The moderating role of market uncertainty in the effectiveness of government policies and R&D activities promoting innovation in manufacturing firms

Abstract

Purpose – The purpose of this study is to examine the impact of government support policies and research and development (R&D) activities on product innovation under market uncertainty.

Design/Methodology/approach – This study applies logistic regression analysis to a sample of 4000 South Korean manufacturing firms in order to investigate the impact of government policies and R&D activities of the firm on firm innovation performance, with particular interest in the moderating role of the firm's perceived market uncertainty.

Findings – Policies supporting Industry/University/Institute/ Local collaboration are found to have greater benefit under high perceived market uncertainty. Surprisingly, support for a consortium among different-sized firms has a negative effect on product innovation, although this negative effect disappears under high perceived market uncertainty. Both support for the protection of intellectual property (IP) and support for the resolution of manpower shortages have strong positive effects on the propensity to innovate products, but in both cases the moderating effects of uncertainty are negative. Finally, all types of R&D activities have positive effects on the propensity to innovate, more so for new product innovation than for improved product innovation.

Originality/value – To the best of the authors' knowledge, this is the first study to examine analytically the moderating effect of perceived market uncertainty in the effectiveness of government policies promoting innovation in the manufacturing sector. The study is potentially useful both for policymakers in deciding which policies to implement under prevailing market conditions, and for entrepreneurs choosing between different forms of government support, particularly given the abnormal levels of market uncertainty prevailing in the Covid-19 era.

Keywords: *government policies, R&D activities, new product innovation, improved product innovation, perceived market uncertainty*

Paper type Research paper

1. Introduction

The innovation activity of firms has been regarded as one of the most important drivers of sustainable economic development and has therefore been a critical topic for the national policy agenda, continuously drawing the attention of policymakers in knowledge-based economies (Schot and Steinmueller, 2018). Furthermore, technological development and innovation can be beneficial for private businesses as well as for the economy and society at large (Jones and Williams, 1998). Government policymakers have attempted to design innovation policies in ways that take account of the role of key factors that enhance or obstruct innovation activities. Government policies for innovation have taken the form of both financial and non-financial support (Kim, 2004; Anwar and Li, 2021), at both national and local levels (Lee and Park, 2006; Walker and Andrews, 2015). Some policies are designed to promote new product innovation, and others to promote improved product innovation (Dodgson *et al.*, 2011).

Many studies have investigated the effectiveness of government support policies promoting the innovation activities of firms (e.g., Cumming, 2007; Dolfsma and Seo, 2013; Doh and Kim, 2014). Others have focused on the complexities of the innovation process and channels through which the innovation inputs are transformed into better performance (e.g., Hashi and Stojcic, 2013). In addition, firms expand their knowledge base through R&D activities (Zahra *et al.*, 2000) that can bring in various forms of new knowledge from outside the firm (Wu and Shanley, 2009) or can combine new knowledge with existing knowledge (Ahuja and Lampert, 2001; Heij *et al*., 2020).

However, to the best of the authors' knowledge, there is no study yet on how the effectiveness of government support policies on the product innovation performance of a firm is moderated by market conditions, particularly market uncertainty. High market uncertainty may be seen to give rise to a situation of market failure (Schot and Steinmueller, 2018), which is highly likely to impact on technological development (Hall, 2002). Hence the role of market uncertainty in the innovation process is something that policymakers should take into account when designing policies to promote innovation.

Consideration of the role of market uncertainty has been particularly relevant since the outbreak of Covid-19, when many firms have been facing higher market uncertainty than possibly at any other time. It is no surprise that the pandemic has provoked a turning point for governments around the world to increase financial support for technological innovation through active market intervention, as part of the package designed to avert or lessen the extent of the expected economic slowdown (OECD, 2020; 2021).

The objectives of this study are to discuss the key types of government policies (e.g., financial vs non-financial support policies) for product innovation and to examine the effects of such support policies on product innovation. The effects of R&D activities (e.g., internal, joint or external R&D activities) on product innovation are also investigated. In addition, and more importantly, another objective of this study is to examine how market uncertainty moderates the effects of government policies or R&D activities on product innovation. As already mentioned, to the best of the authors' knowledge, no previous studies have investigated such moderating effects.

The objectives of this study are therefore to address the following four research questions: (1) what types of government support among various policies are the most effective in promoting successful product innovation? (2) which R&D activities are most beneficial in improving the firm's product innovation performance? (3) how does market uncertainty moderate the relationships between government support policies and product innovation performance? and (4) how does market uncertainty moderate the relationships between R&D activities and product innovation performance?

In order to answer these four research questions, we use data on 4,000 manufacturing firms from the Korean Innovation Survey (KIS), which is a Korean national survey. Logistic regression analysis is applied in order to identify the determinants of firms' innovation performance, with principal independent variables being government policy and firms' R&D activities. Interaction terms are included to capture the moderating effects of market uncertainty. An overall result is that the effects of support policies (e.g., intellectual property (IP) and the resolution of manpower shortages) on innovation performance are usually significantly positive, but the moderating effect of market uncertainty is in some cases to diminish the effectiveness of the policy, and in other cases to enhance it. The results of the study are likely to be of interest both to policymakers designing government policies to promote innovation and to entrepreneurs or managers applying for government support funding and deciding which type of support policy will be most effective for them, particularly under conditions of market uncertainty, such as those brought on by the Covid 19 pandemic.

The case of Korea is particularly interesting in this context, because Korea has become one of the representative countries that have successfully led industrial development and technological innovation through national policy planning. Following the foreign exchange crisis in the late 1990s, they further enacted the Industry Development Act (1999) to promote the advancement of industrial structure in ways that take into account uncertainties in the economic environment.

The paper is organized as follows. Section 2 presents the conceptual framework and the hypotheses to be tested. Section 3 describes the research methods and introduces the data. Section 4 presents the results of the econometric analysis. Section 5 provides further discussion of the results. The final section concludes, and suggests limitations of this research and directions for future research.

2. Hypothesis development

The purpose of this section is to introduce each of the hypotheses to be tested in the logistic regression analysis. Figure 1 presents the conceptual framework in which each of these hypotheses is embedded.

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Insert Figure 1 about here
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2.1 The effects of government support policies on product innovation

According to the Oslo Manual (OECD, 2005) that is the international reference guide for collecting and using data on innovation, product innovation is defined as the introduction onto the market of *a product whose technological characteristics or intended uses differ significantly from those of previously produced products* or *an existing product whose performance has been significantly enhanced or upgraded.* This study follows previous studies in innovation and entrepreneurship (e.g., Gronum *et al.*, 2012; Gallego *et al*., 2013; Grimpe *et al.*, 2019) by adopting this definition.

Studies of the effectiveness of government policies have usually found positive effects on firm innovation (Kang and Park, 2012). Various studies have shown that developed countries, that have actively adopted government policies to support firm innovation or productivity improvement, tend to be successful in enhancing their technological capabilities (Czarnitzki and Hussinger, 2004; Szczygielski *et al.*, 2017). However, it has also been found that the effectiveness of government policies to stimulate innovation differs between high-tech and low-tech (Czarnitzki and Thorwarth, 2012; Maietta, 2015), between the manufacturing and services sectors (Bessant and Rush, 1993; Kim, 2019), and between small and medium-sized enterprises (SMEs) and large enterprises (Yun *et al.*, 2016; Jugend *et al.*, 2018).

South Korea's record of technological innovation in both manufacturing and service sectors offers a success story of government-led industrial development (Kim, 2014; Park and Leydesdorff, 2010) and this reinforces the belief that government support policies can be considered a key factor in the successful innovation performance of the firm. Government support policies take a variety of forms (e.g., Lee and Park, 2006). Governments can provide funding or loans (Kim, 2004; Anwar and Li, 2021), can provide training, mentoring, and coaching of entrepreneurs (Mayer, 2010; Cano-Kollmann *et al.*, 2017), can assist with patent applications, can facilitate access to engineering or marketing knowledge, can provide venues and events to facilitate networking and the creation of linkages between prospective partners (Mayer, 2010), and can bring together different players within the innovation system (Cano-Kollmann *et al.*, 2017).

Given this range of government support policies for innovation, a classification of policies is useful for an understanding of the nature of the policies and of the effects to be expected (Dolfsma and Seo, 2013). Previous studies have classified policies in different ways by focusing on a mix of actors, instruments, and institutions (Flanagan *et al.*, 2011), by distinguishing between demand for innovation (pull strategy) and supply of innovation (push strategy) (Edler and Georghiou, 2007), by distinguishing between financial and non-financial support policies (Kim, 2004; Anwar and Li, 2021).

Guided by this previous literature, this study classifies and focuses on six types of policy as follows: (1) Government subsidies and investment or loans related to R&D for innovation (Doh and Kim, 2014; Guan and Yam, 2015); (2) Support policies for the acquisition, protection, utilization of Intellectual Property (IP) of the firm; (3) Support policies for resolution of manpower shortage (Paraskevopoulou, 2012); (4) Support policies for collaboration among Industry, University, Institute, and Local organizations (Shin *et al.*, 2016; Etzkowitz and Zhou, 2017); (5) Deregulation policies to counter unreasonable regulation; (6) Support policies for consortiums between large firms and SMEs (Kim, 2019). Type (1) is a financial support policy while type (2)-(6) are non-financial support policies.

Again guided by previous literature (Kim, 2014; Kang and Park, 2012; Kim, 2019), this study commences with the view that both financial and non-financial government support policies have positive effects on the product innovation of the firm. This leads to our first hypothesis:

H1: *The government support policies are positively related to the product innovation of the firm*

H1-1: *The financial support policies are positively related to the product innovation of the firm*

H1-2: *The non-financial support policies are positively related to the product innovation of the firm*

2.2 The effects of R&D activities on product innovation

R&D activity of the firm is obviously another important driver of innovation. This study divides R&D activity into three types (Cuervo-Cazurra *et al*., 2018; Jiang *et al*., 2021; Seo, 2020): Internal R&D activities (e.g., In-house R&D), joint R&D activities, and external R&D activities. Internal R&D is defined as activities fulfilled internally within the firm to create new knowledge or to solve scientific or technological problems, while joint R&D is defined as activities fulfilled collaboratively with other firms or organizations in pursuit of the same goals (Shin *et al*., 2016). External R&D activities are defined as external knowledge acquisition (Berchicci, 2013) including purchasing and acquisition of existing know-how, copyrighted works, and patented and non-patented inventions from other firms or organizations to create new knowledge or to solve scientific or technological problems.

The resource-based view (RBV; Barney, 1986) has been widely applied in product innovation research (Kleinschmidt *et al*., 2007; Terziovski, 2010; Verona, 1999). RBV addresses the relationship between product innovation capability and gaining a competitive advantage (Andersén, 2021). A high level of R&D capacity allows firms that rely on internal R&D to recognize and select valuable linkages and to capture the know-how of the partners more efficiently (Berchicci, 2013). Through different types of R&D activities, firms can have more and better opportunities to combine useful knowledge (Kogut and Zander, 1992; Hoffman *et al.*, 1998; Shefer and Frenkel, 2005) that can result in product innovation (Zahra and George, 2002; Zhou and Wu, 2010) by reshaping their knowledge base or revising their existing knowledge (Foss *et al*., 2013; Heij *et al*., 2020). Hence R&D activity is a catalyst for innovative industrial activities, and ultimately it is responsible for the growth in productivity and total revenue (Shefer and Frenkel, 2005).

The causal relationships between R&D activities and firm innovation performance are of great interest to both governments and firms (Raymond and St-Pierre, 2010; Anzola-Román *et al*., 2018; Papanastassiou *et al*., 2020). It is of obvious interest to governments because successful R&D will translate into higher levels of product innovation, growth and internationalization (Wallsten, 2000; Deloitte Research, 2005; Raymond and St-Pierre, 2010). And it is of interest to firms because the decision to invest in R&D can be expected to boost the firm's own innovation performance. Hence, this leads to the second hypothesis:

H2: *The firm's R&D activities are positively related to the product innovation of the firm*

2.3 The moderating effects of perceived market uncertainty

Uncertainty has been identified as one of the most important contingent factors that the firm considers when it adapts its mechanisms to the external environment (Aronson *et al*., 2006; Calantone and Rubera, 2012; Jalonen, 2012; Wang *et al.*, 2011). Uncertainty faced by the firm is of many different types (see Jalonen, 2012) including market, technical, technological, commercial, competitive, consumer, environmental, regulatory, legal, societal, political, economic, organizational, resource, decision-making, acceptance, task, and behavioral uncertainty. Many of these types of uncertainty have increased, and become more salient, in the era of the COVID-19 pandemic.

This study focuses on one of these types of uncertainty: market uncertainty. A firm faces market uncertainty when it sets out to commercialize a new technology or to enter a new market with new products (Chesbrough, 2004). Despite the market environment being one of the most important factors for a firm to survive in the market, there have only been a few studies of the effects of market uncertainty on firm innovation performance (e.g. Lam and Yeung, 2010). One likely reason for this is the difficulties in obtaining an objective measure of market uncertainty.

The measure of market uncertainty used in this study is the response to a survey question which asks firms for the extent to which market uncertainty is impeding their innovative activities. Importantly, this is not an objective measure of market uncertainty, but rather a subjective measure which is best described as the perceived market uncertainty (PMU) of the firm. Similar measures of perceived uncertainty have been used in previous empirical work (e.g. Sawyerr *et al.*, 2003). PMU bears similarities to the concept of "risk perception" which appears in the decision theory literature (Sitkin and Pablo, 1992). The response of a decision-maker to a risky situation is moderated by the decision-maker's risk perception. Extending this idea to the current setting, it may be seen a risk-seeking entrepreneur being discouraged from the innovative activities that they would normally undertake if their current perception of the market is uncertain (i.e. if their PMU is high); alternatively, it may be seen a usually risk-averse entrepreneur being persuaded to innovate if their current perception of the market is stable (i.e. if their PMU is low).

In order to capture such moderating effects of PMU, the variable will be interacted with the policy variables in the econometric model. Although moderating effects have been considered previously in similar contexts, for example, the moderating effect of competition

(Kim, 2019) and that of size disparity of a consortium (Yang, 2020), the authors are not aware of any previous research that investigates the moderating effects of the firm's perception of market uncertainty on the impact of government support policies.

There are several reasons for expecting the moderating effects of perceived uncertainty to be important in the present context. For example, previous work has established that firms operating in environments with different levels of uncertainty should have different levels of collaboration (Rubera *et al*., 2012). When firms face market uncertainty, they need higher information processing than in normal situations (Gupta *et al*., 1986; McGee and Sawyerr, 2003). In rapidly changing environments with high uncertainty of market needs, firms need to frequently exchange information to keep pace with technological and market changes (Ruekert and Walker, 1987; De Luca and Atuahene-Gima, 2007; Kwok *et al.*, 2019) with other sources such as alliance firms or larger firms in the supply chain that they can access or get better and more information. Conversely, the need for information exchange and processing can be reduced when the firm competes in environments with low uncertainty (Calantone and Rubera, 2012). Therefore, it can be expected that government support for collaboration among the firms or other organizations such as Industry/University/Institute/Local organizations, or support policies for a consortium between large firms and SMEs, have a greater impact under high uncertainty than under low uncertainty. Also, assuming that imitation of innovations or business-stealing by competitors becomes more likely under conditions of high uncertainty, we might expect government support policies for the acquisition, protection and utilization of IP to have greater impact under conditions of high market uncertainty. This leads to the third hypothesis:

H3: *Perceived market uncertainty moderates the relationships between government support policies and the product innovation of the firm.*

Turning to the impact of R&D activities, many studies have considered the effect of R&D activities on firm innovation performance (Raymond and St-Pierre, 2010; Anzola-Román *et al*., 2018; Wallsten, 2000, Kuittinen *et al*., 2013; García-Quevedo *et al*., 2017). At least one study (Calantone and Rubera, 2012) has considered the moderating effect of market uncertainty in this context although this study does not find the moderating effects to be significant.

In this study, a moderating effect is expected, in view of the discussion in previous studies (e.g., García-Quevedo *et al.*, 2017). For example, financial uncertainty and information asymmetries about the market condition can reduce the financial returns of R&D investments and the ability to attract external funds or incentives to invest in R&D. Overall, market uncertainty is likely to diminish the effectiveness of R&D. This leads to the fourth and final hypothesis:

H4: *Perceived market uncertainty moderates the relationship between the R&D activities and the product innovation of the firm.*

3. Method

3.1 Data

The empirical analysis in this study is based on the 2016 Korean Innovation Survey (KIS), which is a survey questionnaire of firms, based the Oslo Manual (OECD, 2005). The survey covers the innovation-related activities of firms with ten or more full-time employees that were in operation between 2013 to 2015 in South Korea.

The sample consists of 4000 manufacturing firms. The study focuses on product innovation consisting of new product innovation or/and product-improving innovation. Of the 4000 firms, 382 (10%) introduce new product innovation, 1,141 (29%) introduce improved product innovation, 287 (7%) do both, and 2,764 (69%) do neither. Table 2 contains descriptive statistics for all variables used in the analysis.

3.2 Measures

Table 1 shows the definitions and measurement items of each variable used in this study. Table 2 presents descriptive statistics and the correlation matrix of all variables is presented in Appendix A.

Insert Table 1 about here

Insert Table 2 about here

Dependent variables. As a dependent variable, this study used two different measures of product innovation: whether the firm introduces a *new product* to the market over the three years covered by the survey; whether the firm introduces a significantly *improved product* to the market over the three years. Both variables are measured as binary variables (1 if innovates; 0 otherwise).

Independent variables. Independent variables include six (financial and non-financial) government support policies and three types of R&D activities. The six variables representing government support policies are extracted from responses to survey questions asking firms the extent to which they have utilized each policy (0 = not at all; 3 = very much). The financial government support policy is (as defined above) *subsidies*. The non-financial policies are (as defined above): *IP, manpower, collaboration, deregulation, and consortiums*. The three independent variables representing R&D activities are binary responses to survey questions asking the firms whether (1) or not (0) they have engaged in the three different types of R&D over the three years covered by the survey: internal R&D, joint R&D, and external R&D.

A moderating variable. As discussed in detail above, PMU is used as a moderating variable. This is the response to the survey question asking the extent to which market uncertainty has impeded the innovative activities of the firm (0 = not at all; 1 = low; 2 = medium; 3 = high).

Control variables. The research framework includes four control variables related to the characteristics of a firm, that have been found in previous research to influence the decision to innovate: (1) firm size (measured by the number of employees); (2) the ratio of R&D employees in the workforce; (3) labor productivity (value of sales divided by the number of employees); (4) the type of the industry (high-tech, medium-tech, or low-tech). The last of these has previously been found to be important in explaining product innovation performance (Santamaría *et al*., 2009).

3.3 Econometric model

Following convention, the logistic regression framework is used (see Hair *et al*., 2014).[1] Let p_i be the probability of innovation for firm *i*. Let there be *K* policy variables, z_k $k=1,\ldots, K$. Let there be *J* variables representing R&D, w_j $j=1,\ldots, J$. Let PMU_i be the variable representing perceived market uncertainty (perceived by firm *i*). Let x_i be a vector containing the control variables pertaining to firm *i*.

The model takes the following form.

$$\ln\left(\frac{p_i}{1-p_i}\right)=\sum_{k=1}^{K}\left(\alpha_{1,k}z_{k,i}+\alpha_{2,k}z_{k,i}*PMU_i\right)+\sum_{j=1}^{J}\left(\gamma_{1,j}w_{j,i}+\gamma_{2,j}w_{j,i}*PMU_i\right)+x_i'\beta \quad (1)$$

The α parameters represent the effects of the policies: $\alpha_{1,k}$ represents the main effect of policy z_k; $\alpha_{2,k}$ represents the moderating effect on policy z_k of *PMU*. Likewise, the γ parameters

[1] As a robustness check, the probit model was used as an alternative to logit. As expected, the conclusions were almost identical. For this reason, the probit results are not reported here.

represent the effects of the R&D variables: $\gamma_{1,j}$ represents the main effect of R&D variable w_j; $\gamma_{2,j}$ represents the moderating effect on R&D variable w_j of PMU. Finally, the parameter vector β represents the effects of the control variables contained in x.

4. Analysis and results

STATA 17 (StataCorp, 2021) is used for estimation. Table 3 presents the results of four logistic regression models. The first two columns (Models 1 and 2) are the results from estimation with the dependent variable *new product innovation*. The last two columns (Models 3 and 4) are from estimation with the dependent variable *improved product innovation*. In each case, the first set (Models 1 and 3) of results contains only the main effects for the six financial and non-financial support policies and the three R&D activities (basic model), while the second set of results (Models 2 and 4) includes interactions between each policy or R&D activities and the uncertainty variable, PMU (full model). Four control variables are used in all models.

Insert Table 3 about here

At the end of Table 3, various measures of model performance are reported. Akaike's Information Criterion (AIC) is a measure based on the maximized log-likelihood which penalizes models with more explanatory variables. On this criterion, it is seen that for both *new product innovation* and *improved product innovation*, the model including *PMU*policy* and *PMU*R&D* interactions fits the data better than the one with only the main effects. Another reported measure is the Brier Score (obtained simply as the mean of squared differences between the binary outcome and the predicted probability) which indicates how close the predicted probabilities are to the binary outcomes, with a value of zero indicating perfect calibration, and a value of 0.25 indicating poor calibration. All models have reasonably good calibration. In addition, calibration appears to be better for *new product innovation* than for *improved product innovation*. However, this is purely a consequence of the former binary variable being more unbalanced than the latter. The final measure of model performance is the area under the ROC curve (AUC), which is a measure of discrimination, that is, it indicates how well the model discriminates between actual 1's and 0's.[2] For all estimated models, AUC is between 0.80 and 0.90, and according to the rules of thumb suggested by Hosmer *et al.* (2013), values in this range indicate *excellent discrimination*.

On the basis of all of these measures of model performance, it is clear that the models containing the *PMU*Policy* and *PMU*R&D* interactions are statistically superior to the models with main effects only. To aid the interpretation of each interaction variable, predicted probability plots are presented in Figure 2. The predicted probability graphs are shown for each of the outcome variables (*new product* innovation and *improved product* innovation) against each of the six financial and non-financial policies and the three types of R&D activities. Within each graph, the solid curve is the prediction under minimal uncertainty (PMU=0) while the dashed curve is the prediction under maximal uncertainty (PMU=3). Each curve has 95% confidence intervals appearing as vertical lines, and these are useful for judging whether the two curves are significantly different from each other, and hence whether uncertainty indeed has a moderating effect on the impact of the policy and R&D activity in question.

Insert Figure 2 about here

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[2] A useful way of interpreting AUC: If one firm with innovation, and one firm without innovation, are randomly drawn, AUC is the probability that the model predicts the former to have a higher probability of innovation than the latter. See Adams and Hand (1999).

The plots presented in Figure 2 are useful because they are very easy to interpret. For example, a dashed line appearing steeper than the accompanying solid line simply indicates that the policy in question is more effective in a situation of high perceived uncertainty.

To establish which effects are statistically significant, we examine the t-test statistics[3] appearing in Table 3. Focusing first on the main effects (see Model 1 and 3 in Table 3), the policies sometimes have significant effects on the propensity to innovate **(H1)**, although not always with the expected signs. For example, the financial support policy (*Subsidies*) **(H1-1)** has a significantly positive effect on both new *(t=3.51)* and improved product innovation *(t=5.67)*. This is in line with previous studies (e.g., Doh and Kim, 2014; Guan and Yam, 2015) that show that financial support is an important policy and a significant aid towards product innovation of the firm. Among non-financial support policies **(H1-2)**, support policy for *IP (t=4.12)* has a positive effect on new product innovation while support policies for *Manpower* (resolution of manpower shortage) *(t=4.33)* and *collaboration* (collaboration among industry, university, institute, and local organizations) *(t=2.88)* have positive effects on only improved product innovation. Because of the importance of *IP* for new product development processes, the support policy for *IP* seems to have a significantly positive effect on new product innovation. Unexpectedly, the effect of *Deregulation* (deregulation policies of unreasonable regulation) *(t=-0.71; t=-0.13)* on both product innovation is not significant. Surprisingly and unexpectedly, the result of the analysis related to *Consortium* (support policies for a consortium between large firms and SMEs) affect negatively the product innovation of the firm (both new product innovation *(t=-3.51)* and improved product innovation *(t=-5.79)*).

[3] In the discussion that follows, t-statistics are presented in parentheses as a measure of significance. *t-statistics* are more useful than *p-values* in the present situation because (i) the signs of the statistics are very important in the interpretation and (ii) most of *the p-values* are very close to zero and therefore indistinguishable. The reader is reminded that (given the large sample) a t-statistic larger than 1.96 in absolute value indicates significance ($p<0.05$), while one greater than 2.58 in absolute value indicates strong significance ($p<0.01$).

Turning to the effects of the R&D variables **(H2)**, it is seen that the three types of R&D have positive effects on new product innovation. The effect of Internal R&D *(t=9.85)* appears to be the strongest of the three activities, while that of Joint R&D *(t= 2.69)* is the weakest. Also, it appears that R&D activity has a stronger effect on new product innovation than on improved product innovation.

Turning to the moderating effect of the impact of PMU (see Models 2 and 4 in Table 3), it is seen that some of the **PMU*Policy** interactions on product innovation **(H3)** are significant (e.g. *PMU*Subsidies* on new product innovation *(t=3.22); PMU*Consortium* on both new *(t=1.98)* and improved product innovation *(t=2.53)*; *PMU*Manpower (t=-2.50)* and *PMU*Collaboration (t=2.65)* on improved product innovation), but again some have unexpected signs (e.g., *PMU*IP* is negatively significant on both new *(t=-4.23)* and improved *(t=-3.38*) product innovation). The negative moderating effect of PMU on the impact of support policy for IP, simply confirms what is seen in the second row of Figure 2, that the impact of support policy for IP on product innovation is weaker under market uncertainty.

The **PMU*R&D activities** interactions **(H4)** show significant effects in the case of *external R&D (t=-2.16),* for which *PMU* appears to reduce the positive impact on new product innovation, and *internal R&D activities (t=-3.62),* for which uncertainty appears to reduce the positive impact on improved product innovation. The latter effect is strongly significant. Note that this contradicts the results of Calantone and Rubera (2012) who reported that market uncertainty had no significant moderating role in this context.

5. Discussion

The study has found that government support policies have a significant positive effect on both new-product and improved-product innovation (**H1**) and this is in agreement with previous studies (Doh and Kim, 2014; Guan and Yam, 2015). The study has also found that R&D activities have a significantly positive effect on product innovation **(H2)**, again in agreement with previous studies (Raymond and St-Pierre, 2010; Anzola-Román *et al.*, 2018; Papanastassiou *et al*., 2020).

As mentioned previously, to the best of the authors' knowledge, this is the first study in innovation research in which government policies have been interacted with measures of market uncertainty **(H3)**, hence it is harder to relate the findings to previous literature. The identification of the interaction effects leads us to a distinction of policies according to whether they are beneficial (in terms of increasing the propensity to innovate) under high or low PMU. As is clear from Figure 2, both *Subsidies* and *Collaboration* are beneficial policies under conditions of high PMU. There is previous literature (e.g., Kang and Park, 2012) establishing the importance of these policies in the innovation process. This study can claim to be adding to this literature because it is finding that the positive effects of these policies may be conditional on high PMU. In contrast, *IP* and *Manpower* are beneficial under conditions of low PMU (See Figure 2). The policy for *Consortium*, on the evidence of this data set, appears detrimental under any conditions. Note from Table 3 that, while the interaction effect *PMU*Consortium* is positive, it is greatly outweighed by the negative main effect of *Consortium*.

The findings relating to *Consortium* suggest that support policies for a consortium between large-sized firms and SMEs **(H1)** should be elaborately designed based on each country's context. For example, in the Korean case, a consortium between large firms and SMEs is designed to promote win-win cooperation between enterprises and it is related to financial and non-financial support for the performance-sharing system (called "benefit sharing"). In fact, in Korea, there is public pressure for large-sized firms to share the benefits of their performance with social SMEs, and consortium results are likely to be linked to ethical management or Environment, Social & Governance (ESG) management required by the government (Social Enterprise Promotion Act, 2012). Therefore, large-sized firms tend to just choose partners among social SMEs as "win-win cooperation partners" for the short-term rather than for the long-term. These institutional arrangements may partly explain the negative effects of policies supporting consortiums of different-sized firms.

It is seen that the three types of R&D have positive effects on new product innovation (See Table 3 and Figure 2), with internal R&D having the strongest effect. In terms of the PMU*R&D interactions, some significant moderating effects have been identified, and, as remarked above, this contradicts the findings of Calantone and Rubera (2012) who found no significant moderating effects.

6. Conclusion

6.1 Summary of the findings

Using data on 4,000 manufacturing firms from national data set approved by Statistics Korea, this study has investigated how government support policies affect the innovation performance of firms. A distinction has been made between new and improved product innovation. The most important contribution of the study is that it has investigated the moderating effect of uncertainty of the market environment on policy effectiveness for innovation.

While most of the results are expected, some are unexpected. Some of the unexpected effects of policy effectiveness may be explained in terms of the dependency of SMEs on large firms. Some SMEs behave passively with respect to innovative activities, simply following the policies and decisions of larger firms, with innovation success, therefore, becoming dependent on partners' resources. Given this, government policymakers need to find ways of promoting win-win cooperation between large and small businesses.

6.2 Theoretical implications

This study has extended the understanding of government support policies and R&D activities under market uncertainty and their effects on product innovation through an empirical study of the manufacturing sector in Korea. In particular, to the best of the authors' knowledge, this study is the first empirical study to consider the moderating effect of market uncertainty on the effectiveness of government policies aimed at promoting product innovation. Another contribution of the study is to consider financial and non-financial government support policies separately.

6.3 Managerial implications

Firms typically choose between the various government support policies on offer. The obvious managerial implications are that while most of the policies considered are beneficial in terms of improving innovation performance, the firm's decision of which policy to select should depend on their current perception of market uncertainty (PMU). In particular, if their PMU is high, they are likely to benefit more from subsidies or collaboration, while if their PMU is low, they are more likely to benefit from IP or manpower (see Figure 2).

6.4 Policy implications

The findings relating to the impact of collaboration policies may be particularly useful for policymakers. For example, in South Korea, the objectives of most research support policies or national projects such as *LINC (Leaders in INdustry-university Cooperation) projects applied to universities* (Jin and Lee, 2021) are to improve regional competitiveness and strengthen innovation capabilities of the firms through collaboration among industry-university-research centre. The analysis of this paper has, to a degree, vindicated this approach to policy design because the impact of government support for collaboration among the industry, university and institution on innovation success is positive, but only under conditions of high uncertainty (see Figure 2).

Findings relating to the impact of deregulation policies are also noteworthy. The impact of deregulation on product innovation success has created a political debate that is very important for both conservative and progressive political parties, and there is an expectation that policies such as deregulation on the success of technological product innovation. These results suggest that in-depth case studies will be needed for future research.

6.5 Limitations and future research

One obvious shortcoming of this study is that it is based on a single cross-section of data, and the measure of market uncertainty used in the analysis is a self-reported measure based on survey responses. A useful alternative approach would be to use panel data and exploit the time dimension of the panel by investigating the effect of an objective time-varying measure of market uncertainty applied to all companies.

Moreover, this study did not include other activities that can be relevant for promoting innovation in firms such as collaborations and/or the creation of incubation programs (e.g., Hillemane *et al*., 2019; Mele *et al.,* 2022), open innovation (e.g., Chesbrough and Crowther, 2006; Flamini *et al*., 2021) and intrapreneurship activities (e.g., Lukes and Stephan, 2011).

The results of the analysis of the study are interesting and potentially useful. However, it is stressed that, to the best of our knowledge, because this is the first study in innovation research in which policies have been interacted with perceived levels of market uncertainty, it is suggested that further analysis of these moderating effects using different data sources is called for. Furthermore, the effects of government policies on R&D activities is another interesting topic for firm innovation performance. Future studies can investigate what types of policies strengthen the various types of R&D activities. Follow-up studies are needed to analyze the moderating effect of market uncertainty by considering the technology innovation leadership tendency pursued by individual firms in the same industry. In addition, future research needs to investigate companies within the same industry based on the tendency towards technological innovation and the product life cycle adopted by individual companies. Regrettably, it is not easy to obtain the data required to address such questions. Finally, it is likely that different countries have different government policies to promote innovation, depending on their national contexts (e.g., Eom and Lee, 2010). It is therefore desirable for future studies to perform similar investigations with data from other countries.

Insert Appendix A about here

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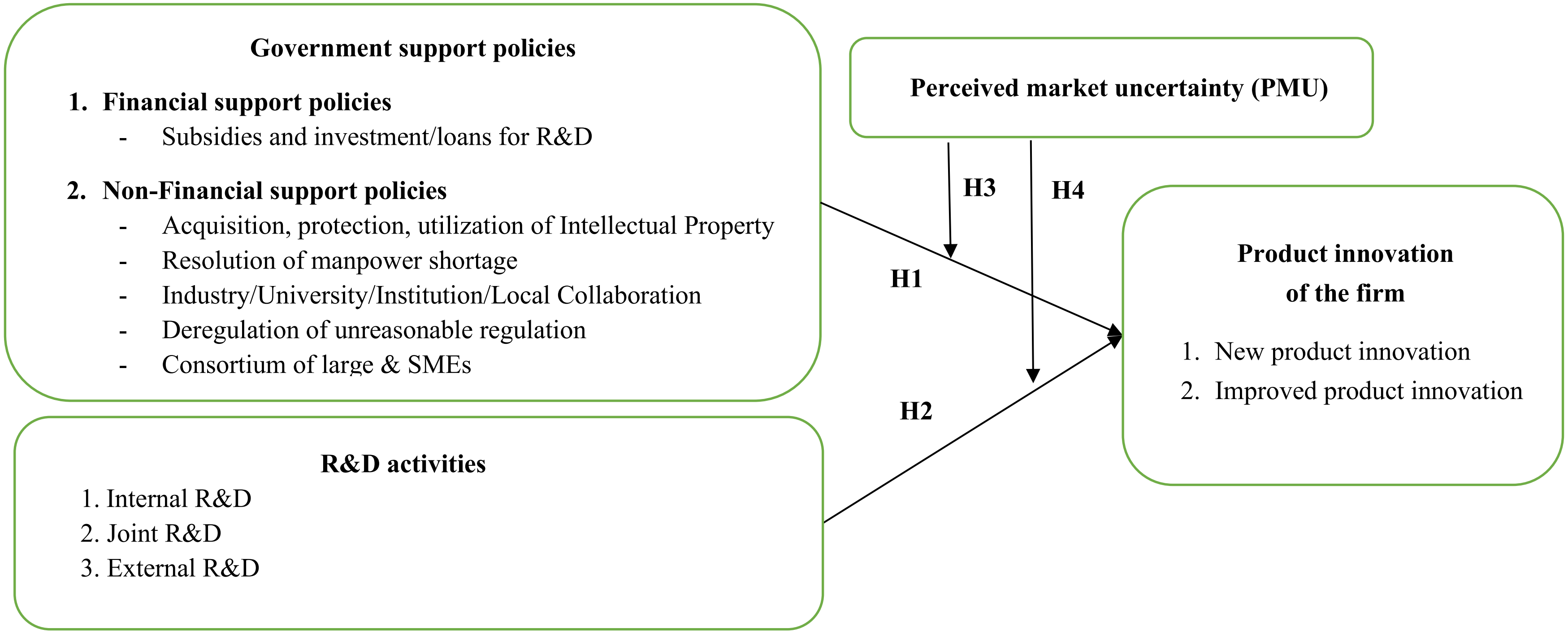
Figure 1. The conceptual framework



Control Variables:

1. Firm size
2. The ratio of R&D employee
3. Labor productivity
4. The types of the industry (R&D intensity)

Figure 2. Predicted probability of New products (left panels) and Improved Products (right panels) against the firm's utilization of the different policies, and three R&D activities.

New Product Innovation Improved Product Innovation

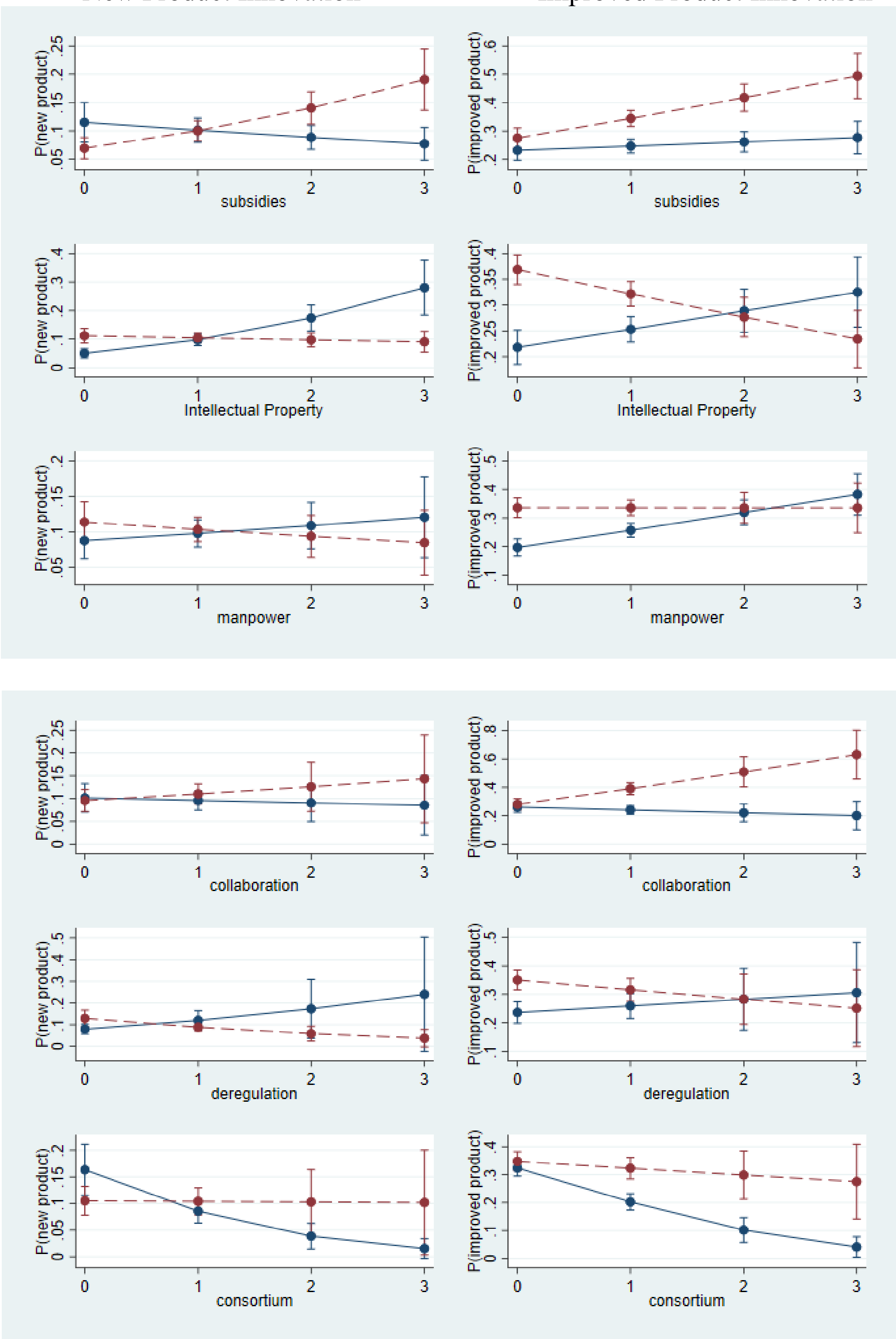
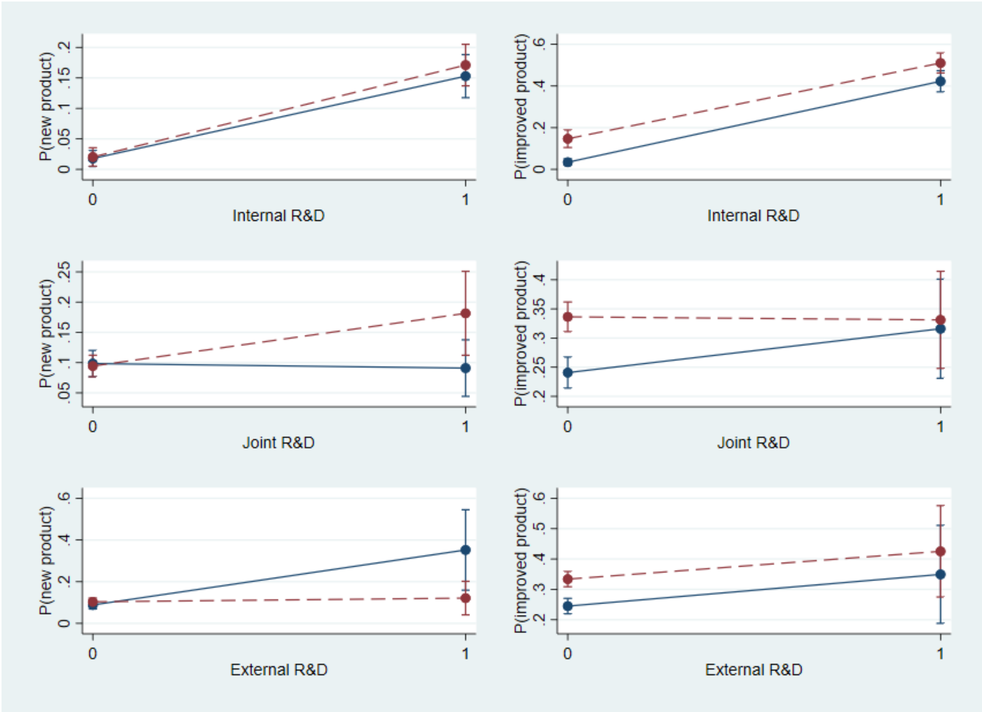


Figure 2 (continued)



Note: Blue solid line: low PMU (PMU=0); red dashed line: high PMU (PMU=3)

Table 1. Definitions of the variables

Variable	Definitions
Dependent variables: product innovation	
New product innovation	1 if the firm introduces an absolutely new product to the market; 0 otherwise
Improved product innovation	1 if the firm introduces a significantly improved product to the market; 0 otherwise
Independent variables: Six government policies and three R&D activities	
Subsidies	Support for loans, funding and subsidies for R&D or related to innovation
Intellectual Property (IP)	Support for acquisition, protection, and utilisation of IP
Manpower	Support for the resolution of manpower shortage
Collaboration	Support for Industry/University/Institute/Local Collaboration
Deregulation	Deregulation of unreasonable regulation
Consortium MS-L	Support for the consortium of large & SMEs
Internal R&D	R&D activities are fulfilled internally within the firm to create new knowledge or to solve scientific or technological problems
Joint R&D	R&D activities fulfilled collaboratively with other firms or organizations to create new knowledge or to solve scientific or technological problems
External R&D	Purchasing and acquisition of existing know-how, copyrighted works, patented and non-patented inventions, etc. from other firms or organizations to create new knowledge or to solve scientific or technological problems
A Moderator	
PMU	Perceived market uncertainty; To what extent market uncertainty has impeded the innovative activities of the firm
Control variables	
Firm Size	The number of employees
The ratio of R&D Labor	The number of R&D researchers divided by the total number of firm employees and then it was multiplied by 100
Log (Labor productivity)	Natural logarithm of (annual turnover divided by the total number of firm employees)
The type of industry	The type of industry classified by OECD (2016). The industry is classified into four technology groups based on R&D intensity, that is R&D expenditure divided by total turnover.

Table 2. Descriptive statistics

		Observations	mean	S.D	Min	Max
Dependent Variables						
New Product		4,000	0.10	0.294	0	1
Improved Product		4,000	0.29	0.452	0	1
Independent Variables						
Subsidies		4,000	0.67	1.058	0	3
IP		4,000	0.55	0.98	0	3
Manpower		4,000	0.59	0.951	0	3
Collaboration		4,000	0.42	0.847	0	3
Deregulation		4,000	0.35	0.747	0	3
Consortium SM&L		4,000	0.40	0.803	0	3
Internal R&D		4,000	0.45	0.498	0	1
Joint R&D		4,000	0.06	0.244	0	1
External R&D		4,000	0.03	0.158	0	1
Moderator						
PMU		4,000	1.42	1.061	0	3
Control Variables						
Firm Size		4,000	1.72	1.014	1	5
R&D Labor %		3,995	2.24	1.428	1	7
log(productivity)		3,449	5.42	0.717	1.95	8.70
Type of Industry	High	4,000	0.10	0.30	0	1
	High-Medium	4,000	0.43	0.50	0	1
	Medium	4,000	0.19	0.39	0	1

Table 3. The results of logistic regression analysis

	New Product Innovation		Improved Product Innovation	
	Model 1: Basic model	Model 2: Full model	Model 3: Basic model	Model 4: Full model
Government policies				
Subsidies	**0.233*****	-0.206	**0.323*****	0.138
	(3.51)	(-1.40)	(5.67)	(1.16)
IP	**0.287*****	**0.840*****	-0.0525	**0.385****
	(4.12)	(5.74)	(-0.84)	(2.98)
Manpower	0.0324	0.162	**0.302*****	**0.573*****
	(0.38)	(0.97)	(4.33)	(4.08)
Collaboration	0.0215	-0.0871	**0.296****	-0.192
	(0.19)	(-0.36)	(2.88)	(-0.92)
Deregulation	-0.109	0.621	-0.0166	0.218
	(-0.71)	(1.44)	(-0.13)	(0.67)
Consortium	**-0.497*****	**-1.190****	**-0.668*****	**-1.279*****
	(-3.51)	(-2.95)	(-5.79)	(-4.51)
R&D activities				
Internal R&D	**2.536*****	**2.613*****	**2.675*****	**3.487*****
	(9.85)	(6.05)	(18.32)	(12.47)
Joint R&D	**0.531****	-0.119	0.280	0.687
	(2.69)	(-0.27)	(1.48)	(1.64)
External R&D	**1.022*****	**2.503*****	**0.688***	0.965
	(3.51)	(3.42)	(2.14)	(1.22)
PMU	0.0564	0.169	**0.203*****	**0.589*****
	(0.83)	(0.82)	(3.93)	(4.98)
Moderating effects				
PMU*Subsidies		**0.220****		0.104
		(3.22)		(1.78)
PMU*IP		**-0.312*****		**-0.227*****
		(-4.23)		(-3.38)
PMU*Manpower		-0.0978		**-0.191***
		(-1.07)		(-2.50)
PMU*Collaboration		0.0914		**0.299****
		(0.71)		(2.65)

PMU*Deregulation			-0.382		-0.156
			(-1.81)		(-0.98)
PMU*Consortium			**0.392***		**0.366***
			(1.98)		(2.53)
PMU* Internal R&D			-0.0661		**-0.478*****
			(-0.29)		(-3.62)
PMU* Joint R&D			0.346		-0.241
			(1.60)		(-1.17)
PMU* External R&D			**-0.762***		-0.113
			(-2.16)		(-0.30)
Control Variables					
Firm Size		0.0501	0.0526	0.192***	0.177**
		(0.69)	(0.71)	(3.42)	(3.13)
R&D Labor %		0.146**	0.139*	0.253***	0.238***
		(2.75)	(2.57)	(6.08)	(5.66)
Log (Labor productivity)		-0.0730	-0.0704	0.154*	0.151*
		(-0.77)	(-0.73)	(2.14)	(2.07)
Type of industry (R&D Intensity)	High	0.122	0.109	-0.188	-0.210
		(0.49)	(0.43)	(-1.03)	(-1.12)
	High-medium	-0.0413	-0.0385	-0.285*	-0.273*
		(-0.22)	(-0.20)	(-2.17)	(-2.07)
	Medium	0.861***	0.866***	-0.415*	-0.412*
		(4.08)	(4.07)	(-2.55)	(-2.53)
constant		-4.788***	-4.945***	-4.868***	-5.429***
		(-8.20)	(-7.48)	(-11.28)	(-11.29)
LogL		-841.9	-825.2	-1300.8	-1276.5
n		3446	3446	3446	3446
k		17	26	17	26
AIC		1717.9	1702.4	2635.6	2605.0
BRIER		0.0741	0.0719	0.1543	0.1542
AUC		0.8458	0.8498	0.8080	0.8128

Note: Asymptotic *t* statistics in parentheses (* p < 0.05, ** p < 0.01, *** p < 0.001)
LogL is maximised log-likelihood; n is the sample size; k is the number of parameters in the model; AIC is Akaike's Information Criterion; BRIER is Brier Score; AUC is the area under the ROC curve (see main text for interpretation of AIC, BRIER and AUC).

Appendix A. Correlation matrix (n=4000)

		mean	S.D	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	New Product	0.10	0.294	1															
2	Improved Product	0.29	0.452	.335**	1														
3	Subsidies	0.67	1.058	.231**	.413**	1													
4	IP	0.55	0.98	.228**	.349**	.670**	1												
5	Manpower	0.59	0.951	.119**	.359**	.602**	.595**	1											
6	Collaboration	0.42	0.847	.119**	.327**	.598**	.657**	.700**	1										
7	Deregulation	0.35	0.747	.077**	.269**	.575**	.625**	.667**	.831**	1									
8	Consortium SM&L	0.40	0.803	.068**	.249**	.574**	.619**	.681**	.798**	.858**	1								
9	PMU	1.42	1.061	.077**	.192**	.208**	.209**	.197**	.244**	.262**	.244**	1							
10	Firm Size	0.45	0.498	.098**	.269**	.283**	.321**	.374**	.355**	.340**	.391**	.104**	1						
11	R&D Labor %	0.06	0.244	.254**	.447**	.381**	.343**	.253**	.255**	.215**	.223**	.141**	.136**	1					
12	log(productivity)	0.03	0.158	.034*	.109**	.084**	.063**	.083**	.061**	.035*	.061**	0.033	.050**	.119**	1				
13	Internal R&D	1.72	1.014	.317**	.599**	.471**	.440**	.420**	.381**	.346**	.366**	.233**	.365**	.612**	.124**	1			
14	Joint R&D	2.24	1.428	.201**	.221**	.264**	.270**	.176**	.285**	.193**	.195**	.089**	.124**	.234**	0.025	.239**	1		
15	External R&D	5.42	0.717	.163**	.144**	.162**	.165**	.113**	.181**	.166**	.176**	.067**	.105**	.136**	0.026	.146**	.426**	1	
16	Type of Industry	0.10	0.30	.047**	-.076**	-.068**	-0.029	-.090**	-.034*	-0.006	-0.009	.112**	-0.024	-.103**	.084**	-.061**	-0.008	-0.028	1

*. α < 0.05; **. α < 0.01