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TESTING BOWMAN'S MANAGERIAL COEFFICIENT THEORY USING A COMPETITIVE GAMING ENVIRONMENT*

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In this paper Bowman's managerial coefficient theory is evaluated in a competitive environment, the Executive Game. The literature on Bowman's theory is surveyed and a review is made to justify using games to test decision theories. The experimental data reveal that decision rules fit the data well. Erratic and biased decision making is found to be a linear function of rank. Learning consistent with oligopolistic theory is found to occur. The applicability of Bowman's theory in competitive environment is established and the theory extended.

Introduction

Linear decision rules are widely used to model decision making and apply managerial intuition. Since Bowman [2] formulated his theory to justify their usage, decision rules have become an important management tool. Unfortuately, the supporting research studies were performed in noncompetitive environments. Although the theory has great potential in competitive environments, until now its appropriateness has not been demonstrated. This study attempts to remedy this deficiency by demonstrating the effectiveness of the theory in a competitive environment, the Executive Game.

The Theory

Bowman's managerial coefficient theory models recurrent decision making in which factors are intuitively or explicitly weighted to arrive at a decision. The weighting is reflected by a linear decision rule of the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n. \tag{1}$$

The dependent variable represents the decision and the X's represent the factors taken into account. The values assigned to the β's are a function of the importance of each factor and may be determined by regression analysis of past decisions. Most managers do *not* think through a problem in the way just described. Nevertheless, a manager's intuition is well represented by such a decision rule. The rule can be used as a substitute for the manager's personal attention when he is gone on business or vacation, or after he has been promoted or has left the firm. Bowman asserted that experienced managers may use decision rules which are as effective as those found by traditional operations research methods. In both laboratory [4] and field [11] production scheduling experiments, decision rules have been observed to occasionally yield better decisions than the optimal models.

Even though a manager makes good decisions on the average he may erroneously adjust his decisions because of inaccurate messages, incorrectly understood cues, rumors, or faulty forecasts. A decision rule minimizes the erratic decision making which the theory asserts and research demonstrates [14], [17] to be the cause of more economic inefficiency than incorrect intuitions. Bowman called erratic decision making "variance" and incorrect intuitions "bias". Both field studies [2], [11] and laboratory studies [3]–[7], [14] have found that decision rules give significantly better economic results than the actual decisions on which the rules are based.

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Circumstances Affecting the Effectiveness of a Decision Rule

Since a decision rule is based on past decisions, the effectiveness of a rule based upon them is naturally affected by the circumstances which surrounded the making of those decisions. A decision rule will be better if:

(a) the actual decision were made by a manager who is experienced in making this particular decision [4]–[6],

(b) adequate performance feedback is given to the decision maker [6],

(c) the performance measures are not obscured by irrelevant factors [7],

(d) significant environmental instabilities do not occur [11],

(e) forecast error is reduced [14],

(f) forecasts are available for more than one period into the future [14].

If the decisions were made under these circumstances, the resulting rule should be very effective. Even if all of the conditions are not fully met, the rule may still perform satisfactorily.

Using Gaming as a Decision Making Laboratory

Numerous experiments have used the business game to study decision making. The objective of this review is to validate the use of gaming to evaluate decision theories by showing that decision making in games does not differ from managerial decision making.

A phenomenological study by Norman [15] on the play of the Executive Game [8] found:

1. Each team developed its own unique pattern of decision making.
2. Differences between teams' decision-making behavior correspond with differences in their stated beliefs about the environment.
3. Each team's focus was changed from the general goal of maximizing return on investment to some more concise action objective around which it could model the game in meaningful terms.
4. Each team organized the elements of the game around their perceived model of the game.
5. A team's perceived model tended to persist even when partially contradicted; it was simply modified to reflect the new data.
6. Each team exhibited a style ranging from ultraconservative to extreme risk taking. This style persisted.

These observations about the behavior of game players are consistent with observations on the behavior of management and will give perspective to the following empirical studies.

A study by Philippatos and Moscato [16] found that gaming subjects learned the rules and objectives of games even when given no information about the game. Carter, Jenicke and Remus [5] noted that gaming subjects correctly respond to changes in the game even when not told of the change. When the game players were given worthwhile additional information about the game, their performance improved [6]. These findings confirm Norman's observation that teams develop models of the game and imply that those models were both useful and accurate.

Game performance is related to subject matter knowledge at least for certain games [18]. While obvious for special purpose games, the finding that knowledge of marketing practices enhances success in a general decision game is consistent with our intuitions.

Risk in decision making is a controversial area in gaming. Lewin and Weber found that student players become more risk-prone as play proceeds [12]. Carter, Jenicke and Remus [4], [5] found the opposite occurring. A study by Moskowitz [13] found students to be more risk-conscious than managers when gaming. Babb et al.'s study

[1] found businessmen took smaller risks than students when gaming; students' behavior was characterized as erratic.

A reasonable explanation of these findings is that the subjects learn to play games well and to intuitively understand which behavior is needed to win. As Norman suggested, they build simple but useful models of the game and use them to make decisions. This behavior is noted and measured in many studies [1], [4]–[6], [14]–[16]. Since different games may require different appropriate behaviors, the appropriate behavior would be risk-taking only if required by the game or necessary to the learning process. Thus, Babb et al.'s assertion that businessmen are initially more cautious than students when playing the farm supply game is not in conflict with Moskowitz's assertion to the contrary made for a different game. The differences between students and managers were explicitly examined by Khera & Benson [10]; they found that the only differences in the decision-making behavior were due to background. If the businessmen had experience in a certain industry and the simulation accurately portrayed that industry, then the students had to learn through gaming alone the appropriate decision-making behavior which the businessmen already knew. Once the learning occurred, the businessmen and students showed similar decision making behavior [1]. Carter, Jenicke, and Remus [4], [5] have noted and measured the reduction of erratic behavior as subjects learned a game. Babb et al. found that erratic behavior may stem from the players' attempts to learn appropriate behavior for the game. This is not an assertion that such learning would be appropriate for or even transfer to the real world. Babb et al. found that businessmen transfer business methodology to the play of a parallel simulation but this transfer did not necessarily lead to gaming success. Apparently farm supply and dairy management simulations required different winning strategies than the game's unsimulated counterparts [1].

The literature demonstrates that game players learn the strategies needed to do well in a game and that different games elicit different strategies. Since the players learn appropriate strategies for the game, the game can be used as a laboratory to study decision-making processes.

The Research Questions

Most of the research on Bowman's theory has been performed in noncompetitive environments [2]–[7], [14], [17]. If the theory were applicable only to such environments, its utility would be severely limited. In this study the theory is tested to demonstrate its effectiveness in modeling the behavior of decision makers in a competitive gaming environment.

The Executive Game [8] was chosen for the experiment. The Executive Game is a top-management simulation game based on oliogopolistic competition. It is one of the more popular computer-based simulation games with its mathematics anchored in economic theory. In this game the players are assigned to firms and the firms are divided into industries. Each firm manufactures a single uniform product and decides product price, marketing expenditure, R&D expenditure, production volume, maintenance expenditure, new plant investment and dividend payout. The firm with the highest return on investment (including dividend payout) when the game terminates wins the game.

Since Bowman asserted that variance (i.e. erratic behavior) was the major source of economic inefficiency, this assertion will be tested by comparing the winners and losers of the Executive Game. If Bowman is right, the winners should be less erratic. The secondary determinant of economic inefficiency, bias (incorrect intuition) will be similarly tested. As Bowman's theory has been used to model learning effects in a non-competitive environment, this study will look for the same effects in a competitive environment. If the learning effects occur, then it would be appropriate to find if they interact with a firm's rank to explain a potential source of the firm's success (namely, fast learning). Hence, this research paper addresses the following questions:

1. Do decision rules capture decision making behavior well in competitive environments?
2. Are the game winners less erratic and biased than other firms?
3. Does Bowman's theory capture and model the decision maker's learning?
4. Do learning and bias or variance interact?

For this experiment, undergraduate students in an introduction to business course played the Executive Game with each subject acting as an independent firm. Participation in the game was a course requirement and counted for no more than 10% of the course grade. The subjects (firms) were divided into eleven industries of 8 competitors each. A practice period plus 8 regular periods were played; the decisions were made weekly. Provisions were made to assure that subjects maintained an ongoing firm even in the final quarter of play. Neither regression analysis nor linear decision rules were part of the course content nor were they covered in course prerequisites.

The key to testing the research questions is to adopt a standard for preferred performance on which to base the calculation of bias and variance. This preferred standard should also be the standard by which to measure learning. Bowman's theory is concerned with reducing intra-decision maker variance; thus, he suggests that a decision maker find his decision rule by using regression analysis on his previous decisions. The use of this rule will reduce the erratic component of decision making. While the latter rule reduces the variance, it is not the best standard for measuring bias and variance. In all of the experiments based on production scheduling [3]–[6] [14], [17], the standard of preferred performance was the optimal rule derived through differential calculus. Thus in the preceding studies bias and variance were measured relative to the optimal rather than the decision maker's regression rule. Moskowitz and Miller [14] elaborate this procedure.

In some games the underlying mathematical model may be solved for an optimal solution. In the Executive Game no global solution has been found, although some conditionally optimal rules exist. Thus Executive Game performance cannot be measured relative to optimal rules. In the business world, firms measure their performance relative to other firms in the industry, particularly the industry leaders. This analysis will use the Executive Game winner's decision rule as the standard of preferred performance. The Executive Game winner's rule can be used in the same spirit as the optimal production scheduling rules. The optimal rule provides the strategy to minimize production scheduling costs; the winner's rule captures the intuition of the most successful firms for keeping a healthy return on investment. Since all of the industries are based on the same oligopolistic mathematical model, one would expect to find little difference in the behavior of the winning firms. Control through marketing (market segmentation and product differentiation) and replacement of price competition with marketing competition are the well known keys to oligopolistic success which the rules should pick up. The nonuse of the preceding strategies or their erratic use should be predictive of low return on investment in the game.

The Results

The first step in finding the decision rules was to use correlation analysis to determine the impact of each of the eight decision variables on return on investment. As business common sense would suggest, product pricing, marketing expenditure, and production volume had the highest correlation with return on investment. Therefore, the latter three decisions were chosen for further analysis.

To find the regression rules characterizing the three decisions, lists of variables which might be used to make each decision were prepared. The decision rules were composed with all the variables entering the stepwise regression equation at 0.05. The price, marketing expenditure, and production volume rules were determined based on the decisions of the Executive Game winner; these rules are shown on Table 1.

TABLE 1
Linear Decision Rules for the Executive Game Winners

Price Decision	$\bar{R}^2 = 0.68$	$p < 0.0005$	$n = 72$
Price =	$-0.33 + 0.027$	(Next period's forecasted Economic Index)	
	$+ 0.658$	(price last period)	
	$- 0.14$	(stock of finished goods)	
	$+ 0.07$	(exponentially smoothed past R & D expenditures)	
	$- 0.03$	(volume produced this period)	
	$- 0.002$	(cash on hand)	
Marketing Decision	$\bar{R}^2 = 0.85$	$p < 0.0005$	$n = 72$
Marketing Expenditure =	$1.366 + 0.98$	(exponentially smoothed past marketing expenditures)	
	$- 0.24$	(market potential)	
	$+ 0.45$	(volume produced this period)	
	$- 0.68$	(exponentially smoothed past R & D expenditures)	
	$- 0.013$	(forecast for next period's seasonal index	
	$+ 0.57$	(this period's maintenance expenditure)	
Production Volume Decision	$\bar{R}^2 = 0.83$	$p < 0.0005$	$n = 72$
Volume =	$-5.14 + 0.09$	(next period's forecasted economic index)	
	$+ 0.46$	(this period's marketing expenditure)	
	$+ 0.12$	(market potential)	
	$- 2.13$	(exponentially smoothed past maintenance expenditures)	
	$+ 0.64$	(exponentially smoothed past R & D expenditures)	

Variance and Bias in Decision Making

Bowman asserted that variance (erratic decision making) is the major source of economic inefficiency. Thus variance should discriminate the levels of firm performance. A reasonable hypothesis is that variance is a linear function of a firm's final rank in the Executive Game; that is, the more erratic a firm's decisions the lower it will be ranked. The mean absolute deviation (MAD) of the actual decision from the preferred decision was used to measure the variance. This measure shows how consistently a firm made the preferred decision and thus provides a measure of erratic behavior.

Although Bowman did not assert that bias (incorrect intuition) is the major source of economic inefficiency, it is reasonable to believe that bias and firm performance are related. Since performance should be reduced as bias increases, an inverse linear relationship was hypothesized. Bias was computed by taking the signed difference between the actual and preferred decisions. This measure shows whether, on the average, the firms made the preferred decisions and thus provides a measure of biased behavior.

The measures of erratic decision making varied significantly across team rank; in each case, the variance in decision making was a direct linear function of a firm's final rank. The bias in decision making also varied significantly across team rank; in each case the bias was an inverse linear function of final rank. In all six cases, the bias or variance had the predicted relationship to final firm rank. The results of these tests are summarized in Table 2.

TABLE 2

Tests on Variance and Bias Across Final Firm Rank

Variance (MAD) Relative to the Executive Game Winner's Rules (n = 701)

LDR	Significance	Linear Fit Equation
Price	0.033	Variance = 0.10 + 0.01 (Rank)
Marketing Expenditure	0.0005	Variance = 0.30 + 0.03 (Rank)
Production Volume	0.0005	Variance = 0.52 + 0.08 (Rank)

Bias Relative to the Executive Game Winner's Rules (n = 701)

LDR	Significance	Linear Fit Equation
Price	0.033	Bias = 0.033 − 0.009 (Rank)
Marketing Expenditure	0.106	Bias = 0.0677 − 0.03 (Rank)
Production Volume	0.003	Bias = 0.196 − 0.064 (Rank)

Learning

An earlier study [4] on production scheduling found that decision rules can be used to measure the learning process in naive decision makers. This paper will examine four interrelated measures of learning:

I. Learning to adopt the policies of the Executive Game winners.

a. The tendency over time to adopt the winner's rules. This is measured by the bias from the preferred rule.

b. The reduction over time in the erratic use of the winner's rules. This is the variance from the preferred rule and is measured in mean absolute deviations.

II. Learning to adopt industry wide policies.

a. The tendency to adopt the aggregate (industry wide) rules. This is the mean signed difference (MSD) between the firm's decisions and the application of the aggregate decision rule; it is analogous to bias.

b. The reduction in the erratic use of the industry-wide rules. This is meassured by the mean absolute deviations (MAD) between the actual decisions and the application of the aggregate decision rule; it is analogous to variance.

The distinction between a and b in each category is that while a decision maker was on-the-average using a decision rule (a), he could also be quite erratic in its use (b).

First we examined the degree to which firms were adopting the same decision rules as the Executive Game winners. Since no global optimum exists, the winners' policies for getting the highest return on investment are taken to be the best. The other firms could be learning how to improve their return by moving toward the winners' policies.

Table 3 shows learning measured as a reduction in bias over time. Both the price and volume rules show linear learning effects as the firms moved toward adoption of the Executive Game winners' pricing and production policies. Table 3 reveals that as the game progressed the firms also became less erratic in both pricing and production decisions. However, the learning effects did not occur on the marketing expenditure decision.

TABLE 3

Tests on Variance and Bias Across Time Periods

Variance (MAD) Relative to the Executive Game Winner's Rules ($n = 701$)

LDR	Significance	Linear fit Equation
Price	0.0005	Variance = 0.29 − 0.04 (Period)
Marketing Expenditure	0.189	
Production Volume	0.0005	Variance = 1.1 − 0.05 (Period)

Bias Relative to the Executive Game Winner's Rules ($n = 701$)

LDR	Significance	Linear Fit Equation
Price	0.0005	Bias = 0.25 − 0.05 (Period)
Marketing Expenditure	0.067	
Production Volume	0.0005	Bias = 0.83 − 0.09 (Period)

It occurred to us that the firms might not be adopting the winner's rules, but were instead moving toward stable industry-wide policies. After all, the Executive Game is an oligopoly. To examine this possibility, learning relative to aggregate rules was measured. These rules were calculated by the same method as the winner's rules except that they were based on the aggregate data. Tests of structural equivalence [9] revealed that the aggregate and the Executive Game winners' decision rules were structurally different.

Table 4 contains the second set of learning measures. In each case, the MSD was linearly reduced as time progressed. The firms do seem to be adopting industry wide policies on price, marketing expenditure, and volume. The measures of learning using MAD yield mixed results. The price and volume rules show significant variation in MAD. The price rule has a linear trend in the predicted direction; however, the volume rule shows no linear trend at 0.05 level of significance. Thus, the firms have become less erratic only in following the industry pricing policy.

TABLE 4

Tests on MAD *and Mean Signed Deviations Across Time Periods*

Mean Absolute Deviations Relative to the Industry Wide Rules ($n = 701$)

LDR	Significance	Linear fit Equation
Price	0.0005	MAD = 0.28 − 0.04 (Period)
Marketing Expenditure	0.920	
Production Volume	0.0005	

Mean Signed Deviations Relative to the Industry Wide Rules ($n = 701$)

LDR	Significance	Linear fit Equation
Price	0.0005	MSD = −0.26 + 0.05 (Period)
Marketing Expenditure	0.037	MSD = 0.14 − 0.02 (Period)
Production Volume	0.0005	MSD = 0.59 − 0.11 (period)

The Interaction of Final Firm Rank and Learning

In the preceding analysis the effects of final firm rank and learning were examined separately. It is possible, however, that final firm rank and learning interact to explain the results of the Executive Game. It is reasonable to hypothesize that because some firms learned the needed strategy faster than other firms, the fast learners had a competitive advantage. For example, IBM was the fastest learner in the computer business and they have continued to dominate the industry. To examine this hypothesis, a two way analysis of variance was conducted, blocking on both final rank and time. The statistical significance of the interaction term was the test of the hypothesis.

First, the significance of the variance interaction effect was found; these were price (0.018), marketing expenditure (0.003), and production volume (0.016). Then significance of the bias interaction effect was found; these were price (0.420), marketing expenditure (0.199), and production volume (0.220). In each case the sample size was 480. These results demonstrate an interaction of the rank and learning for variance, but not for bias. Apparently, the firms that reduced erratic tendencies the fastest were rewarded with a high rank in the game. The last-placed firms often showed no significant learning over the play of the game.

Conclusions and Implications for Further Research

This study demonstrates and extends Bowman's theory. Even in competitive business simulation games, the decision maker can be modeled by a decision rule. Bowman asserted that erratic behavior (variance) is the major source of poor economic performance. In this study variance was found to be a linear function of the firm's final rank, and bias was found to be an inverse linear function of final rank. Thus both bias and variance can be used to discriminate levels of firm performance. If the Executive Game winners are thought of as the industry leaders (although that term often refers to the firm with the largest market share rather than the highest return on investment), then the findings on bias and variance support the use of the industry leaders as bench-marks for decision making.

It was found that learning did occur in the Executive Game; the firms had the oligopolistic tendency to adopt uniform policies, particularly in pricing. Since they adopted both the Executive Game winner's and industry-wide price rules, a "price leader" effect as noted the steel industry may have occurred. That is, the Executive Game winner may have been setting the pricing policy in the industry. Firms became less erratic in using that pricing policy as the game continued.

The weakest oligopolistic effect is found in marketing policy. There was a tendency to adopt an industry-wide policy but not the winner's policy. Perhaps marketing is the Executive Game winner's expertise and source of success. In oligopolies price competition is often replaced by marketing competition.

The research found important rank and learning effects but it also found that these effects interact to explain firm performance. The interaction of the time and rank points to at least one reason why certain firms emerged as Executive Game winners; namely, those firms that rapidly learned to reduce their erratic decision making tended to do well in the game. Those firms that never settled on a strategy or switched from strategy to strategy did poorly. Learning and rank failed to interact to explain bias in decision making. Thus, in this oligopoly consistency in strategy was rewarded more than reduced bias in using the winner's strategy.

In new research learning and rank effects must be controlled for or measures of interest may be obscured. If not controlled these effects just add to the error term; with these blocking variables, increased precision can be gained. The learning and rank effects may have confounded the results of the numerous studies on the relationship between personality variables and gaming. For example, the studies on whether or not students enjoy games are inconclusive. Perhaps the winners and/or fast learners enjoy the game whereas the losers and/or slow learners do not. That is, enjoyment is a function of rank.

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