Individual attitudes, organizational reward system and patenting performance of R&D scientists and engineers

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INDIVIDUAL ATTITUDES, ORGANIZATIONAL REWARD SYSTEM AND PATENTING PERFORMANCE OF R&D SCIENTISTS AND ENGINEERS

ABSTRACT

The interactive process perspective of innovation suggests that the innovation performance of individual R&D scientist or engineers (RSEs) is influenced by a nexus of interaction between individual attributes and organizational characteristics. While numerous empirical studies have investigated the effects of various sets of individual and organizational antecedents on the innovation performance of individuals, few have examined the interaction effects between the two. This paper addresses this gap in the literature by providing empirical evidence on the interactive effects of the attitudes of individual RSEs and the organizational reward system on the patenting performance of these RSEs.

Hyper-competitive technology markets and increasing global competition have inspired broad segments of industry to recognize that the ability of firms to innovate new products/services is critical for their long-term performance and survival in an unpredictable environment. Existing studies on innovation have focused on different levels of analysis such as the individual, organization, industry, and country. While recognizing that innovation can be examined at different levels of analysis, we confine our investigation in this study to the individuals. Past studies have shown that apart from innovation strategies such as acquisitions and imitations, most innovative activities are developed by individuals within the firm (Bolton, 1993; Cohen and Levinthal, 1990). Given that individuals are responsible for "developing, carrying, reacting to, and modifying ideas for innovation" (van de Ven, 1986: 592), the study of what motivates their innovative performance is essential.

The extant literature on individuals' innovative performance reveals a wide array of individual and organizational antecedent factors. Among the many individual antecedents that influence employees' innovative performance are attitudes (Williams, 2004), cognitive styles (Scott and Bruce, 1994), personality (Williams, 2004), and demographic characteristics such as age, education background, and prior R&D experience (Roberts, 1991; Rothwell, 1992). In terms of organizational antecedents, expenditure on R&D (Hadijimanolis, 2000), cooperation with external technology provider (Hadijimanolis, 2000), leader's influence (Hage and Dewar, 1973; Rothwell, 1992; Williams, 2004), and reward system (Eisenberger and Cameron, 1996; Janssen, 2000; Mumford, 2000) are commonly cited as factors that affect individuals' innovative performance.

Despite numerous studies on the influence of individual and organizational antecedents, little is known about the interaction effects between the two. In reality, employees' innovative performance is often interlinked with organizational structures and contextual influences. The rationale is that employees' innovative outputs are not exclusively determined by individuals themselves. Organizations' internal practices play a critical role in influencing employees' innovative performance. Indeed, the interactive process perspective theory supports the view that an employee's innovative performance is contingent upon individual-level antecedents and organizational characteristics (Edwards, 2000; Pierce and Delbecq, 1977:34; Slappendel, 1996; van de ven, 1986). While the innovation literature has acknowledged that the interactive process perspective theory provides the highest "theoretical mileage" (Slappendel, 1996), few empirical studies have modeled after this perspective. For those studies that have examined the innovation phenomena from the interactive process perspective, they were based on a qualitative methodology such as the case study (Edward, 2000; Isaksen and Remoe, 2001).

This study aims to fill this gap in the literature by empirically examining the interactive relationship between individuals' characteristics and organizations' attributes and its impact on individuals' innovative performance. In particular, we investigate how the effects of R&D scientists and engineers' attitudes toward R&D on their R&D performance are influenced by organizational reward systems.

LITERATURE REVIEW

Interactive Process Perspective

The innovation literature can be broadly classified into three theoretical perspectives: individualist perspective, structuralist perspective, and the interactive process perspective (Slappendel, 1996). The individualist perspective attributes innovations in organizations to individuals' characteristics such as age, gender, education level, attitudes, personality, and cognitive styles (Scott and Bruce, 1994), while the structuralist perspective explains innovation in terms of structural characteristics such as the organization's strategy, structure, resource availability, management attitudes and reward policies (Damanpour, 1991; Tushman and Nelson, 1990).

Given that both the individualist and structuralist perspectives partially explain the innovation phenomenon either at the individual or organization level, these perspectives do not provide a holistic depiction of the intricacies of innovative behavior (Giddens, 1995). A third stream of perspective known as the interactive process perspective (Edwards, 2000; Pierce and Delbecq, 1977:34; Slappendel, 1996; van de ven, 1986) essentially relates innovation activities to the interactions between individual determinants and organizational characteristics. The interactive process perspective emphasizes the importance of the interrelationship between individuals and organizations for innovations. It views the interconnection between individual and organizational characteristics as key innovation determinants.

Although conceptually, the interactive process perspective provides a broad rationalization of individuals' innovative performance (Edwards, 2000; Pierce and Delbecq, 1977:34; Slappendel, 1996; van de ven, 1986), there has so far been few empirical work that support this framework. With few exceptions of recent empirical papers (Edwards, 2000; Isaksen and Remoe, 2001), most existing studies have discussed the innovative performance of individuals from either the individualist or structuralist perspective. Our study aims to fill this empirical gap by investigating the interactive impact of the nexus between individual and organizational antecedents on individuals' innovative performance.

While there are a multitude of individual determinants known to have an influence on the innovative performance of individual scientists and engineers such as prior R&D experience and level of technical knowledge, the mindsets of the scientists and engineers, as measured through various attitudinal constructs, are also expected to influence their innovative performance. Similarly, there are copious amounts of organizational antecedents to innovative performance of R&D employees, and the organization's reward system is one of the many organizational factors that influence the innovative performance of research scientists and engineers. In our study, we focus on these two key antecedents i.e. individuals' attitudes and organizations' reward system.

Based on a sample of over 1,000 R&D personnel from diverse industries in Singapore, we specifically examined the interaction effects of individual attitudes and organizational rewards on the patenting intensity of R&D personnel (see Figure 1). While both the concepts of attitudes and rewards have been applied extensively in entrepreneurial (Kolvereid, 1996) and human resource management studies (Baer, Oldham, and Cummings, 2003; Fondas and Steward, 1994) respectively, there has been hitherto little attempt by researchers to apply these concepts in innovation-based studies.

Insert Figure 1 about here

Attitudes

The study of individual attitudes has a long history that has produced a voluminous body of literature focusing on the attitude-behavior relation (Ajzen, 2001). Ajzen's (1982) definition of attitude is probably one of the most popular in the literature. He defined attitude as the "predisposition to respond in a generally favorable or unfavorable manner with respect to the object of the attitude". Evidence in the extant literature indicate that attitudes are essential for understanding and predicting social behavior. The literature demonstrates that workplace attitudes manifest in various forms. Employees could exhibit attitudes toward various aspects of their jobs such as the work itself, benefits received, supervision, impediments to their work, or anything that might trigger positive or negative reactions (Liberman and Chaiken, 1996; Tosi and Mero, 2003:37).

The literature also suggest that the diverse attitudinal aspects of a job can be segregated into two overarching facets i.e. attitudes toward the work itself and attitudes toward the impediments to work. Attitudes toward the work itself or in an R&D context, attitudes toward R&D work tap the research scientists and engineers' level of job satisfaction, commitment and involvement, while attitudes toward the impediments to R&D work measure the research scientist and engineers' perceptions of the barriers or impediments inherent in R&D work. Recognizing that attitude in a work setting is a multi-faceted concept, we externalize attitudes toward R&D from two viewpoints i.e. attitudes toward R&D work and attitudes toward impediments to R&D work. The following discussion presents the reviews of both these dimensions of attitudes and its impact on individuals' innovative performance.

The attitude construct is ubiquitous in many fields of studies i.e. psychology, marketing, entrepreneurship and innovation to name a few. Although many studies have advocated the importance of attitudes for studying innovative performance, the focus has always been on the attitudes of top management (Davenport, Grimes and Davies, 1999; Hage and Dewar, 1973; Rothwell, 1992). In addition, despite the vast literature on the effects of job attitudes, few if any studies have studied the impact of attitudes within an R&D context. Given that R&D personnel are the ones who undertake R&D activities and "who will carry the innovation forward" (Frohman, 1999), it is important for research to investigate the potential influence of R&D employees' attitudes on their innovative performance.

Following Badawy (1988) who posited that positive attitudes of employees are important for the transformation of their creativity and innovative talents into actual innovative outputs, we postulate that positive attitudes of R&D employees are critical factors, which would contribute to their innovative performance. Past researches have ascertained that employees who are positive about their work are more likely to be satisfied with (Eisenberger, Cummings, Armeli and Lynch, 1997), involved with (O'Driscoll and Randall, 1999), and committed to their jobs (Randall, Cropanzano, Bormann and Birjulin, 1999). By the same token, research scientists and engineers with positive attitudes toward R&D work are more likely to be satisfied with, involved with, and committed to their jobs and will ultimately exert more efforts in R&D work. Previous research indicates that increased job efforts are likely to give rise to higher levels of job performance (Brown and Leigh, 1996).

Drawing on Thurstone's (1931) demarcation of attitude as affect for or against an object, we view that employees with positive attitudes toward R&D work have stronger affection for R&D and are therefore more motivated to participate in R&D related activities. Highly motivated individuals tend to assert more efforts in their work to achieve superior levels of performance, and in an R&D context, the patenting intensity of research scientists and engineers (RSEs) is a good indication of their achievements. A positive attitude and affection towards R&D work gives rise to job satisfaction and provides an impetus for R&D personnel to strive for technical excellence, possibly in the form of patent applications.

As opposed to negative attitudes that presumptively drive individuals away from the issue of focus, researchers have demonstrated that positive attitudes are likely to draw individuals toward the object of affection (Chen and Bargh, 1999). In an innovative environment, individuals with positive attitudes toward R&D work are presumably drawn towards research and development, and have greater tendency to toil harder to accomplish success in their R&D work. Researchers have also established the relationship between employees' attitudes and productivity (Patterson, West, Lawthom and Nickell., 1997), and the argument is that the stronger employees' affections are for their jobs, the higher would be their productivity levels. The same can be said of employees in a R&D setting, where positive affections for R&D work would give rise to higher levels of innovative outputs.

Like in all creative occupations, the ability to innovate and create new concepts is an important aspect of a R&D technologist's job scope. Human minds are regarded as the cognitive key to effective solutions of innovative problems and generations of new ideas (Ford, 1996). Positive attitudes literally condition human minds to be more receptive to new ideas and creative ways of implementing technological solutions. R&D personnel who are positive about their work are more likely to persevere in their search for new and varied technologies, and therefore, have greater tendency to perform better in terms of intellectual achievements.

Thus, we propose the following hypothesis.

H1: R&D personnel with positive attitudes toward R&D work have greater likelihood of achieving higher levels of patenting intensity.

Due to the challenging and competitive nature of research environment, it is not uncommon for R&D employees to experience difficulties in their pursuits of innovation-related activities. The prevalence of potential barriers to innovation tends to constrain the capability of research scientists to discover and invent new patentable ideas (Easingwood, 1986; Freel, 2000). Problems such as inadequate communication with employees from other functional departments (Brown and Eisenhardt, 1995) and lack of top management support (Tidd, Bessant and Pavitt,

1997) are commonly cited as typical impediments to R&D. Researchers often expressed that poor mentoring and supervision as well as inadequate provisions of resources (human and financial) by top management hinder their quest for innovative excellence. It is evident that existing studies have recognized the existence of barriers to innovation but we argue that whether these impediments impede the innovative achievements of R&D personnel would depend on their attitudes toward the impediments.

The idea that attitudes toward the impediments to R&D work potentially influence the innovative performance of research scientists is a largely neglected area of research. As mentioned in the preceding discussion, R&D personnel could develop attitudes toward various aspects of R&D work (Liberman and Chaiken, 1996; Tosi and Mero, 2003:37). For example, in a R&D context, the attitudinal issue of R&D could embody both attitudes toward R&D work and attitudes toward impediments to R&D work. It is therefore of interest to researchers to analyze the attitudinal issue of R&D from a holistic sense i.e. general R&D attitudes and impediment attitudes. The impact of research personnel's perceptions of the impediments to R&D on their innovative output is particularly relevant for innovation research because their attitudes toward the barriers to R&D determine their ability to adapt to the environment (Eagly and Chaiken, 1998). The logic is that individuals with positive attitudes toward the impediments to R&D work would adapt better to the R&D environment, and consequently, would be more likely to outperform individuals who hold unfavorable attitudes.

We affirm that both general attitudes and impediment attitudes play a fundamental role in our understanding of R&D personnel's innovative performance, specifically their patenting performance. R&D employees might have positive attitudes toward R&D work in general but if they perceive the presence of obstacles, which might limit or hinder their innovative progress, they would be likely to retract their involvement in the R&D work. As explained by the theory of reasoned action (Ajzen and Fishbein, 1980), people act in accordance with their perceptions and assessments of the situation. One would naturally expect R&D employees with unfavorable perceptions of the impediments to R&D work to be less incline to generate novel ideas for patenting.

Based on the above discussion, we propose that:

> *H2: R&D personnel with positive attitudes toward impediments to R&D work have greater likelihood of achieving higher levels of patenting intensity.*

Attitudes and Organizational Reward System

Existing research has established the importance of a broad variety of personal characteristics and contextual factors for individuals' innovation and creativity performance (Baer et al., 2003; Janssen, 2004; Oldham and Cummings, 1996). Yet, while numerous studies have individually identified the predictive influence of personal characteristics and contextual factors on individuals' innovative performance, few of these prior studies have explicitly tested their interaction effects in the context of innovation. Indeed, Ettlie and O'Keefe (1982) suggested that researchers should consider the moderating influence of contextual factors when examining the attitudinal-innovation relationship. Their call is in line with earlier works by Rokeach and Kliejunas (1972), where behavior towards an object is hypothesized as a function of attitude towards the object under different contextual conditions. Based on this line of argument, we argue that the patenting performance of R&D personnel is a function of their attitudes toward

R&D work and their attitudes toward the impediments to R&D work under the contextual influence of the firm's reward system.

The idea that the firm's reward system is a significant situational factor that influences employees' job performance has long been accepted in the motivation literature (Wiersma, 1992; Wiley, 1997). Commentators in the field have shown that rewards, particularly extrinsic rewards are powerful factors impelling motivation and job performance (Taylor, 1967; Wiley, 1997). In a similar vein, researchers in the technology domain have observed the positive relationship between a supportive reward system and motivation of technologists in information technology companies (Sankar, Ledbetter, Snyder, Roberts, McCreary and Boyles, 1991). Notable volumes of studies on employees' work performance including laboratory experiments and field interventions have shown that improvements in external contingencies such as reward structures have resulted in subsequent rise in employees' motivation and work performance (Hamner and Hamner, 1976; Komaki and Frederiksen, 1982). Specifically, Abbey and Dickson (1983) found that an individual's innovative performance is influenced by perceived attractiveness of the firm's reward system and perceived willingness of the organization in supporting innovative work.

The contextual impact of rewards on employees' performance is also widely applied in the creativity literature. Given that patents, a form of technological innovation are characterized as radical and innovative ideas that could make a major change in a product or procedure, they are accepted as an exemplification of creative performance (Oldham and Cummings, 1996). As Scherer and Ross (1990: 615) precisely expressed, 'Technical innovations do not fall like manna from heaven because they require effort, especially – the *creative* labor of invention'. Thus, it is justifiable for us to draw on studies from the creativity domain to support our argument on the joint effects of attitudes and rewards on individuals' patenting performance.

Many studies in the creativity literature have shown that the firm's reward system plays a critical role in motivating employees to perform creatively (Eisenberger, 1992; Eisenberger, Armeli and Pretz, 1998; Eisenberger and Rhoades, 2001). As an effort to stimulate employees' creativity, many managers have used extrinsic rewards (e.g. monetary incentives and recognition) to motivate their employees (Fairbank and Williams, 2001; Van Dijk and Van den Ende, 2002). While empirical research have shown that extrinsic rewards help enhance individuals' creative performance, the literature is still divided when it comes to its effects on individuals' creativity (Baer et al., 2003). For example, Baer et al. (2003) reported that some studies demonstrated negative (Amabile, Hennessey and Grossman, 1986) or weak effects (Joussemet and Koestner, 1999) of extrinsic rewards on creativity.

One explanation for the inconclusive results involves the aforementioned concept of individuals' attitudes. As postulated in the preceding section, individuals are likely to innovate i.e. develop patents when they have positive attitudes toward R&D work and toward the impediments to R&D work. The reasoning is that individuals with brighter outlooks tend to experience positive mood states such as enthusiasm and excitement, which would inspire them to persist in the face of challenges and barriers. Following the positive relation between attitudes and innovative performance, the mixed and incongruent reward-creativity results observed in earlier studies might be due to the fact that rewards, an organizational contextual factor do not influence creativity directly. Based on the interactive process perspective that postulates individuals' innovative performance as a complex person-situation interaction (Edwards, 2000;

Pierce and Delbecq, 1977:34; Slappendel, 1996; van de ven, 1986), we posit that rewards interact with attitudes to influence individuals' creativity.

The previous section on attitudes rationalized that R&D employees who are positive about their work are likely to take risks, stay more focused, and work longer on an idea or problem, which would probably lead to higher patenting output. In their persistence on the job, they are also likely to evaluate the potential rewards offered by their organizations. According to the social exchange theory (Blau, 1964), employees often evaluate the exchange relationship with the organization in terms of the efforts exerted toward the job and the potential rewards received from these efforts. Employees with positive attitudes would devote more efforts in their work, and if their organizations reward them fairly in the exchange process, they are likely to continue their investments of skills, time, and efforts (Janssen, 2004). This would ultimately translate to higher levels of job performance. In essence, the social exchange theory implies that positive attitudes enhance the innovative performance of employees when firms' reward systems are supportive of innovation.

In this study, we argue that the extent to which employees perform innovatively in response to positive attitudes toward R&D work and positive attitudes toward the impediments to R&D work is contingent upon the supportiveness of organizations' reward systems. Organizations' reward systems that are supportive motivate employees to adapt their positive attitudes toward R&D work and positive attitudes toward impediments to R&D work to maximize patenting output. On the other hand, unfavorable rewards inhibit employees' desire to act on their positive attitudes to achieve high levels of performance as they are likely to be discouraged by the unfair returns from the social exchange relationship with the organizations (Adams, 1963; Blau, 1964).

In sum, our study focuses on organizational rewards as the interacting mechanisms influencing the effects of attitudes on individuals' patenting intensity.

On the basis of the aforementioned arguments, we hypothesize that:

H3: Organizations' reward systems moderate the relationship between individuals' attitudes toward R&D work and patenting intensity: among individuals with positive attitudes toward R&D work, the more supportive organizations' reward systems are, the higher the intensity for patenting.

H4: Organizations' reward systems moderate the relationship between individuals' attitudes toward the impediments to R&D work and patenting intensity: among individuals with positive attitudes toward the impediments to R&D, the more supportive organizations' reward systems are, the higher the intensity for patenting.

Innovative Performance

Among the various measures of individual innovative performance e.g. journal publications, number of patents granted etc, patenting is accepted as the most objective and precise measure of individual innovative performance because it is specific and relevant to the individual concerned. Besides, existing studies in the literature have recognized patents as major drivers of innovation, without which there would be no innovation (Bain, Mann and Pirola-Merlo, 2001; Bommer and Jalajas, 1999). Consistent with studies that have applied patents as a proxy for technological innovation performance (Pavitt, 1985; Patel and Pavitt, 1995), the number of patents applied for or granted to the individuals is used in this study as an indicator of the level of innovation intensity.

METHODS

Data Source

Data for this study were drawn from the 1996 National Survey of Research and Development Personnel in Singapore.[1,2] Questionnaires were mailed to R&D personnel of various organizations and a total of 1,390 usable questionnaires were generated from the survey. Out of the 1,390 respondents, over 70% are male with the majority (65%) in their 30's and 40's. About 66% of the respondents are of ethnic Chinese background and 31% have a postgraduate degree (Masters and above). Electronic systems, manufacturing technology, and material technology account for close to 50% of the technological areas that the respondents represent. A majority (69%) reported that they have been working in R&D for at least 5 years and almost half (45%) stated that they are currently involved in product conception work.

Although this study is based on a sample of R&D personnel in Singapore, the results are generalizable to other developed countries particularly among OECD countries. A cosmopolitan country with high influx of foreign multinational corporations (MNCs), Singapore is comparable to other developed countries like the US and EU. The presence of MNCs is a significant stimulant for indigenous technological development and R&D advancement (Hobday, 1995). Indeed, empirical studies on national innovation reported that Singapore achieved a significantly rapid high-tech industrial growth in comparison to other developing countries (Wong, 1995). In

[1] Apart from a report that was submitted to the government agency that commissioned the survey, this study represents one of the first attempts to analyze the survey data for a research purpose.
[2] Given that the measures used were not developed specifically for this study, there should not be a question on its validity.

terms of R&D expenditure for service businesses, Singapore is comparatively ranked with other OECD countries (OECD, 2001).

Measures

Appendix A describes the items, scales, and response formats used in measuring the independent and dependent variables. We conducted a factor analysis to test whether the items of the independent variables measure more than one construct. Results of the factor analysis (Table I) indicate that the items measure only the construct of relevance, and there are no other underlying constructs in the independent variables.

Insert Table I about here

Dependent Variable

Patents have been used as proxies for innovation in a number of studies (Balkin, Markman and Gomez-Mejia, 2000; Benner and Tushman, 2002; Bommer and Jalajas, 1999). The dependent variable, *patenting intensity* measures the cumulative number of patents the respondent[3] has applied for or been granted over the years.[4] A related but less precise measure of patenting, patenting propensity i.e. a dichotomous measure of the respondent's likelihood of patenting is also used.

[3] We obtained the cumulative number of patents that the R&D personnel has applied for or been granted over the years from the Intellectual Property Office of Singapore (IPOS) and the United States Patent and Trademark Office (USPTO).

[4] While recognizing that there are potential differences between patents filed and patents granted, we were not able to separate between the two in our analysis. Due to the relatively smaller number of patents granted as compared to patents filed, we had to combine both for our analysis. However, Pearson correlation indicates that patents filed and patents granted are positively correlated ($r = 0.492$; $p < 0.01$).

Independent Variables

a) Attitudes toward R&D work

This variable is measured using a 5-point Likert scale with eight items ($\alpha = 0.87$) that seek the respondents' i.e. R&D personnel level of agreement on statements pertaining to R&D work (please refer to Appendix A for items). The items for this variable were adapted from various studies, namely Cammann, Fichman, Henkins and Klesh (1979), Janssen (2000), Kanungo (1982), Meyer, Allen and Smith (1993) and Sims and Szilagyis (1975).

b) Attitudes toward impediments to R&D work

This variable is measured using a 5-point Likert scale with twelve items ($\alpha = 0.82$) that elicit the respondents' i.e. R&D personnel level of agreement on statements concerning the impediments to R&D work. Past studies on the impediments to innovation have applied similar Likert-scale assessments to ascertain respondents' attitudes toward the impediments or barriers to innovation (Calof, 1995; Frenkel, 2003; Hadjimanolis, 1999; Hall and Bagchi-Sen, 2002).

c) Organizational Reward Systems

Consistent with calls for researchers to include non-salary measures when examining the impact of the firm's reward system on an individual's innovative performance (Balkin and Gomez-Mejia, 1984; Jain and Triandis, 1997), we asked our respondents i.e. HR personnel[5] to rate their perceptions on a set of salary and non-salary measures. A 5-point Likert scale with five items ($\alpha = 0.79$) was used to measure the HR personnel's perceptions of the firms' reward system.

[5] An HR employee who holds at least an executive position from the R&D personnel's organization was asked to respond to the questions on the organization's reward system.

Control Variables

All the items related to the control variables were answered by the R&D personnel.

a) Technology sectors

Different industrial sectors and technological areas provide varying degrees of technological opportunities and appropriability regimes resulting in systematic variations in patenting intensity across different technological sectors (Cohen and Levin, 1989; Rothwell, 1992; Wolfe, 1994). We operationalized industrial sectors as manufacturing v. service and used electronic systems, manufacturing technology, materials/chemicals, medical science, and IT as technological area dummies with microelectronics as the reference category.[6]

b) Ethnicity

In a large sample study of the relationship between gender/ethnic background and creativity, Cordero, Ditomaso and Farris (1996) found that male R&D professionals and whites (majority race) were more likely to apply for or been granted patents. They also rated blacks (minority race) as the least innovative among the various ethnic groups. Given that Chinese is the majority race in Singapore, we operationalized respondents' ethnic background as Chinese v. non-Chinese in our study.

c) Prior R&D Experience and Age

Prior R&D experience helps enhance individuals' innovative performance as the experience gained over the years builds up their expertise in a particular product/process area and contributes to the individual's learning curve and ability to innovate (Rothwell, 1992). On the other hand, there are two possible effects of age on the individual's patenting performance. First, as a proxy for work experience, we would expect older individuals to perform better than their

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[6] A dummy, called 'others' was also used to represent technological areas such as Biotechnology, Environment Technology, and Food and Agrotechnology.

younger contemporaries. Second, age could have an inverted U-shaped relationship with innovative productivity (Roberts, 1991)[7], but for those who have worked longer in R&D, the expected positive relationship between age and innovative performance still prevails.[8]

d) Product-oriented work vs. Non-product oriented work

The nature of the individual's job plays a significant role in influencing patenting intensity. Those who engaged in product-oriented work are more likely to generate innovative outputs that are appropriate and applicable for patenting as compared to those who work in non-product oriented work (Roberts, 1991). A dichotomous measure, product-oriented vs. non-product oriented is used to represent this variable. We asked the respondents to indicate if their current work involves the conception and/or creation of new products.

e) Level of education

Education is well cited as an important factor for innovation (Cordero et al., 1996; Romijn and Albalajejo, 2002; Rothwell, 1992). The presence of university-trained engineers has been found to increase the innovative capability of firms (Romijn and Albalajejo, 2002). Higher degrees such as a PhD bring higher prestige and status, which make it easier for individuals to work on innovative projects that are more likely to lead to patenting (Cordero et al., 1996). Higher education i.e. postgraduate education is also a proxy for the level of advanced technical knowledge. As Roberts (1991:59) eloquently put it: "higher degree such as doctoral education provides an entry card for competitive know-how".

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[7] Roberts (1991) found that an individual's technical ability usually peaks between ages 30-40 and declines thereafter.

[8] Our measure of individuals' patenting intensity is based on the cumulative output of patents over the years and not on the rate of increase over a specific period.

Data Analysis

The hypotheses in our study not only postulate that positive attitudes toward R&D work and attitudes toward impediments to R&D work lead to greater patenting intensity but that they are moderated by the firm's reward system. Therefore, the key is to examine whether attitudes toward R&D work and impediments to R&D work positively and significantly interacts with firm's reward system to cause a differential impact on patenting intensity. We used hierarchical Tobit regression to test the hypotheses. To determine the robustness of our results, we also used Logistic regression to examine the impact of the predictors on patenting propensity i.e. a dichotomous measure of whether the respondent has applied for or been granted patents.

Given that all the data were self-reported, we computed Harmon's one factor test (Podsakoff and Organ 1986) to investigate whether common method bias was present. Eight factors with eigenvalues greater than one were extracted from the items used in this study. These factors accounted for 77% of the total variance while the first factor accounted for 13% of the variance. Since no single factor accounted for the majority of the variance, and the items measuring the dependent and independent constructs loaded on different factors, we concluded that common method bias is not solely responsible for the results of this study.

Subgroup Analysis

To test the robustness of the overall findings, we performed a subgroup analysis based on high-low patenting intensity. If the hypothesized predictors are true, the coefficients for the interaction terms should be higher and statistically significant for high patenters than for low patenters. We divided the sample into three parts by computing the cumulative distribution of patents. The upper-third and lower-third-percentile patents were defined as high and low patenters respectively. Further support for the results is obtained if the regression analyzes show that the interaction coefficients are comparatively higher and significant in the case of high patenters.

RESULTS

Table II shows the descriptive statistics and correlation values for the variables in this study. As observed, we found that patenting is moderately correlated with attitudes toward R&D work ($r = 0.38$, $p<0.01$), attitudes toward the impediments to R&D work ($r = 0.35$, $p<0.01$), gender ($r = 009$, $p<0.01$), and R&D experience ($r = 0.22$, $p<0.01$). Patenting is also correlated with other control variables although not as strong and significant as compared with the attitudinal variables. In addition, the results showed that the three explanatory variables are not significantly correlated, indicating that they are indeed distinctly independent constructs. Overall, the control variables did not show an unusual degree of correlation with the dependent variable, and we found that the problems of multicollinearity did not interfere with the interpretation of results for this study.

"Insert Table II about here"

Table III provides the results of the hierarchical Tobit regression. As observed in model 1 that consists of the control variables, both postgraduate degree and R&D experience are significantly related to patenting with coefficients of 1.20 and 1.76 respectively ($p< 0.01$). Industrial sector (B = 1.52), and technology areas such as electronic system (B = 0.31) and information technology (B = 0.87) are related less significantly ($p< 0.05$) with patenting. We included the attitudinal variables i.e. attitudes toward R&D work and attitudes toward the impediments toward R&D work, and firm's reward system in Model 2. While both the attitudinal variables with coefficients of 1.86 ($p<0.01$) and 1.62 ($p<0.01$) are significantly related with patenting, firm's reward system is marginally significant at 10% with a coefficient of 1.34. Nagelkerke R^2 increased from 0.09 to 0.16 with a model chi-square of -995.01 ($p<0.01$). The regression results in Model 2 provide support for both hypotheses 1 and 2.

"Insert Table III about here"

Models 3 and 4 show the results of the interactions between firm's reward system and attitudes. The main effect of reward system (B = 1.54) in Model 3 has a weak significance, suggesting that there is no one-to-one relationship between the firm's reward system and patenting intensity. However, its interaction effects are higher and significant (B = 1.88, $p < 0.01$), indicating its moderating influence on the relationship between attitudes towards R&D work and patenting intensity. That is, a more positive attitude towards R&D work would have a greater impact on patenting intensity when firm's reward system is supportive. Hypothesis 3 is therefore supported.

Similarly, the main effect of reward system in Model 4 is relatively low (B = 1.45; $p < 0.10$) as compared to its moderating influence in the attitudes toward the impediments to R&D work and patenting intensity relationship. The interaction between reward system and attitudes toward the impediments to R&D work is in the hypothesized direction and is statistically significant (B = 1.63; $p < 0.01$), providing support for hypothesis 4. Employees with a positive attitude towards the impediments to R&D work would produce higher number of patents when the firm's reward system is supportive of innovative pursuits. To further analyze the interaction effects, we included both the interaction terms in Model 5, and the results revealed that reward system positively moderates both the relationship between attitudes toward R&D work (B = 1.95; p <

0.01) and impediments to R&D work ($B = 1.77$; $p < 0.01$) and patenting intensity. Both the interaction terms accounted for significant increments in the variance in patenting intensity ($\Delta R^2 = .06$).

Comparatively, the results of the logistic regressions revealed similar findings to the Tobit regressions. Both the attitudinal variables had significant positive relationships with patenting propensity ($B = 1.85$, $p < 0.001$ and $B = 1.70$, $p < 0.001$ respectively). Reward system on the other hand was marginally significant ($B = 0.82$, $p < 0.05$). Hypotheses 3 and 4 were also supported by the results of the logistic regression. Both interaction terms were significant at the 1% level ($B = 1.85$ and 1.90).

The results of the sub-group analysis reported in Table IV provided additional support for both hypotheses 3 and 4. The interaction coefficient for attitudes toward R&D work and organizational reward system of high patenters is higher and significant as compared to low patenters, suggesting that higher patenting results when there are positive attitudes toward R&D work and a supportive firm's reward system. For high patenters, the interaction coefficient for attitudes toward the impediments to R&D work and reward system is significantly higher, suggesting that the effect of reward system on patenting intensity is contingent on employees' attitudes toward the impediments to R&D work.

"Insert Table IV about here"

Eliminating Potentially Competing Hypotheses (CH)

With reference to the research model in Figure 1, we recognize that the results might be influenced by two competing hypotheses. First, the direct effects of reward system on attitudes toward R&D and the mediating role of attitudes toward R&D (CH1). Second, the direct effects of reward system on patenting intensity (CH2). Our analyses showed that both these competing hypotheses were rejected. The following section provides a discussion of the results.

Direct Effects of Organizational Reward System on Attitudes toward R&D and the Mediating Role of Attitudes toward R&D (CH1)

To ascertain if attitudes toward R&D work mediate the effects of reward system on patenting intensity, three conditions have to be met (Baron and Kenny, 1986). The first condition is that reward system affects attitudes toward R&D work. In a separate multiple regression analysis, we found that reward system is not significant in its impact on attitudes toward R&D work ($B = 0.93$, $p < 0.18$). The second condition is that reward system affects patenting intensity. In a regression model where only reward system is entered along with other control variables, we found that the former is statistically non-significant on patenting intensity ($B = 0.73$, $p < 0.29$).

The third condition requires a significant effect of attitudes toward R&D work on patenting intensity, while the relationship between reward system and patenting intensity estimated in the same equation is weaker than that found under the second condition [i.e. strength of beta (B) should be smaller than 0.73 and statistically non-significant]. Test of the third condition revealed that reward system is in fact larger ($B = 1.34$) and statistically stronger ($p < 0.10$) than the test results of the second condition ($B = 0.73$, $p < 0.29$). Collectively, we found that all three conditions for demonstrating the potential presence of mediating effects of attitudes toward R&D are not satisfied, thus ruling out the possible presence of competing hypothesis 1 (CH1). Similar tests were also conducted for attitudes toward impediments to R&D work and the results obtained were identical to attitudes toward R&D work.

Direct Effects of Reward System on Patenting Intensity (CH2)

It is evident from the results presented in Models 3, 4 and 5 (Table III) that the direct impact of the firm's reward system on an individual's patenting intensity is weak. Organizational reward system has a significantly stronger effect on patenting intensity through its interactions with R&D attitudes i.e. attitudes toward R&D work and attitudes toward impediments to R&D work, thus eliminating the presence of competing hypotheses 2 (CH2).

DISCUSSION

The primary aim of our study was to investigate how organization's reward system influence the relationship between attitudes and individuals' innovative performance. Drawing on the interactive process perspective theory, it was hypothesized that the extent to which R&D personnel's attitudes toward R&D work and impediments to R&D work affect their innovative performance is contingent upon the supportiveness of the firm's reward system. Our empirical results are consistent with the prediction of this theory.

From a practical standpoint, the results suggest that management should consider both personal and contextual factors to increase individuals' innovative performance at work. Essentially, an individualized approach to the management of employees' technological performance is required to achieve maximum creative output from individuals. Organizations should discerningly offer extrinsic rewards to those who are likely to benefit from them i.e. employees with positive attitudes toward their work. Given that employees with positive attitudes are likely to generate more creative outputs, rewards should only be targeted at specific employees with the right job attitudes. This is because rewards that are channeled to employees irrespective of their attitudes would be largely unsuccessful in encouraging creative output.

Therefore, it would be beneficial for managers to regularly assess the attitudes of employees and to selectively administer rewards on the basis of this assessment (Baer et al., 2003). The present results provide clear support for a contingency approach to rewarding employees with the appropriate attitudes toward R&D work.

The core of our findings is that if R&D employees with positive attitudes toward R&D work and the impediments to R&D work operate in an environment that positively rewards employees for innovative pursuits, their patenting achievements are likely to be higher, *ceteris paribus.* This interpretation provides management with opportunities for intervention as they predominantly have control over the implementations of reward systems in organizations, and thus, are able to influence employees' innovation performance. As Leboeuf (1985) notably commented, "If you want to change employees' behavior and motivate them to improve their performance, you must influence their perceptions of how you reward them for their behavior and performance." Consequently, one effective way to achieve this is to compensate employees who are positive about their work with extrinsic rewards for their innovative achievements. The results of this study showed that this strategy is particularly important for employees who are positive about their work and the impediments to their work. In addition, management may also consider using attitudes toward R&D work and impediments associated with R&D work as recruitment criteria, and put in place organizational reward system that attracts such people to the organization.

In terms of theory development, our study provides empirical support for the interactive process perspective theory (Slappendel, 1996) that postulates the innovation performance of individual R&D scientist or engineers (RSEs) is influenced by a nexus of interaction between individual attributes and organizational characteristics. Organizational practices such as reward systems by themselves have only a weak direct effect on individuals' performance. Rewards, particularly extrinsic rewards are less effective as a performance motivating tool when administered independently. The common view that organizational rewards by themselves can inspire all employees to improve their performance is questionable. Our findings provide corroborative evidence that rewards would only make an impact on employees' performance if these employees have favorable attitudes toward the job. The premise that a 'one size fits all' reward system could enhance employees' performance is weak. Existing reward theories (e.g. Hertzberg, 1966; Skinner, 1953; Vroom, 1964) have largely neglected the attitudinal influence when theorizing the relationship between rewards and employees' performance. Theoretically, we found that the interactive process perspective theory of innovation, which integrates organizational rewards with employees' attitudes, provides a well-substantiated explanation of employees' innovation performance. Essentially, our findings imply that organizational factors such as firms' reward systems do not by themselves promote innovative efforts among employees; instead, their effectiveness is largely contingent upon individual-level determinants such as attitudes.

A second contribution of our study is to highlight the perception of impediments as an integral component construct of individuals' attitudes toward their work, a facet that we believe has been neglected in the existing attitudinal literature. The concept of impediment attitudes is related to cognitive theory in the sense that it emphasizes that employees' self-perceptions can strongly influence the ways in which they would interpret the level of difficulty in performing a task and hence, their tendency to perform it. An important implication of impediment attitudes is that because people avoid challenges or barriers that they perceive would impede their job performance, management need to first identify what these pre-conceptions are, before introducing their organizational rewards system.

A couple of directions for future research are warranted from the findings of this study. Firstly, while the results are generally consistent with our hypotheses, we were not able to absolutely rule out the existence of bidirectional causality. Longitudinal or experiment-based studies are needed to provide absolute evidence of the proposed causality. Secondly, we have applied only the concept of extrinsic rewards in this study, and did not control for intrinsic rewards. Given the complexity of the relationships between rewards and patenting performance, future research should apply a mix of rewards, both intrinsic (e.g. pride, growth, and simulation) and extrinsic (e.g. money, status, and promotion) to examine the relationships between each type of reward on the attitudinal-innovation equation.

CONCLUSION

This paper empirically examined the interactive process i.e. person-situation perspective of innovation. Specifically, we investigated the interactive effects of individual attitudes and organizational rewards on R&D employees' patenting performance. We found support for our hypotheses that R&D personnel with positive attitudes toward R&D work and positive attitudes toward the impediments to R&D work have greater likelihood of achieving higher levels of patenting intensity. In addition, these individual antecedent factors have a positive interaction with the organizational reward system.

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APPENDIX 1

Questionnaire measures

A.1. Attitudes toward R&D

Please circle the number on the scale that best reflects how you feel about being involved in R&D work (1: Strongly Disagree; 3: Neutral; 5: Strongly Agree).

1. I have regrets about being a research scientist/research engineer.
2. I see long term prospects in a R&D career.
3. All in all, I am satisfied with my current job.
4. I am enthusiastic about performing research and its related tasks.
5. I sometimes think of leaving R&D work completely.
6. I am satisfied with my career in R&D.
7. I am proud to be involved in R&D work.
8. I often think of quitting my job.

A.2. Attitudes toward impediments to R&D

To what extent do you agree with the following statements regarding factors limiting your R&D work? (1: Strongly Disagree; 3: Neutral; 5: Strongly Agree).

1. Inadequate time allotted to R&D work.
2. Inadequate coaching and supervision.
3. Inadequate market research and customer feedback.
4. Inadequate technical support.
5. Lack of clear strategic directions provided by the organization.

6. Ineffective communication between R&D and manufacturing.
7. Inadequate R&D evaluation criteria.
8. Too much control by management.
9. Inadequate training for the job.
10. Ineffective communication between R&D and marketing.
11. Lack of R&D project management skill.
12. Inadequate facilities and equipment.

A.3. Organizational reward system

Indicate the extent to which you agree or disagree with the following statements (1: Strongly Disagree; 3: Neutral; 5: Strongly Agree).

1. The criteria for technical promotions are clear in this organization.
2. The career path for technical personnel in this organization is adequate.
3. Performance reviews for technical personnel in this organization are done well.
4. The criteria for promotions are clear in this organization.
5. R&D employees are fairly rewarded in this organization.

A.4. Patenting Propensity/Intensity

Please indicate if you have been involved in R&D that resulted in the application/granting of:

Patents: ☐ No ☐ Yes

Table I

Factor analysis for the composite scores of each independent variable

		Bartlett's test of sphericity [2]		Factors with eigenvalue > 1	
Variable	KMO[1]	Value	Sig.	Factor	Eigenvalue
Attitudes toward R&D work	0.88	783	0.000	1	3.95
Attitudes toward impediments to R&D work	0.85	619	0.000	1	3.48
Organizational reward system	0.90	642	0.000	1	3.77

[1] KMO, the Kaiser-Meyer-Olkin measure of sampling adequacy is an index for comparing the magnitudes of the observed correlation of the composites to the magnitudes of the partial correlation coefficients. KMO values that are close to 1 indicate that there is a high degree of common variance among the items and that the items measure a single construct.

[2] Bartlett's sphericity test is used to test whether the correlation matrix of the composites is an identity matrix, i.e. all diagonal items are 1 and all off-diagonal items are 0. The large values of the test statistics and small significance level indicate that the underlying population correlation matrix of the respective composites is an identity matrix.

TABLE II

Means, Standard Deviations, and Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dependent variable																		
1. Patenting Intensity (Actual number)	1.00																	
Control variables																		
2. Manufacturing vs. Service Sector	0.15*	1.00																
3. Electronic Systems	0.11*	0.01	1.00															
4. Manufacturing Technology	0.12*	0.00	0.02	1.00														
5. Materials/Chemical Technology	0.22†	0.02	0.00	0.03	1.00													
6. Medical Sciences	-0.20†	0.00	0.02	0.04	0.03	1.00												
7. Information Technology	0.18*	0.00	0.01	0.01	0.01	0.01	1.00											
8. Microelectronics	0.17*	0.01	0.01	0.03	0.02	0.00	0.05	1.00										
9. Others[a]	0.08†	-0.09†	0.01	0.02	0.01	0.04	0.02	0.03	1.00									
10. Gender (Male = 1)	0.09**	0.08	0.12†	0.09†	0.12*	0.13	0.09	0.12	0.13	1.00								
11. Ethnic Group (Chinese vs. non-Chinese)	0.15*	0.11	0.10	0.07	0.08	0.05	0.03	0.06	0.04	0.15	1.00							
12. Age	0.19*	0.13	0.12	0.10	0.13	0.11	0.12	0.14	0.15†	0.05	0.10	1.00						
13. Postgraduate Degree (Masters & above)	0.16*	0.04	0.11	0.12	0.13	0.12	0.12	0.14†	0.13	0.15†	0.18*	0.04	1.00					
14. R&D Experience	0.22**	0.03†	0.02†	0.09	0.08	0.10	0.11	0.09	0.08	0.17†	0.29**	0.16†	0.05†	1.00				
15. Product-oriented work	0.19*	0.10†	0.03†	0.10	0.09	0.12†	0.10	0.08	0.09	0.12†	0.01	0.10	0.12†	0.12	1.00			
Independent variables																		
16. Attitudes toward R&D work	0.38**	0.01	0.03	0.05	0.12	0.11	0.10	0.09	0.05	0.05†	0.05†	0.08	0.07†	0.06	0.04	1.00		
17. Attitudes toward impediments to R&D work	0.35**	0.01	0.02	0.05	0.06	0.07	0.04	0.05	0.11	0.07†	0.04†	0.09	0.07	0.07	0.04	0.08	1.00	
Moderating variable																		
18. Organizational Reward system	0.12†	0.01	0.01	0.02	0.05	0.02	0.05	0.06†	0.10	0.09	0.06†	0.06	0.06†	0.08	0.08†	0.06	0.05	1.00
Mean	6.00	0.53	0.16	0.18	0.13	0.16	0.17	0.13	0.07	0.72	0.66	38.00	0.31	5.00	0.45	3.28	3.52	3.21
Std. Deviation	0.30	0.53	0.47	0.46	0.42	0.37	0.45	0.26	0.22	0.38	0.92	1.59	0.37	1.84	0.64	0.57	0.50	0.53

N = 1,390

a Others include Biotechnology, Environment Technology & Food and Agrotechnology

** $p < .01$

* $p < .05$

† $p < .10$

TABLE III

Results of Hierarchical Regression Analyses

Variables	TOBIT Regression					LOGISTIC Regression [a]				
	Dep. Var. – Number of patents applied for or been granted					Dep. Variable – Applied for or been granted patents (Yes, No)				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	12.89***	14.45**	11.03**	13.59**	14.01**	21.46***	28.04**	23.97**	23.64***	26.99***
Controls										
Electronic systems	0.31*	0.22*	0.35*	0.35*	0.40*	0.94*	1.10*	1.05*	1.08*	1.31*
Manufacturing technology	-0.30	-0.32	-0.22	-0.12	-0.19	-1.07	-0.77	-0.32	-0.77	-0.82
Materials/Chemical	0.77	0.78	0.73	0.67	0.97	1.21	0.88	0.78	1.10	1.05
Medical science	0.59	0.32	0.28	0.28	0.44	0.94	0.98	0.57	0.98	0.85
Informational technology	0.87*	0.79*	0.84*	0.91*	1.99*	1.25*	1.22*	1.13*	1.23*	1.38*
Others[b, c]	-0.25	-0.29	-0.28	-0.30	-0.40	-0.32	-0.31	-0.33	-0.23	-0.44
Manufacturing vs. Service sector	1.52*	1.35*	1.55*	1.29*	1.77*	1.80**	1.37**	1.44**	1.68**	1.58**
Gender (Male = 1)	0.59	0.53	0.42	0.37	0.66	1.60	1.54	1.23	1.56	1.63
Ethnic group (Chinese vs. non-Chinese)	0.88	0.62	0.68	0.72	0.90	1.06	1.26	1.05	1.06	1.26
Age	1.95†	0.95	1.01†	1.58†	1.34†	1.25†	1.04†	1.23†	1.02†	1.33†
Postgraduate degree (Masters & above)	1.20**	1.15*	0.91*	1.21*	1.65*	1.47*	1.84*	1.23*	1.39*	1.57*
R&D experience	1.76**	1.23*	1.31*	1.42**	1.55**	1.20***	1.17**	1.16**	1.17**	1.54**
Product-oriented work	0.89†	0.92*	0.45*	0.62*	0.88*	0.69†	1.04*	0.75*	1.35*	1.09*
Predictors										
Attitudes toward R&D work		1.86**	1.64**	1.67**	1.79**		1.96***	1.85**	1.95***	1.81***
Attitudes toward impediments R&D work		1.62**	1.19**	1.17**	1.23**		1.75**	1.09**	1.88**	1.70***
Organizational reward system		1.34†	1.54†	1.45†	1.23†		1.84†	0.77†	0.68†	0.82†
Org. reward system * Attitudes toward R&D work			1.88**		1.95**			1.79**		1.85**
Org. reward system * Attitudes toward impediments to R&D work				1.63**	1.77**				1.81**	1.90**
Model indices — LL Function/Chi-square	-1241.84***	-995.01**	-857.45***	-851.33***	-771.38***	92.19***	102.14**	109.44***	108.02***	112.48***
R^2	0.09	0.16	0.20	0.20	0.22	0.12	0.18	0.23	0.22	0.24
R^2 Change		0.07**	0.04**	0.04** [d]	0.06** [d]		0.06**	0.05**	0.04** [d]	0.06** [d]

a Explanatory Betas (Exp) B are used to illustrate the relative impact of the variables

b Others include Biotechnology, Environment Technology & Food and Agrotechnology

c Microelectronics is used as the reference category

d Change from Model 2

† p < .10 ** p < .01

* p < .05 *** p < .001

Table IV

Regression results for high and low patenters

	High Patenters (N = 456)			Low Patenters (N = 510)			
Variables	Beta	S.D.	R^2	Beta	S.D.	R^2	t
Attitudes toward R&D work * Reward System	2.93^{**}	0.45	0.23	1.66^{+}	0.58	0.15	10.82^{***}
Attitudes toward impediments to R&D work * Reward System	2.54^{**}	0.51	0.23	1.58^{+}	0.53	0.16	9.43^{**}

$^{+}$ $p < 0.10$; ** $p < 0.01$; *** $p < 0.001$
Betas are standardized coefficients.
t is the t-test score for the difference in betas for high and low patenters

FIGURE 1.

Interactive Process Perspective of Innovation