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Exploring the impact of innovation strategy on R&D employees' job satisfaction: A mathematical model and empirical research

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ABSTRACT

This study develops a mathematical model to examine the effect of innovation strategy on R&D employee's job satisfaction and to identify the optimal guidelines of innovation strategy, with conflict and organization performance being treated as the intermediary variables. The study further conducts an empirical survey to illustrate the contributions of this mathematical model. The results indicate that the product innovation has a greater influence on organizational performance, while the process innovation has a greater influence on conflict resolution among R&D employees. The mathematical and empirical results have provided an optimal guideline for determining the allocation of resources, which suggests that firms must focus on product innovation to gain the optimal R&D employee's job satisfaction. In addition, the types of innovation policies along with rivals' attitudes influence the advantages to be taken from a firm innovation strategy.

1. Introduction

In a highly competitive environment, innovation is critical to a firm obtaining a dominant position and gaining higher profits. Innovation is capable of revitalizing the organization in that it requires exploring and exploiting the firm's existing competencies (Hu and Hsu, 2008; Kaminski et al., 2008). Thus, it has become the principal method for adapting to a dynamic environment (Doloreux and Melancon, 2008; Hua and Wemmerlov, 2006; Roberts and Amit, 2003). Researchers in the fields of strategic management and organization theory have focused on the antecedents, consequences, and typologies of innovation. The issue of antecedents has been primarily concerned with the key factors or determinants leading to successful innovation (Nerkar and Roberts, 2004). As for the consequences of innovation, research has focused on addressing market acceptance, performance, and satisfaction (Hua and Wemmerlov, 2006). These studies have provided valuable contributions to the knowledge of innovation. Although numerous researchers have engaged in innovation-related studies (e.g., Hu and Hsu, 2008; Hua and Wemmerlov, 2006; Karniouchina et al., 2006; Nerkar and Roberts, 2004), they tended to investigate from the perspective of the firm. The perspective of the R&D employees, the critical element to the success of innovation, in studying the impact of innovation strategy on performance, has been less addressed.

Why do people engage in innovation activities? Both classical economics and transaction cost theory assume that people always act on the basis of their own interest (Williamson, 1991). That is, the R&D employee will engage in innovating only if those innovation activities can maximize his/her utility or satisfaction. Specifically, if the innovation activities are able to stimulate the R&D employee's job satisfaction, the employees will be inclined to devote themselves to innovation. Thus, the task of managers is to understand how to satisfy R&D employees to enhance innovation activities.

According to Bhoovaraghavan et al. (1996), product innovation and process innovation are the major facets of innovation strategy. Product innovation brings new products or services to meet market demands (Doloreux and Melancon, 2008), while process innovation is the operations technology that is new to the organization or changes the way products are made or delivered (Avermaete et al., 2003; Bhoovaraghavan et al., 1996). The impact of innovation strategy on R&D employees' job satisfaction should be considered from both the economic and non-economic psychosocial aspects (Geyskens et al., 1999). The non-economic psychosocial perspective examines the direct impact of conflict on affective response to the non-economic, such as whether the interactions with the exchange partner are fulfilling, gratifying, and easy (e.g., Lira et al., 2007; Rose et al., 2007). As for the economic perspective, Webb and Hogan (2002) suggested that the primary source of an employee's job satisfaction was

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organizational performance. Therefore, the intermediary variables involving organizational performance and conflict are taken into account. Accordingly, the first purpose of this study is to evaluate the impact of product innovation and process innovation on organizational performance (i.e., economic aspect) and conflict (i.e., non-economic aspect), respectively. The second purpose is to evaluate the impact of organizational performance and conflict on R&D employees' job satisfaction. In sum, this article attempts to clarify the relationships between innovation strategy and R&D employees' job satisfaction. Conflict and organizational performance are both regarded as intermediary variables that may complicate but also help to identify the relationships between innovation strategy and an R&D employee's job satisfaction.

To accomplish these objectives, we developed a mathematical model to identify the optimal combination of product innovation and process innovation in order to gain optimal R&D employee job satisfaction under the given resources or R&D budget. Since constraints are usually required to derive the optimal solutions in the mathematical models, that may limit the explanation ability or application in real world settings, we conducted an empirical study with the participants from the R&D departments. Empirically testing the mathematical model would allow us to develop specific guidelines for determining the R&D budget allocation to maximize R&D employee's job satisfaction.

2. Literature review and hypotheses development

2.1. Innovation to organization performance

The relationships among innovation, competition, and the persistence of superior profits have been of great interest to researchers (e.g., Avermaete et al., 2003; Doloreux and Melancon, 2008; Sawers et al., 2008). Avermaete et al. (2003) claimed that product innovation, process innovation, organizational innovation, and market innovation were all domains of innovation. Organizational innovation and market innovation deal with the changes in the organizational structures and moves to exploit new territorial markets or new market segments within existing markets. Product innovation can be seen as the degree that any goods, service or idea is perceived by someone as new (Avermaete et al., 2003). Comparatively, process innovation is defined as any operations technology that is new to the organization that adopts it, or a change in the way products are made or delivered (Avermaete et al., 2003; Bhoovaraghavan et al., 1996). Most scholars have proposed that a firm's product innovation and process innovation have a positive effect on its performance and/or competitive position (e.g., Doloreux and Melancon, 2008; Hua and Wemmerlov, 2006; Kaminski et al., 2008; Mansury and Love, 2008; Nerkar and Roberts, 2004). Other studies further suggested that organizational performance is determined by product innovation and process innovation (e.g., Karniouchina et al., 2006; Roberts and Amit, 2003). Organizational performance must include both strategic performance and financial performance (Zou and Cavusgil, 2002). Strategic performance signifies a firm's market share and competitive position relative to major rivals, whereas financial performance involves the firm's efficiency in terms of its cost position, sales growth, and profitability in the market. Roberts and Amit (2003) proposed that sustaining high profitability might result when a firm repeatedly introduces valuable innovations. Avermaete et al. (2003) further proposed that product innovation and process innovation could be seen as technology-related innovations. The emphasis of this study is only placed on product innovation and process innovation, in that they are technology-related innovations that are more related to R&D employees' satisfaction. Previous studies examining the role of innovation in R&D management have only focused on product innovation and process innovation (e.g., Bhoovaraghavan et al., 1996; Ornaghi, 2006).

Although empirical evidence supports that product innovation and process innovation can be advantageous to a firm in improving its competitive position relative to its rivals, as well as its profitability in the market, the impacts of product innovation and process innovation on organizational performance are different. Nerkar and Roberts (2004) pointed out that the development of a firm depended on its ability to introduce new products over time and that the success of new products correlated with competitive advantage and financial performance. Customers should be comfortably raising their willingness and reserve price to purchase the product when they perceive higher attractiveness from new offers. Therefore, product innovation has a significantly positive effect on the seller's organizational performance, such as market share and profitability, in the market.

In other words, process innovation should enhance the efficiency of product and delivery, thus creating the advantage of reducing production cost. Although literature proposes that process innovation can also enhance organizational performance (e.g., Karniouchina et al., 2006; Roberts and Amit, 2003), the product innovation should be a primary way to enhance the firm's strategic performance and financial performance in the competitive environment, as discussed. Process innovation has greater impact on production cost but lower influence on firm's sales growth or market share than product innovation. Therefore, the following hypothesis is developed.

H1. *Product innovation has greater influence on organizational performance than does the impact of process innovation on organizational performance.*

Conflict: Conflict represents the level of tension, frustration, and disagreement in relationships when an employee perceives that another is engaged in behavior that is preventing or impeding him/her from achieving his/her goals (Geyskens et al., 1999). Academic researchers have discussed conflict from three major perspectives: relationship conflict, task conflict, and process conflict (e.g., Jehn and Mannix, 2001; Song et al., 2006). Relationship conflict refers to emotional conflict or affective conflict which represents an awareness of interpersonal incompatibilities (Jehn and Mannix, 2001). This type of conflict can be characterized by anger, annoyance, distrust, fear, frustration, tension, and other forms of negative effect (Jehn and Mannix, 2001). Task conflict is defined as the level of perceived or recognized disagreements among the employees or group members concerning the ideas and opinions related to the tasks being performed (Lira et al., 2007; Rose et al., 2007). Rose et al. (2007) proposed that task conflict focuses on disagreements over the means of achieving specific ends. This type of conflict consists of disagreements about task issues such as goals, money or property settlements, viewpoints, ideas, and opinions (Jehn and Mannix, 2001). Process conflict, which is similar to the construct of distributive conflict, pertains to the process rather than the content of tasks and is defined as an awareness of controversies over aspects of how task accomplishment will proceed (Jehn and Mannix, 2001). This type of conflict concerns the issues of duty, responsibility, and resource delegation, or the means to accomplish specific tasks (Jehn and Mannix, 2001). Most studies believe that moderate levels of task conflict are functional, whereas relationship conflict is dysfunctional (e.g., Jehn and Mannix, 2001; Song et al., 2006).

Several studies have proposed a positive association between innovation, including product innovation and process innovation, and conflict (e.g., McAdam, 2005; Song et al., 2006). Innovation has been shown to drive organizational renewal and to lead to organizational change (e.g., Bhoovaraghavan et al., 1996; Nerkar and Roberts, 2004). Organizational change will lead to some negative emotions among employees, such as the level of tension or disagreement in relationships (Avermaete et al., 2003). Accordingly, both product innovation and process innovation will induce organizational changes that may incur negative emotions among R&D employees.

When the firm encourages its employees to produce new goods, services or ideas which lead to higher levels of product innovation, a higher degree of competition will appear among R&D employees, which may result in task conflict (McAdam, 2005). Specifically, process innovation focuses on the production effectiveness and efficiency, while the new operations technology is associated with how the products or services are made or delivered. When the firm adopts new operations technology that produces change in their process, R&D employees need to accommodate this new change and may argue over how tasks are to be accomplished, and clash in regard to opinions expressed about the new technology. Therefore, the process innovation will lead to higher levels of R&D employee task conflict and process conflict. Although both product innovation and process innovation may enhance the degrees of R&D employees' relationship conflict and task conflict, process innovation is a more complex and multifunctional process. In other words, process innovation creates more organizational change, which requires higher degrees of coordination and integration. Moreover, the heterogeneity and interdependence among different functions may contribute to process conflict (Jehn and Mannix, 2001; Xie et al., 1998). Accordingly, we develop the following hypothesis:

H2. *Process innovation has a greater influence on conflict than does the impact of product innovation on conflict among R&D employees.*

Satisfaction: The cause and effect relationship between organizational performance and job satisfaction has long been debated (Webb and Hogan, 2002). Geyskens et al. (1999) showed that job satisfaction is defined most frequently as "a positive affective state resulting from the appraisal of all aspects of a working relationship among employees". Moreover, satisfaction should capture both the economic and the non-economic psychosocial aspects. Economic satisfaction relates to the economic rewards such as compensation to employees and profit to organization margins. The primary source of economic rewards is organizational performance. Bagozzi (1980) first used a methodology to test for a simultaneous relationship and found that organizational performance has a significant positive causal effect on job satisfaction, but that job satisfaction has no direct effect on performance (Webb and Hogan, 2002).

Several studies support the idea that employee conflict reduces the degree of affective response to non-economic rewards, such as the relationship or interaction among the partners (e.g., Lira et al., 2007; Rose et al., 2007). Although a higher level of employee conflict may reduce the R&D employee's job satisfaction, compensation is a critical part of the incentive mechanism of human resource management in practice. While the firm is looking for maximizing into profits from its human capital, the employees are looking for maximizing utility of income and compensation, which is conditional upon their contribution. In other words, organizational performance may have a greater influence on a R&D employee's job satisfaction. Therefore, we propose the following hypothesis.

H3. *The impact of organizational performance is greater than the impact of conflict on R&D employees' job satisfaction.*

As mentioned above, this study integrates the relevant research variables such as product innovation, process innovation, conflict, organizational performance, and R&D employees' job satisfaction, into a more integrative framework. In addition, previous studies on these research topics tended to use only either purely theoretical model development or conceptual model elaboration. This paper attempts to develop a theoretical model and associated method for researching the interrelationship among the elements embraced in the context of innovation, and their influences on R&D employee's job satisfaction.

3. The mathematical model

Mathematics, as the language of science, allows for the interplay between empirical and theoretical research (Shugan, 2002). To model advanced innovation strategy in a competitive environment, this article develops a model based on the concept of game theory. Game theory has been generally accepted as a normative model of decision-making and is widely applied as a powerful analytical tool for the analysis of competitive behavior. Since several decision problems can be thought of as games, game theorists have developed a large body of concepts and methods for analyzing games. Game theory has been popularly applied to the fields of economics, sociology, and psychology. The existing literature has expressed a strong interest in making strategic decisions based on game theory in the competitive environment (e.g., Abreu and Pearce, 2007; Bierman and Fernandez, 1998). Based on the representative study on game theory by Bierman and Fernandez (1998), players, strategic profile, and payoff matrix are the major elements to develop the optimal strategy or dominant strategy for plays in the competitive environment. Furthermore, this study employs the Lagrange function to calculate the optimal value of both product innovation and process innovation.

The innovation strategies here include product innovation (PT) and process innovation (PS). Specifically, if the firm places more emphasis on product innovation, more R&D budget will be allocated to product innovation than to process innovation. The innovation strategies portfolio thus provides three options for each firm, involving product innovation orientation, process innovation orientation, and tie orientation, which represents that the firm allocates the R&D budget equally to both product and process innovations. We also consider the types of innovation policies along with rivals' attitudes. Let P_1, $1-P_1-P_2$, and P_2 denote the probability of rivals using strategies based on product, tie, and process innovation orientations, respectively. In terms of the types of customers, θ_{PT} and θ_{PS} denote the ratio of customers that show a partiality for product innovation and process innovation in the market, respectively. The organizational performance gained from the three types of innovation orientations for the firm and its rival in a competitive market are calculated and shown in Table 1.

The expected values of organizational performance under three types of innovation orientations for the firm, i.e., $E(PT)$, $E(Tie)$, and $E(PS)$, are computed in Table 1 (cf. Appendix A). Under the condition of $\alpha_1\theta_{PT} \geq \alpha_2\theta_{PS}$, E (PT) is always greater than both $E(Tie)$ and $E(PS)$ (cf. Appendix B). This condition reflects two relevant implications. First of all, the decision of utilizing which innovation orientations hinge on the magnitude of $\alpha_i\theta_j$ instead of α_i. The concept of $\alpha_i\theta_j$, which is the product of the influence of innovation orientation and proportion of market that favor that innovation, can be regarded as corrected influence of innovation orientation on performance given the market base. Moreover, H_1 reveals that product innovation seems to be dominant in that its advantageous effect on performance is always greater than

Table 1
Gain of firm's organizational performance under competitive environment.

Strategy			
Competition (rival)	**Your company (firm)**		
Gain	Product innovation orientation	Tie orientation	Product innovation orientation
Product innovation orientation	$\alpha_0+0.612\ln(PT)+0.331\ \ln(PS)$	$\alpha_0+0.612(1-\theta_{PT})\ln(PT)+0.331(1+\theta_{PS})\ln(PS)$	$\alpha_0+0.612(1-\theta_{PT})\ln(PT)+0.331(1+\theta_{PS})\ln(PS)$
Tie orientation	$\alpha_0+0.612(1+\theta_{PT})\ln(PT)+0.331(1-\theta_{PS})\ln(PS)$	$\alpha_0+0.612\ln(PT)+0.331\ln(PS)$	$\alpha_0+0.612(1-\theta_{PT})\ln(PT)+0.331(1+\theta_{PS})\ln(PS)$
Process innovation orientation	$\alpha_0+0.612(1+\theta_{PT})\ln(PT)+0.331(1-\theta_{PS})\ln(PS)$	$\alpha_0+0.612(1+\theta_{PT})\ln(PT)+0.331(1-\theta_{PS})\ln(PS)$	$\alpha_0+0.612\ln(PT)+0.331\ln(PS)$

Note: $E(PT)=\alpha_0+\alpha_1[1+(1-P_1)\theta_{PT}]\ln(PT)+\alpha_2[1+(P_1-1)\theta_{PS}]\ln(PS)$
$E(\mathrm{Tie})=\alpha_0+\alpha_1[1+(P_2-P_1)\theta_{PT}]\ln(PT)+\alpha_2[1+(P_1-P_2)\theta_{PS}]\ln(PS)$
$E(PS)=\alpha_0+\alpha_1[1+(P_2-1)\theta_{PT}]\ln(PT)+\alpha_2[1+(1-P_2)\theta_{PS}]\ln(PS)$

process innovation. However, the corrected effect of product innovation on performance is not necessarily greater than that of process innovation even though $\alpha_1>\alpha_2$. Hence, product innovation orientation is not always dominant. In other words, the power of innovation orientation on performance cannot be defined only by pure influence of innovation strategy without regard to market base. Accordingly, corrected effect of innovation strategy on performance is the key of utilization of innovation orientation.

In addition, the law of diminishing marginal utility is the prevalent theory in the economic filed. The marginal utility of goods or services decreases as the quantity of the goods or services increases, and total utility increases more and more slowly as the quantity consumed increases (Mankiw, 2009). Many studies have developed research models as nonlinear approach based on the law of diminishing marginal utility (e.g., Horowitz et al., 2007; Mankiw, 2009). Several studies employ logarithms or negative exponential forms to reflect the nonlinear relationship (e.g., Ekstrom and Tysk, 2008; Ermini and Hendry, 2008). Accordingly, this study utilizes the concept of natural logarithms to develop a conceptual model that conforms to the law of diminishing marginal utility.

Based on H_1 and H_2, product innovation (PT) and process innovation (PS) may influence organizational performance (OP) and conflict (C). Thus, the equations of organizational performance and conflict can be written as Eqs. (1) and (2). According to H_3, organizational performance (OP) and conflict (C) may influence R&D employees' job satisfaction (JS). Therefore, the equation of R&D employee's job satisfaction can be written as Eq. (3):

$$OP=f_1(PT,PS)=\alpha_0+\alpha_1\delta_1\theta_{PT}\ln(PT)+\alpha_2\delta_2\theta_{PS}\ln(PS) \quad (1)$$

$$C=f_2(PT,PS)=\beta_0+\beta_1\ln(PT)+\beta_2\ln(PS) \quad (2)$$

$$JS=f_3(OP,C)=\gamma_0+\gamma_1\ln(OP)+\gamma_2\ln(C) \quad (3)$$

In terms of the types of rivals' attitudes, δ_1 and δ_2 indicate the moderating effects of types of rivals' attitudes on the impacts of product innovation and process innovation on organizational performance, respectively. According to classical economics and transaction cost theory, the R&D employee will engage in innovating only if those innovation activities can maximize his/her job satisfaction. Thus, the major task of managers is to understand how to satisfy R&D employees to enhance innovation activities. Since employees' views play a central role in this article, we assume that a firm's major objective is to maximize R&D employee job satisfaction (JS). Thus, determining how to employ an innovation strategy to maximize an R&D employee's job satisfaction indirectly is the focal problem. Based on Eq. (1) through Eq. (3), the objective formula (i.e., Max JS) can be derived as follows:

$$Max\ \gamma_0+\gamma_1\ln[\alpha_0+\alpha_1\delta_1\theta_{PT}\ln(PT)+\alpha_2\delta_2\theta_{PS}\ln(PS)] + \gamma_2\ln[\beta_0+\beta_1\ln(PT)+\beta_2\ln(PS)]$$

A firm can adjust the proportion of different perspectives of an innovation strategy to achieve its objective. However, with the limitation of resources, product innovation and process innovation may be represented as both ends of a continuum (Bhoovaraghavan et al., 1996). In other words, product and process innovation are trade-offs where one becomes prominent when the other diminishes. Accordingly, assuming that a firm has 100% budget, the summation of different innovation orientations cannot exceed 100%. In general, the innovation activities usually are subjected to the given R&D budget. If the firm places more emphasis on product innovation, more R&D budget will be allocated to product innovation. Comparatively, R&D budget allocated to process innovation will accordingly be reduced. In addition, innovation activities can create the experience and knowledge of innovation. Since learning effect depends on accumulation of experiences and knowledge from operating (Tarakci et al., 2009), this effect may decrease the innovation time or cost that results from performing additional innovation activity. Therefore, PT and PS are transformed by taking natural logarithms to reflect the learning effect. Specifically, a firm devotes more in innovation activities, and then the increment of resources that innovation activities consume diminishes.

According to preceding discussion, we specify $\ln(PT)$ as the ratio of resources that product innovation activities consume relative to total R&D resources, and $\ln(PS)$ as the ratio of resources that process innovation activities consume relative to total R&D resources, respectively. Since innovation activities need to consume resources, $\ln(PT)$ and $\ln(PS)$ are assumed to be greater than zero. To capture these concepts, the subjective formula of a firm adjusts innovation strategy can be derived as follows:

$\ln(PT)+\ln(PS)\le\tau$, where τ is parameter that represents given R&D budget.

For the sake of deriving the optima of product innovation and process innovation, this study writes the objective formula (i.e., $\gamma_0+\gamma_1\ln[\alpha_0+\alpha_1\delta_1\theta_{PT}\ln(PT)+\alpha_2\delta_2\theta_{PS}\ln(PS)]+\gamma_2\ln[\beta_0+\beta_1\ln(PT)+\beta_2\ln(PS)]$) and subjective formula (i.e., $\tau-\ln(PT)-\ln(PS)$) in Lagrangean form as

$$L=\gamma_0+\gamma_1\ln[\alpha_0+\alpha_1\delta_1\theta_{PT}\ln(PT)+\alpha_2\delta_2\theta_{PS}\ln(PS)]+\gamma_2\ln[\beta_0 +\beta_1\ln(PT)+\beta_2\ln(PS)]+\varepsilon[\tau-\ln(PT)-\ln(PS)];$$
where ε is the Lagrange multiplier. (4)

According to the Lagrange multiplier method, the optimal ratio of product innovation relative to innovation strategy is equal to the value of

$$\frac{[\gamma_2(\beta_2-\beta_1)+\gamma_1(\beta_0+\beta_2)](\alpha_0+\alpha_2\delta_2\theta_{PS})-\gamma_1\alpha_1\delta_1\theta_{PT}(\beta_0+\beta_2)}{(\gamma_1+\gamma_2)(\beta_1-\beta_2)(\alpha_1\delta_1\theta_{PT}-\alpha_2\delta_2\theta_{PS})}$$

Similarly, we obtain the optimal ratio of process innovation relative to innovation strategy:

$$\frac{\gamma_2(\beta_2-\beta_1)(\alpha_0+\alpha_1\delta_1\theta_{PT})-\gamma_1(\alpha_1\delta_1\theta_{PT}-\alpha_2\delta_2\theta_{PS})(\beta_0+\beta_1)}{(\gamma_1+\gamma_2)(\beta_2-\beta_1)(\alpha_1\delta_1\theta_{PT}-\alpha_2\delta_2\theta_{PS})}$$

According to the optimal ratios, we find that α_1, β_1, γ_1, and θ_{PT} enhance the optimal ratio of the product innovation, whereas α_2, β_1, and θ_{PS} reduce the optimal ratio of the product innovation. Furthermore, with regard to the optimal guideline, firms must focus on the product innovation to gain optimal R&D employees' job satisfaction if $\gamma_2(\beta_1-\beta_2)(2\alpha_0+\alpha_1\delta_1\theta_{PT}+\alpha_2\delta_2\theta_{PS})\geq\gamma_1[\alpha_0(\beta_0+\beta_2)+(\beta_1-\beta_2)(\alpha_1\delta_1\theta_{PT}-\alpha_2\delta_2\theta_{PS})]$ or $G=\gamma_2(\beta_1-\beta_2)(2\alpha_0+\alpha_1\delta_1\theta_{PT}+\alpha_2\delta_2\theta_{PS})-\gamma_1[\alpha_0(\beta_0+\beta_2)+(\beta_1-\beta_2)(\alpha_1\delta_1\theta_{PT}-\alpha_2\delta_2\theta_{PS})]\geq 0$. Otherwise, firms must focus on the process innovation in the global market.

4. Empirical study

4.1. Sampling frame and sample

To validate the optimal model of strategy of innovation on R&D employees' job satisfaction and draw specific guidelines, we conducted an empirical study, which was followed by drawing specific guidelines. To survey the applicability of the conceptual model, this study constructed a questionnaire and distributed it to a randomly drawn sample from the managers and employees of R&D departments of firms. The target firms were randomly selected from the list of the top 2000 manufacturing firms in Taiwan. Respondents were contacted and solicited to participate in the survey through e-mail to the R&D department of the target firms. Either R&D managers or employees of R&D departments were invited to fill out our questionnaire. Three hundred and thirty seven valid responses were collected from eighty-two companies, including 32 optoelectronics companies, 25 computer manufacturing companies, 16 mechanical companies, and the rest represented by a variety of industries such as chemicals, biochemistry, etc. Table 2 shows the sample distribution. More than 76% of the respondents are male, more than 55% of the respondents are single, more than 68% of the respondents are 26-to-35 years old, more than 97% of the respondents held graduate or postgraduate degree, and 77% of the respondents earned between US$ 11,000 and 30,000 annually.

4.2. Measurement of the constructs

Previous research related to research constructs were reviewed to develop our empirical measures. The items were selected and filtered according to the definitions of constructs. We also invited two experts, including a professor who is specialized in the research of R&D management and a R&D manager who works in a well-established high-tech company, to participate in the process of selecting appropriate items. Then the initial questionnaire was pretested with 92 Executive MBA students who were the senior managers or CEO of companies. Based on the results of pilot study, some items were deleted. The final version of measurements was described below.

As to innovation, product innovation describes the changes of any goods, services, or ideas perceived by someone as new, whereas process innovation involves an entirely new infrastructure and the implementation of new technologies (Avermaete et al., 2003). The measurements of product innovation and process innovation are diverse among related literature. Hence, this study summarizes these items and sieves appropriate ones according to two experts and pilot study. Finally, nine items for product innovation, assessing the extent to which R&D managers or employees are concerned with issues such as volume, speed, and time to release on the market of new products, were adopted from Alegre et al. (2006), Garcia and Calantone (2002), Li et al. (2007), van den Berghe and Guild (2008), and Wong et al. (2008). In addition, ten items for process innovation, assessing the extent to which new technologies, machines, materials, and methods, were adopted from Garcia and Calantone (2002), Li et al. (2007), and Wong et al. (2008).

As to organizational performance, Zou and Cavusgil (2002) proposed that performance could be evaluated from two perspectives: strategic performance and financial performance. The former captures an organization's market share and competitive position relative to major rivals, whereas the latter involves the organizational efficiency in carrying out planning, including its cost position, sales growth, and profitability in the market.

Table 2
Characteristics of the respondents.

Question		*Frequency*	*Percentage (%)*
Gender	Male	258	76.6
	Female	79	23.4
Marriage	Single	187	55.5
	Married	150	44.5
Age	Less than 25 years old	96	28.5
	26–30 years old	149	44.2
	31–35 years old	83	24.6
	36–40 years old	9	2.7
	More than 41 years old	0	0.0
Education	Senior high school	0	0.0
	Vocational school	8	2.4
	College	236	70.0
	Graduate school	93	27.6
Annual income (US dollars)	Less than 10 thousands	27	8.0
	11–20 thousands	102	30.3
	21–30 thousands	158	46.9
	31–40 thousands	62	18.4
	More than 41 thousands	13	3.9

Thus, we developed ten items to measure strategic and financial performance based on Glaister et al. (2008) and Zou and Cavusgil (2002). In terms of conflict, five items were adopted from Jehn and Mannix (2001) and Rose et al. (2007) used to measure three types of conflict, including relationship conflict, task conflict, and process conflict. In terms of R&D employee job satisfaction, economic and non-economic aspects are considered (Geyskens et al., 1999). Four items were revised from Geyskens et al. (1999) and Valentine and Fleischman (2008) to measure two aspects of job satisfaction. All of the items were measured on seven-point Likert scales and the detailed information is shown in Appendix C.

5. Results

The main purpose of this study is to build and test a mathematical model of innovation strategy based on empirical evidence. Empirical research from the R&D employee's perspective is adopted in this study in order to confirm the validity of the integrated framework for evaluating the effectiveness of innovation strategy. To develop an integrated theoretical model, this study attempts to clarify the impact of product innovation and process innovation on organizational performance and conflict, respectively. In addition, we further evaluate the impact of organizational performance and conflict on R&D employees' job satisfaction. The dominant innovation strategy and the optimal innovation strategy were obtained through mathematical modeling. Empirical data were then collected to test the viability of the model. These detail processes are shown in Fig. 1.

5.1. Results of mathematical model

This study utilizes the concept of natural logarithms to develop a conceptual model that conforms to the Law of Diminishing Marginal Utility. According to this law, the marginal utility of goods or services decreases as the quantity of the goods or services increases, and total utility increases at a slower pace as the quantity consumed increases. For example, in addition to the influence of innovation strategy on organizational performance or conflict, the marginal effect among constructs in this study is assumed to be diminishing. Accordingly, the functions of organizational performance, conflict, and R&D employee's job satisfaction are developed based on the law of diminishing marginal utility and payoff matrix, respectively. Among others, Eq. (1) represents the impacts of product innovation (PT) and process innovation (PS) on organizational performance (OP) given the moderating effects of types of rivals' and consumers' attitudes. Eq. (2) represents the impacts of product innovation and process innovation on conflict (C). In addition, Eq. (3) represents the impacts of organizational performance and conflict on R&D employee's job satisfaction.

Next, in order to identify an optimal innovation strategy, including product innovation and process innovation under given resources, this study utilizes Lagrangean functions. This study develops the objective formula (i.e., Max *JS*) based on Eq. (1) through Eq. (3) and subjective formula (i.e., under the given R&D budget) in Lagrangean form as Eq. (4). According to the Lagrange multiplier method, the optimal ratios of product innovation and process innovation relative to innovation strategy can be obtained. To achieve maximum R&D employee's job satisfaction, this study derives optimal guidelines (G) which provide direction for the allocation of R&D budget based on comparison between the optimal ratio of product innovation and that of process innovation relative to innovation strategy. According to the optimal guidelines, the firm or practitioner can use the formula to calculate the optimal portfolio of innovation strategy, including production innovation and process innovation under the given resources or R&D budget to achieve maximum R&D employees' job satisfaction. The firm's innovation strategy, including a combination of production innovation and process innovation, needs to be adjusted under the given resources in the competitive environment according to optimal guidelines, in that innovation strategy can enhance R&D employees' job satisfaction.

5.2. Results of empirical study

This study further conducts an empirical study to validate the optimal model of strategy of innovation on R&D employees' job satisfaction. Table 2 shows the sample distribution, in which most of the respondents are male, single, 26-to-35 years old, held graduate or postgraduate degree, and earned between US$ 11,000 and 30,000 annually. The reliabilities and validities for the constructs are shown in Table 3. The major diagonal, rectangle (1), presents the Cronbach's alpha for each construct. The coefficients of Cronbach's alpha for all variables are greater than .6, showing a high reliability coefficient. Furthermore, the cumulative percentage of total variance extracted by factors, block (3), and discriminate validity, triangle (2), of the research variables, all follow the requirements suggested by Hair et al. (2010), indicating that the reliabilities and validities of these constructs are acceptable.

In order to assess the fitness of the model and obtain the values of the parameters of the equations above, this study used natural logarithms and structural equation model (SEM) for path analysis. To obtain the values of the parameters of the equations above, we examined the data with respect to the scales by means of natural logarithmic regression. The coefficients of the SEM model are displayed in Fig. 2. The results of SEM suggest an adequate fit of the proposed model to the data (i.e., $\chi^2=35.694$, $df=18$, $CFI=0.914$, $GFI=.942$, $RMSEA=.032$; the criteria of model fit static as suggested by Hair et al., 2010). With regard to the path analysis, the path coefficients of product innovation and process innovation contributing to organizational performance are .612 (α_1, $t=3.721$, $p<.01$) and 0.331 (α_2, $t=2.144$, $p<.05$), respectively. Therefore, H_1 is supported, and demonstrates that the impact of product innovation is greater than the impact of process innovation on organizational performance. The path coefficients of product innovation and process innovation relating to conflict are .247 (β_1, $t=1.633$, $p>.05$) and .427

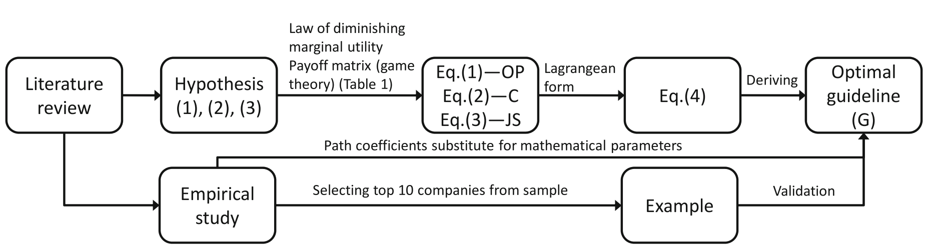
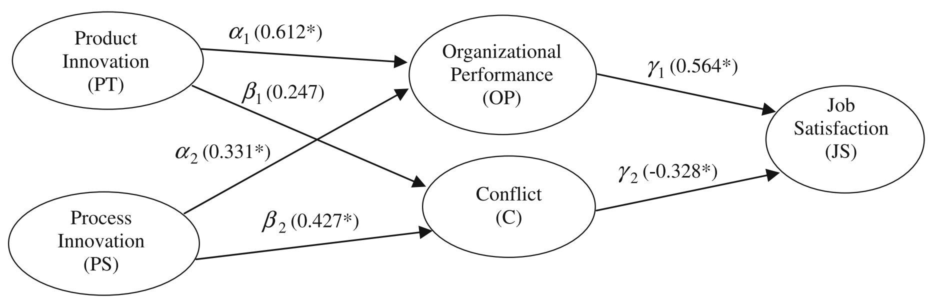


Fig. 1. The mathematical model and empirical research.

Table 3
Construct reliabilities and validities.

	Product Innovation (PT)	Process Innovation (PS)	Organizational Performance (OP)	Conflict (C)	Job Satisfaction (JS)	Validities
PT	(1) 0.647					(3) 0.6468
PS	(2) 0.354*	0.747				0.7469
OP	0.427*	0.420*	0.789			0.9991
C	0.228	0.448*	-0.160*	0.679		0.6526
JS	0.317	0.477*	0.465*	0.387*	0.771	0.7531

Note: * correlation significant at P < 0.05, and ** correlation significant at P < 0.01



Note: * correlation significant at P < 0.05, and ** correlation significant at P < 0.01
$X^2 = 35.694$, d.f. = 18, CFI = 0.914, GFI = .942, and RMSEA = .032
$\alpha_0 = 0.461^{**}$, $\beta_0 = 0.293^{*}$, and $\gamma_0 = 0.235^{*}$

Fig. 2. The results of path analysis.

(β_2, t=2.684, $p<.01$), respectively. Therefore, H_2 is supported, and proposes that the process innovation has a greater influence on conflict resolution than does product innovation. The path coefficients of organizational performance and conflict that contribute to R&D employee job satisfaction are .564 (γ_1, t=2.613, $p<.01$) and $-.328$ (γ_2, $t=-1.975$, $p<.05$), respectively. Therefore, H_3 is supported and demonstrates that the impact of organizational performance is greater than the impact of conflict on an R&D employee's job satisfaction.

5.3. Combination of mathematical model and empirical study

This study replaces the symbols of the mathematical model with the values of the coefficients from empirical analyses. Several results can be drawn from the integrated mathematical model, and these results indicate the mathematical model is appropriate for explaining the effectiveness of innovation strategy in a competitive environment. According to Bierman and Fernandez (1998), players, strategic profile, and payoff matrix are the major elements to develop the optimal strategy or dominant strategy for plays in the competitive environment. Therefore, this study develops the payoff matrix for the innovation strategy in a competitive market between firms and rivals. Table 1 illustrates the moderating effects of types of customers' attitudes and the types of innovation policies along with rivals' attitudes on the relationships between the innovation strategy and the organizational performance. For instance, if both rivals and firm use the product innovation orientation ($P_1=1$), the types of customers' attitudes cannot influence the relationship between innovation strategy and organizational performance. Therefore, the expected ratio of organizational performance affected by product innovation, $E(\mathrm{PT})=\alpha_0+\alpha_1[1+(1-P_1)\theta_{PT}]\ln(PT)+\alpha_2[1+(P_1-1)\theta_{PS}]\ln(PS)$, can be revised as $E(\mathrm{PT})=\alpha_0+\alpha_1\ln(PT)+\alpha_2\ln(PS)$. With regard to the path analysis, the path coefficients of product innovation and process innovation contributing to organizational performance are .612 (α_1, t=3.721, $p<.01$) and 0.331 (α_2, t =2.144, $p<.05$), respectively. Therefore, the $E(PT)$ can be further revised as $\alpha_0+0.612\ln(PT)+0.331\ln(PS)$. Based on Table 1, this study attempts to identify the dominate innovation strategy in a competitive environment. According to the dominate innovation strategy, the equation of organizational performance is identified.

Specifically, the optimal guideline of innovation strategy is that firms must focus on product innovation to gain the optimal level of R&D employee job satisfaction if the value of $0.139+0.086\delta_1\theta_{PT}+0.046\delta_2\theta_{PS}$ is greater than the value of $0.187-0.147\delta_1\theta_{PT}+0.080\delta_2\theta_{PS}$. Otherwise, firms must focus on process innovation. In other words, when the condition (i.e., G) that $-0.048+0.233\delta_1\theta_{PT}-0.034\delta_2\theta_{PS}\geq 0$ holds, the firm should place its emphasis on product innovation.

5.4. Example

In order to validate the guideline derived from mathematical model to illustrate the predictive power and the robustness of the analysis, we select the top 10 companies from the sample based on their R&D expenditures retrieved from their annual financial reports. Apart from items related to research constructs, R&D manager of each case company was asked to answer four additional questions during survey. The answers to these four questions denote some parameters of mathematical model. First, based on your knowledge, what is the extent to which the positive impact of product innovation on performance is reduced due to competition as comparing with your expectation (i.e., $1-\delta_1$)? Second, based on your knowledge, what is the extent to which the positive impact of process innovation on performance is reduced

Table 4
Assessment of innovation strategy orientation.

Companies	$\delta_1=1-(1)$[a]	$\delta_2=1-(2)$	$\theta_{pt}=(3)$	$\theta_{ps}=(4)$	$\delta_1\theta_{pt}$	$\delta_2\theta_{ps}$	G^*10^{-3}	ln(*PT*)	ln(*PS*)	Result	Rank of JS[b]
Company A	0.63	0.33	0.37	0.24	0.24	0.08	4.29	0.56	0.44	Supported	1
Company B	0.57	0.45	0.40	0.17	0.23	0.08	2.59	0.49	0.51	Unsupported	9
Company C	0.48	0.52	0.46	0.14	0.22	0.07	0.44	0.55	0.45	Supported	4
Company D	0.41	0.59	0.46	0.16	0.19	0.10	−7.24	0.48	0.52	Supported	7
Company E	0.57	0.45	0.39	0.13	0.23	0.06	2.66	0.61	0.40	Supported	2
Company F	0.49	0.54	0.46	0.18	0.22	0.10	0.81	0.51	0.49	Supported	8
Company G	0.48	0.52	0.47	0.22	0.23	0.11	0.77	0.53	0.47	Supported	5
Company H	0.52	0.49	0.44	0.21	0.23	0.10	1.59	0.55	0.45	Supported	3
Company I	0.44	0.58	0.49	0.12	0.22	0.07	−0.22	0.51	0.49	Unsupported	10
Company J	0.50	0.51	0.45	0.21	0.23	0.11	1.15	0.52	0.48	Supported	6

[a] The number in parentheses denotes the additional question of the questionnaire that R&D manager had to answer.
[b] 10 companies are ranked according to the mean value of variables of R&D eployees' job satisfaction. 1 represents the highest levels of job satisfaction among 10 companies, and so on.

due to competition as comparing with your expectation (i.e., $1-\delta_2$)? Third, based on your knowledge, what is the percentage of customers who prefer product innovation (i.e., θ_{pt})? Fourth, based on your knowledge, what is the percentage of customers who prefer process innovation (i.e., θ_{ps})?

We replace symbols of guideline derived from mathematical model with these answers and the path coefficients to obtain a value (G). Whether G is greater than zero will decide the innovation strategy. Specifically, a firm should allocate more resources to product innovation (i.e., $\ln(PT)>\ln(PS)$) if $G>0$. Accordingly, the firms are suggested to focus on the product innovation to gain optimal R&D employees' job satisfaction. The G values of 10 companies are calculated and shown in Table 4. When G is greater than zero, and $\ln(PT)$ is greater than $\ln(PS)$, it is suggested that the situation of sample company is consistent with guideline. Take company A as an example. The values of four additional questions that R&D manager of company A was asked to answer during survey are 37% (i.e., $\delta_1=1-0.37=0.63$), 67% (i.e., $\delta_2=1-0.67=0.33$), 37% (i.e., $\theta_{pt}=0.37$), and 24% (i.e., $\theta_{ps}=0.24$), respectively. Therefore, the conditional parameter G of company A is greater than zero ($G=4.29\times10^{-3}>0$). According to the optimal guideline, company A should focus on the product innovation to gain optimal R&D employees' job satisfaction. In fact, the ratio of product innovation relative to innovation strategy (i.e., $\ln(PT)$) of company A is greater than the ratio of process innovation (i.e., $\ln(PS)$) relative to innovation strategy (i.e., $0.56>0.44$). Company A actually possesses the greatest value of R&D employees' job satisfaction of these 10 companies.

Table 4 shows that the innovation orientations of most companies are parallel to the guidelines of this study except for company B and company I. In other words, their innovation strategies are incompatible with G values. Their G values suggest that company B should place more emphasis on product innovation, whereas company I should place more emphasis on process innovation, in order to gain more R&D employees' job satisfaction. In fact, company B and company I have the lower values of R&D employees' job satisfaction among 10 companies. The result implies that violation of optimal guidelines may be detrimental to R&D employees' job satisfaction.

6. Conclusions

Based on the results of previous research, this study extends the knowledge of innovation strategy (i.e., product innovation and process innovation) to develop the optimal model of R&D employees' job satisfaction via intermediary variables of organizational performance and conflict. We examine the intermediary roles of organizational performance and employee conflict on the relationship among product innovation, process innovation, and job satisfaction by means of a mathematical model and an empirical study. Several conclusions can be derived from the development of the mathematical model. First, the optimal ratio of portfolio of two innovation strategies (i.e., product innovation and process innovation) is developed. Accordingly, firms can use the formula to calculate the optimal portfolio of innovation strategy. To model advanced innovation strategy in order to enhance the job satisfaction of R&D employees in a competitive environment, this article develops a model based on the conception of game theory. Therefore, the optimized formula not only considers the firm's moderating effects of types of customers' attitudes, partiality for product innovation and process innovation in the market, on the relationship between product innovation and organizational performance, but also integrates the competitive moves of the rivals. The parameters in the formula denote the magnitudes of the influences of product innovation and process innovation on the organizational performance, conflict, and R&D employee's job satisfaction. Thus, the managers can determine the optimal product innovation and process innovation as long as they examine the magnitudes of influences among these variables in the competitive environment.

Second, the game implies that a product innovation orientation is a dominant strategy that can create more competitive advantage when it is more contributive to organizational performance and the majority of consumers are in favor of product innovation. Otherwise, process innovation orientation will strictly dominate a tie or product innovation orientation. Furthermore, the types of innovation policies, along with rivals' attitudes, influence the competitive advantage of each innovation orientation. The influence of product and process innovation on organization performance will be moderated by rivals' attitudes. For example, product innovation may enhance competitive advantage and organization performance without regard to competitors' moves. Nevertheless, if both the firm and its rivals adopt product innovation simultaneously, the increment of organization performance stemming from increased product innovation may shrink. Accordingly, game theory is a proper tool for decision making as it considers the influences of rivals' moves. Finally, we also provide the optimal guideline for determining the allocation of resources.

To illustrate the viability of mathematical models, this study transforms the data into the forms of natural logarithms. This study employs structural equation model to evaluate the parameters of the mathematical models. The empirical results of structural equation modeling support the use of these mathematical transformations. From the perspective of R&D managers or employees of R&D department, the empirical results support all hypotheses and forms of natural logarithms, which are the bases and premises of mathematical model. Specifically, both product innovation and process innovation can increase organizational performance. Although the marginal effects decrease, the impact of product innovation on organizational performance is greater than the impact of process innovation on organizational performance. This result implies that firm should allocate more resources to product innovation if the firm only focus on enhance organizational performance.

The empirical findings indicate that the process innovation is significantly and positively related to conflict, whereas the product innovation is not significantly related to conflict. This result indicates that firm should encourage product innovation instead when the firm plans to control the levels of conflict among R&D employees. Empirical research also supports that organizational performance enhances R&D employees' job satisfaction, but higher conflict among R&D employees will inhibit their job satisfaction. However, the impact of organizational performance on R&D employee's job satisfaction is greater than the impact of conflict on R&D employee's job satisfaction. Accordingly, if firm cannot enhance organizational performance and reduce conflict simultaneously, the firm should put forward a plan for improving organizational performance to achieve better R&D employees' job satisfaction.

The final question is which innovation strategy should be utilized when the firm endeavors to increase R&D employees' job satisfaction. Our empirical findings imply that the firm is unlikely to use process innovation to enhance R&D employees' job satisfaction through higher levels of organizational performance and lower levels of conflicts. Rather, the firm should use product innovation to enhance organizational performance, and in turn, the R&D employees' job satisfaction.

7. Managerial implications

The main contribution of this study is to develop and empirically examine a mathematical model which captures the relationship between innovation strategy and R&D employees' job satisfaction. The theoretical model comprises product innovation, process innovation, organizational performance, conflict among R&D employees, and R&D employees' job satisfaction. The results of this study can provide a very valuable insight for practitioners in their evaluation of innovation strategies and a solid base for academics to link the concept of innovation strategy with motivation theory of employee. The findings of this study have several implications for managers of firms.

First, as to Eq. (4), the optimal ratio of portfolio of product innovation and process innovation indicates that firms can obtain the values of parameters in the mathematical model by means of systematic surveying. After substituting the values of parameters in the mathematical model, the optimal values of product innovation and process innovation, which can lead to maximal value of R&D employees' job satisfaction, given limited resources and competitive environment, will be derived. Accordingly, the firms' managers may be updated to include a combination of product innovation and process innovation which enhance their R&D employees' job satisfaction under the given resources based on these guidelines. In other words, if firms' innovation strategies are incompatible with the optimal values, they may have chance to enhance their R&D employees' job satisfaction by reallocating R&D budget. For instance, company I has the lowest values of R&D employees' job satisfaction among 10 companies, it may place more emphasis on process innovation based on the optimal values for creating opportunity to enhance R&D employees' job satisfaction.

Second, the changes of parameters of optimal ratio of portfolio for product innovation and process innovation imply a strategic meaning in practice. For example, the effect of organizational performance on R&D employees' job satisfaction is positively associated with the optimal ratio of product innovation relative to innovation strategy. This implies that firms should increase the proportion of product innovation employed if organizational performance is more contributive to R&D employees' job satisfaction. Contrarily, firms should decrease the proportion of product innovation employed if the positive association between product innovation and conflict among R&D employees is stronger. Although the advantageous effects of both product innovation and process innovation on organizational performance can enhance R&D employees' job satisfactions, the relationship between product innovation and organizational performance has stronger effect on the optimal ratio of product innovation relative to innovation strategy particularly. Thus, for the purpose of maximizing R&D employees' job satisfaction, firms should increase the proportion of product innovation employed when product innovation can lead to higher organizational performance. Third, according to the optimal guideline of innovation strategy, firms can use the formula to calculate the optimal portfolio of innovation strategy, including product innovation and process innovation, under the given R&D resources or budget. In other words, based on the guideline, R&D resources can be deployed and assigned to product innovation and process innovation given the maximal job satisfaction.

Fourth, the power of innovation orientation cannot be identified only by pure influence of innovation strategy on organizational performance without regard to market base. Without reference to the factor of market base, the firm should place more emphasis on the product innovation in the condition of the pursuit of maximal organizational performance. Nevertheless, the contribution of product innovation and process innovation should be determined by taking the market base, including customers' and rivals' attitudes, into consideration. Specifically, the firm should mainly adopt process innovation strategy to enhance organizational performance when its customers prefer process innovation and its rivals are more likely to use produce innovation strategy. This result implies that firms should not rely on the pure effect of innovation strategy on organizational performance to gain the optimal profit in the competitive environment. Accordingly, corrected effect of innovation strategy on performance, which is adjusted by market base, is the key of utilization of innovation orientation.

Fifth, both product innovation and process innovation are significantly and positively related to the organizational performance. These results suggest that firms can influence the organizational performance by enhancing product innovation and process innovation. Based on the empirical validation of this study, the effect of product innovation on organizational performance is greater than that of process innovation, and thus firms can focus on product innovation to generate higher organizational performance. Sixth, process innovation does have a significant positive causal effect on employee conflict which will further reduce the R&D employee's job satisfaction. Firms may inevitably invest their efforts in pursuit of high organizational performance by means of innovation strategy, but neglect the negative effect of conflict occurring unavoidably among R&D employees. For example, a new technology is introduced to the firm to enhance its effectiveness. However, some of R&D employees may not adapt to the change and refuse to accept the new technology. Thus, conflict will happen and then reduce employees' job satisfaction. In terms of product innovation, it does not have a significant positive effect on employee conflict. Based on this result, firms must focus more on product innovation than on process innovation.

Finally, although both organizational performance and employees' conflict also have significant effects on R&D employee's job satisfaction, the impact of organizational performance is greater than the impact of conflict on an R&D employee's job satisfaction. Thus, firms should focus on enhancing organizational performance rather than reducing employee conflict in order to capture higher R&D employee's job satisfaction. Specifically, the firm can design an incentive mechanism based on organizational performance in order to increase R&D employees' job satisfaction. This action is reasonable in that performance-oriented compensation scheme is a critical part of the strategic thrust of human resource management rather than strategy of conflict management in practice. Accordingly, firm should place more attention on organizational performance and employ economic incentives, such as profit-sharing bonus, quota-based bonus, share options grants, or stock option, to create more R&D employee's job satisfaction.

8. Limitation and future research

There are some limitations associated with this study. Strong assumptions produce powerful models (Shugan, 2002). To parsimoniously analyze the model, some assumptions are necessary. However, the assumptions of this mathematical model present one of the main limitations of this study. Many specific assumptions were made in the process of deriving the general results. According to the law of diminishing marginal utility, this study utilizes the concept of natural logarithms to develop a conceptual model. Nevertheless, this study offers a robust explanation of the impact of innovation strategy and develops an optimal decision model for innovation strategy in consideration of organizational performance, conflict among R&D employees, and R&D employees' job satisfaction.

There are several ideas requiring extension in future research. First, other dimensions such as organizational innovational, risk attitude or characteristics of R&D employees can be integrated into the research model to verify their impacts. Second, further research can employ different function forms such as negative exponential or trigonometric function to develop the mathematical model and further compare the optimal guidelines within this study. Third, our findings offer a basis for future research in exploring differences in R&D employees' efforts in various organizational structures. Specifically, the proposed interrelationships among research variables may vary with the types of organizational structures. For instance, the extreme formalized organization may not adjust its innovation strategies and incentive structures according to organizational performance or environment, as comparing with the flexible organization. Thus, the influences of innovation strategies on organizational performance or conflict in formalized organization may differ from those in flexible organization. Finally, different industries may prefer a specific innovation strategy. For example, the oil company is likely to utilize new technology to reduce the manufacturing cost and thus lead to higher organizational performance in that most of its products are indifferent. On the other hand, the pharmaceutical company emphasizes developing new medical products to intensify its competitive advantage. Hence, the oil companies may focus on process innovation, whereas the pharmaceutical companies may focus on product innovation. In this regard, the comparison between different industries as to the research interrelationships needs to be investigated in the future research.

Acknowledgement

Many thanks for anonymous reviewer's suggestions about the third and the final ideas of future research.

Appendix A. Proofs of the *E*(*PT*), *E*(*Tie*), and *E*(*PS*)

A1. Proofs of the expected values of organizational performance under product innovation orientations for the firm, i.e., E(PT)

$$\begin{aligned}E(PT) &= P_1[\alpha_0+\alpha_1\ln(PT)+\alpha_2\ln(PS)]+(1-P-P_2)[\alpha_0+\alpha_1(1+\theta_{PT})\\ &\quad\times\ln(PT)+\alpha_2(1-\theta_{PS})\ln(PS)]+P_2[\alpha_0+\alpha_1(1+\theta_{PT})\ln(PT)\\ &\quad+\alpha_2(1-\theta_{PS})\ln(PS)]\\ &=\alpha_0+\alpha_1[P_1+(1-P_1-P_2)(1+\theta_{PT})+P_2(1+\theta_{PT})]\ln(PT)\\ &\quad+\alpha_2[P_1+(1-P_1-P_2)(1-\theta_{PS})+P_2(1-\theta_{PS})]\ln(PS)\\ \Rightarrow E(PT) &= \alpha_0+\alpha_1[1+(1-P_1)\theta_{PT}]\ln(PT)+\alpha_2[1+(P_1-1)\theta_{PS}]\ln(PS)\end{aligned}$$

A2. Proofs of the expected values of organizational performance under tie innovation orientations for the firm, i.e., E(Tie)

$$\begin{aligned}E(Tie) &= P_1[\alpha_0+\alpha_1(1-\theta_{PT})\ln(PT)+\alpha_2(1+\theta_{PS})\ln(PS)]\\ &\quad+(1-P-P_2)[\alpha_0+\alpha_1\ln(PT)+\alpha_2\ln(PS)]\\ &\quad+P_2[\alpha_0+\alpha_1(1+\theta_{PT})\ln(PT)+\alpha_2(1-\theta_{PS})\ln(PS)]\\ &=\alpha_0+\alpha_1[P_1(1-\theta_{PT})+(1-P_1-P_2)+P_2(1+\theta_{PT})]\ln(PT)\\ &\quad+\alpha_2[P_1(1+q_{PS})+(1-P_1-P_2)+P_2(1-\theta_{PS})]\ln(PS)\\ \Rightarrow E(Tie) &= \alpha_0+\alpha_1[1+(P_2-P_1)\theta_{PT}]\ln(PT)+\alpha_2[1+(P_1-P_2)\theta_{PS}]\ln(PS)\end{aligned}$$

A3. Proofs of the expected values of organizational performance under process innovation orientations for the firm, i.e., E(PS)

$$\begin{aligned}E(PS) &= P_1[\alpha_0+\alpha_1(1-\theta_{PT})\ln(PT)+\alpha_2(1+\theta_{PS})\ln(PS)]\\ &\quad+(1-P-P_2)[\alpha_0+\alpha_1(1-\theta_{PT})\ln(PT)+\alpha_2(1+\theta_{PS})\ln(PS)]\\ &\quad+P_2[\alpha_0+\alpha_1\ln(PT)+\alpha_2\ln(PS)]\\ &=\alpha_0+\alpha_1[P_1(1-\theta_{PT})+(1-P_1-P_2)(1-\theta_{PT})+P_2]\ln(PT)\\ &\quad+a_2[P_1(1+\theta_{PS})(1-P_1-P_2)(1+\theta_{PS})+P_2]\ln(PS)\\ \Rightarrow E(PS) &= \alpha_0+\alpha_1[1+(P_2-1)\theta_{PT}]\ln(PT)+\alpha_2[1+(1-P_2)\theta_{PS}]\ln(PS)\end{aligned}$$

Appendix B. Proofs of the condition of $\alpha_1\theta_{PT}\geq\alpha_2\theta_{PS}$

B1. Proofs of the condition of E(PT) ≥ E(Tie)

Let $E(PT)\geq E(Tie)$

$$\begin{aligned}&\Rightarrow \alpha_1[1+(1-P_1)\theta_{PT}-1-(P_2-P_1)\theta_{PT}]\ln(PT)\\ &\quad\geq\alpha_2[1+(P_1-P_2)\theta_{PS}-1-(P_1-1)\theta_{PS}]\ln(PS)\\ &\Rightarrow \alpha_1[(1-P_2)\theta_{PT}]\ln(PT)\geq\alpha_2[(1-P_2)\theta_{PS}]\ln(PS)\\ &\Rightarrow \alpha_1\theta_{PT}\ln(PT)\geq\alpha_2\theta_{PS}\ln(PS)\end{aligned}$$

B2. Proofs of the condition of E(PT) ≥ E(PS)

Let $E(PT)\geq E(PS)$

$$\begin{aligned}&\Rightarrow \alpha_1[1+(1-P_1)\theta_{PT}-1-(P_2-1)\theta_{PT}]\ln(PT)\\ &\quad\geq\alpha_2[1+(1-P_2)\theta_{PS}-1-(P_1-1)\theta_{PS}]\ln(PS)\\ &\Rightarrow \alpha_1[(2-P_2-P_1)\theta_{PT}]\ln(PT)\geq\alpha_2[(2-P_1-P_2)\theta_{PS}]\ln(PS)\\ &\Rightarrow \alpha_1\theta_{PT}\ln(PT)\geq\alpha_2\theta_{PS}\ln(PS)\end{aligned}$$

B3. Proofs of the condition of E(Tie) ≥ E(PS)

Let $E(Tie)\geq E(PS)$

$$\begin{aligned}&\Rightarrow \alpha_1[1+(P_2-P_1)\theta_{PT}-1-(P_2-1)\theta_{PT}]\ln(PT)\\ &\quad\geq\alpha_2[1+(1-P_2)\theta_{PS}-1-(P_1-P_2)\theta_{PS}]\ln(PS)\\ &\Rightarrow \alpha_1[(1-P_1)\theta_{PT}]\ln(PT)\geq\alpha_2[(1-P_1)\theta_{PS}]\ln(PS)\\ &\Rightarrow \alpha_1\theta_{PT}\ln(PT)\geq\alpha_2\theta_{PS}\ln(PS)\end{aligned}$$

Table C1

Product innovation (PT)	
PT01	Product use (needs served) new to the firm
PT02	A product is totally new to the firm
PT03	Improvements/revisions to existing company products
PT04	Responds to important changes in customer needs/wants
PT05	Product was more complex than we have introduced into the same market
PT06	The product technology is new to the customer
PT07	Average innovation project development time (an innovation project refers to the creation of a new product or a new component)
PT08	Change in product mix
PT09	Our new product is unlike anything seen in the marketplace before
Process innovation (PS)	
PS01	New technology is required in order to develop the product
PS02	Science and technology knowledge base newness to firm's R&D
PS03	Production process is new to the firm (e.g., new equipment or re-engineering of operational process)
PS04	Product technological newness to the firm
PS05	Modification of technology currently in use at the firm
PS06	Degree of difference for other products in technical characteristics or specifications
PS07	Complexity of manufacturing technology
PS08	Reduction in material inputs
PS09	Savings on energy inputs
PS10	Materials required are new to the firm
Organizational performance (OP)	
OP01	The strategic position of our business unit is very strong
OP02	Relative to our major competitors, our business unit is very competitive
OP03	Our market share is very high relative to our competitors
OP04	We have been able to build a leadership position in our industry
OP05	Compared to major competitors, the productivity of our business unit is very high
OP06	Compared to major competitors, sales of our business unit have been increasing rapidly
OP07	Compared to major competitors, average costs of our business unit have been decreasing
OP08	The operations of our business unit are very profitable relative to our major competitors
OP09	Our return on investment is higher than that our major competition
OP10	Our return on assets is higher than that our major competition
Conflict (C)	
C01	There are disagreements in my work group about aspects of how task accomplishment will proceed
C02	There is relationship tension in my work group
C03	There are disagreements about who should do what in my work group
C04	There are conflicts of opinions in my work group
C05	There are disagreements in my work group about ideas
R&D employee job satisfaction (JS)	
JS01	The interaction with the partner are fulfilling and gratifying
JS02	I have sufficient resources to perform my job well
JS03	I think that my workload is reasonable
JS04	Overall, I am satisfied with my job

B4. A proof of the condition whereby product innovation is a dominant strategy

Based on B1 through B3, $\alpha_1\theta_{PT}\ln(PT) \geq \alpha_2\theta_{PS}\ln(PS) \Rightarrow E(PT) \geq E(Tie) \geq E(PS)$. In general, firm may allocate the R&D budget equally to both product and process innovations when it is uncertain about specific magnitude of expected values of organizational performance gained from types of innovation orientations. Therefore, $\ln(PT)$ will equal $\ln(PS)$. In this regard, $\alpha_1\theta_{PT} \geq \alpha_2\theta_{PS} \Rightarrow \alpha_1\theta_{PT}\ln(PT) \geq \alpha_2\theta_{PS}\ln(PS) \Rightarrow E(PT) \geq E(Tie) \geq E(PS)$. Under the condition of $\alpha_1\theta_{PT} \geq \alpha_2\theta_{PS}$, $E(PT)$ is always greater than both $E(Tie)$ and $E(PS)$.

Appendix C. The questionnaire items

See Table C1.

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