Vocational Training Support and Innovation at SMEs

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Purpose: While the value of human capital for technological innovation is well acknowledged, literature on the role of vocational training in corporate innovation is notably scarce. This study assesses the effect of government support for small and medium-sized enterprise (SME) competencies on Korean firms' innovation. We investigate SMEs' patent applications (supported by the government to varying degrees) while accounting for firms' market position, ownership and management structure, as well as prior changes in firms' technologies, products, processes and other characteristics. Alternative hypotheses about management motivation – the 'lazy manager', 'career concerns', and 'special East Asian institutional constraints' hypotheses – are also evaluated.

Design: Censored and count data analysis methods are used on a panel of 595 Korean firms covering 2005–2015 from the Korean Human Capital Corporate Survey, Intellectual Property Office, and National Investment Commission. A regression discontinuity estimator accounts for potential endogeneity due to support for vocational training at firms.

Findings: Firms receiving training support are more innovative than firms without support, but latent effects may play a role. The regression-discontinuity model suggests that firms that succeeded only marginally in obtaining support had higher innovative output than non-recipients near the eligibility threshold.

Originality: Our findings establish that government support had the intended effect on SMEs' technological capacity. This cannot be discounted as a simple crowding-out effect. We also establish that management–ownership separation within firms was conducive to innovation, that product competition had an inverse *U*-shaped effect, and that management–ownership separation had a substitutable relationship with competition in overcoming managers' effort avoidance. The findings support the 'lazy manager' hypothesis over the 'career concerns' and the 'special East Asian institutional constraints' hypotheses.

Keywords: innovation, patents, vocational training, corporate governance, lazy manager hypothesis, regression discontinuity
JEL Codes: O32, O38, M53, P46.

I. Motivation and Background

Technological innovation and its protection through patent registration have been crucial driving forces of economic performance and competitiveness for firms, as well as for economic sectors broadly. Firms choose the speed and form of innovation in consideration of market uncertainties, product market competition, net costs of research and development (R&D), and the appropriability of investment in innovation by firms and their decision-making managers. Firm innovation is therefore driven by firms' technological, market and regulatory conditions, as well as their corporate governance, including firms' ownership and management structures and access to technological and human capital.

Prior literature has identified the effects of capitalisation, ownership and management structures, and human resources on Asian firms' choices to pursue innovation. Another branch of literature has considered the achievements of various government support systems for Korean small and medium-sized enterprises (SMEs) and their long-term performance.

Our study strives to bridge and extend these bodies of literature by examining the role played by government support for SME competencies, particularly the system of incentives for SME workers' vocational training, in firms' observed innovation – an area in which empirical assessments are conspicuously missing.

We formulate several hypotheses regarding the implications of the following factors of firm innovation: government support for workers' vocational training, the presence of professional managers, the presence of foreigners among firms' majority owners, executives' independence from owners, market competition – and their interplay. We evaluate these hypotheses using high-quality panel data for Korean companies spanning 11 years from the databases of the Korea Research Institute for Vocational Education and Training (KRIVET) and the Korean Intellectual Property Office (KIPO). Since companies' decision-making environments may vary over time and across different types of firms, the panel structure allows us to isolate factors that are changeable across the years from the inherent time-invariant effects prevailing in individual market segments.

The study is organised as follows. The following paragraphs evaluate the regulatory conditions under which Korean firms decide on their innovation strategy, including R&D and intellectual property (IP) regulations and fiscal policies towards SMEs, firms' human capital, and innovation. The following section reviews the existing literature investigating the governance- and human resource-related determinants of companies' innovation, particularly in the Korean context. Section III delineates our empirical strategy, including our reliance on the data. Section IV reports the results of the estimated models and several robustness tests. Section V concludes with policy implications and suggestions for further research.

Economic and regulatory background

Korean firms are under pressure to innovate, pursue efficient R&D and protect their innovations aggressively. Their managers are also under pressure to select the extent and form of innovation based on their relationship with the firms' owners and boards of directors, subject to available human resources. Owners' capacity to supervise, influence and reward managers' choices – as well as workers' implementation of the decisions – affects the intensity of innovative activities at firms.

Our analysis covers 2005–2015, a fascinating period for a review of firm innovation and government support systems for firms. The Korean economy experienced an upheaval amid the worldwide economic crisis; the country's trade regime – including that for professional services and intellectual property – became liberalised in important ways, and the intellectual-property registration process was streamlined and promoted through various public policy schemes.

In the 2000s, the economy saw continuous resurgence from the 1998 Asian financial crisis and the 2001 dot-com bubble until 2007–2008, when the global great recession brought a correction, followed by an uneven recovery from 2010–2015. Corporate governance rules were amended following each crisis. Trade agreements with major global partners were signed post-2010, with significant implications for the country's intellectual property market and legislation as well as firms' sales and technology-exchange prospects. Figure 1 illustrates the co-movement of trends in the aggregate economy and firms' patent registrations across the time frame of our study. In sum, Korean firms operated in different economic climates under variously straitened conditions regarding output and innovation markets in the 2005–2015 period.

The intensity of firms' R&D also depends on public policies towards their acquisition of skills and information, as well as R&D, and even sectoral policies, such as the regulation of institutional cross-ownership among conglomerates, relations with subsidiaries and joint R&D ventures. Korea lacks universal legislation for all types of intellectual property and rather relies on multiple acts covering the various types, including the most recently revised Patent Act (amended in 2022), the Utility Model Act (amendment forthcoming), the (Game) Contents Industry Promotion Act (amended in February 2023), the Semiconductor Chip Protection Act (amended in March 2023), the Industrial Design Protection Act (amended in 2012), as well as the older Unfair Competition Prevention and Trade Secret Protection Act, Protection Act for Computer Programmes, and Seed Industry Act. These pieces of legislation and the loopholes between them have led to inadvertent or deliberate circumventions, disruption of marketplace competition and increased costs of doing business for Korean and foreign entities pursuing patent-related engagements. The European Commission has kept Korea on a watch list due to the country's soft and haphazard upholding of intellectual property rights.

Regulatory reforms

Over the past decade, the Korean government has invested resources into improving the capabilities of micro-, small and medium-sized enterprises (broadly, SMEs) to compete with their large corporate counterparts (*chaebol*) as well as with overseas firms. These initiatives aim to improve SMEs' access to credit, resources and product demand. They also provide support for the acquisition of technology, talent and manpower. The government has also invested effort into modernising existing legislation to improve the functioning of the intellectual property market in terms of efficiency and transparency and has instituted economic measures streamlining and promoting competition and innovation (Hlasny, 2008). At the same time, efforts have been made to usher in equitable working conditions at firms and promote workers' mobility through the tightening of labour standards, harmonising them across more firm and employee types and expanding the provisions for worker up- and re-skilling.

Such efforts were expanded following the signing of the Korea–European Union and Korea–United States Free Trade Agreements (KOREA-EU and KORUS FTA). The KORUS FTA forced Korean policymakers to revise a number of intellectual property acts to align them with U.S. standards. Trade secrets were granted stronger safeguards, and the expiration of various protections was deferred. Regarding interaction with European markets and firms, the European Commission forced Korean regulators to abide by the property rights stipulations of the KORUS FTA to strengthen protections, especially in advanced high-tech, pharmaceutical and chemical product sectors (Park, 2008). In response to growth in foreign trade, Korea's Industrial Technology Spill Prevention Act was enhanced in 2007 to avert wrongful leakages of trade secrets to foreign parties. For-profit firms and non-profit entities, including educational and research institutions possessing strategically critical technologies, were covered by the law.

The Korean regulators have also worked on influencing business executives' decisions by overhauling the fiscal environment – reforming the tax code and offering firms opportunities and direct incentives for staff upskilling, the acquisition of information, R&D, and intellectual-property management. For instance, in 2013, the government-run Korea Development Bank (KDB) joined forces with the KIPO to offer loans to SMEs that allowed them to use their registered intellectual property as collateral – thus demonstrating their growth prospects by registering their intangible assets – to receive cheap credit of up to 2 billion won.

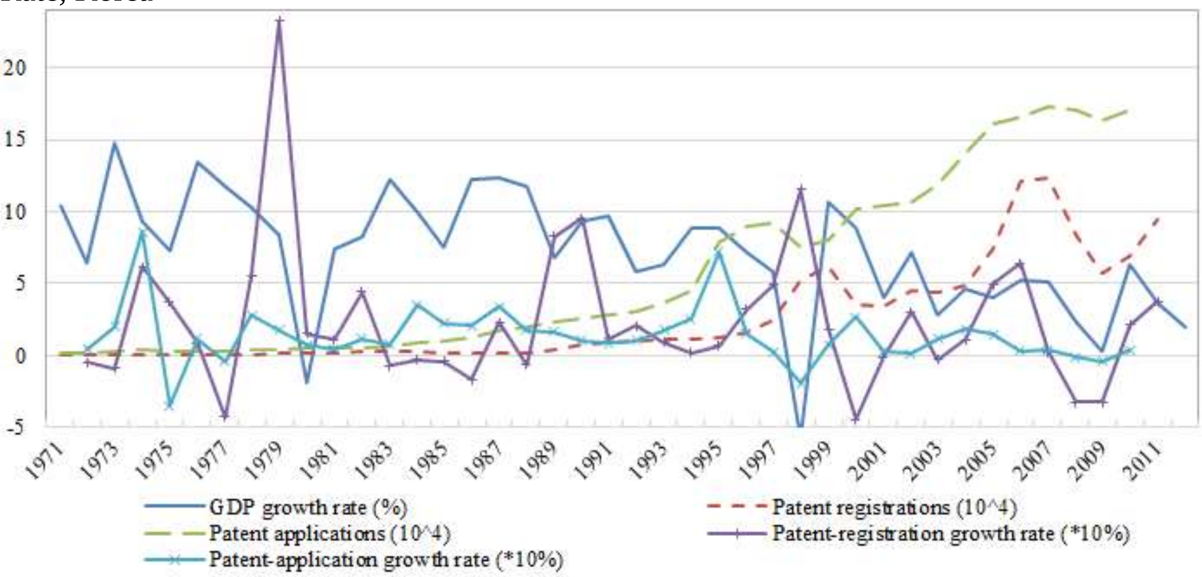
Specifically in relation to firms' human capital and staff training, the vocational and lifelong training of workers has been regulated under the mandate of the Workers' Vocational Skills Development Act of 1997. This was amended and strengthened in 2015 amid Korea's shift towards a knowledge economy. In the past decade, the Ministry of Employment and Labour (MOEL) has rolled out various schemes, such as on-the-job training through the industry-funded employment insurance fund and the Re-employment Programme of Non-profit Vocational Training Centres. Further, the Ministry of Education has operated the College Lifelong Education Centre Programme, and the Academic Credit Bank System has been set up to provide universal access to lifelong retraining opportunities (UNESCO-UNEVOC, 2018).

The MOEL has also enacted a support system empowering technology workers in SMEs (thought of as a *secondary* labour market offering inferior working conditions and irregular contracts) to ensure that their innate skills are put to their best uses and to integrate them in the same nationwide market for talent as their peers in the *chaebol* (the *primary* industrial sector). Moreover, the MOEL has put into place support for workers' vocational training and offers special support to SMEs in the form of assistance with training consortia, organising SME learning, improving the core job skills of the SME workforce, and providing systematic field training. The government also allows employers and workers to claim vocational skill development expenses as credit towards unemployment insurance fees.

Regarding firm innovation, the government offers tax credits for technology roll-out expenses, financial assistance for technological advances and commercialisation, invites firms to participate in government R&D projects, as well as technical support, guidance and critical information.

In our sample, 33% of the firms (154 out of 464) reported that they had received a tax reduction for technology development in 2009 (the only year surveyed). Twenty-seven per cent of firms received financial support for technology development and commercialisation, 32% participated in government R&D projects, 13% received technical support and guidance from the government, and 13% were provided technical information by the government – of which only one-half received both guidance and technical information. Individual programmes have thus operated independently, and the only common denominator appears to be the eligibility rules for grants.

Figure 1. Patent Applications and Registrations and Real Gross Domestic Product Growth Rate, Korea



Sources: Figure by author. Author's analysis of data from the Bank of Korea and KIPO.

II. Literature Review

Firms' motivation to innovate has been the subject of a vast stream of economic literature. Most relevant to our undertaking, a number of studies have considered firms' internal governance structures and managers' motives for pursuing innovation, assuming that firms have the physical and human resources to implement their managerial vision. The critical role of human capital in spurring R&D is well acknowledged (ADB, 2004; Dakhli and De Clercq, 2004; Edralin, 2007; Tullao and Cabuay, 2014). Its effect is further mediated by a supportive organisational structure, which demonstrates the benefits of broader institutional social responsibility for firm innovation (Santos-Jaén et al., 2021; Chaubey et al., 2022). Investing in staff training may be profitable even with the risk of future separation (Acemoglu, 1997; Scicchitano, 2007; Na, 2021). In fact, continuous firm-provided staff training appears to lead to continuous product and process innovation and a rise in productivity (Gallié and Legros, 2012; Boadu et al., 2018; Dostie, 2018).

The existing corporate governance literature views staffing and staff skilling as within the purview of managerial tactical decisions, and thus secondary to understanding firms' strategic orientation. Agency theory views firm managers as agents who carry out operational decisions for the firm and stockholders as principals who offer capital and either face the pitfalls of innovation or enjoy its benefits (Alchian and Demsetz, 1972). This separation of roles affects the risk-taking and technology investment decisions of firms (Miozzo and Dewick, 2002).

Management supervisory boards play a role in between firm owners and decision-making managers (Adams and Ferreira, 2005). Corporate boards serve to advise managers but also to monitor and reward their performance. Owner–manager separation may facilitate beneficial management actions as long as owners have adequate information regarding the challenges that managers face. Supervision by owners then becomes less critical than their advisory interventions. By contrast, tighter manager–owner interaction and more frequent reviews can promote intelligence sharing, which is conducive to better corporate decisions at the risk of exerting too much monitoring pressure on managers. Depending on the circumstances of firm management – managers' career concerns under tight monitoring (resulting in overzealous management), loose advisory guidance (leading to timid or uninformed management), or effort avoidance by lazy managers amid a monitoring vacuum (lazy management) – divergent degrees of monitoring and advising roles and owner–manager separation are warranted.

The structure of ownership is also thought to affect firms' decisions regarding innovation, but the direction is unclear. On the one hand, widely dispersed minority shareholders are thought to face short-term credit constraints; therefore, they are prone to favour short-term returns and be risk-averse. By contrast, institutional owners and block owners tend to be associated deeply with the firm, including decision-making managers, and may possess strategic information conducive to more extensive and better-informed risk taking (Hoskisson and Turk, 1990). An alternative view is that scattered minority owners may be more risk-indifferent as they can diversify risks through portfolio investment, while highly concentrated block owners may be risk-averse through their severe exposure to specific companies' risks (Ortega-Argiles et al., 2005). These effects operate through the advisory relationship between boards of directors and managers, particularly if the manager faces career concerns about the decision to invest in innovation.

The interaction of company ownership and the composition of boards of directors with market competition also affects managers' investment choices (Aghion et al., 2013). Two alternative hypotheses regarding the managerial decision environment have been promulgated – that of independent, informed decision-making versus that of effort avoidance ('career concerns' vs. 'lazy manager' hypotheses) – in the presence of the institutional ownership of firms. Institutional owners are less diffuse than small stockholders, are typically better informed about the nature of the firm's business and give managers space and possibly guidance to make shrewd decisions.

Under the 'career concerns' hypothesis, close monitoring by block owners eases managers' career concerns and promotes innovative activity – and it does so particularly in competitive environments. The risk of managerial turnover is expected to incentivise managers to pursue more innovation. Under the 'lazy manager' hypothesis, managers are more motivated to innovate in circumstances involving uncertainty, close contests between firms or close monitoring by owners than when they are independent and free in their decision-making. According to this view, block ownership is less valuable for monitoring managers' efforts as market competition heats up, as managers are already sufficiently motivated to exert effort in order to survive in the competitive market.

An alternative to agency theory is individual-based prospect theory, which states that managers' approaches to uncertainty are affected by the gap between their target outcome and the actual outcome. If the outcome, such as company sales, falls short of the goal, managers' tend to seek risk. If the actual outcome exceeds the target, individuals become risk-averse (Hoskisson et al., 1993). Song and Lee (2012) confirmed the tenets of this theory in the Korean setting, but their test relied on a small sample of only 267 firm observations.

In East Asia, evidence is mixed regarding the agency issues of professional CEOs – specifically, whether firm ownership affects managers' incentives in the same way as in the West (Hlasny and Cho, 2017). One stream of literature has found that managers at Korean companies strive to innovate under idiosyncratic institutional circumstances and constraints. Korean firm ownership may be either highly concentrated in the hands of a handful of individuals or under the control of a conglomerate group (*chaebol*), which may meddle in the firm's operation. Block shareowners with significant voting rights may also be responsible for reduced innovation activity due to their aversion to risk (Kim et al., 2009). Hlasny and Cho (2017), relying on Human Capital Corporate Panel (HCCP) panel data, found support for the 'lazy manager' hypothesis at Korean firms but found little evidence for prospect theory, the 'career concerns' hypothesis or the 'East Asian institutional constraints' hypothesis.

Market competition is consistently found to affect innovation activity non-linearly, suggesting an inverse *U*-relationship (Aghion et al., 2005, 2013; Sapra et al., 2008). Competition also interacts with corporate governance, increasing the salience of short-term achievements. Complementarity may exist between the role of competition and institutional ownership in spurring innovative activity. Competition eases managers' career concerns when ownership and management are better separated (Aghion et al., 2013). With regard to the role of government support systems, stronger intellectual property protection systems improve firms' appropriability of the fruit of their innovation and encourage R&D investment (Czarnitzki and Toole, 2006).

East Asian studies show that the 'lazy manager' and information asymmetry theses may play an outsized role compared to the 'career concerns' hypothesis (Hlasny and Cho, 2017). Improvements in monitoring or stimulating CEOs' efforts are conducive to innovative activity. East Asian managers' decisions regarding innovation typically take into account their firms' economic stability and the robustness of their operations. By contrast, non-East Asian executives treat innovation as more of a tool to increase the value and competitive position of their companies.

Ensuring the stability and soundness of East Asian firms – particularly SMEs – amid technological change requires active management of human resources, including the stock of workers' human capital and continuous vocational training (Curtain, 2004; Bosch and Charest, 2008; Lee et al., 2019). Support for workers' training would thus promote a virtuous circle of productivity enhancement and innovation. Firms' innovation can be fostered using various fiscal incentives, including indirect subsidies and direct public requisitions (Kwon et al., 2012). Government support through technological development assistance funds encourages the forging of upstream and downstream collaborative partnerships, as well as networking relationships among SMEs (Kang and Park, 2012; Doh and Kim, 2014). This support has a distinctly greater effect on SMEs and economically distressed firms than on large conglomerates (Kim et al., 2016). A word of caution is that government support also leads to some crowding out of private innovation funds (Song, 2012).

East Asian firms' innovation should not be assessed over a short-term year-to-year timeframe since they have 3–4-year innovation plans. They also typically maintain their R&D programmes as permanent institutions. Correspondingly, R&D investments exhibit strong positive 1–2-year autocorrelation (Choi, 1997). These stylised facts suggest that empirical analyses of firm innovation should account for firms' financial circumstances, government support systems for firms' human capital and R&D, within-firm governance and relationships, and firm and industry effects. The empirical analysis below follows these prior lessons.

III. Models and Empirical Methods

Our empirical strategy is to first sketch an estimable model of firm innovation in which their governance structure and government support systems play an explicit role. We then formulate hypotheses for our variables of interest and test those hypotheses empirically.

Estimable model of firms' pursuit of innovation

Suppose that firm i's owners are concerned about the change in the present value of the stream of the firm's expected future profits (π_i), which depend on its R&D activity (x_i) and managerial effort (e_i) less a one-time net R&D outlay of government support s ($c(x_i)\times(1-s)$) and contractual compensation to management (bonus $b(\cdot)$, which, for simplicity, is assumed to cover the possibilities of termination, demotion or promotion). The firm develops new technologies with an expected return $r(\cdot)$, which depends on managerial decisions in the innovation process e_i.

The actual change in discounted future profits has two parts: the expected return $r(x_i,e_i)$, which depends on the extent of R&D, as well as on the level of managerial effort, and a multiplicative random shock (u_i) distributed under a probability distribution function $f(u_i)$. Suppose that effort e_i is unobservable or that it cannot be compensated directly due to stipulations on compensation contracts. Managers can only be compensated using the firm's actual return and R&D expenditure. Thus, we can write the compensation as a function of observed R&D and the realisation of the random shock, $b(x,u)$. Equation 1 shows the firm's expectation objective function. For brevity, expectation operators and subscripts for individual firms, managers and years are not shown.

$$\pi = r(x,e)u - b(x,u) - c(x)(1-s) \tag{1}$$

The company owners' and manager's interaction can essentially be modelled as a three-stage game. First, company owners realise the level of government support s and set the management compensation policy $b(x,u)$. Second, the manager selects the volume of R&D and his/her level of effort (x, e), and the firm's expected return and profit can be computed. Third, the actual r, u, b, c and π are realised.

Effort e_i affects the expected return r_i directly and positively but is unobservable or non-actionable to owners, who therefore cannot reward it directly. Actual manager compensation $b(x,u)$ is a strictly increasing function of its arguments and may be modelled as a function of the weighted difference between the present value of the firm's expected future inflows subject to prior uncertainty, $r(x,e)u$, and the one-time risk-free outlay on R&D, $c(x)(1-s)$ (subject to the weights $1-\gamma,\ \gamma$):

$$b(x,u) = b[(1-\gamma)r(x,e)u - \gamma c(x)(1-s)]. \tag{2}$$

Parameter $\gamma \in [0,1]$ is interpreted as a measure of firm owners' intertemporal discount rate (short-termism or borrowing constraint), uncertainty regarding future return, or the time constraint on concluding and approving management pay. γ is given exogenously to each firm, and managers observe it and take it as given. A higher γ may indicate the tendency of the board of directors to evaluate the CEO based on quarterly results or as subject to information asymmetry. Management–ownership separation may imply low γ as it prevents owners from terminating the manager before the actual return is realised.

The manager chooses R&D intensity and effort to maximise his/her expected private welfare W, the difference between compensation and cost of effort exerted (subscripts omitted for simplicity):

$$\max_{x,e} E(W) = E[b(x,u)] - e = E\ \{b[(1-\gamma)r(x,e)u - \gamma c(x)(1-s)]\} - e. \tag{3}$$

Equation 3 is the manager's expectation objective function. Without loss of generality, we can assume that effort incurs a constant incremental cost to the manager of \$1 per unit of effort. Under standard sufficiency conditions, including the continuous differentiability and strict concavity of $b(x,u)$ with respect to both arguments, and the initial viability of innovation and effort ($\partial E(W)/\partial x|_{x\to 0^+} > 0$ and $\partial E(W)/\partial e|_{e\to 0^+} > 0$), we could identify the unique interior expected welfare-maximising levels of investment in innovation and effort, x^* and e^*. Even without specifying the form of functions $r(x,e)$, $c(x)$ and $b(x,u)$, we can write x^* as a function of u and firm characteristics that have a bearing on γ, r, c and b.

The reduced-form framework introduced above, as well as hypotheses proposed and tested in previous literature, guide our selection of the model specifications. The hypotheses can be tested using the following reduced-form model, which is equivalent to a structural model under certain plausible assumptions regarding the functional form of the expectations for $r(x,e)$, $c(x)$ and $b(x,u)$. The observable degree of innovation (x^*) is a function of government support (*sup*), market concentration in the firm's sector (*conc*), the structure of the firm's management (*mgmt*), the interaction term of management structure and market concentration, the interaction term of management structure and government support, other time-variant or time-constant firm characteristics, including fixed effects (z), and an idiosyncratic firm- and time-specific error term ε[1]:

$$\begin{aligned} x^* = \operatorname*{argmax}_x E(W) = \beta_0 + \beta_1 conc + \beta_2 mgmt + \beta_3 mgmt \times conc \\ +\beta_4 sup + \beta_5 mgmt \times sup + \beta_6 z + \varepsilon. \end{aligned} \tag{4}$$

The various effects described in existing studies on the role of competition, owner–manager separation, and the advisory role of ownership can be verified from the signs of coefficients β_1–β_3. Market competition may affect innovation positively (or in an inverse-U fashion), as it raises the expected return on innovation and avoids cannibalisation of the firm's would-be no-innovation profit stream. In terms of market concentration: $\beta_1 < 0$.

Under the 'career concerns' hypothesis, the degree of management–owner separation – as measured by the degree of independence of managers or of the presence of foreigners among majority shareholders – is thought to affect expected innovation positively because it allows owners to compensate managers efficiently for their performance in the long run rather than in the short run before the outcome of innovation is realised: $\beta_2 > 0$.

Under the 'career concerns' hypothesis, the owner–manager separation and market competition exhibit a complementary relationship vis-à-vis expected innovation due to owners' and managers' greater engagement in the competitive environment. Using market concentration, this suggests $\beta_3 < 0$. Under the 'lazy manager' hypothesis, on the other hand, the effort-inducing effects of owner–manager separation and competition have a substitutive

[1] The model notably excludes the direct effect of R&D inputs or investment as these would lead to overfitting of the model and would prevent the estimation of the partial effects of other indirect drivers of innovation. Controlling for the direct determinant could cause indirect determinants to drop out, since their indirect effects are largely channeled through R&D investment.

relationship, $\beta_3 > 0$. The degree of government support for firm innovation affects expected innovation positively ($\beta_4 > 0$), but the size of the impact hinges on the form of support and what the firm's management does with it. Under the agency theory of firm management, management that is distanced from firm ownership may put the support to better long-term uses than management that is forced to prioritise short-termism (under career concerns), $\beta_5 > 0$.

Empirical identification

The model delineated above and the hypotheses that motivated it can be tested using regressions. In order to identify the effects of the variables of interest, other firm characteristics (i.e., reliance on exports, overseas operations, industry), business conditions (i.e., company size, earnings-to-costs ratio), and firm-level random or fixed effects are controlled out. This is in recognition of the heterogeneous composition of the set of companies and the potential effect of latent firm-level effects on model efficiency and consistency.

As in most economic problems dealing with decision-makers' choices, endogeneity of selection is a concern. First, because government support may be assigned endogenously to firms or associated with firms' latent characteristics that have a bearing on their strategies and outcomes (e.g., firm size, economic distress, worker characteristics), government support may be endogenous in the model. Second, more generally, all estimates may be biased and inconsistent in the presence of omitted variables correlated with the included variables. To identify a consistent effect of government support (or management structure or market competition) on innovation, we would need to either control for all factors correlated with it, as well as with innovation, such as by finding adequate proxies for them, or use valid instruments for the endogenous variables.

One approach to dealing with cases in which policy interventions are imposed based on known eligibility rules is a regression discontinuity estimator (Fuji et al., 2009; Nichols, 2011). A regression discontinuity model is a quasi-experimental policy evaluation design that identifies the causal effects in the local neighbourhood around an eligibility threshold for policy intervention. The estimator fits a local linear regression model on both sides of the threshold value of a continuous instrumental variable. This estimator hinges on three conditions: the order condition (i.e., irrelevance of the instruments in the structural model in the vicinity of the threshold value), the rank condition (i.e., strong association with *sup*), and the continuity of the valid instrument. In our research, several candidates satisfy the order and rank conditions and instrument continuity. We use the size of a firm's workforce as an eligibility criterion for SME support, with the threshold value set at 100 workers. There is a jump in the (conditional) expectation of eligibility for government support at this firm-size threshold level. This allows us to estimate the impact of policy support as if it were assigned randomly in the neighbourhood of the threshold (Shadish et al., 2002; Imbens and Lemieux, 2007; Imbens and Wooldridge, 2009).

Concerns over endogeneity are not limited to the role of government support but extend to other regressors as well due to the possibility that other important factors have been omitted from the model. The omission of inputs to the innovation process, such as firms' investment in R&D, may bias our estimates.[2] If investment in R&D is associated near perfectly with the innovative output (i.e., both can be thought of as the *argmax* choice variables maximising welfare in Equation 4 and as proxies for one another), and if investment in R&D is determined within the model by the same factors that are already controlled for,

[2] The author is grateful to an anonymous referee for this reminder.

the bias may be trivial. However, if investment in R&D is not perfectly associated with the innovative output and is determined outside the model (hence, investment in R&D belongs in the model but is not adequately proxied for by the included regressors), its omission may bias the results.

In the absence of data on investment in R&D or adequate proxies and in the absence of suitable instruments correlated with investment and uncorrelated with innovation, the bias cannot be formally tested or eliminated. Controlling for factors that are likely to be correlated with R&D investment mitigates potential bias. Moreover, working through the bias, we can shed light on its likely size and direction. The omitted variable bias depends on the sign and size of the correlation between the omitted variable and the included regressors of interest as well as the sign and size of the correlation between the omitted variable and the dependent variable. Because investment in innovation has a positive expected partial effect on innovation (after controlling for other determinants) and the investment is likely to be positively correlated with government support, market concentration and management type, we expect positive biases in their coefficients.

Regression specifications for firm innovation

The defining characteristic of our problem is the wide distribution of the dependent variable. The raw dependent variable is a count variable that is left-censored at zero and has a wide range (0–4,218) and a long right tail (refer to Figure A1 in Supplementary Materials).

The models estimating firm innovation can be fitted using the method of ordinary least squares (OLS) when model errors are distributed symmetrically or using limited dependent variable specifications, such as tobit, negative binomial, Poisson or gamma models, when the errors exhibit a long-tail distribution. These alternative specifications have their relative advantages and pitfalls depending on the problem at hand. The Poisson model, importantly, assumes that the mean and variance of the dependent variable are equal and performs poorly under overdispersion. The negative binomial model is a generalisation of the Poisson that allows for excess variance but may be less efficient compared to other simpler specifications, since it requires the parametric modelling of the dispersion (Hausman et al., 1984). If the dependent variable is non-integer, such as when the dependent variable is transformed to treat the long right tail, Poisson and negative binomial models are no longer valid. A generalised linear model based on gamma distribution may then be suitable if the dependent variable strictly exceeds zero.

In what follows, we compare two of the above general approaches: 1) taking the logarithmic transformation of the dependent variable and estimating models that are robust to the expected residual skew in model errors, namely tobit or OLS with heteroskedasticity and error-autocorrelation robust standard errors; and 2) keeping the dependent variable as a count variable and estimating the negative binomial model.

On the one hand, logarithmic transformation can successfully remove much of the skew in the original dependent variable, has generally better distributional properties and collapses the dispersion of the variable into a tractable range. The logarithmic transformation of patent applications (+1) ranges from 0 to 8.35, and this variable can be studied using tobit or OLS specifications. On the other hand, a well-known problem is that this transformation does not distinguish between the values of 0 and 1 despite their commonality in data (O’Hara and Kotze, 2010). Using the original highly dispersed count variable and an estimator suited for it – such as the negative binomial regression – could yield the better results.[3]

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[3] The author is grateful to an anonymous referee for this suggestion.

Tobit and negative binomial regressions may thus be the most appropriate estimators for the skewed, left-censored dependent variable, while OLS might provide a good third option that is robust to arbitrary data irregularities. Tobit may be more efficient since it treats the left tail of the dependent variable more sensibly, but OLS may be the most robust since it relies on fewer assumptions and can be supplemented by corrections for various statistical issues.

In the following empirical analysis, OLS, tobit and negative binomial models are estimated and compared. These specifications facilitate neat interpretation of coefficients (exponentiated coefficients in the case of the negative binomial) as the predicted percentage changes in patent applications associated with a one-unit increase in the corresponding explanatory variables. Standard errors in all specifications are corrected for arbitrary heteroskedasticity and autocorrelation at the level of companies to correct for remaining issues with model errors, such as institutional constraints on innovation in any given year (Choi, 1997; Kwon et al., 2012). This correction is thought to be particularly appropriate in regressions using large sample sizes, such as the dataset used here.

Data

Company-level data for the analysis come from the patent registration database administered by the KIPO, the Korea Investment and Securities database by the Korea National Investment Commission (NICE), and the HCCP by the Korea Research Institute for Vocational Education and Training (KRIVET). The three datasets are provided jointly as modules in the HCCP database. This database is a nationally representative panel survey of Korean enterprises. The survey is based on an unbalanced panel containing 4,578 observations for 763 firms and six rounds two years apart (2005, 2007, 2009, 2011, 2013, 2015). No sampling weights are provided, and firm observations are assumed to be close to self-weighted. Additional information on firm innovation and financial status from the KIPO and NIC is available annually. For our purposes, we use firm innovation and financial status data for all available years in the period 2005–2015, and we interpolate the missing values of other variables in even years using values observed in odd years. We thus increase our effective sample size to 11 years and 6,251 firm-year observations (refer to Table A1 in Supplementary Materials). Because firms in the HCCP database are anonymous, our information is restricted to the variables included in the database.

Surveyed firms were chosen randomly from among firms across most industries, firm sizes, and ownership and management types. Attrition of firms across survey rounds is low, is thought to be due to a variety of reasons (dissolution, merger or acquisition, or another change preventing matching across waves, such as a name change or transition out of the sampling frame) and is not thought to introduce conceptual problems in the aggregate. The reasons for the attrition (or nonresponse to any survey question) of any specific firm are unknown.

The dependent variable in the main regressions is the count of patent applications (log count in OLS and tobit regressions). This measure of innovation is linked to the degree of government support for the firm, the degree of professionalism of firm managers, the presence of foreigners among firm majority owners, the degree of the firm's concentration in the industry labour market and other aspects of the nature of firms' consumer markets and production processes.

Government support for firms is gauged by firms' self-reports of being beneficiaries of MOEL's special support for SMEs in the form of assistance with SMEs' training. Fiscal support by Korean labour law is also gauged by the share of firms' unemployment insurance fees reimbursed in lieu of firms' vocational skill development expenses offered to both employers and workers.

Management–ownership separation emphasised in the agency theories of manager decision-making is proxied by indicators of the degree of professionalism of managers and the presence of foreigners among majority owners. Foreign ownership may also serve as an indicator for the divergence of information that owners and managers hold about the firm, as well as for the relevance of an advisory relationship between the owners, the board of directors and management. Market competition is gauged by firms' share in the labour markets – the ratio of a firm's current employment to industry total employment.

IV. Results

Table I shows the results of baseline OLS models estimated on a sample of 595 firms (6,251 firm–year observations). Table II then reports the analogous tobit regressions and Table III the negative binomial regressions. The first three columns in Tables I–III report standard specifications, while the middle three and last three columns add firm-level random effects and fixed effects, respectively, to address potential inefficiency and bias due to latent heterogeneity in the sample. Individual columns (1–3) report on alternative model specifications, with each subsequent column using additional controls besides those in the preceding columns.

The first column in Tables I–III shows a baseline model evaluating the effect of government support for SMEs' vocation training, as well as hypotheses concerning management–ownership separation gauged by an indicator of management professionalism interacted with market concentration. The linear and quadratic effects of market concentration are controlled for. Column 2 evaluates an additional measure of government support for vocation training through tax refunds and an agency-theory hypothesis about the interaction of manager professionalism and the degree of government support for SME vocational training. Column 3 introduces controls for firm performance (earnings-to-costs ratio), firm size, exporting activity, organisational history, process and product changes at the firm and industry indicators. One last hypothesis is tested, namely that government support for vocational training becomes more effective at inducing innovation in larger firms. Comparing the first three columns with the last three columns allows us to comment on the strength of latent firm-level effects, or a bias, on the coefficients of interest.

The first couple of rows in Tables I–III indicate that firms' market share has an inverted *U*-relationship with innovation, just as prior empirical literature has found. The relationship has a turnaround point occurring at very low degrees of market concentration across all columns. For the vast majority of firms, the positive impact of competition on innovation proposed by previous literature appears to hold. Firms with professional management also tended to innovate more (insignificantly) in agreement with the agency hypothesis commending owner–manager separation. The interaction term of management professionalism (owner–manager separation) and firms' market share has a positive sign across most columns, suggesting substitutability between the pressure from owner–manager separation and that from competition on managers to pursue innovation. These effects are weaker in the fixed-effects model specification.

Firms receiving vocational training support tend to innovate slightly more than others (Column 1), suggesting that government support empowered SME workers to innovate breakthrough products in order to dominate their output markets, to enter new markets where the SMEs would potentially face less uncertainty, or simply to survive. However, the difference in innovative output disappears when one accounts for firms' technological, process or product changes in the past, their industry or their reliance on exports (Columns 2–3).

Columns 2–3 test additional hypotheses. Other measures of government support for firms' vocational training have weaker estimated effects. Providing tax refunds in lieu of education and training expenses has coefficients of both signs across columns in Tables I–III. The effect of vocational-training support weakly rises with the degree of professionalism of firms' management ($\beta_{prof.\ mgmt.\times\ SME\ support} > 0$), suggesting that the degree of separation between firm owners and managers improves the utilisation of resources at a firm. The final hypothesis of special interest – whether the effect of vocational-training support rises with firm size ($\beta_{log\ workers\ \times\ SME\ support} > 0$) – is weakly supported in Table I, but not in Tables II and III, where the coefficients adopt a negative sign.

The bottom halves of Tables I–III report the effects of the control variables. Firms' earnings-to-costs ratio has a consistently negative, albeit weak, effect across most columns. Firms with looser credit constraints – or firms with persistently higher expected performance – tended to innovate less. At face value, this may support the agency hypothesis of firm innovation (as well as 'prospect theory') maintaining that managers at poorly faring firms have higher marginal incentives to innovate in order to restore company performance and protect their own jobs. Among other results, it was found that larger firms submitted a clearly higher number of patent applications. Firms that have experienced technological changes in previous years appear to innovate slightly less, while firms that have experienced process or product changes appear to innovate more, although some of these coefficients switch signs between OLS and fixed-effects model runs. Exporting firms do not systematically differ from non-exporting firms in terms of innovation. Across industries, manufacturing, energy and ICT firms tended to innovate more, while finance firms tended to innovate less than firms in construction and other sectors. These trends are overturned in the fixed-effects specification, where the industry effects can only be identified among firms that change their main industry classification between panel waves. Essentially, reaffirming the negative coefficients on '*past tech. Δ*', firms freshly entering any industrial sector tended to innovate less than long-established firms in those sectors. If this finding (significant only for finance and other services) can be trusted, one could draw a policy implication that the government should emphasise providing support for new and transitioning firms, not just small or human capital-deprived firms. More research is needed to identify the characteristics of firms in particular need of support with their competencies.

Overall, the estimates of interest are analogous qualitatively as well as in their statistical significance across Tables I–III. The differences are not systematic. We conclude that all models – least squares, tobit and negative binomial regressions – have similar consistency and efficiency properties in our application. All three tables provide some support for the 'lazy-manager' hypothesis, particularly compared to the alternative 'career-concerns' hypothesis. Model Wald tests indicate that the specifications in Tables I–III are significant compared to more limited or intercept-only model alternatives. Model R-squared statistics in Tables I–II show that the estimated OLS models explain 5%–30% of the variation in patent registrations, and the tobit models explain 3%–9% of the variation in patent registrations. Given the small number of covariates used, this is viewed as an adequate degree of fit.

To evaluate whether the fixed effects are necessary in order to offset the potential bias due to the correlation between our variables of interest and the error term ε (as per Equation 4), Hausman specification tests are performed. For all three model specifications in Table I, the chi-square statistics of the tests are 78.3, 99.8 and 141.1 for Columns 1–3, respectively. These are highly significant statistics, indicating that random-effects coefficients are systematically different from the consistent fixed-effects coefficients and that the fixed-effects models may be preferable.

Lastly, to test the estimated effect of the MOEL's vocational training support for potential endogeneity, the effect is re-estimated using the regression-discontinuity method in the local vicinity of a threshold of eligibility for SME support. Taking the threshold for firm size to be 100 workers (log workers = 4.61), we estimate a local linear regression on both sides of the threshold and evaluate the jump in the dependent variable at the threshold. The fall in log applications around the threshold is 0.258, which is highly significant, suggesting that eligible firms that were randomly assigned support have significantly higher innovation output than similarly situated firms that did not receive support (refer to Figure A2 in Supplementary Materials). A local Wald estimate provides the ratio of the local jump in outcome to the jump in treatment. This estimate is 2.227 (a ratio of 0.2582206/0.1159522), which is significant at the 1% level, suggesting a large difference in innovation output for a modest difference in the prevalence of government support across the evaluated eligibility threshold.

One concern with the results in Tables I–III is that they depend on the relevant models to be dynamically complete, with no missing variables. Despite controlling for a number of characteristics at the industry or firm level, we may worry that firms' patent applications may depend on other omitted factors, such as unmeasured management expectations and constraints, including firms' prior investment in R&D. This may lead to endogeneity of the included variables, rendering their coefficients biased and inconsistent. If R&D investment is not perfectly associated with the innovative output and is determined outside the model – hence, investment in R&D belongs in the model but is not adequately proxied by the included regressors – its omission may bias the results. Unfortunately, the regression discontinuity approach is not applicable in this case. In the absence of data on investment in R&D or adequate proxies and in the absence of suitable instrumental variables satisfying the necessary rank and order conditions, formal tests and corrections cannot be undertaken.

One mitigating factor is that the specifications in Tables I–III already include a number of controls that address some of the omitted variable endogeneity. We can also evaluate the direction and size of the residual association between the unobserved omitted variable(s) and the dependent and independent variables in the models in order to appraise the likely bias. Investment in R&D is expected to have a positive partial effect on innovation – even after controlling out other determinants. At the same time, R&D investment may be weakly positively correlated with government support for firms' human capital training, the explanatory variable of interest, potentially leading to a positive bias in our estimates. Since government support for training was found to have a positive effect on firms' innovative output, this bias may work to slightly accentuate the effect. Similarly, the omission of R&D investment may work to accentuate the effects of market concentration and professional manager–owner separation because of the respective positive expected associations among the relevant variables. In sum, the results obtained in Tables I–III might be slight overestimates of the true effects of government support for training, as well as of market position and corporate professionalism, on firms' innovative output. Nevertheless, given the number of firm-level and industry controls that work to neutralise the effect of omitted variables, the suspected residual biases are likely to be rather small.

[Tables I–III approximately here]

V. Conclusions

Firms' pursuit of innovation plays a central role in Korea's national development strategy, including the reorientation of the country towards an information economy driven by domestic consumption and investment. To this end, the Korean government has launched various programmes to support firms' competencies, human capital and R&D. This paper assessed the performance of a particular support system in fostering innovation in firms.

The study recognised that the effect of government support depends critically on firms' expectations regarding the returns on resources invested in innovation and on the within-firm mechanisms linking firm accomplishments to rewards for decision-making managers. This study has reviewed predictions regarding the effects of government support on firms' innovation through the prism of agency theory – the 'career-concerns', 'lazy-manager', and 'special East-Asian institutional constraints' alternative hypotheses – and has tested the predictions empirically. Under the 'career-concerns' hypothesis, the market pressures that firms face to survive, through competition or risk of default, motivate their owners to encourage informed decision-making and long-termism by managers. Factors facilitating informed long-term decision-making operate in a complementary fashion. Under the 'lazy-manager' hypothesis, managers strive to avoid effort inherent in informed decision-making. Any factor that strengthens the monitoring or rewarding of managers' efforts can overcome this tendency to shirk. These alternative factors effectively serve as mutual substitutes. The 'East Asian institutional constraints' hypothesis stipulates that firm ownership by a family syndicate and the presence of foreigners in firm leadership have idiosyncratic effects on managerial decision-making in East Asian firms.

Using a large representative panel dataset on Korean firms, we find that firms receiving vocational training support have a bit higher innovative output than similarly situated firms without support. The results of a regression-discontinuity model, however, suggest that firms that apparently succeeded only marginally in obtaining support were more active in innovating than non-recipients near the firm-size threshold for support eligibility. This indicates that public support had the intended causal effect on firms' capabilities. It should be noted that latent time-constant effects or other omitted variables could play a role in explaining the uncovered effects, but such biases are likely to be mitigated by the inclusion of multiple control variables. In any case, whether the cost of the government support programme for firm innovation was justified calls for further research.

Regarding agency theory, we find compelling evidence that market-competitive pressures and owner–manager separation have a substitutable relationship in enticing managers to pursue innovation, supporting the predictions of the 'lazy-manager' hypothesis over the 'career-concerns' hypothesis. We find no evidence that managers at Korean firms operate under severe career concerns or are subject to the special East Asian institutional constraints identified in several prior studies. The presence of foreigners among majority owners and the share of the largest stockholder (which helps to identify family-owned conglomerates) have little bearing on firm innovation. Among other results, we confirm several sightings from prior literature: manager–owner separation in firms is conducive to innovation, and competition has an inverse *U*-shaped relationship with innovation. These findings, some of which do not conform to prior evidence, give rise to several prospective research directions. First, our study did not differentiate the nature of vocational training (e.g., general versus specific and on- versus off-the-job training), which may have different implications for SMEs' innovation and profitability (Boadu et al., 2018). Similarly, focusing on different innovative outputs (e.g., process or product and minor or major innovation) could yield different conclusions (Cozzarin, 2022). Second, with the East Asian hypothesis not supported by the current findings, applications to other world regions could ascertain whether and how 'lazy manager' tendencies differ across the world and between the global North and South. Third, alternative identification approaches, such as difference-in-difference or triple-difference estimators, should be evaluated under appropriate data structures.

As a final word, the conclusions in the present study have important implications for public policy towards SMEs, their workers and their R&D activity. Specifically, they support the calls for public–private partnerships for economic development, as well as industry–academia collaboration in curriculum development (Borah et al., 2019), in order to start the virtuous circle of productivity enhancement and innovation. The stakes could not be higher in the government's pursuit of national growth through the buttressing of domestic consumption and investment.

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Table I. Results of linear regressions using least squared error specifications

	OLS			RE			FE		
	1	2	3	1	2	3	1	2	3
marketshare	0.183**	0.053	0.045	0.068**	0.009	0.041	0.025	-0.004	-0.009
	(0.040)	(0.035)	(0.070)	(0.022)	(0.023)	(0.057)	(0.016)	(0.019)	(0.044)
marketshare^2	-0.005**	-0.001	-0.005*	-0.001**	-0.000	-0.002+	-0.000	0.000	0.001
	(0.001)	(0.001)	(0.002)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
professional	0.049	-0.023	0.011	0.024	0.013	0.029	0.010	0.007	0.014
mgmt.	(0.034)	(0.036)	(0.041)	(0.019)	(0.022)	(0.025)	(0.021)	(0.024)	(0.026)
prof. mgmt.×	0.021	0.002	0.040	0.009	0.001	0.008	0.002	-0.011	-0.020
market share	(0.018)	(0.018)	(0.026)	(0.012)	(0.014)	(0.019)	(0.012)	(0.015)	(0.017)
SME train.	0.012**	0.003	-0.012	0.002*	0.001	0.002	0.001	0.001	0.000
support	(0.003)	(0.003)	(0.018)	(0.001)	(0.002)	(0.009)	(0.001)	(0.002)	(0.008)
tax refund for		-0.002	-0.002		0.000	0.002		0.000	0.002+
training		(0.002)	(0.003)		(0.001)	(0.001)		(0.001)	(0.001)
prof. mgmt.×		0.003	0.001		0.000	0.001		0.000	-0.001
SME support		(0.002)	(0.002)		(0.001)	(0.001)		(0.001)	(0.001)
log(workers)×			0.002			0.001			0.001
SME support			(0.003)			(0.002)			(0.001)
earn2cost		-0.000*	-0.000		-0.00**	-0.000+		-0.00**	0.002
		(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.001)
log(workers)		0.589**	0.511**		0.550**	0.546**		0.376**	0.389**
		(0.058)	(0.072)		(0.050)	(0.056)		(0.066)	(0.076)
past tech Δ		0.121**	0.124**		-0.011	-0.017		-0.048*	-0.057*
		(0.038)	(0.042)		(0.022)	(0.025)		(0.023)	(0.026)
past.proc Δ		0.102*	0.060		0.023	0.002		-0.008	-0.014
		(0.045)	(0.050)		(0.029)	(0.032)		(0.030)	(0.033)
past prod Δ		0.149**	0.138**		0.022	0.031		-0.012	0.001
		(0.040)	(0.045)		(0.024)	(0.028)		(0.025)	(0.029)
exports			0.004*			-0.000			-0.003+
			(0.002)			(0.001)			(0.002)
manufact.			-0.488			0.036			0.071
			(0.845)			(0.507)			(0.533)
energy			-0.340			0.011			0.058
			(0.842)			(0.500)			(0.529)
finance			-1.680*			-0.692			-1.040*
			(0.834)			(0.535)			(0.466)
ICT			-0.541			-0.413			-0.848*
			(0.815)			(0.460)			(0.411)
other service			-0.843			-0.487			-0.748
			(0.829)			(0.494)			(0.481)
constant	0.628**	-3.43**	-2.43**	0.801**	-2.32**	-2.24**	0.90**	-1.00**	-0.985+
	(0.056)	(0.342)	(0.801)	(0.045)	(0.276)	(0.543)	(0.031)	(0.385)	(0.600)
R^2	0.071	0.288	0.295	0.055	0.258	0.252	0.046	0.218	0.124
Wald Chi^2	57.154**	302.4**	112.8**	16.73**	134.8**	139.6**	1.232	16.322+	14.063
Observations	6,251	5,072	1,936	6,251	5,072	1,936	6,251	5,072	1,936
Firms	595	512	410	595	512	410	595	512	410

+ significant at 10%, * 5%, ** 1% two-sided test, using standard errors robust to arbitrary heteroskedasticity and autocorrelation at the level of firms (in parentheses).
Sources: Author's analysis of KLOSA data.

Table II. Regression results using tobit specifications

	Tobit			RE Tobit			FE Tobit[a]		
	1	2	3	1	2	3	1	2	3
marketshare	0.573**	0.099+	0.249*	0.204**	0.021	0.114	0.046	-0.030	-0.079
	(0.111)	(0.060)	(0.105)	(0.064)	(0.069)	(0.106)	(0.056)	(0.067)	(0.135)
marketshare^2	-0.019**	-0.002	-0.009+	-0.005	0.000	-0.004	-0.001	0.001	0.003
	(0.005)	(0.002)	(0.005)	(0.004)	(0.002)	(0.005)	(0.001)	(0.002)	(0.004)
professional mgmt.	0.056	-0.058	-0.029	0.025	0.012	0.009	0.022	0.005	-0.007
	(0.067)	(0.069)	(0.080)	(0.037)	(0.043)	(0.042)	(0.041)	(0.045)	(0.048)
prof. mgmt.× market share	0.003	-0.034	0.028	0.001	-0.019	0.014	0.004	-0.013	-0.022
	(0.028)	(0.023)	(0.028)	(0.017)	(0.022)	(0.027)	(0.017)	(0.022)	(0.017)
SME train. support	0.036**	0.010+	-0.038	0.005*	0.003	0.013	0.005*	0.002	0.012
	(0.006)	(0.006)	(0.034)	(0.002)	(0.004)	(0.021)	(0.002)	(0.004)	(0.019)
tax refund for training		-0.000	-0.004		0.000	-0.004		-0.004+	-0.003
		(0.004)	(0.006)		(0.003)	(0.003)		(0.002)	(0.003)
prof. mgmt.× SME support		0.006	0.007		0.000	0.000		0.001	0.001
		(0.004)	(0.005)		(0.002)	(0.002)		(0.002)	(0.003)
log(workers)× SME support			0.007			-0.002			-0.002
			(0.006)			(0.003)			(0.003)
earn2cost		-0.001+	-0.000		-0.001	-0.001		-0.001**	0.000
		(0.000)	(0.000)		(0.001)	(0.001)		(0.000)	(0.003)
log(workers)		0.907**	0.700**		0.877**	0.871**		0.748**	0.748**
		(0.084)	(0.113)		(0.063)	(0.090)		(0.113)	(0.132)
past tech Δ		0.233**	0.199**		-0.015	-0.044		-0.098*	-0.108*
		(0.073)	(0.078)		(0.045)	(0.053)		(0.044)	(0.049)
past.proc Δ		0.226**	0.168+		0.075+	0.042		-0.010	-0.019
		(0.087)	(0.090)		(0.041)	(0.058)		(0.060)	(0.067)
past prod Δ		0.283**	0.255**		0.044	0.057		-0.012	0.012
		(0.079)	(0.085)		(0.047)	(0.051)		(0.047)	(0.054)
exports			0.005			-0.001			-0.003
			(0.003)			(0.002)			(0.002)
manufact.			1.028			0.302			-0.892
			(0.726)			(0.723)			(1.208)
energy			1.086			0.197			-0.911
			(0.737)			(0.700)			(1.156)
finance			-1.147+			-0.418			-0.812+
			(0.689)			(0.290)			(0.466)
ICT			1.124+			-0.425			-2.139+
			(0.682)			(0.651)			(1.191)
other service			0.324			-0.844			-1.860
			(0.739)			(0.744)			(1.268)
constant	-0.821**	-7.07**	-6.64**	-0.343**	-5.19**	-5.17**	--	--	--
	(0.148)	(0.541)	(0.872)	(0.109)	(0.379)	(0.929)			
R^2	0.025	0.090	0.090	--	--	--	--	--	--
Wald Chi^2	167.19**	437.6**	112.6**	24.99**	292.5**	242.1**	6.370	156.92**	86.42**
Observations	6,251	5,072	1,936	6,251	5,072	1,936	6,251	5,072	1,936
Firms	595	512	410	595	512	410	595	512	410

+ significant at 10%, * 5%, ** 1% two-sided test, using bootstrap standard errors (in parentheses).

[a] Static panel-data tobit model estimating firm-specific (conditional) fixed effects semi-parametrically (Honoré 1992).

Sources: Author’s analysis of KLOSA data.

Table III. Regression results using negative binomial model specifications

	Neg. Binomial			RE Neg. Binomial[a]			FE Neg. Binomial[a]		
	1	2	3	1	2	3	1	2	3
marketshare	0.951**	0.048	0.185	0.046**	0.013	-0.035	0.037*	0.015	-0.127
	(0.190)	(0.033)	(0.154)	(0.015)	(0.018)	(0.060)	(0.016)	(0.019)	(0.085)
marketshare^2	-0.016**	-0.001	-0.005	-0.000*	-0.000	0.002	-0.000+	-0.000	0.004
	(0.003)	(0.001)	(0.007)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.003)
professional mgmt.	0.290*	-0.051	-0.116	0.031	-0.004	-0.090	0.026	-0.003	-0.081
	(0.117)	(0.145)	(0.138)	(0.023)	(0.040)	(0.058)	(0.023)	(0.041)	(0.061)
prof. mgmt.× market share	0.023	0.010	0.048	0.008	0.008	0.026	0.006	-0.014+	-0.016
	(0.023)	(0.010)	(0.031)	(0.006)	(0.007)	(0.016)	(0.006)	(0.007)	(0.018)
SME train. support	0.196	0.190	0.993+	0.017	0.000	0.260	0.000	-0.043	-0.021
	(0.149)	(0.118)	(0.509)	(0.028)	(0.041)	(0.192)	(0.029)	(0.042)	(0.215)
tax refund for training		-0.004	-0.003		-0.001	-0.000		-0.001	-0.001
		(0.002)	(0.002)		(0.001)	(0.001)		(0.001)	(0.001)
prof. mgmt.× SME support		0.075	0.124		0.016	0.080*		0.014	0.068*
		(0.084)	(0.085)		(0.024)	(0.032)		(0.024)	(0.033)
log(workers)×SME support			-0.140+			-0.050+			-0.007
			(0.084)			(0.030)			(0.034)
earn2cost		-0.001+	-0.005		-0.000	0.003+		0.000	0.003+
		(0.001)	(0.004)		(0.000)	(0.002)		(0.000)	(0.002)
log(workers)		1.132**	1.188**		0.285**	0.471**		0.222**	0.314**
		(0.104)	(0.157)		(0.031)	(0.075)		(0.033)	(0.088)
past tech Δ		0.305**	0.312**		-0.038	-0.026		-0.055+	-0.062
		(0.091)	(0.088)		(0.030)	(0.042)		(0.031)	(0.042)
past.proc Δ		-0.009	-0.079		-0.011	-0.010		-0.031	-0.033
		(0.110)	(0.096)		(0.040)	(0.056)		(0.041)	(0.057)
past prod Δ		0.456**	0.346**		0.103**	0.049		0.084*	0.021
		(0.109)	(0.091)		(0.038)	(0.053)		(0.038)	(0.054)
exports			0.006+			-0.000			-0.002
			(0.003)			(0.002)			(0.002)
manufact.			1.728			-0.613			-1.613+
			(1.378)			(0.681)			(0.920)
energy			2.295+			-0.604			-1.576+
			(1.351)			(0.674)			(0.901)
finance			-4.607**			-2.209			9.660
			(1.698)			(1.343)			(8.546)
ICT			2.239+			-0.571			-1.539+
			(1.324)			(0.648)			(0.868)
other service			1.102			-0.873			-1.530+
			(1.354)			(0.664)			(0.887)
constant	0.972**	-7.239**	-8.666**	0.155*	-1.516**	-2.350**	0.189**	-0.950**	-0.026
	(0.276)	(0.618)	(1.537)	(0.063)	(0.224)	(0.822)	(0.064)	(0.235)	(1.016)
log(dispersn. param)	1.856**	1.365**	1.307**						
	(0.060)	(0.063)	(0.067)						
log(β shape param *s*)				-.436**	-.301**	-.298**			
				(0.059)	(0.065)	(0.078)			
log(β shape param *s*)				-.651**	-0.453**	-0.226*			
				(0.067)	(0.077)	(0.113)			
Wald Chi^2	64.11**	350.05**	412.24**	11.29*	112.97**	75.68**	8.1	64.50**	34.42*
Observations	6,251	5,072	1,936	6,251	5,072	1,936	5,076	4,196	1,501
Firms	595	512	410	595	512	410	482[b]	416[b]	295[b]

+ significant at 10%, * 5%, ** 1% two-sided test, using bootstrap standard errors (in parentheses). Exponentiated regression coefficients – or incidence-rate ratios – are shown, giving the relative changes in the expected outcomes of the count variable. [a] Random effects or fixed effects apply to the model of dispersion. In the random-effects model, the dispersion follows a β(r,s) distribution (Hausman et al. 1984). [b] 113, 96 and 115 firms, respectively were dropped because they had only one observation, or only zero outcomes.
Sources: Author's analysis of KLOSA data.

Supplementary Materials: Additional Information

Questionnaire items about government support

Regarding the Ministry of Employment and Labor (MOEL) support system for vocational training of enterprises and workers, which of the following did you actually utilize in 2008:

Vocational competency development training support [w2: D04_01_01; w3,5,6: C03_01_01]
(1 almost never; 2 a little; 3 to some degree; 4 a lot)

Special support for SMEs:

- Support SME training consortium [w2: D04_01_13; w3: C03_01_17; w5: C03_01_15; w6: C03_01_07]
(1 almost never; 2 a little; 3 to some degree; 4 a lot)
- Support organizing SME learning [w2: D04_01_15; w3: C03_01_19; w5: C03_01_17; w6: C03_01_09]
(1 almost never; 2 a little; 3 to some degree; 4 a lot)
- Support improving core job skills of SMEs [w3: C03_01_21; w5: C03_01_19; w6: C03_01_11]
(1 almost never; 2 a little; 3 to some degree; 4 a lot)
- Support systematic field training [w5: C03_01_21; w6: C03_01_13]
(1 almost never; 2 a little; 3 to some degree; 4 a lot)

If you did not have the MOEL support, how would you rate your education and training investment? [w2: D04_02; w3,5,6: C03_02]
(1 would have been less than with support; 2 no change; 3 higher)

Please fill in your expenses for education and training, and government support in the past year:

Unemployment insurance fee reimbursement in lieu of vocational skill development expenses [w2: D03_02_02; w3-6: C02_01_02] (mil. won)
Support for employers (employer cost of training) [w4-6: C02_01_03] (mil. won)
Support for workers (program enrolment fees) [w4-6: C02_01_04] (mil. won)

Firm's total education and training expenses [w1: D02_03_04; w2: D03_02_04; w3: C02_01_04; w4-w6: C02_01_06] (mil. won)
- Purchase (replacement) of training facility and equipment [w2: D03_02_05; w3: C02_01_05; w4-w6: C02_01_07] (mil. won)
- Direct education expenses [w2: D03_02_06; w3: C02_01_06; w4-w6: C02_01_08] (mil. won)

In the past two years, what was the status of the R&D-related government support system at your firm:

Tax reduction for technology development [w3: D01_08_01] (0 available; 1 unavailable)
Support for technology development and commercialization (funding) [w3: D01_08_03] (0 available; 1 unavailable)
Participation in government R&D projects [w3: D01_08_05] (0 available; 1 unavailable)
Government technical support and guidance [w3: D01_08_07] (0 available; 1 unavailable)
Providing technical information [w3: D01_08_09] (0 available; 1 unavailable)

Sample descriptive statistics

Table A1. Definition of variables used in regressions

Name	Definition (Units)	Observations[i]	Avg. (St.Dev.)[i]	Min.–Max
pat_appl	Patent applications (count)	6,251	18.581 (139.66)	0–4,218
log pat_appl	Log(pat_appl+1)	6,251	0.981 (1.376)	0–8.35
SME train. support	Support SME training consortium (1= almost never, 2= a little, 3= to some degree, 4= a lot)	6,251	1.361 (0.754)	1–4
SME learning support	Support organizing SME learning (1= almost never, 2= a little, 3= to some degree, 4= a lot)	6,244	1.242 (0.641)	1–4
SME job support	Support improving core job skills of SMEs (1= almost never, 2= a little, 3= to some degree, 4= a lot)	6,244	1.529 (0.884)	1–4
SME field train. support	Support systematic field training (1= almost never, 2= a little, 3= to some degree, 4= a lot)	4,443	1.246 (0.606)	1–4
Voc. training support	Vocational competency development training support (1= almost never, 2= a little, 3= to some degree, 4= a lot)	6,243	2.382 (1.049)	1–4
tax refund for training	Share of education and vocational skill development expenses credited toward unemployment insurance fees (%)	5,704	21.857 (27.204)	0–100
professional mgmt	Degree of separation between ownership & management (Likert: 0= owner-managed firm, 1= owner & manager separated but owner intervenes a lot, 2= owner & manager separated but owner intervenes a bit, 3= manager operates firm without owner intervent.	6,251	1.201 (1.179)	0–3
foreign owned	Binary indicator for foreign ownership in firm (0= no share, 1=some share)	6,251	0.096 (0.290)	0–1
exports	Exports share of total sales (%)	2,567	24.608 (27.921)	0–85
workers	Workers[ii] (count/1,000)	6,251	0.865 (2.169)	0.011–34.124
log workers	Log workers (log count)	6,251	5.917 (1.095)	2.398–10.438
market share	Ratio of firm workers to nationwide industry workers (%)	6,251	0.962 (3.635)	.004–92.621
industry	Industry indicator (54% manufacturing, 12% manuf-energy, 10% software/information and communication service, 8% finance, 15% other services – binary indicators)[ii]	5,199	--	--
past tech Δ	Degree of past change in technology (Likert: 1= almost no change, 2= slight change, 3= some change, 4= significant change, 5= immense change)	6,251	2.700 (0.851)	1–5
past proc Δ	The degree of change in production process (Likert: 1= almost no change, 2= slight change, 3= some change, 4= significant change, 5= immense change)	5,796	2.551 (0.811)	1–5
past prod Δ	The degree of change in products (Likert: 1= almost no change, 2= slight change, 3= some change, 4= significant change, 5= immense change)	6,251	2.488 (0.858)	1–5
earn2cost	Earnings-to-costs ratio (%/100)	5,537	109.76 (477.47)	.23–28,631.99

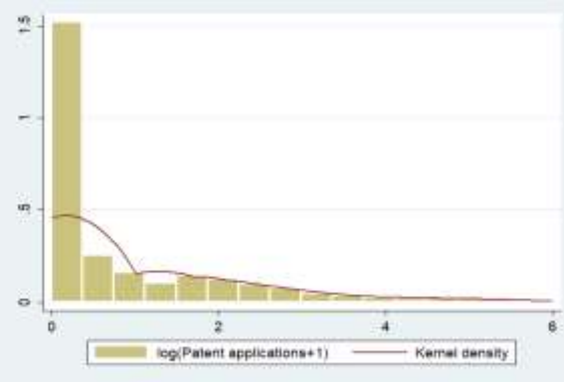
[i] Evaluated in an unbalanced panel of all the available observations used in regressions (595 firms, 6,251 obs.), over 11 years. Monetary variables are deflated to year-2010 won using Bank of Korea producer price index for investment goods.

[ii] Manufacturing contains beverage and groceries, fiber, chemistry/rubber/plastic, general machine, electric equipment, car/transportation equipment, metal/nonmetal. Manufacturing-Energy contains energy (oil refining/nuclear fuel/coke/etc), bio energy, environment, semiconductor equipment and electronic equipment, picture/sound, communications, computer and peripheral, optics/precision/medical treatment/machine, advanced material. Software/Information and Communication Service contains internet, e-commerce, solution/contents, software development. Other Services contain finance related services like credit evaluation, R&D related service, business support, education, movie/broadcast/performance, entertainment/culture/exercise, tourism, etc.

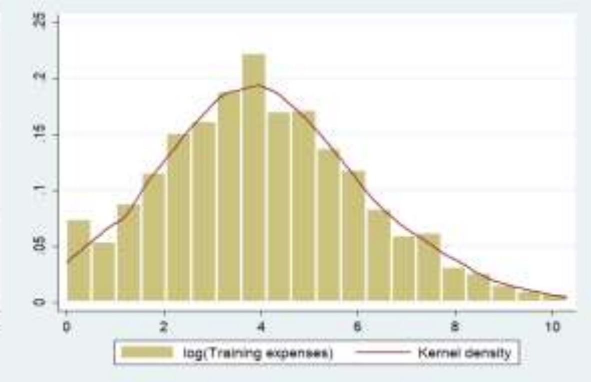
Data sources: KIPO and NICE (2005-2015): patents, earnings-to-costs; KRIVET–Human Capital Corporate Panel (2005, 2007, 2009, 2011, 2013, 2015): rest of variables.

Sources: Author’s analysis of KLOSA data.

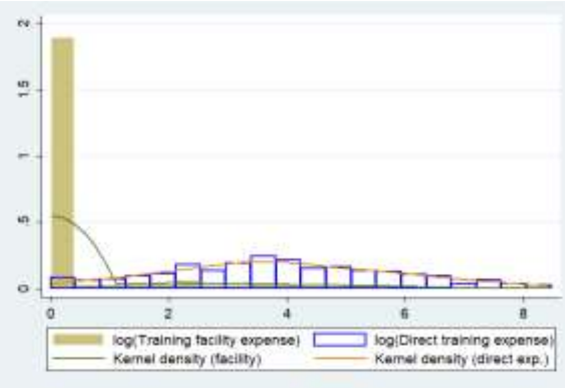
Figure A1. Sample distribution of important variables used in regressions



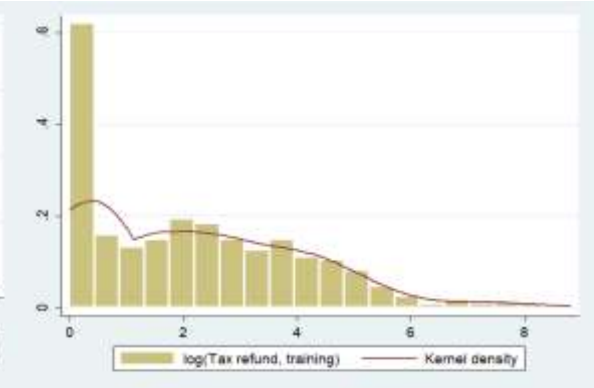
i. Patent applications (Log scale)



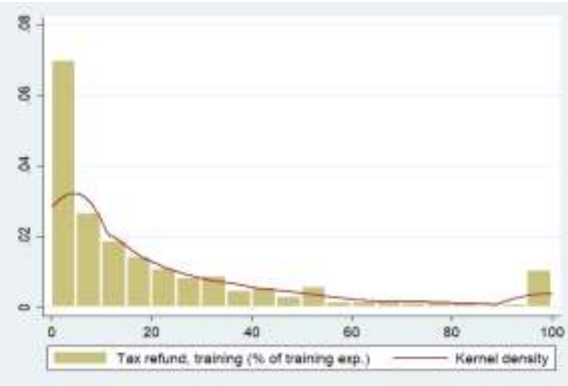
ii. Expenses on training



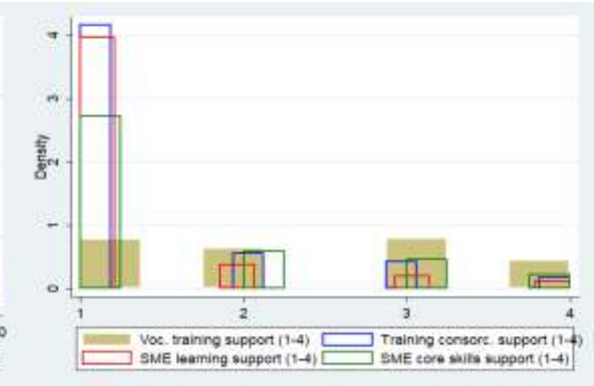
iii. Expenses on direct training, and on training facilities



iv. Tax refund for training expenses (Log scale)

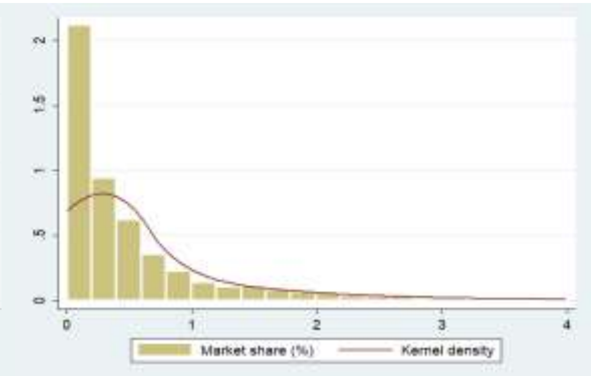


v. Tax refund for training expenses (% of train. expenses)



vi. Vocational training support (1-4 Likert)

vii. Management independence (Likert scale),
foreign ownership (binary)

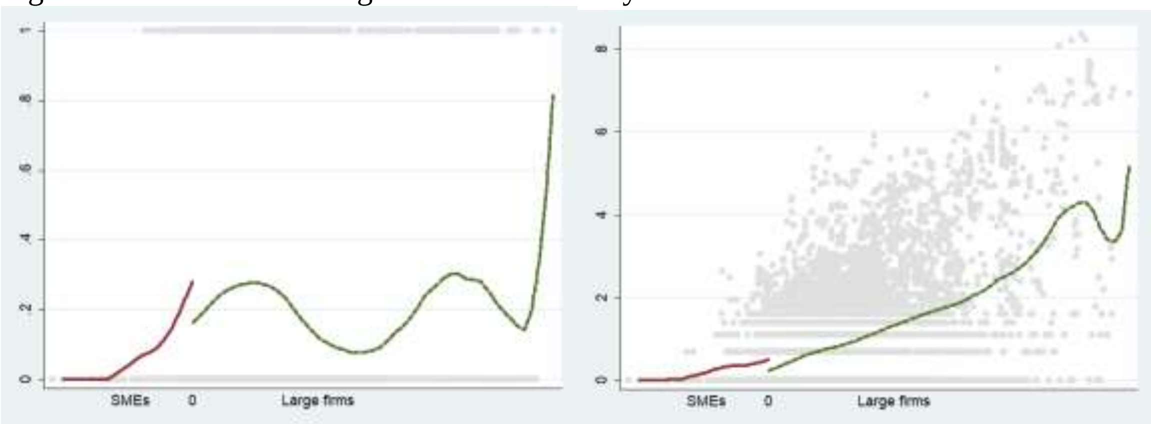


viii. Market share (%)

Note: For clarity of presentation, values of patent applications are cut off at 6. There are few observations with 6.0-9.5 log-applications.

Sources: Figure by author. Author’s analysis of KLOSA data.

Figure A2. Results of the regression discontinuity model



i. Conditional mean of government support ii. Conditional mean of log patent applications

Sources: Figure by author. Author’s analysis of KLOSA data.