P is the payoff function of every player in different strategy association. Set is the set of players' strategies. If $\{\overline{\sigma_1}, \overline{\sigma_2}\}$ satisfied the following:

$$\begin{cases} P^1(\overline{\sigma_1},\overline{\sigma_2}) = \max\limits_{\sigma_1 \in S^1} P^1(\sigma_1,\sigma_2) \\ P^2(\overline{\sigma_1},\overline{\sigma_2}) = \max\limits_{\sigma_2 \in S^2} P^2(\sigma_1,\sigma_2) \end{cases}$$

Then strategy set $(\overline{\sigma_1},\overline{\sigma_2})$ is Equilibrium. For game set $(\overline{\sigma_1},\overline{\sigma_2}) \in V$, if there is no strategy set (σ_1,σ_2) satisfying the following at the same time:

$$\begin{cases} P^1(\overline{\sigma_1},\overline{\sigma_2}) \prec P^1(\sigma_1,\sigma_2) \\ P^2(\overline{\sigma_1},\overline{\sigma_2}) \prec P^2(\sigma_1,\sigma_2) \end{cases}$$

Then it is called Pareto optimality.

3. Applying cooperative evolutionary game theory in BSC

This might be far-fetched to define the proportional probability of playing the cooperation strategy as the collaboration effort. This problem can be solved by introducing the continuous-strategy cooperative game. According to Doebeli and Knowlton (1998), Doebeli et al. (2004), Killingback and Doebeli (2002), Wahl and Nowak (1999a), Wahl and Nowak (1999b), it is natural to assume that players adopt continuous strategies in SD games. Similarly in an cooperative evolutionary game, it is natural to assume that players can make continuously varying collaboration effort. In a four-player cooperative game, we assume that each player has a maximum resource budget, $x_{1m}, x_{2m}, x_{3m}, x_{4m}$, respectively. However four players might determine their collaboration effort during the cooperative process.

Let p_1, p_2, p_3, p_4 be the effort index of Player $i\,(i=1,2,3,4)$. Accordingly, $p_i x_{im}$ is the total collaboration effort of Player $i\,(i=1,2,3,4)$. We denote $B(p_1x_{1m}, p_2x_{2m}, p_3x_{3m}, p_4x_{4m})$ as common benefit of four players. Because of the efficiency of different players, we adopt $B(p_1x_{1m}, p_2x_{2m}, p_3x_{3m}, p_4x_{4m})$, which allows asymmetric efficiency between players as the benefit function. Let $C(p_i x_{im})$ be the cooperation costs of four players respectively. Thus, Player i's payoff function can be written as follows.

$$\Pi_i(p_1,p_2,p_3,p_4) = B(p_1x_{1m}, p_2x_{2m}, p_3x_{3m}, p_4x_{4m}) - C(p_i x_{im})$$

Here we would like to emphasize that we are discussing an asymmetric continuous cooperation game. First, x_{im} could be different from another and p_i could be different. Player i may not be as efficient as Player j in contributing to the collaboration result $(i, j=1,2,3,4\ \ ; i \neq j)$. If Eqs.above are concave and we obtain a vector of $\{p_1^*, p_2^*, p_3^*, p_4^*\}$ where $0 \le p_i \le 1$, then $\{p_1^*, p_2^*, p_3^*, p_4^*\}$ is a unique equilibrium for this asymmetric continuous cooperation game. We first focus on case where the payoff functions are linear to the collaboration efforts. We have the following observation.

Table 1 : The players' effort matrix

		Player 1			
		Cooperate		Defect	
Player 2	Cooperate	Player 3 (Cooperate), Player 4(Cooperate)	Player 3 (Defect), Player 4(Cooperate)	Player 3 (Cooperate), Player 4(Cooperate)	Player 3 (Defect), Player 4(Cooperate)
		Player 3 (Cooperate), Player 4(Defect)	Player 3 (Defect), Player 4(Defect)	Player 3 (Cooperate), Player 4(Defect)	Player 3 (Defect), Player 4(Defect)
	Defect	Player 3 (Cooperate), Player 4(Cooperate)	Player 3 (Defect), Player 4(Cooperate)	Player 3 (Cooperate), Player 4(Cooperate)	Player 3 (Defect), Player 4(Cooperate)
		Player 3 (Cooperate), Player 4(Defect)	Player 3 (Defect), Player 4(Defect)	Player 3 (Cooperate), Player 4(Defect)	Player 3 (Defect), Player 4(Defect)

		Player 1			
		Cooperate		Defect	
Player 2	Cooperate	$p_1p_2p_3p_4$	$p_1p_2(1-p_3)p_4$	$(1-p_1)p_2p_3p_4$	$(1-p_1)p_2(1-p_3)p_4$
		$p_1p_2p_3(1-p_4)$	$p_1p_2(1-p_3)(1-p_4)$	$(1-p_1)p_2p_3(1-p_4)$	$(1-p_1)p_2(1-p_3)(1-p_4)$
	Defect	$p_1(1-p_2)p_3p_4$	$p_1(1-p_2)(1-p_3)p_4$	$(1-p_1)(1-p_2)p_3p_4$	$(1-p_1)(1-p_2)(1-p_3)p_4$
		$p_1(1-p_2)p_3(1-p_4)$	$p_1(1-p_2)(1-p_3)(1-p_4)$	$(1-p_1)(1-p_2)p_3(1-p_4)$	$(1-p_1)(1-p_2)(1-p_3)(1-p_4)$

Proposition. A four-person discrete-strategy collaboration game with mixed strategies can be described equivalently by a four-person continuous-strategy collaboration game with a payoff function linear to their collaboration efforts and a correlated item $\prod_{i=1}^{4} p_i x_{im}$.

Proof of Proposition. We show that the payoff of a player in a special continuous-strategy collaboration game can be used to describe the payoff of the player in a discrete- and mixed-strategy collaboration game. For a discrete-strategy game, we argue that the mixed strategies might be considered as a continuous effort that a player is willing to contribute to the collaboration. Thus, we can consider a mixed strategy essentially as an effort matrix (see Table 2).

To study the discrete-strategy game for four players, we start with the intuitive symmetric model as shown in Table 2. In this article, we conglomerate a single factor called social punishment, which is denoted by δ . In this collaboration game, we assume that a player will be punished, e.g., his/her reputation gets hurt, etc., if he/she decides to defect while the other cooperates. As a result, the defector's payoff decreases due to the impact of δ . We model a symmetric collaboration as shown in Table 2.

Table 2 : A symmetric collaboration game

		Player 1			
		Cooperate		Defect	
Player 2	Cooperate	$b-\frac{c}{4},b-\frac{c}{4},b-\frac{c}{4},b-\frac{c}{4}$	$b-\frac{c}{3},b-\frac{c}{3},b-\delta,b-\frac{c}{3}$	$b-\delta,b-\frac{c}{3},b-\frac{c}{3},b-\frac{c}{3}$	$b-\delta,b-\frac{c}{2},b-\delta,b-\frac{c}{2}$
		$b-\frac{c}{3},b-\frac{c}{3},b-\frac{c}{3},b-\delta$	$b-\frac{c}{2},b-\frac{c}{2},b-\delta,b-\delta$	$b-\delta,b-\frac{c}{2},b-\frac{c}{2},b-\delta$	$b-\delta,b-c,b-\delta,b-\delta$
	Defect	$b-\frac{c}{3},b-\delta,b-\frac{c}{3},b-\frac{c}{3}$	$b-\frac{c}{2},b-\delta,b-\delta,b-\frac{c}{2}$	$b-\delta,b-\delta,b-\frac{c}{2},b-\frac{c}{2}$	$b-\delta,b-\delta,b-\delta,b-c$
		$b-\frac{c}{2},b-\delta,b-\frac{c}{2},b-\delta$	$b-c,b-\delta,b-\delta,b-\delta$	$b-\delta,b-\delta,b-c,b-\delta$	$0,0,0,0$

Thus, Player $1's$ expected payoff is given by :

$$
\begin{aligned}
\Pi_1(p_1) &= p_1p_2p_3p_4(b-\frac{c}{4})+p_1p_2(1-p_3)p_4(b-\frac{c}{3})+(1-p_1)p_2p_3p_4(b-\delta)+(1-p_1)p_2(1-p_3)p_4(b-\delta) \\
&+p_1p_2p_3(1-p_4)(b-\frac{c}{3})+p_1p_2(1-p_3)(1-p_4)(b-\frac{c}{2})+(1-p_1)p_2p_3(1-p_4)(b-\delta)+(1-p_1)p_2(1-p_3)(1-p_4)(b-\delta) \\
&+p_1(1-p_2)p_3p_4(b-\frac{c}{3})+p_1(1-p_2)(1-p_3)p_4(b-\frac{c}{2})+(1-p_1)(1-p_2)p_3p_4(b-\delta) \\
&+(1-p_1)(1-p_2)(1-p_3)p_4(b-\delta)+p_1(1-p_2)p_3(1-p_4)(b-\frac{c}{2})+p_1(1-p_2)(1-p_3)(1-p_4)(b-c) \\
&+(1-p_1)(1-p_2)p_3(1-p_4)(b-\delta)
\end{aligned}
$$

Let $\frac{\partial \Pi_i(p_i)}{\partial p_i}=0 \quad (i=1,2,3,4)$ and we obtain the optimal solution. We use an example to show the implementation of our proposed method. We assume the existence of an adaptive effect that takes place as the collaborators use a particular medium. The effect essentially is that the more the collaborators use the same medium, the more effective they become at using the medium. Hence, we assume a piece-wise linear learning curve for the collaborators as a result of the adaptive effect, whose slope is denoted by $1+\lambda_{i,j}$, where i stands for the specific medium and j stands for the cumulative frequency of Medium i being utilized by the collaborators previously.

We define $\lambda_{i,0}=0 \quad \forall i$. The sum of j for all media equals the total number of component games played until the current round (component game).

Suppose the overall collaboration tasks are divided into a series of component games, in which collaborators might choose different media for each component game. Thus, the expected payoff of Player i in the tth component game of this dynamic collaboration game can be expressed as :

$$\prod_t(P_j,i)=\max_{p,i}\left\{(1+\lambda_{i,0})B(p_1x_{m_1},p_2x_{m_2},p_3x_{m_3},p_4x_{m_4})_i-C(p_jx_{m_j})_i\right\}+\prod_{t-i}(P_j,i)$$

4. Conclusion

Game theory, in the last decades has emerged as a powerful method to describe and to give way-outs when facing interactive problems solving. However, one big constraint to make it more applicable seemingly is in determining alternative pay-offs. Especially when the problems are dominated by qualitative considerations like what usually happens in strategic problems. Qualitative inputs cannot be processed directly by game theory. They should be translated first into quantitative inputs (pay-offs). As run the model by MATLAB software, I see that is Nash equilibrium point in $p_i = 0.5 \;\; i = 1,2,3,4$

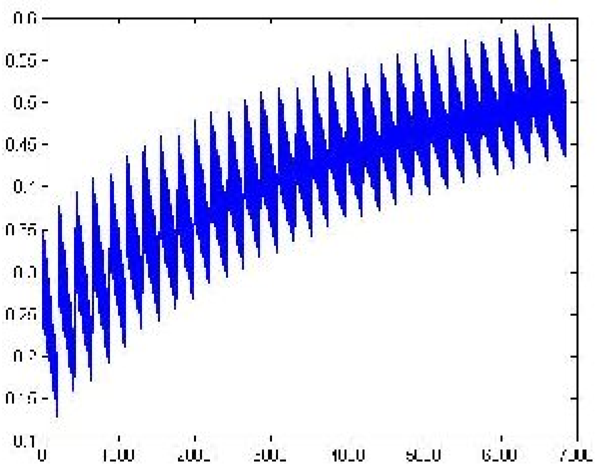

Fig. 1: Error of run model

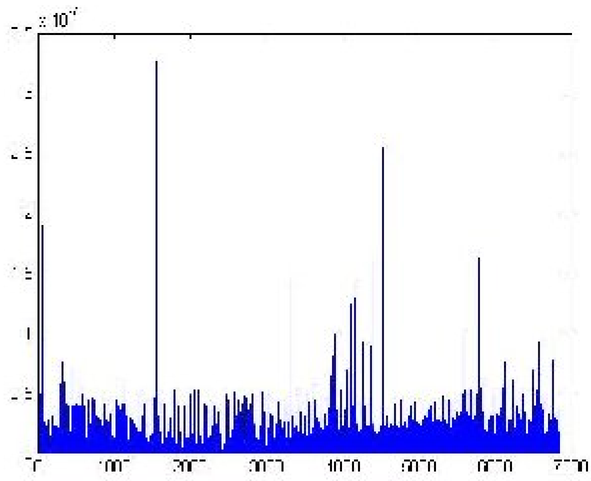

Fig.2: Nash equilibrium point

This paper shows how game theory can be used to balance that perspective of BSC. The research found that the best Equilibrium point for the four players in BSC is by $p_i = 0.5 \;\; i = 1,2,3,4$. To deal with that, they need to unite their efforts and to support one another.

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