The Effectiveness of Reward Systems on Innovative Output: An Empirical Analysis

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ABSTRACT. This study investigated the relationship of patent output to the reward systems for individual R&D scientists in high technology firms. A survey of technical managers in 57 Connecticut firms collected information on firm size, R&D expenditure, and the frequency of use of eighteen different reward systems. Using a regression model, patent output was found to be dependent on firm size, R&D expenditure, and on monetary and non-monetary reward systems, informal award programs and variable bonuses based on the issue of patents. When a subset of small firms was investigated separately, non-monetary rewards were shown to be ineffective. However, variable bonuses remained important to patent output and large sum reward payments ($50,000) also demonstrated a significant effect.

1. Introduction

An examination of the literature on entrepreneurship and motivational theory reveals mixed evidence on the effectiveness of various types of reward systems on creativity and innovation, particularly with regard to technicians and professionals, such as scientists and engineers. The purpose of this study is to empirically measure the impact of monetary and non-monetary reward systems on innovation output in high technology firms as measured by patent productivity. The study also attempts to assess the impact of firm size on the relationship of reward systems to patent output.

Early studies of reward systems for R&D scientists in high-technology firms were primarily descriptive of large firm practices. In a study of organizational scientists, Glaser (1964) found that highly motivated investigators tend to put more time into their own research work. Allowing scientists to set their own time resulted in higher quality performance. Other studies investigated the interaction of intrinsic rewards, rewards that increase feelings of self-esteem and accomplishment, and extrinsic rewards such as bonuses and promotions. Pelz and Andrews (1976), studying attitudes and factors relating to the laboratory performance of scientists, professors, engineers and research personnel, concluded that intrinsic rewards, such as freedom and ability to communicate with colleagues, as well as extrinsic rewards are important.

DeCharms (1968) found that extrinsic rewards lowered the perceived intrinsic reward. However, further research in this area showed no interaction (Deci, 1972a and 1972b; Lepper, Greene, and Nisbett, 1973; and Hammer and Foster, 1975).

More recent studies identify a motivational dichotomy. Several reports suggest that monetary rewards are not the best motivational tool for technical professionals. On the other hand some studies have shown that technical personnel in technology-driven firms are primarily motivated by monetary performance-related incentives.

In descriptive case studies of 21 major organizations, Walcoff, Ouelette and Cheremisinoff (1983), found that individuals involved in a new venture were given greater incentives to succeed.

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To encourage technical personnel to stay with a firm and to increase the level and rate of innovation, alternative career ladders to maintain professional interest and challenge were built into the reward systems. This technique was associated with a greater number of new inventions and patents. Souder (1985), utilizing a sample of Industrial Research Institute members, assessed award practices for R&D personnel. He observed that the sampled firms placed greater emphasis on technical professionals communicating to top management than on granting monetary rewards.

Griggs and Manning (1986) report that traditional reward and recognition practices seem to be supportive rather than primary processes for validating a sense of value to a firm. For the technical person, traditional reward and recognition practices are useful as symbols but do not contribute significantly toward motivation or retention. They conclude that innovation is best served in technically-driven firms when they foster organizational climates that inspire the best creative efforts by technical professionals.

In studies which demonstrate support of monetary rewards as effective motivational tools for increasing innovation, differences in the impact of the various types of monetary rewards have also been found. Balkin and Gomez-Mejia (1985) showed that high technology scientists and engineers receive more annual incremental equity pay than merit pay. They conclude that incentives which are company-performance based stimulate risk taking and entrepreneurship, leading to invention and creativity. Further research by these authors indicated that individual rewards such as merit pay or bonuses are perceived as less effective than aggregate reward system practices for R&D workers (Gomez-Mejia and Balkin, 1989). In an empirical study, Smayling (1987), observed that small per-patent or application payments were of little value as incentives while larger sum awards and recognition tied to individual patent output had positive effects.

The divergent results presented in the literature may be explained partially by differences in the type of firms studied. Originators of technology in large firms are likely to be different from the small firm entrepreneur (Knight, 1987). Technical personnel within large firms seem more likely motivated by nonmonetary rewards that affect intrinsic values than by monetary rewards (Walcoff, Ouelette, and Cheremisinoff, 1983; and Souder, 1985). Entrepreneurs in smaller, newly-emerging firms (often inventors, scientists or technicians) are more likely to be motivated by extrinsic rewards that encourage a "stake" in the venture (Balkin and Gomez-Mejia, 1985 and 1987). Therefore, size and recency of formation may result in differences in the effectiveness of reward structures on innovation.

2. Sample design

In order to investigate the effectiveness of various types of reward systems on innovative output, a sample survey of reward practices in high-technology firms was undertaken. The sample was drawn from a data base of 1330 high-technology firms in Connecticut which was compiled by CorpTech™ (a data base designer and directory publisher). The data base contained approximately 80% of the total potential high-technology firms in the state.[1] For research cost minimization purposes, every other firm listed in the directory was sent a questionnaire.[2] The response rate was 16.2%, or 111 returns.

The measure of innovative output was number of granted patents. The use of patents as an output measure of technological performance or innovative activity is substantiated in the literature (Mansfield, 1968a; Schuyler, 1984; Shapiro, 1985; Smayling, 1987; Acs and Audretsch, 1989; and Griliches, 1990). Of the 111 companies returning questionnaires, 57 firms reported that they had received at least one patent over the period 1983 through 1988, or that in a ranking of importance of patents, copyrights, and trade secrets, they placed greater emphasis on patents. This subset of the total returns was used in the subsequent analysis and these firms are defined, for purposes of this study, as having a "patent-culture." Because the sample represents a convenience sample of a population in a limited geographic area, the generalizations drawn from the data will be restricted to the population of high technology patent-culture firms for the state of Connecticut.

The questionnaire respondents were the highest ranking technical managers of the firm. In some firms, this person was the Chief Executive Officer. The respondents provided information on the frequency of use and the importance of various rewards for motivating R&D personnel to produce protected patentable technology. Selection of the specific reward systems presented in the questionnaire were based on the theoretical implications provided by previous research. A listing of the rewards by reported frequency of use is given in Table I. Increased recognition was the most frequently used reward system by the sampled firms. Salary increases and small sum awards were also cited as generally used. Monetary and non-monetary reward systems were utilized approximately with the same frequency.[3]

TABLE I
Frequency of use of reward variables for individuals in patent-culture firms (M: monetary reward; NM: non-monetary reward)

Rewards	Means[a]	s.d.	n
Increased recognition (NM)	3.5	1.3	56
Salary (M)	3.2	1.4	56
Small Sum Awards ($100—$200) (M)	3.0	1.7	55
Accelerated Promotion (NM)	2.5	1.2	55
Patent Award Program (NM)	2.5	1.9	53
More autonomy (NM)	2.4	1.4	55
Variable bonuses based on issue of patent/copyright (M)	2.1	1.4	55
Informal or unpublicized award program (NM)	2.1	1.4	53
Fixed bonuses for milestone achievements (M)	2.0	1.4	53
Options in parent company equity (M)	1.9	1.5	53
Options in new venture (M)	1.9	0.6	53
Increased research budget (NM)	1.8	1.1	55
"Nobel-type" award program (NM)	1.7	1.4	53
Award for published papers (NM)	1.6	1.2	55
Large sum awards (about $50,000) (M)	1.3	0.8	54
Equity in new venture (M)	1.3	0.9	55
Royalty (M)	1.2	0.7	55
Participant's share of venture return (M)	1.1	0.6	54

[a] Means within a rating scale of 1 to 5, with 1 as "not at all" and 5 as "all the time"

Information was also obtained on the number of patents received during the years 1983 through 1988, and the number of employees and R&D budgets for the years 1984 through 1988. Average values for these variables are presented in Table II. The average number of patents awarded per firm per year was 16. The average number of employees and R&D investment was highly sensitive to the impact of a few large firms. Median values indicate half of the sampled firms had fewer than 200 employees and an R&D budget of less than $10,720,000. Therefore, the sampled firms were primarily small in terms of employment and had extensive R&D investment.

3. Model specification

The model utilized in this study is based in part on Mansfield's specification for innovation as a function of R&D expenditure and firm size (1968b). The specification may be expressed as:

$$\log(patents_i) = \beta_0 + \beta_1 \log S_i + \beta_2 RD_i. \quad (1)$$

The Mansfield equation, (1), is extended to include reward systems effects (Smayling, 1987). The following equation was estimated

$$\log\left(\sum_{i=1}^{6} patents/6\right) = \beta_0 + \\ + \beta_1 \log\left(\sum_{i=1}^{5} S_i/5\right) + \\ + \beta_2 \log\left(\sum_{i=1}^{5} RD_i/5\right) + \\ + \sum_{j=1}^{k} \beta_j \cdot RW_j \quad (2)$$

where i indicates values for 1984 through 1988 (1983 through 1988 for patents). S_i represents the size of the firm as measured by number of employees, RD_i is the value of R&D spending in thousands of dollars, and RW_j indicates the

TABLE II
Descriptive measure on patent-culture firms

	1984	1985	1986	1987	1988	5-year average
Number of Patents						
mean[a]	16.7	15.5	15.0	16.6	17.7	16.23
(Standard Deviation)	(32.4)	(31.4)	(28.9)	(29.8)	(30.7)	(30.0)
Number of Employees						
mean	1,266	1,303	1,296	1,321	1,295	1,325
median[b]	175	175	175	175	175	195
R&D Investment (in thousands)						
mean	$16,547	$16,264	$17,756	$18,231	$19,175	$16,547
median[b, c]	$900	$775	$650	$900	$26,000	$10,720

[a] The respondents were requested to check either 0 or a range of values for number of patents received. These were 1—5, 6—10, 11—50, 51—100, or 101—150. The midpoint of each range was used to calculate the mean. It was assumed that the actual number of patents received were randomly distributed throughout each range.
[b] The median is reported since the distribution is skewed due to the values reported by a few large firms.
[c] R&D investments were sensitive to the ranges available for response. These were $0—$99,999, $100,000—$299,999, $300,000—$499,999, $500,000—$799,999, $800,000—$999,999, $1 million—$50 million, and over $50 million.

ranking of importance for each of the k rewards ($k = 18$).

The dependent variable, average patents granted, was expressed as a logarithm (base 10) to correct for heteroscedasticity and non-linear effects.[4] Previous research on the correlation of firm size to innovation indicates that the relationship is non linear. Scherer (1965) found that medium size firms as defined by sales had proportionally greater inventions and innovations. Brock and Evans (1989) observed that firms with fewer than 500 employees generated more innovations per employee than large firms. Mansfield also employed the log specification (1968b).

Number of employees was selected as the measure of firm size rather than sales (Mansfield, 1968b) because the partial correlation of number of patents with sales, controlling for number of employees and R&D expenditure, was not significant ($r = -0.005$). Alternatively, the partial correlation of number of patents with number of employees was significant ($r = 0.29$) at the 5% level when controlling for sales and R&D expenditures. Therefore, once the effect of R&D investment is controlled, the number of employees, rather than sales, is related to patent output.

The average values of patents, firm size and R&D expenditure were used in the model to account for two effects. First, there is a lag between invention and the actual granting of a patent (Mansfield, 1968a and 1968b). Smayling (1987) assumed a three-year administrative lag from patent application to granting. Furthermore, it could be anticipated that an additional two years would be needed for initial development.[5] Secondly, research has shown that in high-technology firms, individual year investment in R&D is not important to higher levels of scientific output, but rather average level of expenditures over time (Chakrabarti, 1990). By averaging, it is assumed that the data represents a cross-sectional view during which a firm invested in research that resulted in patent output.

The model specifies a linear relationship between patents and the reward systems which are additive with each other.[6] Eighteen different types of reward systems were listed in the questionnaire (see Table I). The frequency of use for each of these reward systems was considered as the measure of RW_j in the equation. Frequency of use reflects the intensity to which the reward system is utilized by the firm, and previous research has suggested that the intensity of use is more important than the particular type of reward when comparing the effectiveness of a reward system to patent productivity (Ellis and Honig-Haftel, 1992).

Many of the reward systems are highly intercorrelated which prevents the inclusion of all the systems in a single regression model. Partial correlation of average patent output with each individual reward system, controlling for average firm size and average R&D expenditure, indicated that six reward systems were individually significantly related to patent output. Two of these were monetary rewards, variable bonuses based on the issue of a patent and large sum awards (≅ $50,000). Four represented non-monetary rewards, patent award programs, "Nobel-type award programs, informal or unpublicized award programs, and increased research budgets (Table III).

Initially a stepwise regression procedure was used to search for the set of reward systems which would yield the best fit. Informal award programs were shown to significantly improve the explanatory power of the model when only average employment and average R&D expenditure were included [the Mansfield equation (1)]. The results, appearing in column (2A) of Table IV, demonstrate that while informal award programs influence patent output, increases in either employment or R&D expenditure would have a greater impact. (Since the variables are measured in log values, the coefficients of the independent variables may be interpreted as elasticities. Thus a 1% increase in employment would generate a 4% increase in patent productivity.)

The next procedure tested the impact of each of the other non-monetary reward systems. None were found to improve the model. Subsequently the monetary systems variables were individually added to the equation. Only variable bonuses on issue of a patent increased the explanatory power of the model (Column (2B), Table IV). The addition of variable bonuses to the equation does not significantly alter the influence of the other independent variables. Informal awards, firm size, and R&D investment remained significant with similar coefficient values.

The result that variable bonuses and informal awards appear to both strongly relate to increased patenting activity by individual scientists may be inconsistent with some motivational findings.

TABLE III
Partial correlation of patent output with reward systems controlling for size of firm and R&D expenditure

Rewards	Pearson's r
Increased recognition (NM)	0.14
Salary (M)	0.02
Small sum awards ($100–$200) (M)	0.02
Accelerated promotion (NM)	0.00
Patent award program (NM)	0.24*
More autonomy (NM)	0.05
Variable bonuses based on issue of patent/copyright (M)	0.26**
Informal or unpublicized award program (NM)	0.26**
Fixed bonuses for milestone achievements (M)	−0.09
Options in parent company equity (M)	−0.03
Options in new venture (M)	0.04
Increased research budget (M)	0.21*
"Nobel-type" award program (NM)	0.20*
Award for published papers (NM)	0.04
Large sum awards (≅ $50,000) (M)	0.28**
Equity in new venture (M)	0.02
Royalty (M)	0.12
Participant's share of venture return (M)	0.04

* $p < 0.10$.
** $p < 0.05$.

DeCharms (1968) hypothesized that an extrinsic reward contingency would lower the perceived intrinsic reward received by the individual performing the task. While there were no direct measures of intrinsic motivation in this study, an underlying assumption was that high levels of intrinsic motivation in individual scientists are associated with increased levels of patenting activity. However, the results of this study suggest that more frequent use of extrinsic rewards, both monetary and non-monetary, increase patent output. This finding is supportive of others, who

TABLE IV
Regression results for patent-culture firms [dependent variable = log (average patents)]

Indepdnent variables	(1) β^a	(2A) β^a	(2B) β^a
Log (average employment)	0.36*** (0.08)	0.40*** (0.88)	0.45*** (0.88)
Log (average R&D)	0.21*** (0.06)	0.20*** (0.06)	0.14** (0.07)
Informal Awards		0.09** (0.04)	0.08* (0.04)
Variable Bonuses			0.09** (0.04)
Constant	−0.88*** (0.19)	−1.17*** (0.24)	−1.26*** (0.24)
Adj. R^2	0.58	0.59	0.62
F	37.04***	23.34***	20.11***
n	48	48	48
Partial F		5.39**	4.63**

[a] Standard errors in parenthesis.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

found no reduction in intrinsic motivation for rewarded individuals (Deci, 1972, 1972a; and Lepper, Greene and Nisbett, 1973). Additionally, the results support the theory that monetary rewards and non-monetary rewards provide additive motivation to individuals.

To investigate the influence of firm size on the relationship between reward systems and patent output, a subset of small firms were selected for analysis. Firms whose average five year employment was less than 500 were chosen.[7] The model was tested separately for the small-firm group.

In all equations, firm size and R&D expenditure are significantly related to patent output (Table V). Comparison of the results of equation (2A) and (2B), Table IV, of small firms to all firms, equation (2A) and (2B), Table V, indicate some interesting differences. Informal award programs do not significantly effect patent output in small firms. In fact, variable bonuses (a monetary reward) has much greater importance. Similarly, another monetary reward, large sum bonuses (≅ $50,000) entered the model significantly (2C). Furthermore, both variable bonuses and large sum awards impact patent output additively (2D). In small firms, the importance of non-cash rewards diminishes and monetary rewards increases.

Previous case study research has suggested that scientists employed in newly emerging small firms were more likely to be motivated by monetary rewards granting a stake in the company (Balkin and Gomez-Mejia, 1985 and 1987). In this subset of small firms, reward systems which motivate through equity interest awards (such as options in new ventures and options in parent company equity) were not important. (The small firms tested were not exclusively newly emerging. However, testing recency of formation by including dummy variables that indicate year of formation showed that firm age was not a significant factor.)

4. Discussion and conclusions

A model testing for the influence of firm size,

TABLE V
Regression results for small patent-culture firms [dependent variable = log (average patents)]

Dependent variables	(1) β^a	(2A) β^a	(2B) β^a	(2C) β^a	(2D) β^a
Log (average employment)	0.15** (0.07)	0.15* (0.08)	0.34*** (0.10)	0.19** (0.08)	0.32*** (0.10)
Log (average R&D)	0.16*** (0.04)	0.16*** (0.04)	0.09** (0.13)	0.16*** (0.04)	0.11 (0.04)
Informal Awards		0.01 (0.30)	−0.01 (0.04)	−0.01 (0.02)	−0.02 (0.03)
Variable Bonuses			0.12** (0.04)		0.09* (0.04)
Large Sum Awards				0.12** (0.04)	0.08* (0.04)
Constant	−1.37** (0.16)	−0.41** (0.21)	−0.77** (0.23)	−0.59*** (0.20)	−0.80*** (0.72)
Adj. R^2	0.43	0.36	0.49	0.49	0.54
F	13.01***	6.25***	7.74***	7.75***	7.62***
n	31	28	28	28	28
Partial F		0.33	7.24***	7.45***b	3.65*c

[a] Standard errors in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
[b] Measures change in F from Col. (2A) to Col. (2C).
[c] Measures change in F from Col. (2C) to Col. (2D).

R&D expenditure, and reward systems on patent output was estimated. The log of average R&D expenditure was shown to have a significant effect on patent productivity and firm size seems to be a critical determinant of the type of incentives important to patent output. Only monetary-based reward systems are found to be effective in increasing patent output in small firms. Conversely, when all patent-culture firms are considered, an incentive "mix" of monetary and non-monetary reward systems was observed to be significant.

There are several implications of the findings. First, sustained R&D expenditure is necessary to maintain patent output in high-technology companies. Secondly, in patent-culture firms, increased patent output depends on the specific type of reward system used. In general, informal award programs will have the most consistent impact on patent output. Variable bonus plans are also effective in both large and small firms. Thirdly, since the specific type of reward system is highly dependent on firm size, managers of small firms or of separate business units for corporate new ventures should structure the reward systems based primarily on monetary rewards such as variable bonuses or large sum payments. It is interesting to note that both of these awards represent delayed monetary payment, contingent upon final patent approval.

Many factors remain to be investigated. Because the sample consisted entirely of firms in one state, the findings might be dependent upon the industrial mix of high technology firms in that state. A more extended time-series study could help build a relevant model which would include additional variables that relate to time effects, such as growth curves and abbreviated time lags which are crucial to high-technology firms. Also a long-term study that captures time effects could help further understanding of the relevance of the output measure, patents, to the innovation process. Finally, studies of reward system practices for technical personnel in large non U.S.-owned high technology firms and cross-cultural comparative studies could provide insights into the extent that cultural conditioning creates predispositions to motivational reward variables.

Notes

[1] High-technology firms were defined as businesses that manufacture or develop high technology products (including operating units or independent subsidiaries of larger corporations and emerging growth companies). The following technologies were included: advanced materials, automation, biotechnology, chemicals, computer hardware, defense, energy, manufacturing, materials, medical, pharmaceuticals, phototonics, services, software, subassemblies and components, telecommunications, test and measurement, and transportation.

[2] A copy of the questionnaire may be obtained from the authors.

[3] Monetary rewards are salary, small-sum awards, variable bonuses, fixed bonuses, options in company, options in new ventures, large-sum awards, equity in new ventures, and royalties. The average frequency of use was 2.0 for monetary rewards and 2.13 for non-monetary.

[4] To avoid the problem associated with taking the log of zero, one-half unit (0.5) was added to the number of patents.

[5] Although Mansfield (1968b) found that the lag from invention to innovation was industry specific and ranged from 2 years to as long as 25 years, Birch (1990) indicates that this process is frequently much shorter in high-technology industries.

[6] Multiplicative effects were tested but these measures did not add significantly to the model.

[7] This definition is specified by Federal statute. Firms are defined as small based on one or more parameters used individually or in combination: number of employees, sales, and industry category. In high-technology industries, small companies are those with less than 500 employees. (Federal Register, Small Size Standards Rules and Regulations, 10 February 1992, SBA13CFR, Part 121, Vol 57 (27).)

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