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Identification of Overall Innovation Behavior by Using a Decision Tree: The Case of a Korean Manufacturer

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Abstract: Based on the two recent consecutive Korean Innovation Surveys in 2014 and 2016, this research empirically identifies the influencing factors and overall behavior of innovation success and failure in the manufacturing industry by using decision-making tree analysis (DT). The influencing factors and behavior of a successful innovator are also investigated from the perspectives of financial contribution, innovation activity, and research and development (R&D) activity. By using DT, this study acquires comprehensive knowledge of the arguments on innovation factors and behaviors in different contexts over time while dealing with all the factors in a single statistical framework based on the Oslo manual. Results with around 80% predictive accuracy show that the role of R&D is crucial for innovation success. The larger the firm size and the older the firm, the higher the success achieved by the firm will be. Firms in a low-technology industry prefer other innovation activities rather than R&D. Concerning a successful innovator's behavior, target market characteristics that drive a firm to seek market needs influence innovation behavior and the use of information for innovation. Firms prefer implementing low-cost R&D activities across sectors, but firms in low-technology sectors prefer non-R&D activities. Regional characteristics of well-established business environments help firms to focus on R&D activities and reduce costly non-R&D activities. Most firms having R&D institutes focus on conducting in-house R&D using their own information. Cooperative R&D is conducted for closing capability gaps, but absorptive capacity is required to complement cooperative R&D. These empirical findings reaffirm the arguments on innovation behavior and arrange them in the overall perspective; they also provide managerial and political implications. Establishing and strengthening private or public R&D support programs to increase the capability of both in-house and cooperative R&D through funding as well as leveling up the information environment on technology and the market is crucial to the national innovation system.

Keywords: innovation success and failure; innovation factors and behavior; financial contribution; innovation activity; R&D activity; manufacturing industry; decision-making tree analysis

1. Introduction

Given the fiercely competitive business environment in the globalized economy that has evolved over the years, innovation success plays a crucial role in promoting sustainable growth at the firm, industry, and national levels [1–7]. Therefore, numerous academic researchers, managers, and policymakers have conducted frequent examinations on the structure of successful innovation in terms of its inherent factors and behaviors in various aspects of political, strategical, or managerial landscapes [8–14].

The famous Scientific Activity Prediction from Patterns with Heuristic Origins (SAPPHO) project conducted by the Science Policy Research Unit (SPRU) was deliberately designed in the 1970s to test generalizations of innovation based on a comparative analysis of paired successful and unsuccessful innovations on the first large-scale national level [15–17]. Since then, innovation studies have mainly focused on factors influencing the success and failure of innovations and their behavior as well as successful innovative firms. Additionally, the focus of these studies has gradually shifted to specific subjects to acquire knowledge of the in-depth mechanism of innovation behavior, thereby leading to a close investigation of the overall structure [18–25].

Despite these efforts that have evolved over the past decades, there is a lack of understanding of the precise prescription of innovation [18,19]. Previous studies have pointed out the following three underlying reasons. First, the intrinsic complex context of innovation makes it difficult to contribute toward a comprehensive and precise prescription of successful innovation [20,21]. Additionally, several variables and behaviors related to innovation have been identified in various empirical studies. These variables have sometimes led to a conflicting conclusion or have failed to exert a significant impact on innovation. Second, the aforementioned gap can be attributed to the difficulty faced by empirical studies in maintaining consistency in measuring innovation based on the existing definition of innovation and by various proxy measures with differing perspectives [22,23]. Third, changes in the business environment and different contexts of innovations over time may have also attributed to the gap [24–26].

The aforementioned shortcomings emerge from different contexts of empirical studies and their proxy measures, which have been changed over time. Additionally, the reason studies were conducted on specific subjects can be attributed to innovation data and statistical methodologies. Innovation data have been measured together by various types of ratio, interval, ordinal, and nominal variables. These characteristics of innovation data in terms of type and scale have restricted methodological application. Innovation data are usually measured on a nominal scale (categorical variable). Additionally, they are frequently measured on a binomial scale, such as innovation success and failure, regardless of whether R&D is performed and whether innovation activities are conducted. These kinds of whether or not problems make it difficult to apply advanced statistical methodology. This problem, involving different types of variables, requires well-structured analytical models, which can ensure comprehensive results in a single statistical significance framework. Since previous research results cannot be put in a single frame while retaining the same statistical significance, comprehensive research based on a single frame would be necessary.

The development of data mining methodologies has recently increased the application of these methodologies to studies on innovation [27,28]. Decision-making tree analysis (DT) is one of the predictive modeling techniques commonly employed in the data mining domain. DT produces a robust model that predicts the value of a dependent or target variable from various independent or input variables. Additionally, the DT algorithm provides an accurate prediction model and visualization. It also deals with both numerical and categorical variables. In addition, DT performs very well with large datasets and produces easily comprehensible and interpretable results [28]. In this respect, the application of DT to innovation studies can be considered suitable in terms of the freedom of using various proxy measures together, which are mostly measured categorical variables with numerical variables. Additionally, DT reduces the burden of developing structured analytical scenarios required when employing statistical methodologies due to constraints involving innovation data characteristics. In these regards, DT can present a comprehensive knowledge of factors influencing innovations and their behaviors in an interpretable format through a single and statistically significant predictive framework treating different types of variables together, regardless of them being categorical or numerical variables.

The methodological advancements in the field of data mining and the increased feasibility of using large-scale innovation data have increased the possibility of facilitating a comprehensive understanding of factors influencing innovation and behavior. Given the improved innovation study environment in terms of data and methodology, this study aims to acquire knowledge of sustainable innovation behavior based on evidence from the Korean manufacturing industry. Considering these aspects, this study investigates factors influencing the success and failure of innovation and behavior as well as successful innovative firms from a longitudinal perspective, by using the DT analysis model based on the Korean Innovation Survey (KIS) data on 8075 manufacturing firms for the past two consecutive surveys (in 2014 and 2016).

Accordingly, the first objective of this study is to examine the sustainable behavior for the success and failure of innovation by capturing changes from a longitudinal view in accordance with the guidance from the Oslo Manual, which maintains international principles for measuring innovation. The second objective of this study is to investigate the sustainable behavior of successful innovative manufacturers from the perspectives of innovation activities and contribution. With these research objectives in mind, this study intends to contribute toward mitigating the shortcomings of comprehensive knowledge by treating all the factors, which are used in KIS based on the Oslo Manual, in an analytical and predictive DT model through a single statistical significance framework. As an empirical study on the Korean manufacturing industry, this study reaffirms comprehensive innovation behavior investigated in previous studies by determining factors that significantly influence innovation and behavior. From empirical findings on the Korean business environment, this study provides sustainable implications for the current era.

On the other hand, although the aims of this study focus on the identification of comprehensive innovation behavior by using DT that is highly predictable and easily interpretable, the nature of DT regarding a non-parametric analysis makes it difficult to comprehend the in-depth underlying mechanism of innovation behavior. Thus, it is worthwhile to validate the hypotheses constructed based on the significant findings from DT. In advance, regional and sectoral factors are particularly identified in the success and failure of innovation in this study, in addition to the role of R&D, which is the most significant and important factor, and factors, such as firm size and age, which are intrinsic general factors of the firm involving R&D. In addition, concerning successful innovative firms, these regional and sectoral factors related to the target market are determined to influence the innovation behavior of focal firms. Therefore, this study subsequently tests the hypotheses that there are differences in innovation success according to the region and sector.

The rest of this article is organized as follows. In Section 2, the previous relevant studies in the domain of innovation are introduced. In Section 3, data, variables, research framework, methodology, and the model used in this study are presented. Section 4 presents the empirical results of the DT analysis model and discusses the findings derived from them. Section 5 constructs and verifies hypotheses derived from the findings in Section 4. Section 6 provides the implications drawn from the findings and future directions of the research.

2. Literature Review

Innovation has been understood and defined in different contexts according to the time and circumstances of previous studies as concepts of invention, exploitation, implementation, and commercialization [16,18,19,29]. It has been operationally defined with various proxy measures. This has made it difficult to maintain consistency in innovation measurement and interpret results across empirical studies with different perspectives in different contexts. Previous studies have identified the main influencing factors determining the innovative behavior along with its definition [18,19,30–34]. It is claimed that the definition and measurement of innovation in the literature is highly theoretical [35]. Additionally, it has been claimed that these cannot be straightforwardly applied to businesses [35,36], as they are complex and include diverse influencing factors [18,19,26,37]. It was claimed that a common overall innovation measurement framework does not exist [18,19].

Thus, standardized guidance for measuring innovation needs to be used to maintain consistency and to facilitate comparativeness with another context [19,21,38]. Hence, the Organization for Economic Co-operation and Development (OECD) has provided guidelines through the Oslo Manual for measuring innovation and related factors in the international perspective. It has been standardized and applied empirically worldwide [38]. The KIS has also been developed on the basis of the Oslo Manual. It has been conducted since 2003, biennially or triennially, by the Science and Technology Policy Institute (STEPI). The KIS is the national authorized statistics approved by "Statistics Korea," which is a central government agency. It has been well-conducted over the past two decades by trained facilitators to measure innovation activities with high quality. The survey questionnaires of "KIS: manufacturing industry" have been consistent over time. Accordingly, this study can design a longitudinal research framework and produce consistent results in the manufacturing industry. Based on the Oslo Manual, related innovation factors involving not only contextual factors, but also intrinsic ones can be considered from theoretical, managerial, and political perspectives.

In this study, innovation is defined as "the implementation of a new or significantly improved product, or process, a new marketing method, or a new organizational method in business practice, workplace organization or external relations," according to the guidance of the third edition of the Oslo Manual in 2005 (fourth edition was published in 2018 in which the definition of innovation was changed) [38]. The data used in this study are obtained from the "KIS: manufacturing industry" in 2014 and 2016, which are based on the third edition of the Oslo Manual. In this sense, innovation activities are defined as "including all scientific, technological, organizational, financial and commercial steps which actually lead, or are intended lead, to the implementations of innovations," as per the third edition of the Oslo Manual [38].

Concerning the identification of innovative behavior, extrinsic and intrinsic determinants have been empirically explored in various perspectives. Extrinsic determinants are related to a firm's business environment. The main extrinsic factors comprise the industry to which the firm belongs and the region where it is located. The other factors are related to the cooperative networking environment involving knowledge or technology flow. Additionally, market-related factors were noticeably examined for innovation behavior.

It is widely accepted that industry and regional characteristics are significant to innovation behavior. Examinations have revealed that the industry factor has significantly affected innovation in terms of technological dynamism, demand growth, and industrial structure. Concerning technological dynamism, it is found that high-tech industries are more innovative than traditional ones [29,39–42]. Concerning testing the demand-pull theory, demand growth has a significant positive impact on innovation [43–45]. Regarding industrial structure, the empirical results are diverse. Industry concentration is found to have a negative [45–47] or positive [48,49] effect. Additionally, other studies showed a bell-shaped [50] or an insignificant [43,51–53] relationship between innovation and industry concentration. The regional factor is found to have had a significant impact on innovative capacity [29,54–59]. Concerning location characteristics of proximity to partners, which increases cooperation with suppliers, customers, and universities, it was found to positively influence innovation [42,58,60–63]. Proximity facilitates tacit knowledge transfer [64,65] and reduces communication costs [66]. Cooperative networking could be understood as a corporate capability, but it is more reasonable to be considered in relation to the business environment [35,62,67–69]. Several studies show that the correlation between innovation and interaction with networking partners is positive [58,62,67–71]. However other studies identified that it is not significant [50,72]. Despite these conflicting findings, it is consciously accepted that cooperative networking helps a firm to bridge gaps in its information, scientific knowledge, resources, and competencies [61]. Market focus plays an important role in product success [18,73–75]. Demand and supply determine the success of a business [45,67,74,76]. Hence, target market characteristics, including customer type and customer feedback, affect innovative behavior for product and business success [18,77–79]. These market-related factors have driven firms' innovative behavior, such as detecting customer needs [22,69,80–82], advertising [47,83], and elaborating marketing strategies [79,84]. Although there are some negative or insignificant effects of industrial and regional characteristics as well as cooperative networking and market characteristics on innovation, their positive effects are widely accepted from the perspective of promoting innovation [18,19,24,55,61,63,79]. This study considers these extrinsic innovation-related factors, and information on these factors are collected in the KIS.

Intrinsic determinants of innovation have mainly been studied in the view of capability theory by organizational theorists since the late 1960s [69]. It could be categorized into the following: (1) The general characteristics of a firm, (2) innovative capability, and (3) innovative activities.

Although a firm's general characteristics, size, age, and ownership have been determined, but these have not provided an understanding of the precise prescription of innovation. Concerning the relationship between firm size and innovation, there have been conflicting results. The main arguments are as follows. On the one hand, small firms have an advantage in the management of innovation [85]. On the other hand, large firms have more resources to innovate than small ones [86–91]. Another study revealed two different relationships, which are U-shaped and hump-shaped in the case of German, France, and Belgium firms in the 1980s [92]. It is argued that this phenomenon might be influenced by other factors, such as industry condition and structure [92]. The debate on these Schumpeter Mark I and II hypotheses [93,94] is still being explored. There are also arguments about the relationship between firm age and innovation. On the one hand, firms accumulate the experience and knowledge to innovate with age [95,96]. On the other hand, older firms resist innovation by establishing procedures with a stable barrier [97]. This claim of two positions has not been verified sufficiently. Thus, hasty generalization cannot further our understanding. Regarding ownership, results were also mixed. It is revealed that foreign ownership is positively correlated with innovation [44,52,98], whereas it was found that foreign ownership had a rather negative [52,72,99], or insignificant [100,101] impact on innovation. These arguments lie between the viewpoint of a lack of important management in a foreign-owned firm and that of compensation for the advanced management of knowledge for innovation from the foreign parent [18].

Concerning a firm's innovative capability, R&D capability has been mainly examined. R&D capability is related to the firm's financial and organizational capacity [51]. The capacity in this sense refers to employees, including R&D personnel, and investment resources, which have a relationship with budget and cost. For example, the R&D personnel ratio and R&D investment (e.g., R&D intensity) have a positive effect on innovation [102,103]. Additionally, the R&D budget is a factor influencing innovation [35,104–106]. However, given that R&D cost is limited and secured, these factors are not enough to explain innovation [107]. Although investment in innovation leads to innovation performance [57] and R&D-related factors are good representatives of organizational capacity [61], these cannot contribute toward a firm's overall innovative capability [18]. It is also argued that all innovations are not based on R&D [19].

Concerning the firm's innovative activities, R&D activities have been mostly examined. R&D is accepted to be the most important determinant of innovation [18,19,35,57,61,62,67,69,74,102–105,108–112]. The manner in which R&D activities are performed can be categorized into in-house R&D, cooperative R&D, and external R&D. In-house R&D constitutes the major channel for carrying out R&D activities, and it is considered the most crucial factor of innovation for the manufacturer. In-house R&D naturally supports a firm to develop new products or processes [62,67,110,113]. It also provides the capability to absorb external knowledge and technologies [18,19,50,112,114–116] and to cooperate with different organizations, such as universities and research institutions [9,55,62,63,67,69,71,108,109,117]. By engaging in cooperative R&D, firms gain access to complementary technologies or knowledge [114,118,119], and they can improve the probability of success of an innovation project [120–123]. However, the instability and risks associated with R&D cooperation cannot lead to successful innovation [124–129]. Firms that have limited resources and capabilities for internal R&D consider external R&D [130–132]. Subsequently, they expand the possibility to develop new products with commercial success [133–135]. However, absorption capacity was found to be essential for complementing external R&D [136]. The role of external R&D for innovation by itself and its complementarity with internal R&D remains inconclusive [130,137]. While some findings of the effects of cooperative and external R&D are still being debated, the role of R&D for innovation has been widely accepted. Meanwhile, innovation is not only driven by R&D, and R&D activities cannot reflect the firm's innovative capability [18,19,107,138]. In terms of business management, non-R&D activities are divided into the following six categories [38]: (1) Acquiring machine, tool, software, and building for operational management; (2) procuring external knowledge to develop new product or to improve process; (3) providing job training for educated, qualified, and experienced personnel; (4) undertaking market launching activities for new product penetration; (5) undertaking design activities for new product development; and (6) performing other activities.

This study considers these intrinsic innovation-related factors along with extrinsic ones to investigate innovative behavior because all these factors have been shown to be important determinants of innovation in the literature. These are summarized in Table 1.

Table 1. Examples of the main determinants of innovation in the literature.

Category	Sub-Category	Main Determinants	Main Results and Arguments	Relevant References
Extrinsic determinants	Industry	· Technological dynamism	· High-tech industries are more innovative than the traditional one	[29,39–42]
		· Demand growth	· Positive	[43–45]
		· Industrial structure (industry concentration)	· Negative · Positive · Bell-shaped · Insignificant	[45–47] [48,49] [50] [43,51–53]
	Region	· Location characteristics of proximity to partners	· Positive · It promotes knowledge transfer and reduces communication costs	[42,58,60–62] [64–66]
	Cooperative networking environment	· Cooperative networking environment	· Positive · Insignificant	[58,62,63,67–71] [50,72]
			· It promotes interaction and helps for closing capability gaps	[61]
	Market	· Demand and supply	· Positive	[45,67,74,76]
		· Target market characteristics involving customer type and feedback	· Positive	[18,77,78]
			· It drives seeking market needs, advertising, and elaborating market strategies	[22,47,69,79–84]
Intrinsic determinants	General characteristics of a firm	· Size	· Small firms have an advantage · Large firms have an advantage · U- or hump-shaped	[85] [86–91] [92]
		· Age	· Older firms have an advantage · Younger firms have an advantage	[95,96] [97]
		· Ownership	· Positive · Negative · Insignificant	[44,52,98] [52,72,99] [100,101]

Table 1. *Cont.*

Category	Sub-Category	Main Determinants	Main Results and Arguments	Relevant References
Intrinsic determinants	Innovative capability	· R&D capability	· R&D personnel affects positive	[102,103]
			· R&D investment (budget and cost) affects positive	[35,104–106]
			· It is crucial, but it does not reflect overall innovation capability	[18]
	Innovative activities	· In-house R&D	· In-house R&D is crucial	[18,19,35,57,61,62, 67,69,74,102–105, 108–112]
		· Cooperative R&D	· Positive · Unstable and negative	[63,114,118–123] [124–129]
		· External R&D	· Positive but complementary	[133–135][115,130, 136,137]

Factors that are shown in the literature as affecting innovation are presented from a viewpoint of factors that affect innovation success or innovation performance. This innovation success or performance is mostly measured by patents [35,139–142], R&D intensity [105,140], and number of innovations (e.g., new product development or commercialization) [25,31,77,143–147]. These measurements focus entirely on the innovation itself, from mostly a technological perspective. Given the importance of innovation in business management, it is essential to look at the relationship between the firm's financial performance and innovation [7,148–151]. Financial performance is defined as the earnings of a business through the sale of innovative products in the market [18]. For financial performance measurement, proxy measures, such as return on investment with innovation [152] and new-to-market and new-to business sales [150], are used. However, these studies examined the impact of technological innovation on financial performance. A study that examines the differences between companies with good financial performance and those with poor financial performance, among successful innovators, is still lacking. In this respect, this study attempts to explore the behavioral difference between groups contributing to sales through innovation and those without a contribution.

Additionally, there is a lack of research on the differences between companies that focus on R&D activities and those that focus on non-R&D activities, among successful innovators. Therefore, it would be worthwhile to identify differences in the innovation behavior among these groups by distinguishing successful innovators based on their R&D and non-R&D activities.

3. Research Design

3.1. Data and Variables

This study aims to identify sustainable influencing factors on innovation and behavior by using DT analysis with various innovation variables, based on a single structured framework, in the Korean business environment. Hence, the "Korean Innovation Survey (KIS): manufacturing industry" in 2014 and 2016 is used to analyze the behavior of manufacturers in Korea from a longitudinal perspective. The survey questionnaires of the "KIS: manufacturing industry" have been consistent over time. Based on this, the longitudinal analytical framework is structured in this study. The "2014 KIS" and "2016 KIS" contain firm-level data on the innovation-related activities from 2011 to 2013 and from 2014 to 2015, respectively.

Since the KIS is well-known for its reliability and the focal point on innovation, it has been used in the field of empirical innovation studies in Korea [153–157]. Concerning the representativeness of the national innovation activities of the KIS sample data on the manufacturing industry, the sample frame comes from the recent nationwide business survey by the National Statistical Office (NSO). It is stratified by the multistage-stratified-systematic-sampling based on the Korea Standard Industry Code (KSIC) and the number of employees in the firm. The Neyman allocation method was used for sample allocation. The 2014 KIS of the manufacturing industry covers 4075 manufacturers taken from a sample frame of 46,101 firms in the period from 2011 to 2013. The 2016 KIS of the manufacturing industry covers 4000 manufacturers taken from a sample frame of 49,704 firms in the period from 2013 to 2015. Manufacturers were categorized into 23 industrial sectors in the ninth version of KSIC, in which KSIC 10 to 33 fall under the manufacturing sector, except KSIC 12 (manufacturers of tobacco products). Firms were defined in 17 regions comprising 7 metropolitan cities, including the capital city, 1 special self-governing city, 8 provinces, and 1 special self-governing province.

In the KIS, firms were asked to indicate their status related to innovation and innovation activities. Basically, they were questioned about the success or failure of the innovation of products and processes. In this study, innovation success is defined as "an implementation of a new or significantly improved product or process." Regardless of whether firms succeeded in innovation, they were commonly questioned about the following items in each category. In the category of the firm's general information in terms of corporate capabilities for innovation, the following items were asked: (1) Form of the firm (legal unit); (2) statuary types (by the size of the employees from the sample frame); (3) designation status (in the Korean context); (4) listed status (in the Korean stock market); (5) size (sales, exports, and employee); and (6) age. Additionally, data on the sector to which the firm belonged, in terms of the KSIC at the two-digit-code level, was taken from a sample frame. The firms were also questioned about their regional location. Regarding the general R&D status, data regarding the "ratio of R&D personnel" and "manner of R&D activities" were collected. Concerning external factors that affect innovation, data on the "main target market" and "main customer types" were collected. These variables, measurement responses and descriptions, and scale are shown in Table 2, and their details are shown in Table A1 of Appendix A. Details of the sector variables as KSIC's industrial codes on the manufacturing industry are listed in Table A3 of Appendix B.

Companies that succeeded in innovation were asked the following items. Concerning innovation activities, the following items were asked: (1) Whether or not eight types of innovation activities were implemented, (2) cost of each innovation activity, and (3) budget source of each innovation activity. In terms of knowledge flow and their relationship, the following items were asked: (1) Information sources used for innovation, (2) whether or not cooperative activity was carried out, (3) cooperative partner if the cooperative activity was carried out, and (4) the best cooperative partner if the firm had a cooperative partner. Concerning innovation outcomes, the firm was questioned about its "contribution of innovation to sales." These variables, measurement description and responses, and types are shown in Table 3, and their details are shown in Table A2 of Appendix A.

Table 2. Summary of the variables in the general information of 2014 Korean Innovation Survey (KIS) and 2016 KIS.

Category	Variable	Measurement Responses and Description	Type
General status	Form of firm	· Independent company · Affiliates of a domestic company · Affiliates of a foreign company	Nominal
	Statuary types (by the size of employee from sample selection)	· Large-sized company · Medium-sized company · Small-sized company	Nominal
	Designation status (in Korean context)	· Venture company · InnoBiz (certificated as innovative small and medium-sized firm) · n/a	Nominal
	Listed status (in Korean stock market)	· KOSPI · KOSDAQ · n/a	Nominal
Size status	Size of sales and exports	· Level of actual annual value over the last three years	Ordinal
	Size of employee	· Level of actual annual value over the last three years	Ordinal
R&D status	Ratio of R&D personnel	· Level of the percentage of R&D personnel in the last year	Ordinal
	Manner of R&D activities	· Operation by R&D institutes · Dedicated department · Irregular operation if necessary · Not implemented	Nominal
Market status	Main target market	· Domestic · Asia · Europe · North America · Others	Nominal
	Main customer types	· Private company · Government and public sector · Individual customer · Overseas market · Others	Nominal
Another status	Sector	· Industrial code (23 codes)	Nominal
	Region	· Region (17 areas)	Nominal
	Age	· Age	Interval

Table 3. Summary of the variables for the successful innovative firm.

Variable		Measurement Responses and Description	Type
Success of innovation		· Success on the innovation of product or process	Nominal
Contribution to the sales		· Percentage of contribution from innovation for the sales of the last year	Ratio
Innovation activities	R&D activities (whether or not)	· Performing in-house R&D · Performing cooperative R&D · Performing external R&D	Nominal
	Non-R&D activities (whether or not)	· Acquisition of machine, tool, software, and building · Buying external knowledge · Performing job training · Performing market launching activities · Performing design activities · Performing others	Nominal
Innovation Cost	Level of total innovation cost	· Level of the total cost for innovation activities performed in the last year	Ordinal
	Level of the percentage of cost on each innovation activities	· % level for In-house R&D · % level for External R&D · % level for Acquisition of machine, tool, software, and building · % level for Buying external knowledge · % level for Others	Ordinal
Source of budget		· Owned capital · Affiliate fund · Government fund · Loan · Stock Issuance · Corporate Bond fund · No expenditure	Nominal
Information source for innovation		· In-house or within the affiliate · Supplier · Private customer · Public customer · Competitors in the same sector · Private service firms · Higher educational institutes · Institutes of government, public, and private sector · Conference, exhibition, and fair · Professional journal and publications · Industrial association	Nominal
Cooperative activities	Implementation	· Whether or not	Nominal
	Cooperative partner	· Affiliates · Supplier · Private customer · Public customer · Competitors in the same sector · Private service firms · Higher educational institutes · Institutes of government, public, and private sector	Nominal
	Best cooperative partner		Nominal

3.2. Methodologies

Traditional statistical methods in innovation research have been restricted by characteristics of the innovation study data, although they intended to consider the overall factors. This study aims to solve this shortcoming by considering the overall factors in innovation by using DT analysis. This method allows the usage of various proxy measures comprising categorical and numerical variables in a single frame statistically.

Classification tree analysis and regression analysis are the two principal types of DT. The classification and regression tree (CART), chi-squared automatic interaction detection (CHAID), quick, unbiased, efficient statistical tree (QUEST), C5.0, and C4.5 are the most commonly used DT algorithms. The CHAID algorithm is capable of processing both continuous and categorical predictive (or independent) variables along with the target (or dependent) variables. Thus, CHAID develops decision trees for both the classification-type and regression-type prediction problems, regardless of whether the dependent variable is a nominal or a continuous numerical variable. Additionally, the

CHAID algorithm is a nonparametric procedure that requires no assumption of the underlying data; for example, it does not require the data to be normally distributed [28,158–162].

In the CHAID algorithm, the F test is used if the dependent variable is continuous, and the chi-square test is used if it is categorical. The CHAID algorithm uses a multi-way splitting strategy, thereby creating interpretable models compared to CART [158,159]. Beginning with a root node that includes all cases, the tree branches are divided into different child nodes. CHAID is not a binary tree algorithm, and hence it can produce more than two categories at any level in the tree that differs from other decision tree algorithms. The criterion for branching (or partitioning) is selected after examining all possible values of all available predictive variables (at the Bonferroni-adjusted *p*-value of the statistical significance level). In the terminal nodes, a grouping of cases is obtained, such that the cases are as homogeneous as possible with respect to the value of the dependent variable.

Based on the advantage of the CHAID algorithm in terms of application and interpretation, this study used the CHAID algorithm by employing IBM SPSS 22. The settings in this study are as follows: (1) The value of the maximum tree depth is set autonomously; (2) both the splitting significant value and the merging significant value are set at 0.05; (3) the maximum number of recursive calculation is set at 100; (4) the misclassification cost is set to the same value for all categories; (5) the missing value is treated as not valid but missing; and (6) the minimum size of the parent and child nodes are set to be 100 and 50 cases, respectively.

In terms of validation, cross-validation is a general method used to estimate the unbiased accuracy of a predictive model's performance in practice [28,159,162]. Ten-fold cross-validation is widely used in the data mining field since empirical studies have demonstrated that 10 constitutes an "optimal" number of folds [163]. It creates a fine balance between the sampling bias in terms of diversification of training and testing subsamples and demonstrating the time taken to build the model and test activities. In 10-fold cross-validation, the dataset is randomly separated into 10 mutually exclusive subsets of approximately equal sizes. The models are built and trained first and then tested, and the process is repeated 10 times. At each iteration, the model is trained on nine folds, combining training data that includes 90% of the total dataset. Additionally, it is tested on the remaining fold, which is 10% of the total dataset. The estimate of the cross-validation of the overall accuracy of the model is calculated by averaging the 10 individual accuracy measures that come from each fold. For the performance measure of prediction models, a coincidence matrix is used. It contains the actual and predicted classifications created by the model [164]. The overall accuracy is defined as the percentage of records that are correctly predicted by the model. In this study, a 10-fold cross-validation method is used to estimate the performance and overall accuracy. Additionally, the ratio of the number of true positive, which means the ratio of the correctly predicted case, is provided for each model.

3.3. Research Framework

The first research objective is to explore the overall behavior that affects the success and failure of an innovation. The second objective is to investigate the behavior of successful innovative firms in terms of innovation activities and contribution to sales. These two research objectives are presented in the research framework, as shown in Figure 1.

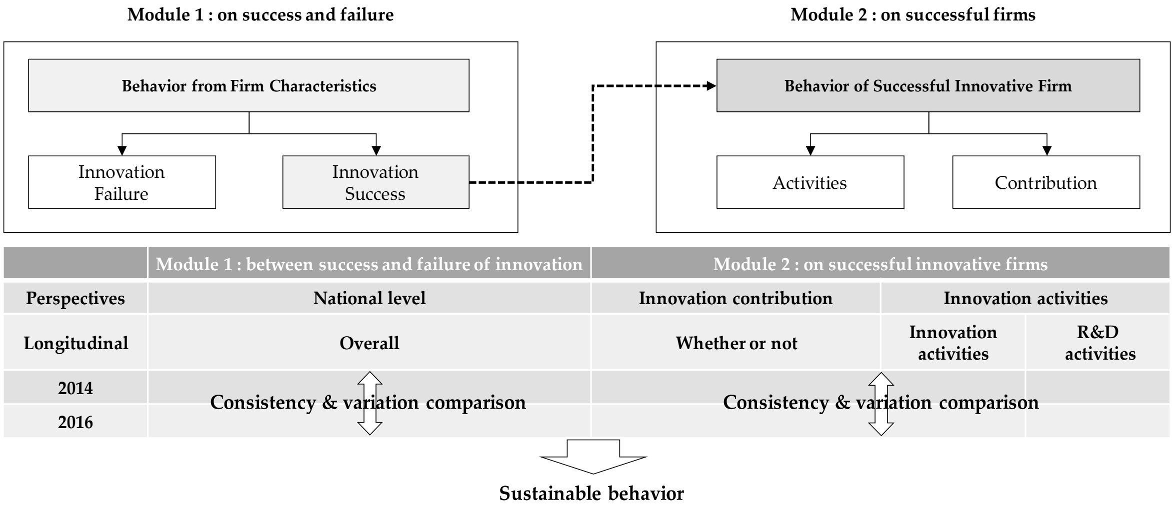

Figure 1. A research framework for the investigation of innovation behavior.

In order to gain recent comprehensive knowledge of factors influencing the innovation and behavior of the manufacturing industry, based on the latest KIS data, a sustainable perspective through a longitudinal analysis framework is developed, as seen in Figure 1. It is structured to examine the longitudinal consistency and variation based on the two consecutive 2014 and 2016 KIS.

The first module (Module 1) consists of two models, and the second module (Module 2) consists of eight models, as shown in Table 4. "Innovation success and failure" is used as a target variable in Module 1. In Module 2, each model has different target variables according to each of their corresponding purposes, which involve innovation contribution and innovation activities. The variables for which data is commonly collected, regardless of whether firms succeeded in innovation, are used in Module 1. In Module 2, variables that were asked only of successful innovative firms and those used in Module 1 are used.

Table 4. Models with target and input variables.

Module	Perspective		Year	Model	Target Variable	Input Variable
1 (success and failure)	Overall		2014 2016	Overall in 2014 Overall in 2016	Innovation success and failure	All variables in Table 2
2 (successful innovative firm)	Contribution to sales	Whether or not	2014 2016	Contribution in 2014 Contribution in 2016	Contribution to sales (Y/N)	All variables in Tables 2 and 3 (without the variable of success of innovation)
	Innovation activity	Innovation activity [a]	2014 2016	Innovation activity in 2014 Innovation activity in 2016	Class of innovation activity manners	
		R&D activity [a]	2014 2016	R&D activity in 2014 R&D activity in 2016	Class of R&D activity manners	

Notes: [a] Independent variables related to innovation activities in Table 3 are excluded.

4. Results and Discussion

4.1. *Overall Influencing Factors and Behaviors between Innovation Success and Failure*

Table 5 summarizes the case statistics and results of the two models of Module 1. This table presents influencing factors at the significance level of 0.05. It also provides the overall accuracy as well as the predicted accuracies of the success and failure classes.

Table 5. Case statistics and DT results of Module 1.

Year	Number of Cases			Result	Accuracy		
	Total	Success	Failure		Overall	Success	Failure
2014	4075	967	3108	Ratio of R&D personnel; Manner of R&D activities; Size of exports (one year ago); Statuary types	79.4%	40.2%	91.6%
2016	4000	1616	2384	Manner of R&D activities; Size of employee (one year ago; Sector; Firm age; Size of sales (two years ago); Size of employee (three years ago); Region; Listed status (Korean stock market)	79.4%	71.2%	85.0%

Based on the 10-fold cross-validation, the overall forecasting accuracies of the models in 2014 and 2016 are the same at 79.4%. These accuracy levels are relatively high, close to 80%. Accuracies of the success class of each model are 40.2% and 71.2%, respectively. Accuracies of the failure class are 91.6% and 85.0%, respectively. Basically, based on the general information of firms, it is very complicated to forecast successful innovation. However, the accuracy levels of the classifications between innovation success and failure demonstrate the quality of the model. Additionally, the overall accuracy levels appear stable, coming from cross-validation and the big data scale. Thus, it allows us to conclude that these DTs are rational and sustainable. These results indicate that the general information of firms used in KIS, which are related to the general resources of capability for innovation, can distinguish innovation success from failure. Especially, these significant influencing variables obtained from the results of the DT analysis can effectively filter out firms that are more likely to fail in innovation.

At the national level, in the order of significance, factors affecting innovation success and failure in 2014 are found as follows: Ratio of R&D personnel; manner of R&D activities; size of exports (one year ago); and statuary types. In 2016, the following factors are found to be significant influencing ones: Manner of R&D activities; size of employee (one year ago); sector; firm age; size of sales (two years ago); size of employee (three years ago); region; and listed status. The results of these two models are much different from each other. The success class in 2016 was larger than that in 2014. It could be interpreted that the data in 2016 provides enough evidence for forecasting the success class compared to 2014. Nevertheless, the factor of the manner of R&D activities is identified to be a significant factor influencing successful innovation over 2014 and 2016 from a longitudinal viewpoint.

Concerning the behavior between innovation success and failure, the results of DT in 2014 and 2016 are shown in Figures A1 and A2 in Appendix C. First, examining Figure A1 in 2014, DT starts with the first parent node of the ratio of R&D personnel. In the case wherein the value of the ratio of the R&D personnel is zero, which means an absence of R&D personnel, 98.8% of firms had failed in innovation. In the case wherein no R&D activity was carried out under the above condition (the absence of R&D personnel), entire firms failed in innovation. However, 16.1% of the cases of firms irregularly operating R&D if necessary, succeeded in innovation in the above group. In other cases, wherein the value of ratio of R&D personnel was not zero, factors of statuary types and exports level mostly explained the success and failure of innovation. Especially, the factors of the ratio of R&D personnel and statuary types (in terms of size) are presented in the third layer. These results indicate that these factors mostly explain the behavior of innovation success and failure, given that firms have R&D personnel. Comprehensively, the higher the ratio of R&D personnel and the bigger the firm size, the greater the success realized by firms will be. It reaffirms the arguments that R&D personnel affects positively [102,103] and that large firms have an advantage [86–91].

Second, investigating Figure A2 in 2016, DT starts with the first parent node of the manner of R&D activities. Of the 31% of firms with R&D institutes, 73.5% succeeded in innovation. In the case in which no R&D activity was carried out, only 7% of firms succeeded in innovation. This result reaffirms the argument that the role of the R&D organization is very important for the success of innovation, and this role should coincide with the capacity of the firm to perform R&D [18,19,35,57,61,62,67,69,74,102–105,108–112]. In the case of firms having R&D institutes to carry out R&D, the larger the employee size, the higher the success rate will be. The success rate is 57.6%, 73.1%, and 85.0% in the case of firms with less than 50 employees, 50 and 99 employees, and 99 employees, respectively. In the case of firms having R&D institutes with less than 100 employees, regional differences are identified between innovation success and failure. While in firms having R&D institutes with more than 99 employees, the success rate varies depending on the listed status in the Korean stock market. In these respects, the findings of this study support the observations that firm size positively affects innovation [86–91], innovation is influenced by regional differences [42,58,60–62,64–66], and R&D is crucial for innovation [18,19,35,57,61,62,67,69,74,102–105,108–112].

Concerning the cases in which R&D activity is not carried out, 18% of firms with 100 to 499 employees were successful. Under the above condition (no R&D activities with 100 to 499 employees), 28.4% of firms over 17 years of age and 10.6% of those under 17 years of age were successful. It indicates that, even though there is no R&D activity, the larger the firm size and the older the firm age, the greater the success of the firms will be. It supports the arguments that large firms have an advantage [86–91] and that older firms have an advantage [95,96] with successful innovation. Meanwhile, under the same condition that no R&D activity was carried out, 5.6% of firms with relatively low employees (less than 100) were successful. Among them, 13.6% of the firms belonging to the low-technology industry, such as the food processing (KSIC 10), printing and reproduction of recorded media (KSIC 18), and furniture manufacturing (KSIC 32) industries, were successful. Their success rate was relatively higher than the other industries. Based on this, for the low-technology industry, it can be interpreted that innovation is achieved in a different way from R&D. This behavior is also found in other branches wherein irregular R&D is carried out, if necessary, in the first layer. Under the above condition, firms belonging to middle- and low-technology industries, such as the food processing industry (KSIC 10); apparel, clothing accessories, and fur articles' manufacturers (KSIC 14); and the manufacturers of leather, luggage, and footwear (KSIC 15), showed a higher success rate of 83% when compared to firms belonging to other industries, such as manufacturers of medical, precision and optical instruments, watches, and clocks (KSIC 27); manufacturers of electrical equipment (KSIC 28); manufacturers of other machinery and equipment (KSIC 29); and manufacturers of pharmaceuticals, medicinal, chemical, and botanical products (KSIC 21), which showed a 43.5% success rate. In this respect, this result identifies that firms belonging to the low-technology industry prefer other innovation activities than R&D. This finding supports the sectoral difference in innovation behavior [29,39–45].

The primary objective of this article is to find sustainable factors influencing innovation success. From the overall perspective at a national level, longitudinal common influencing factors over the years and variation over time are shown in Table 6. The factor of the manner of R&D activities is determined as a sustainable influencing factor. This finding reaffirms the argument that the role of the R&D organization is very important for the success of innovation, and this role should coincide with the capacity of the firm to perform R&D [18,19,35,57,61,62,67,69,74,102–105,108–112]. Additionally, the findings of this study confirm the significance of the influencing factors, such as the ratio of R&D personnel [102,103], exports size [61,67,96,108,150], statuary type (in terms of size), employee size [85–92], sector [29,39–45], firm age [95–97], sales size [74,77,78,103,150], and region [29,42,54–62,64–66], which have been determined in previous studies and have undergone changes over time.

Table 6. Summary of sustainable influencing factors and variations over time from an overall perspective.

Category	Year	Sustainable Influencing Factors	Variation over Time		
Overall	2014	· Manner of R&D activities	· Ratio of R&D personnel	· Exports level	· Statuary type
	2016		· Employee size level · Sectors	· Age · Sales level	· Region · Listed status

4.2. Factors and Behaviors Influencing Successful Innovative Firms

4.2.1. Contribution of Innovation

To investigate the factors and behavior influencing successful innovative firms, in the order of significance, innovation contribution, case statistics, accuracies, and results at the significance level of 0.05 are presented in Table 7. The overall forecasting accuracies of the models on innovation contribution in 2014 and 2016 are 85.16% and 84.79%, respectively, as seen in Table 7.

Table 7. Case statistics and DT results of innovation contribution models.

Model	Year	Number of Cases			Missing	Results	Accuracy		
		Total	Contribution	No contribution			Overall	Contribution	No contribution
Contribution to sales	2014	856	729	127	111	Market launching activities; Using information from Public customer; Using information from higher educational institutes; In-house R&D; Using information from private customer	85.16%	100.00%	0.00%
	2016	1236	1048	188	380	Cost on acquisition of machine, tool, software, and building; Source of budget; Using information from in-house or within the affiliate	84.79%	100.00%	0.00%

These accuracy levels are relatively high. However, accuracies for the contribution and no-contribution cases of the models are 100.00% and 0.00%, respectively. These prediction models clearly identified successful innovative firms based on their contribution to sales in terms of their behavior. However, these models could not identify successful innovative firms that did not contribute to sales. These results indicate that successful innovative firms contribute via innovation to sales [150,152].

Factors influencing innovation contribution in 2014 are as follows, in the order of significance: Market launch activities; using information from the public customer; using information from a higher educational institute; in-house R&D; and using information from the private customer. A DT result examining the behavior between groups with and without a contribution to sales in 2014 is shown in (a) of Figure A3 in Appendix C. The (a) of Figure A3 starts with the first parent node of market launch activities. In the case wherein no market launch activities were carried out, information from the public customer and higher educational institute mainly distinguished the groups. Meanwhile, in the case wherein market-launch activities were carried out, in-house R&D and information from the private customer mainly distinguished the groups. These results, first, indicate that firms carrying out in-house R&D with information from the private customer emphasize more on R&D than on marketing. Second, it indicates that firms emphasize marketing by using information from the public customer. Third, firms, which do not use information from the public customer, focus on information from higher educational institutes. These results imply that an innovation's contribution to sales is influenced by target market characteristics in terms of the public or private sector, which also affect the behavior of R&D activity [22,47,69,80–84].

In 2016, the significant influencing factors are identified as follows: Cost for acquiring a machine, tool, software, and building (level of percentage); source of budget; and using information from in-house or within the affiliate. A DT result of the innovation contribution model in 2016 is shown in (b) of Figure A3 in Appendix C. The (b) of Figure A3 starts with the first parent node of the cost for acquiring a machine, tool, software, and building; this is followed by branches divided by the nodes of source of budget and using information from in-house or within the affiliate. In the case of the low percentage of the cost for acquiring machine, tool, software, and building, firms that used information from in-house or within the affiliate are more likely to contribute to sales based on innovation. This result indicates that innovation increases the sales contribution to firms, which do not invest heavily in assets and focus on using their own information for innovation. Comprehensively, these results imply that firms' strategical behavior related to in-house R&D, marketing, and investment on assets based on the characteristics of the target market affects contribution to sales from innovation. It is consistent with the claim that market characteristics drive a firm to seek market needs and to advertise [22,47,69,79–84,115] and that R&D investments positively affect innovation [35,104–106].

Another objective of this study is to find sustainable factors and behavior influencing successful innovators in terms of their contribution to sales. Among all the variables, intrinsic innovation activity-related factors are identified to significantly influence innovation behavior compared to the extrinsic factors that are related to the general innovation capacity of the firm. Although there have been no precise common factors, over the years, common categorical factors have served as the information source. It indirectly supports the arguments that cooperative networking for bridging information gaps among partners promotes innovation [58,61–63,67–71]. These findings are summarized in Table 8.

Table 8. Summary of the influencing factors from the perspective of innovation's contribution to sales.

Category	Year	Sustainable Factors	Variation over Time
Contribution to sales	2014	n/a	· Information activity (market launching activity, in-house R&D) · Information source (private customer; public customer; higher educational institutes)
	2016		· Level of activity cost (acquisition of machine, tool, software, and building) · Source of budget · Information source (in-house or within the affiliate)

4.2.2. Innovation Activities

Table 9 presents case statistics, accuracies, and results of the innovation activity models at the significance level of 0.05, in the order of significance. These models aim to identify the behavior of firms by emphasizing a mix of R&D and other R&D activities.

Table 9. Case statistics and DT results of innovation activity models.

Model	Year	Number of Cases				
		Total	R&D and Non-R&D Activities	R&D Activities only	Non-R&D only	No Activities
Innovation activity	2014	967	722	146	76	23
	2016	1616	1134	285	189	8
Year	**Results**	**Accuracy**				
		Over-All	**R&D and Non-R&D Activities**	**R&D Activities Only**	**Non-R&D Only**	**No Activities**
2014	Manner of R&D activities; Using information from competitors in the same sector; Statuary types; Using information from professional journal and publications; Using information from in-house or within the affiliate; Using information from conference, exhibition, and fair	74.7%	100.0%	0.0%	0.0%	0.0%
2016	Manner of R&D activities; Sector; Using information from private customer; Total Innovation cost (level of one year ago); Region	79.0%	89.1%	48.1%	68.8%	0.0%

The overall accuracies of the innovation activity models in 2014 and 2016 are 74.7% and 79.0%, respectively, as seen in Table 9. As a result, a total 71.9% (74.2% in 2014 and 70.2% in 2016) of successful innovative firms carried out both R&D and non-R&D activities. In 2014, the model is biased to fit the class of R&D and non-R&D activities; subsequently, the prediction accuracy of this class is 100% and the accuracies for others are 0%. It means that the difference between each class is very small, as seen in Figure A4 in Appendix C; this leads to the prediction that successful innovative firms carried out all innovation activities, including R&D and non-R&D activities, in 2014.

This section aims to identify the sustainable factors and behavior influencing successful innovators in terms of innovation behavior. Although a result of the model in 2014 does not provide sufficient evidence of the behavioral difference between classes of innovation activities, the result of the model in 2016 indicates that successful innovative firms exhibit a different behavior involving R&D and non-R&D activities. As a result of the observation and prediction on each class of the two models, it is reasonable and worthwhile to explore the result of the model in 2016 to identify the difference in behavior and to focus on those between the classes of R&D activities only and non-R&D activities only in 2016.

Factors influencing innovation activities in 2016 are found as follows, in the order of significance: Manner of R&D activities; sector; using information from the private customer; total cost for innovation activities in the last year (level of percentage); and region. The DT result of the model in 2016 is shown in Figure A5 in Appendix C. Figure A5 starts with the first parent node of the manner of R&D activities. In the case of firms having an R&D institute, 78.8% of the firms carried out both R&D and non-R&D activities, 18.4% of the firms carried out only R&D activities, and 2.5% of the firms carried out only non-R&D activities.

Among the firms having R&D institutes, 46.8% of firms, which belong to the middle-technology industry, such as manufacturers of rubber and plastics products (KSIC 22), manufacturers of fabricated metal products, except the manufacturers of machinery and furniture (KSIC 25), and manufacturers of other transport equipment (KSIC 31), carried out only R&D activities. Under the above conditions, 74.3% of the firms carried out only R&D activities, among those that spent less than 0.5 B₩ on the total innovation cost. Meanwhile, under the same conditions, 85.9% of the firms carried out both R&D and non-R&D activities, among those that spent more than 0.5 B₩ on the total innovation cost. Overall, firms spending more than 0.5 B₩ on the total innovation cost carried out both R&D and non-R&D activities, as seen in Figure A5. This finding indicates that even if firms have a research institute, innovation activities vary according to industrial characteristics in coherence with the argument that the technological dynamism of an industry affects innovation [29,39–42]. It also indicates that firms prefer carrying out only R&D activities at a relatively low cost across the industries. Especially, firms belonging to electronic component and computer manufacturing industries and to visual, sound, and communication equipment industries (KSIC 26) showed different behavior, based on the regional characteristics. In the metropolitan areas, such as Seoul, Incheon, Daejeon, Daegu, Gwangju, and Ulsan of Korea, 39.7% of firms carried out only R&D activities. Whereas 1% of firms in another area carried out only R&D activities, and 99% of the firms carried out both R&D and non-R&D activities. It can be interpreted that regional characteristics in terms of a well-established business environment, such as a metropolitan area, can help firms reduce efforts for non-R&D activities along with cost. Therefore, firms can concentrate on R&D. This finding supports previous findings [42,58,60–62,138] that regional characteristics affect a firm's behavior pertaining to innovation activities.

Examining a branch in which the firms did not conduct any R&D, 69.7% of firms conducted non-R&D activities. However, looking at firms that conducted R&D with a dedicated department or those that carried out R&D irregularly, if necessary, the behavior of innovation activities differed with industrial sub-sectors. Among the firms having a dedicated department for R&D, 53.5% of the firms belonging to the low or middle-technology sectors carried out only R&D activities; these sectors included manufacturers of chemicals and chemical products, except pharmaceuticals and medicinal chemical (KSIC 20) manufacturers, manufacturers of rubber and plastic products (KSIC 22), manufacturers of fabricated metal products, except machinery and furniture (KSIC 25) manufacturers, and manufacturers of electrical equipment (KSIC 28). In other cases, 87.7% of the firms belonging to other sectors carried out both R&D and non-R&D activities. Meanwhile, among the firms that carried out R&D irregularly if necessary, 61% of the firms carrying out only non-R&D activities belonged to low-technology sectors, such as manufacturers of apparel, clothing accessories, and fur articles (KSIC 14); manufacturers of pulp, paper, and paper products (KSIC 17); manufacturers of food products (KSIC 10); and manufacturers of other transport equipment (KSIC 31). These findings indicate and support that firms' behaviors associated with innovation activities differ according to industrial characteristics in terms of technological dynamism, in line with previous studies [29,39–42]. Even though it belongs to the low-technology sector, firms with a dedicated department for R&D still conduct R&D activities. However, more than half of the firms have an occasional R&D focus on non-R&D activities. Although a sustainable influencing factor is not identified, it is found that the main mode of conducting R&D [18,19,35,57,61,62,67,69,74,102–105,108–112], as well as the industrial [29,39–42] and regional [42,58,60–62] differences in technological dynamism, play a major role in the behavior of innovation activities.

4.2.3. R&D Activities

Table 10 presents case statistics, accuracies, and results of R&D activity models at the significance level of 0.05, in the order of significance. These models aim to identify the behavior of firms by emphasizing a mix of R&D activities in terms of in-house and cooperative R&D.

Table 10. Case statistics and DT results of R&D activity models.

Model	Year	Number of Cases				
		Total	In-House R&D only	In-House and Cooperative R&D	Cooperative R&D only	No R&D Activities
R&D activity	2014	967	509	308	51	99
	2016	1616	1186	209	24	197
Year	**Results**	**Accuracy**				
		Over-All	**In-House R&D only**	**In-House and Cooperative R&D**	**Cooperative R&D only**	**No R&D Activities**
2014	Manner of R&D activities; Using information from institutes of government, public, and private sector; Using information from conference, exhibition, and fair; Using information from in-house or within the affiliate; Using information from supplier	61.8%	92.3%	35.4%	0.0%	19.2%
2016	Manner of R&D activities; Sector; Using information from private customer; Using information from professional journal and publications; Size of employee (level of one year ago), Statuary types, Using information from private service firms	78.5%	95.8%	0.0%	0.0%	67.5%

The overall accuracies of the R&D activity models in 2014 and 2016 are 61.8% and 78.5%, respectively, as seen in Table 10. A total 65.6% (52.6% in 2014 and 73.4% in 2016) of the successful innovative firms conducted in-house R&D only, while 2.9% (5.3% in 2014 and 1.5% in 2016) of these firms carried out cooperative R&D only. The 31.9% ratio of firms that carried out both in-house and cooperative R&D in 2014 is relatively higher than the one in 2016 at 12.9%. As a result, both models are biased to fit the class of in-house R&D only; subsequently, the prediction accuracies for this class are 92.3% and 95.8%, respectively. This result means that the firms carrying out in-house R&D exhibit distinctly different behavior when compared to the ones carrying out other R&D activity types. Based on the results of the two models, as seen in Table 10, it is worthwhile to compare the behavior of classes between in-house R&D only and in-house and cooperative R&D in 2014, and to those between in-house R&D only and no-R&D activities in 2016.

DT results on the behavior between groups of the R&D activity class are shown in Figures A6 and A7 in Appendix C. In 2014, Figure A6 started with the first parent node of the manner of R&D activities. In the case of firms having an R&D institute, 41.9% of the firms carried out both in-house and cooperative R&D. Among firms having an R&D institute, 74.1% of the firms using information from institutes of the government, public, and private sector (IGPPS) carried out both in-house and cooperative R&D, while 30.2% of the firms that did not use such information carried out both R&D activities. Under the conditions of having an R&D institute and using information from IGPPS, 83.7% of the firms that used information from a conference, exhibition, and fair (CEF) carried out both in-house and cooperative R&D, while 59.2% of the firms that did not use such information from a CEF carried out both R&D activities. However, 67.7% of the firms using information from in-house or within the affiliate (IHWA) carried out in-house R&D only, under the conditions of having an R&D institute and not using IGPPS. These behaviors indicate that the majority of firms having R&D institutes focused on carrying out in-house R&D only with their own information or from information within the affiliate. However, some firms having R&D institutes carried out cooperative R&D with information from IGPPS and CEF as well as in-house R&D. It can be interpreted that, for conducting innovation, firms that carried out both in-house and cooperative R&D seek to collect other information from external R&D-related institutes and the most contemporary competitive information from CEF rather than market-related information. Additionally, in the case of firms having a dedicated R&D department at the first branch and those not using information from the supplier at the second branch, 80.5% of the firms used information from IHWA. This result also supports the behavior that firms having a dedicated R&D department carried out in-house R&D only with information from IHWA. From the above findings, cooperative R&D activities are carried out to close capability gaps for innovation [61], and it helps innovation [63,118–123]. However, R&D institutes or R&D departments are required to complement cooperative R&D [63,130–132,136,137].

In 2016, Figure A7 also starts with the first parent node of the manner of R&D activities. In the case of firms having an R&D institute or a dedicated R&D department at the first branch, a majority of those firms (79.9%) carried out in-house R&D only through overall branches without using information from the private customer, private service firms, and professional journal and publications. Firms using this information carried out cooperative R&D. These results indicate that firms having an R&D institute or a dedicated R&D department carried out in-house R&D only based on own capability to innovate without cooperation. It can be interpreted that successful innovative firms do not prefer cooperative R&D due to its instability and risks [124–129]. In another case of firms that did not have a channel to carry out R&D at another first branch, the result clearly shows that 72.3% of those firms did not carry out any R&D at all. Additionally, in the case of firms irregularly carrying out R&D, if necessary, at the first branch, 29.8% of those firms did not conduct any R&D activities at all. Especially, under the above condition, 61% of firms belonging to the low-technology sectors did not perform any R&D activity, including food processors (KSIC 10); manufacturers of apparel, clothing accessories, and fur articles (KSIC 14); manufacturers of pharmaceuticals, medicinal chemical, and botanical products (KSIC 21); and manufacturers of pulp, paper, and paper products (KSIC 17). Meanwhile, 81.2% of the firms that belong to other sectors carried out in-house R&D only. This finding indicates that firms' behavior of R&D activities differ according to industrial characteristics in terms of technological dynamism [29,39–42]. Even though it belongs to the low-technology sector, 39% of the firms that irregularly carried out R&D if necessary still carried out both in-house and cooperative R&D. Concerning the identification of sustainable influencing factors and behavior in terms of R&D activity, the manner of R&D activities is determined to influence innovation behavior. Additionally, some types of information sources for innovation were examined, such as IHWA, CEF, and IGPPS. The other factors identified comprise the sector, employee size, and statuary type at other local branches. These are shown in Table 11.

Table 11. Summary of influencing factors from the perspective of the R&D activity class.

Category	Year	Sustainable Factors	Variation over Time
R&D activity	2014	· Manner of R&D activities	· Information source (institutes of government, public, and private sector; conference, exhibition, and fair; in-house or within the affiliate; supplier)
	2016		· Sector · Employee size level · Statuary type
			· Information source (private customer; private service firm; professional journal and publications)

Based on the above analyses of DT, it is also found that the main way of carrying out R&D plays a major role in the behavior pertaining to innovation [18,19,35,57,61,62,67,69,74,102–105,108–112]. Additionally, successful innovative firms prefer to conduct their own in-house R&D rather than cooperative R&D with their own information source. It indirectly supports the characteristics of instability and risks of cooperative R&D for innovation [124–129]. However, other findings support that firms carrying out cooperative R&D seek information [62,80,165–167] related to, not the market, R&D for the closing of capability gaps [61]. Additionally, it reaffirms that an internal capability for R&D is required to complement cooperative R&D [114,130–132,136,137].

5. Regional and Sectoral Differences of Innovation

5.1. Hypotheses on Regional and Sectoral Differences of Innovation

The main goals of this study are the identification of the overall innovation behavior of firms from both the perspectives of success and failure of innovation, and successful innovative firms by considering all innovation activities of a firm with all their intrinsic and extrinsic characteristics by using DT, which is highly predictable and easily interpretable. According to these goals, comprehensive knowledge on innovation behavior is acquired, but the nature of DT involving a non-parametric analysis makes it difficult to comprehend the in-depth underlying mechanism of innovation behavior. Therefore, theoretically and managerially meaningful factors according to the important findings derived from the result of this study can be validated in terms of traditional statistical methodology, and this could provide some grounds for innovation scholars.

From the result of Module 1 in Section 4, the role of R&D involving factors of R&D organization and R&D personnel is determined as the most significant and crucial factor for innovation success; this finding is reasonably and preliminarily natural. In relation to this, firm age and firm size, which are related to the factors of the exports level, statuary type (in terms of firm size), and employee size, are also identified as significant influencing factors, which are intrinsic factors of the firm with regard to its general characteristics. These factors, such as R&D, firm size, and firm age, have been heavily investigated, in relation to their in-depth impact and mechanism on innovation, statistically by scholars and their positive roles in the domain of innovation study are greatly accepted [18,19,35,57,61,62,67,69,74,77,78,85–89,92,95–97,102–105,108–112,150].

On the other hand, regional and sectoral factors are particularly identified to be significant influencing factors on the behavior of innovation success and failure. Additionally, with regard to successful innovative firms, it is found that their innovation behavior is affected by these regional and sectoral factors in relation to the target market. According to the literature review in Section 2 of this study, these regional and sectoral factors were investigated in relation to their characteristics on the impact of innovation. However, there are some negative or insignificant effects of industrial and regional characteristics on innovation. In addition, these factors are mainly considered under their specific relationship with innovation, such as industrial structure and regional proximity. Concerning a sectoral factor, in more detail, sectoral innovation studies were mostly conducted for figuring out the sectoral landscape and its particular characteristics in specific sectors of each country by qualitative and descriptive analysis [168–170]. Concerning regional innovation study, the relationship and networks of institutes, such as a university, government, and industry institutions, and their roles in the regional innovation ecosystem under different contexts have been mainly emphasized through qualitative and descriptive analysis [171–176], as well as sectoral research approaches. Especially, in those studies, it is preliminarily assumed that there is a significant difference between sectors or regions statistically, but it was not tested.

Therefore, it is worthwhile to identify the differences of the distribution of innovation success and failure regarding the regional and sectoral difference of innovation in light of the significant findings from the DT analysis in this study and the shortcomings of previous studies. For this goal, the following hypotheses are constructed.

Hypothesis 1 (H1). *There is a difference in innovation success and failure between sectors.*

Hypothesis 2 (H2). *There is a difference in innovation success and failure between regions.*

Hypothesis 3 (H3). *There is a difference in innovation success across sectors and regions.*

Although a binomial logistic regression analysis on the innovation success and failure, as a dependent variable, could be used as advanced analysis to clarify the relationship contained in the contingency table, the model cannot be built due to the different independent variable types and scales in KIS. In this regard, to verify the hypotheses, the cross-tabulation analysis (CA) and chi-square (χ^2) test are used because both the dependent variable and independent variable are categorical variables measured in the nominal scale, such as success and failure as a dependent variable, and region and sector as an independent variable, respectively. CA is used to aggregate and jointly display the distribution of two or more variables by tabulating their results one against the other in a two-dimensional grid. It uses a process of creating contingency tables from the multivariate frequency distribution of variables, which are presented in a matrix format. Regarding assumptions for usage of the χ^2 test, data is satisfied with independent observations, not a biased sample, mutually exclusive on observations in all categories. Regarding H3, when applying CA, the observation of innovation success across the sectors and regions is used because the observation of success and failure of innovation across the sectors and regions cannot be included at the same time.

5.2. Hypotheses Testing Result and Discussion on Regional and Sectoral Differences of Innovation

The summary of CA and χ^2 test results are presented in Table 12. The CA results of six models between sectors, between regions, and across sectors and regions in 2014 and 2016 are shown in Tables A4–A9 in Appendix D. Concerning H1 and H2, the value of χ^2 is calculated by an asymptotic method depending on the satisfaction with an assumption of CA through the λ measure according to the dependent and independent variables, which are nominal. Concerning H3, the value of χ^2 is computed by the Monte-Carlo method depending on the dissatisfaction, with the assumption that cells with an expected count less than 5 should not exceed 25% of the total.

These results support all hypotheses at a significance level of 0.001 in 2014 and 2016 as seen in Table 12. From these results, it can be concluded that there are significant differences on innovation success and failure between sectors, and between regions over the years. Also, it is affirmed that there is a difference in innovation success across sectors and regions. In addition, when comparing the degree of difference between the sectoral and regional effect of success and failure of innovation, values of the contingency coefficient in each year indicate that the sectoral difference is significantly larger than the regional difference over the years, with a p-value of 0.000. Moreover, the contingency coefficients of the linkage between each sector and region in each year demonstrate a greater impact on the success of innovation than the effects of each continuously at a significance level of 0.01. Based on the overall CA and χ^2 test results, it is found that the distributions of success and failure between sectors, and between regions, as well as the distribution of innovation success across sectors and regions, are firmly diverse.

Table 12. Summary of hypotheses testing results.

Hypothesis	Perspective	Year	Total Valid Case	Pearson χ^2	Sig.	Contingency Coefficient	Sig.	Result
H1	Sectoral difference	2014	4075 [1]	216.766 *	0.000 **	0.225	0.000 **	Accepted
		2016	4000 [1]	340.875 *	0.000 **	0.280	0.000 **	Accepted
H2	Regional difference [1]	2014	4075 [1]	83.008 *	0.000 **	0.141	0.000 **	Accepted
		2016	4000 [1]	169.460 *	0.000 **	0.202	0.000 **	Accepted
H3	Sectoral and regional difference [2]	2014	967 [2]	616.200 *	0.000 ***	0.624	0.003 ***	Accepted
		2016	1616 [2]	1123.935 *	0.000 ***	0.602	0.000 ***	Accepted

[1] analysis value: success and failure of innovation; [2] analysis value: success case; * p-value < 0.001; ** asymptotic significance; *** Monte Carlo significance.

Concerning the sectoral innovation study, previous studies have evolved that mainly focus on how sectoral differences influence innovation and shape its sectoral pattern in terms of technological dynamism involving the technology regime and trajectories, and knowledge flow based on sectoral taxonomy, such as Pavitt's taxonomy [177–179]. Findings of this study statistically provide a rigid ground of sectoral diversity to establish innovation policies, which should take different approaches to design an institutional system to support innovation according to the innovation mechanisms and patterns, and characteristics of innovation players from the perspective of the sectoral innovation system [180]. However, in linkage to regional diversity, findings on sectoral and regional connectivity imply that differentiation of innovation is more magnified in conflict with the prominences of the sectoral regime rather than regional characteristics in the sectoral innovation system [181]. In this respect, this finding is more consistent with the perspective of the regional innovation system, which has focused on network and cooperative learning within the regional ecosystem in the specific sectors, such as the milieu of innovation or innovation clusters [64,182–184]. It can be attributed to a well-established local business environment in terms of cooperative networking between innovation actors with government supporting programs for specific regional sectors [57,60–62]. Overall, based on the identification of sectoral and regional differences on innovation success and failure across all sectors and regions statistically, their significant impact on innovation is reaffirmed, and it provides a basic ground for the sectoral and regional innovation system in the current business landscape.

6. Implications and Conclusions

After the SAPPHO project for testing generalizations regarding innovation success and failure was conducted by SPRU during the 1970s [15–17], innovation studies have evolved and gradually focused on specific subjects to identify in-depth mechanisms of innovation behavior [18–21,23]. However, previous innovation studies have been tied down by the characteristics, types, and empirical scope of innovation data with statistical methodology; this limitation is also attributed to the various definitions of innovations and proxy measurements on innovation. Although the general consensus on influencing factors and behavior has been widely accepted, there are conflicting arguments or insignificant conclusions drawn in different contexts. They also lack comprehensive and sustainable perspectives.

This study contributes toward expanding the methodological landscape with advanced data mining methodology; it also increases the feasibility of using innovation data on a large scale. It also contributes toward obtaining the overall significant influencing factors in a single framework by considering all the variables together, which are determined from previous studies. It also maintains international consistency based on the guidance of the Oslo manual. Unlike previous studies that focused on micro perspectives with various controversies, this study takes a comprehensive approach toward investigating sustainable factors and behavior, based on a macro and single statistical framework by using DT with 10-cross validation.

Concerning factors and behaviors influencing innovation success and failure at a national level, R&D is crucial for innovation success in terms of the capacity for carrying out R&D. As a result, the role of R&D [18,19,35,57,61,62,67,69,74,102–105,108–112] and the ratio of R&D personnel [102,103] positively affect the success of innovation. Even if there is no R&D activity, the result of this study supports the arguments that the larger the firm size [86–91] and the older the firm age [95,96], the greater the success achieved by firms will be. Concerning firm size, findings in this study are consistent with previous studies that the employee size level [85–92], sales level [74,77,78,103,150], and exports level [61,67,96,108,150] significantly affect the success of innovation. Additionally, it is witnessed that innovation behavior is affected by regional [42,58,60–62,64–66] and sectoral [29,39–45] differences. Concerning the industrial differences, it is inferred that firms belonging to a low-technology industry prefer other innovation activities rather than R&D. Concerning managerial or political implications based on the above findings, this study reemphasizes the importance of preparing and strengthening an overall support program for not only implementing R&D in collaboration with R&D institutes or organizations but also for increasing the number of R&D personnel employed for innovating products or processes [1,2,111,134,166]. Additionally, in terms of extrinsic factors of the business environment, the regional and sectoral innovation landscape should be focused on to establish and strengthen the innovation support program [1,2,64–66].

Concerning the factors and behaviors of successful innovative firms, this study first observed them in terms of financial contribution. Previous studies have dealt with the financial performance of innovation [7,18,148–152], but they did not cover the factors and behaviors of differences between high and low innovation contributions of groups to financial performance. As a result, this study identified the influencing factors and four types of behavior between those groups. The first type of firms with a financial contribution from innovation focuses on in-house R&D with information from the private customer. The second type focuses on marketing with information from the public customer. The third type focuses on using information from higher educational institutes. The last type focuses on their own information and does not invest heavily in assets. These findings show that the behavior related to activity and information use [62,80,165–167] for innovation is influenced by target market characteristics. It is consistent with the argument that market characteristics drive firms to seek market needs and to advertise [22,47,69,79–84]. Overall, intrinsic innovation activity-related factors are identified to exert a significant influence on innovation behavior rather than the extrinsic factors related to the general innovation capacity of firms, in terms of innovation's contribution to financial performance. To increase the contribution of innovation to a firm's financial performance, a policy should be implemented to level up the information environment and to build a public or private system to provide diverse market information. Additionally, managers should strengthen the activity to seek information corresponding to the target market to which the firm belongs.

To fulfill the lack of studies on the difference in the nature of a firm's innovation behavior to engage in R&D and non-R&D activities, this study identified their behavioral characteristics in terms of the overall innovation activity. Generally, firms prefer implementing R&D activities at a low cost across sectors. However, in low-technology sectors, firms prefer non-R&D activities. Additionally, well-established business environments, such as metropolitan areas, help firms reduce non-R&D activities as well as associated costs. The aforementioned findings of this study on innovation behavior reaffirm that the main way of carrying out R&D [18,19,35,57,61,62,67,69,74,102–105,108–112], the industrial difference with the technological dynamism [29,39–42], and regional characteristics of a well-established business environment [42,58,60–62] play a major role in the behavior associated with innovation activities. In terms of the overall R&D activity involving in-house R&D, cooperative R&D, and no R&D with higher resolution, this study found that a majority of firms having R&D institutes focus on carrying out in-house R&D only with their own information. However, it is also witnessed that some firms having R&D institutes carry out cooperative R&D with external R&D-related information. As a result, these findings support the claim that successful innovative firms do not prefer cooperative R&D due to its instability and risks [124–129]. This finding is also consistent with claims that cooperative R&D activities are carried out to close the capability gaps for innovation [61]. However, an absorptive capacity, such as R&D institutes or a dedicated R&D department, is required to complement cooperative R&D [114,130–132,136,137]. Concerning managerial or political implications, it should mainly prepare and strengthen an R&D support program in terms of the R&D budget as well as establish a business environment for non-R&D activity for both in-house R&D and cooperative R&D [1,2,64–66,138].

According to the main objectives, this study reaffirmed the roles of significant factors influencing innovation, such as R&D, size, and age, that are claimed in previous studies, and investigated the firm's behavior in intrinsic innovation activities from an overall perspective. In addition, sector and region are identified to be significant factors affecting innovation success and failure, and the firm's behavior is affected by the characteristics of these factors in relation to the target market. Subsequently, the differences of innovation success between sectors, regions, and across the sectors and regions were verified statistically, which was preliminary assumed but was not tested in previous studies. This provides ground for sectoral and regional diversity for scholars studying the sectoral and regional innovation system in the current business landscape. Careful discriminatory approaches should be taken to design an innovation system according to the innovation mechanisms and patterns, and characteristics of innovation players from the perspectives of the sectoral and regional innovation system [182,184].

The findings and implications presented in this study are beneficial to understand factors influencing innovation and behavior, from a comprehensive and sustainable viewpoint; especially, the DT methodology allows various types of innovation data to be addressed together in a single statistical framework. Despite the contribution, this study carries a limitation. The underlying mechanism involving DT as a non-parametric analysis is difficult to comprehend. Additionally, methodologically, there is room for enhancing the predictive power by altering the algorithm conditions in terms of tree depth, recursive calculation level, misclassification cost adjustment, the node scale related to the data class and size, and data balancing to avoid overfitting and underfitting. Even though it can interpret results easily, highly predict performance with 10-fold cross-validation, and allow unrestricted application without requiring underlying assumptions on data distribution, an in-depth scenario-based analysis of DT is required to fathom the ambiguous mechanism of innovation behavior. Theoretically and practically, different categorical classification principles and their levels can be considered to develop a research framework for other research questions. More extended or detailed standards of the innovation spectrum can be applied to specific research scopes from political and managerial viewpoints.

Furthermore, the approach of this study to shed light on the comprehensive knowledge of innovation behavior has important implications for scholars investigating innovation behavior. Most of the existing studies on innovation focus on in-depth behavior with narrow research scopes based on advanced statistical methodologies. Hence, over time, there have been conflicts in innovation behavior in the overall business landscape with different contexts. Additionally, it is important to understand factors influencing innovation and innovation behavior continuously from a contemporary perspective. In this sense, during each contemporary period, future studies can be replicated by applying the DT methodology from a comprehensive perspective. With guidance from the Oslo Manual, such studies, conducted at a global level, must maintain international consistency. For comparativeness, these studies must refer to the revised fourth edition of the Oslo Manual. Future studies should collect and use a large sample in time series and in multiple cross-country settings to improve the sustainability of the results of the analysis and draw a more generalizable consensus.

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Conflicts of Interest: The author declares no conflicts of interest.

Appendix A

Table A1. Variable codes, description, value, response, and type in Modules 1 and 2.

Variable Code KIS 2014	Variable Code KIS 2016	Measurement Description	Variable Value	Response	Type
Q 1_1		Form of firm	Independent company Affiliates of a domestic company Affiliates of a foreign company	1 2 3	Nominal
Q 1_2		Statuary types (by the size of employee from sample selection)	Large-sized company Medium-sized company Small-sized company	1 2 3	Nominal
Q 1_3_1 Q 1_3_2 Q 1_3_3		Designation status on corporative certification in Korea	Venture company InnoBiz (certificated as innovative small and medium-sized firm) n/a	1 2 3	Nominal
Q 1_4		Listed status in Korean stock market	KOSPI KOSDAQ n/a	1 2 3	Nominal
Q 2_1_1 Q 2_1_2 Q 2_1_3		size of sales	Level of actual sales in three years ago Level of actual sales in two years ago Level of actual sales in one year ago	0. None 1. ~1 B₩ 2. 1 B₩~5 B₩ 3. 5 B₩~10 B₩ 4. 10 B₩~50 B₩ 5. 50 B₩~100 B₩ 6. 100 B₩~ d.k. unknown	Ordinal
Q 2_2_1 Q 2_2_2 Q 2_2_3		size of exports	Level of actual exports in three years ago Level of actual exports in two years ago Level of actual exports in one year ago		
Q 3_1_1 Q 3_1_2 Q 3_1_3	Q 3_1 Q 3_2 Q 3_3	size of employee	Level of actual employee in three years ago Level of actual employee in two years ago Level of actual employee in one year ago	1. ~49 2. 50~99 3. 100~299 4. 300~499 5. 500~	Ordinal
Q 3_1_6	Q 3_4_3	Ratio of R&D personnel	Level of percentage of R&D personnel in the last year	1. none 2. ~5% 3. 5%~10% 4. 10%~20% 5. 20%~30% 6. 30%~50% 7. 50%~	Ordinal
Q 5_1 Q 5_2 Q 5_3 Q 5_4 Q 5_5		Main regional target market in the world (multiple response)	Domestic Asia Europe North America Others	If yes, 1; else, blank If yes, 2; else, blank If yes, 3; else, blank If yes, 4; else, blank If yes, 5; else, blank	Nominal
Q 6		Manner of R&D activities (main ways performing R&D)	R&D institutes Dedicated department Irregular operation if necessary Not implemented	1 2 3 4	Nominal
Q8_1	Q7	Main customer types	Private company Government and public sector Individual customer Overseas market Others	1 2 3 4 5	Nominal
Ind_mid		Industrial code	23 codes in the manufacturing industry are in Appendix B	Code number	Nominal
Region		Region (17 area)	Seoul, busan, daejeon, daegu, incheon, gwangju, sejong, ulsan, Gyeonggi, Chungcheongbuk, ChungCheongnam, Ganwon, Gyeongbuk, Gyeonnam, Jeollabuk, Jeollnam, Jeju	Region name	Nominal
Age		Firm age	Firm age	Number	Interval

Table A2. Variable codes, description, value, response, and type in Module 2 (added on Module 1).

Variable Code		Measurement Description	Variable Value	Response	Scale
KIS 2014	KIS 2016				
Q 18_1		In-house R&D	Performing in-house R&D in last three years	If yes, 1; else, 2	Nominal
Q 18_2		Cooperative R&D	Performing cooperative R&D in last three years		
Q 18_3		External R&D	Performing external R&D in last three years		
Q 18_4		Acquiring machine, tool, software, and building	Acquiring machine, tool, software, and buildingin last three years		
Q 18_5		Procuring external knowledge	Procuring external knowledge in last three years		
Q 18_6		Providing job training	Providing job training in last three years		
Q 18_7		Market launching activities	Market launching activities in last three years		
Q 18_8		Design activities	Design activities in last three years		
Q 18_9		Others	Others in last three years		
Q 19 t	Q 19	Total innovation cost for all innovation activities in the last year	Level of total cost for innovation activities in the last year	0. None 1. ~0.1 B₩ 2. 0.1 B₩~0.5 B₩ 3. 0.5 B₩~1 B₩ 4. 1 B₩~5 B₩ 5. 5 B₩~10 B₩ 6. 10 B₩~50 B₩ 7. 50 B₩~100 B₩ 8. 100 B₩~ d.k. unknown	Ordinal
Q 19_1		Level of percentage of each innovation activity cost	Level of percentage of cost on in-house R&D	0. 0% 1. ~25% 2. 26%~50% 3. 51%~75% 4. 76%~100% d.k. unknown	Ordinal
Q 19_2			Level of percentage of cost on external R&D		
Q 19_3			Level of percentage of cost on acquisition of machine, tool, software, and building		
Q 19_4			Level of percentage of cost on buying external knowledge		
Q 19_5			Level of percentage of cost on others		
Q 20		Source of budget in the last three years	Owned capital	1	Nominal
			Affiliate fund	2	
			Government fund	3	
			Loan	4	
			Stock Issuance	5	
			Corporate Bond fund	6	
			No expenditure	7	
			Others	8	
Q 21 a1	Q 21_1	Information source for innovation	In-house or within the affiliate	In 2014, use or not If yes, 1; else, 2 In 2016, Use and importance 0. No use 1. Use and low importance 2. Use and middle importance 3. Use and high importance	Nominal
Q 21 a2	Q 21_2		Supplier		
Q 21 a3	Q 21_3		Private customer		
Q 21 a4	Q 21_4		Public customer		
Q 21 a5	Q 21_5		Competitors in the same sector		
Q 21 a6	Q 21_6		Private service firms		
Q 21 a7	Q 21_7		Higher educational institutes		
Q 21 a8	Q 21_8		Institutes of government, public, and private sector		
Q 21 a9	Q 21_9		Conference, exhibition, and fair		
Q 21 a10	Q 21_10		Professional journal and publications		
Q 21 a11	Q 21_11		Industrial association		
Q 22		Cooperative activities	Whether or not cooperative activity implement	If yes, 1; else, 2	Nominal
Q 23_1		Cooperative partner	Affiliates	If yes, 1; else, 0	Nominal
Q 23_2			Supplier		
Q 23_3			Private customer		
Q 23_4			Public customer		
Q 23_5			Competitors in the same sector		
Q 23_6			Private service firms		
Q 23_7			Higher educational institutes		
Q 23_8			Institutes of government, public, and private sector		

Table A2. *Cont.*

Variable Code		Measurement Description	Variable Value	Response	Scale
KIS 2014	KIS 2016				
Q 24		Best cooperative partner	Affiliates	1	Nominal
			Supplier	2	
			Private customer	3	
			Public customer	4	
			Competitors in the same sector	5	
			Private service firms	6	
			Higher educational institutes	7	
			Institutes of government, public, and private sector	8	

Appendix B

Table A3. Industrial code on the manufacturing industry.

The Manufacturing Industry	
Code	**Description**
10	Manufacture of food products
11	Manufacture of beverages
13	Manufacture of textiles, except apparel
14	Manufacture of wearing apparel, clothing accessories and fur articles
15	Manufacture of leather, luggage and footwear
16	Manufacture of wood and of products of wood and cork; except furniture
17	Manufacture of pulp, paper and paper products
18	Printing and reproduction of recorded media
19	Manufacture of coke, briquettes and refined petroleum products
20	Manufacture of chemicals and chemical products; except pharmaceuticals and medicinal chemicals
21	Manufacture of pharmaceuticals, medicinal chemical and botanical products
22	Manufacture of rubber and plastics products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and furniture
26	Manufacture of electronic components, computer; visual, sounding and communication equipment
27	Manufacture of medical, precision and optical instruments, watches and clocks
28	Manufacture of electrical equipment
29	Manufacture of other machinery and equipment
30	Manufacture of motor vehicles, trailers and semitrailers
31	Manufacture of other transport equipment
32	Manufacture of furniture
33	Other manufacturing

Appendix C

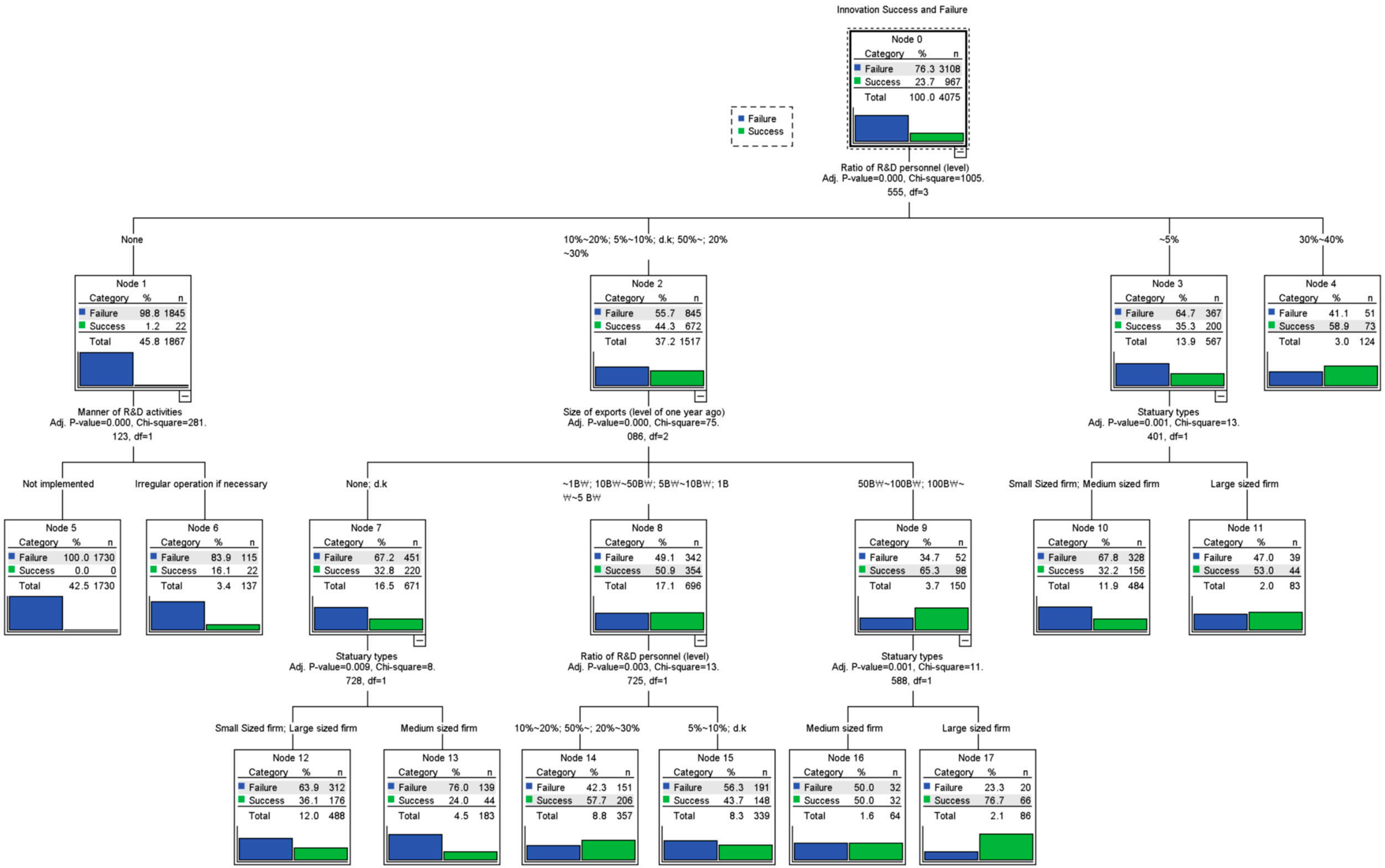


Figure A1. DT result of an overall model in 2014.

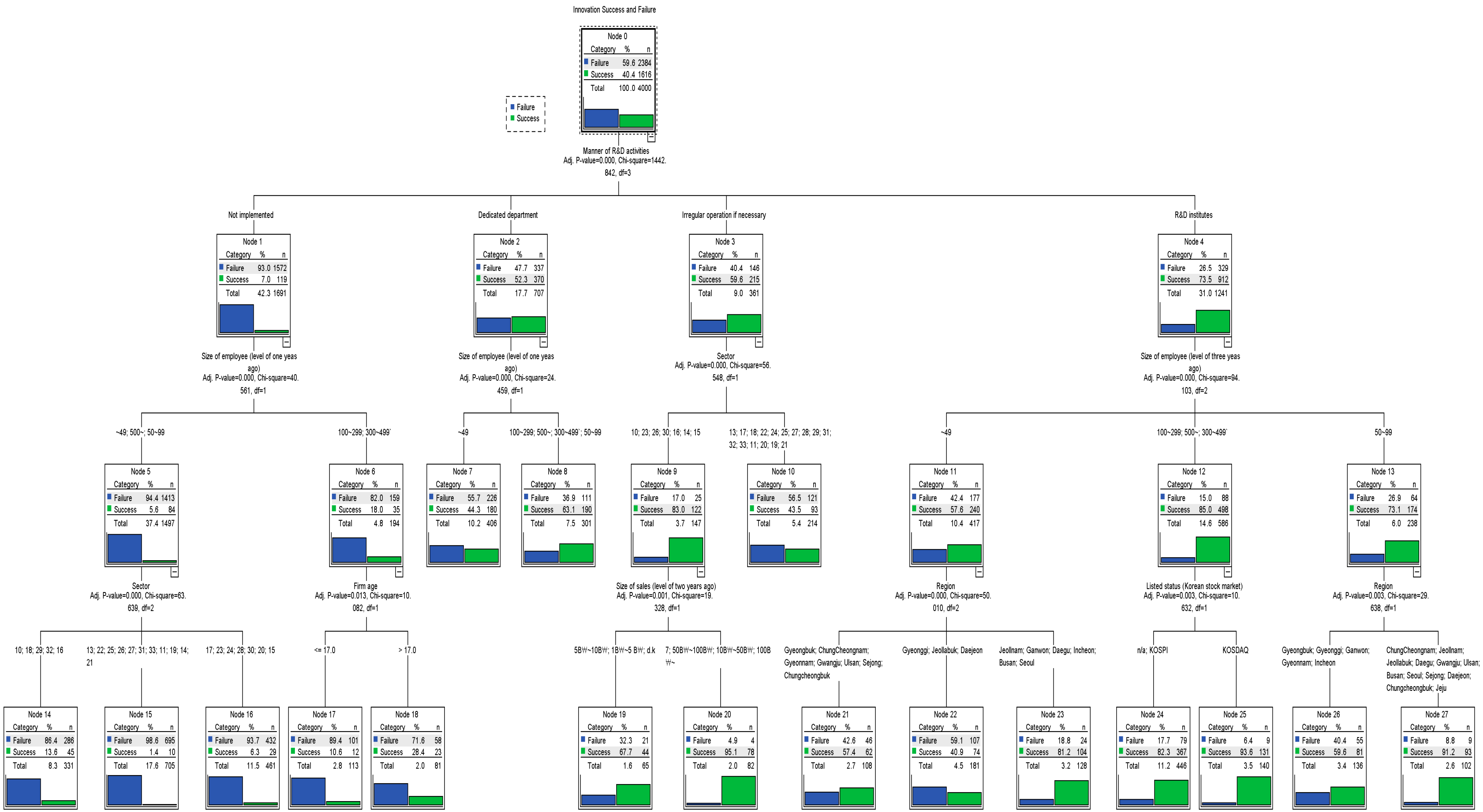
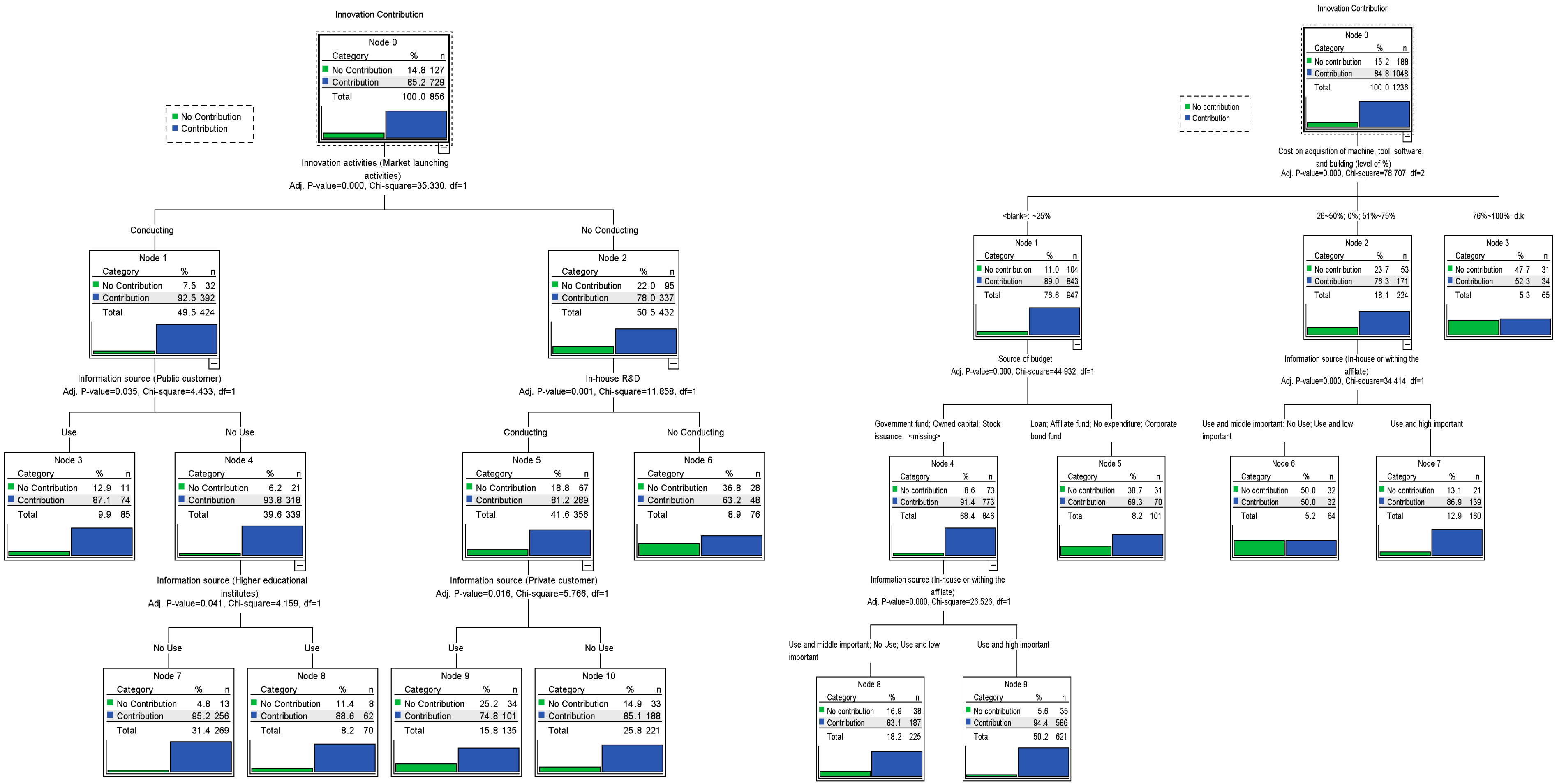


Figure A2. DT result of an overall model in 2016.



(a) (b)

Figure A3. DT results of (**a**) a contribution model in 2014 and (**b**) a contribution model in 2016.

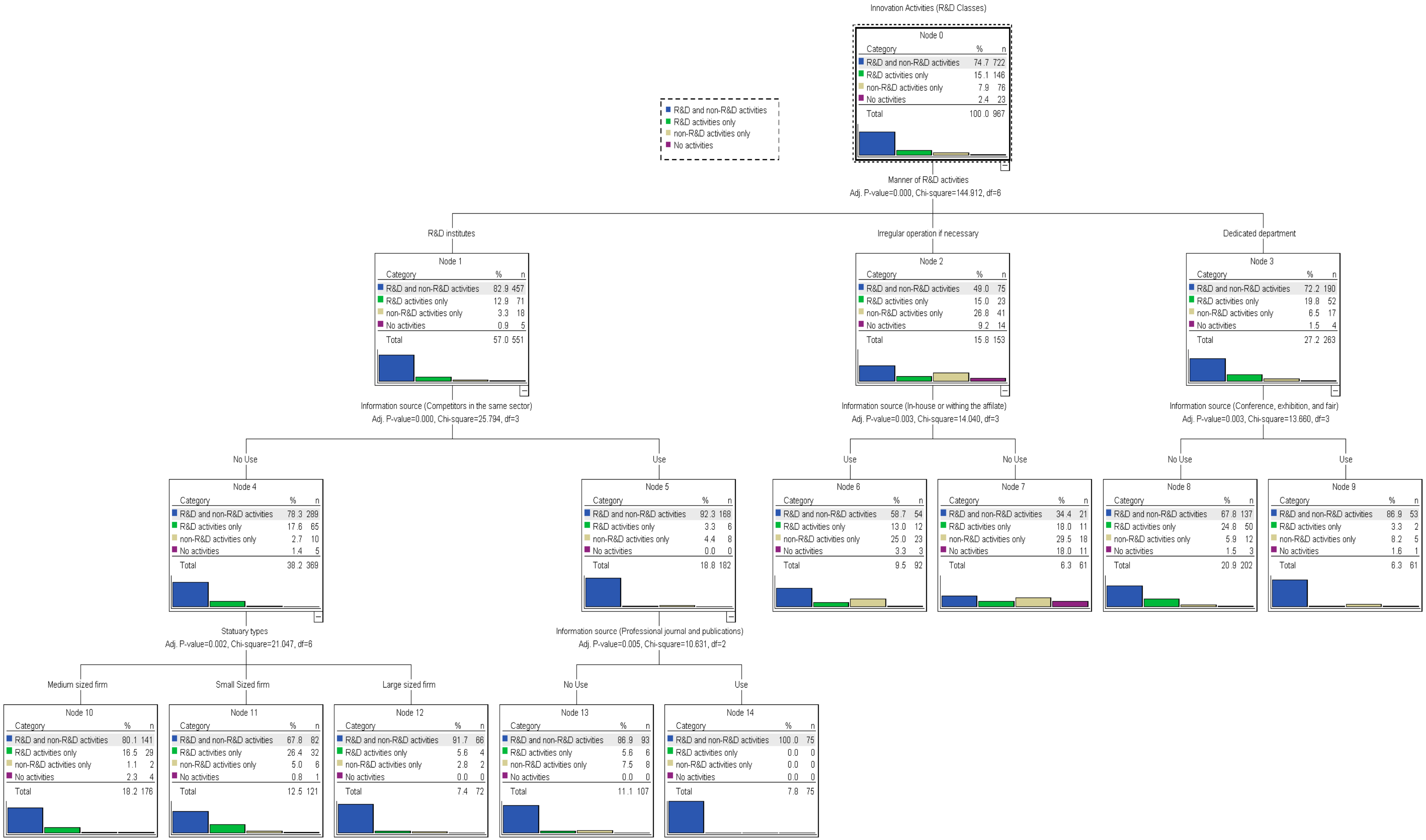


Figure A4. DT result of an innovation activities model in 2014.

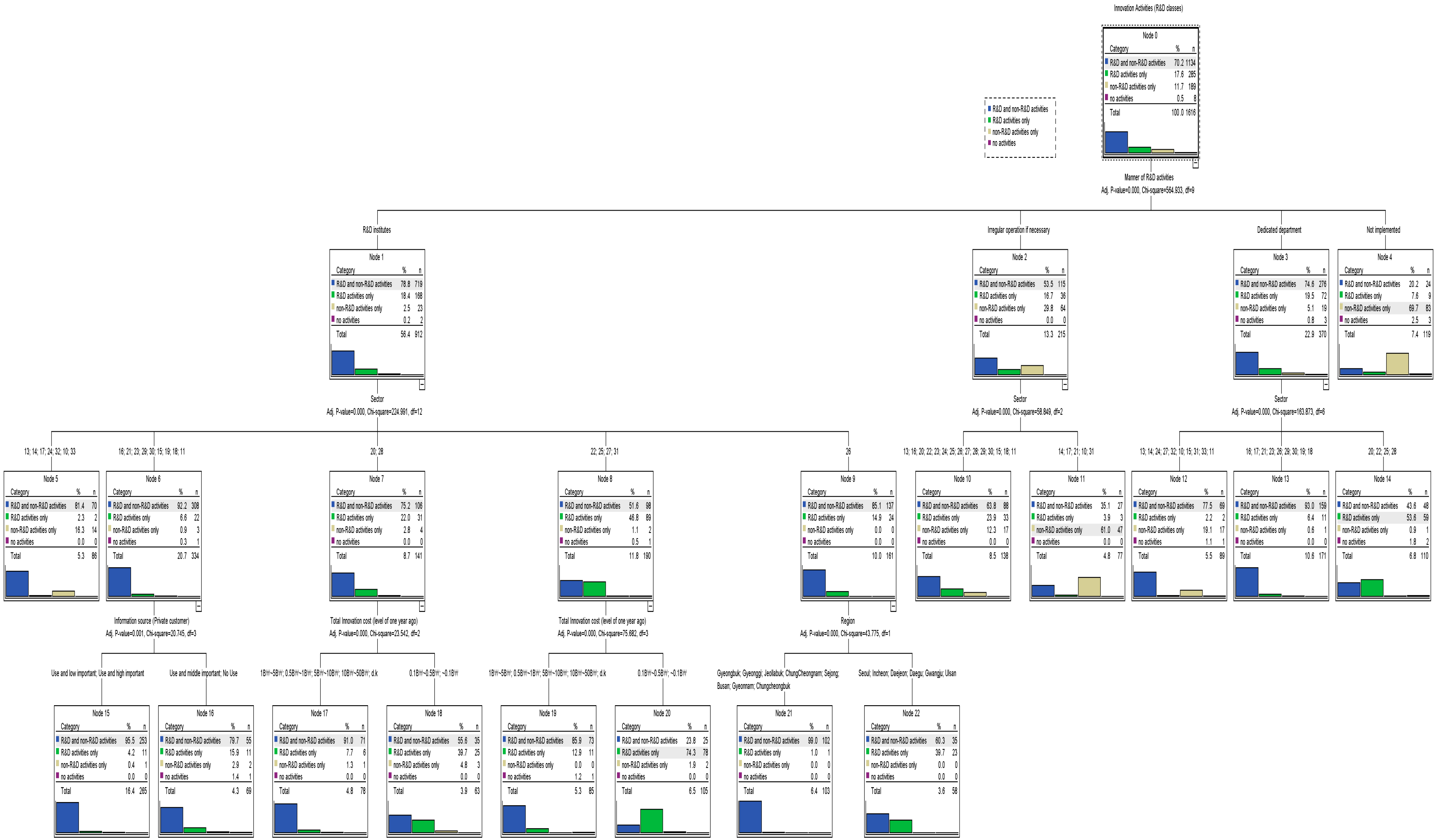


Figure A5. DT result of an innovation activities model in 2016.

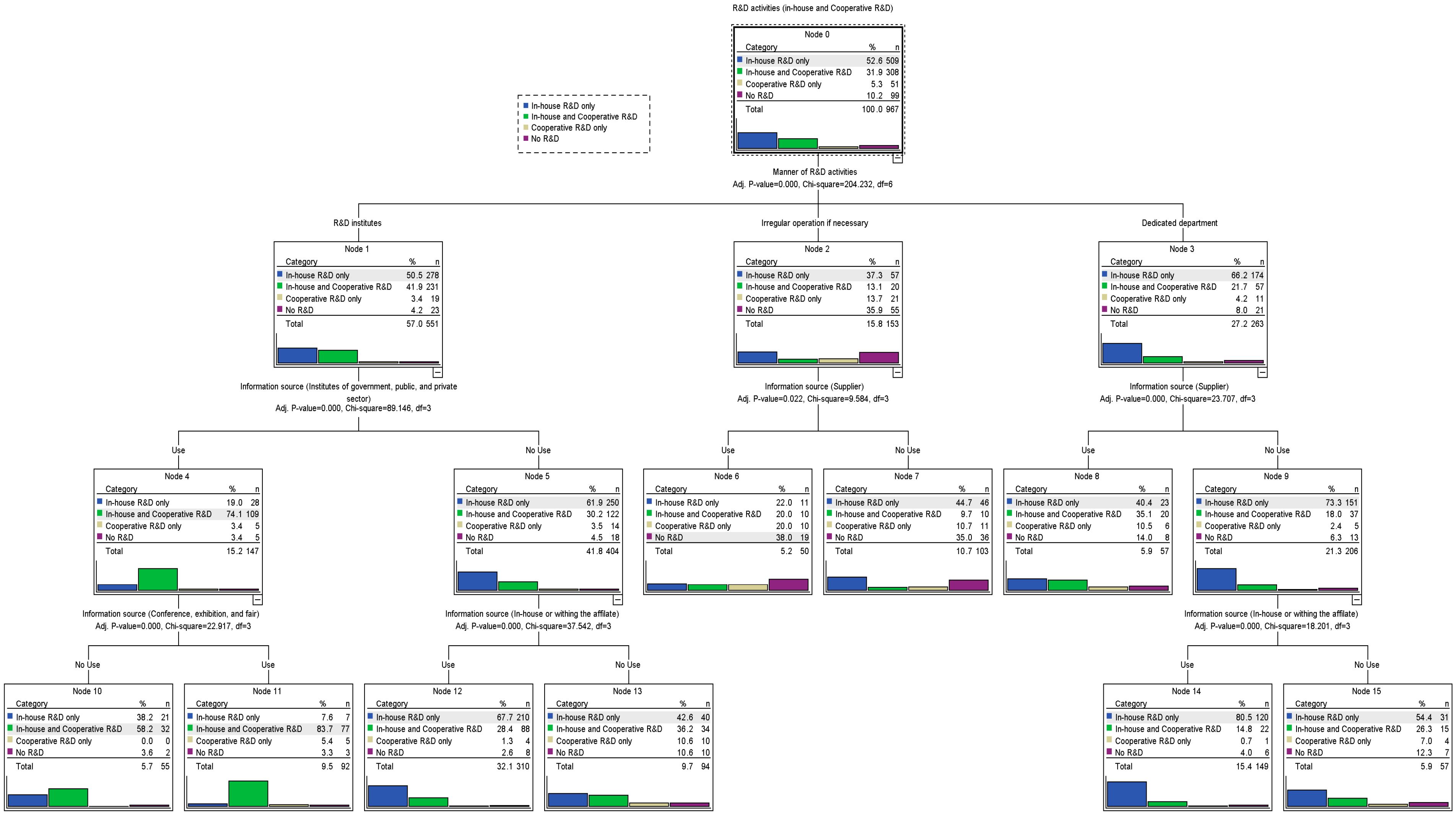


Figure A6. DT result of an R&D activities model in 2014.

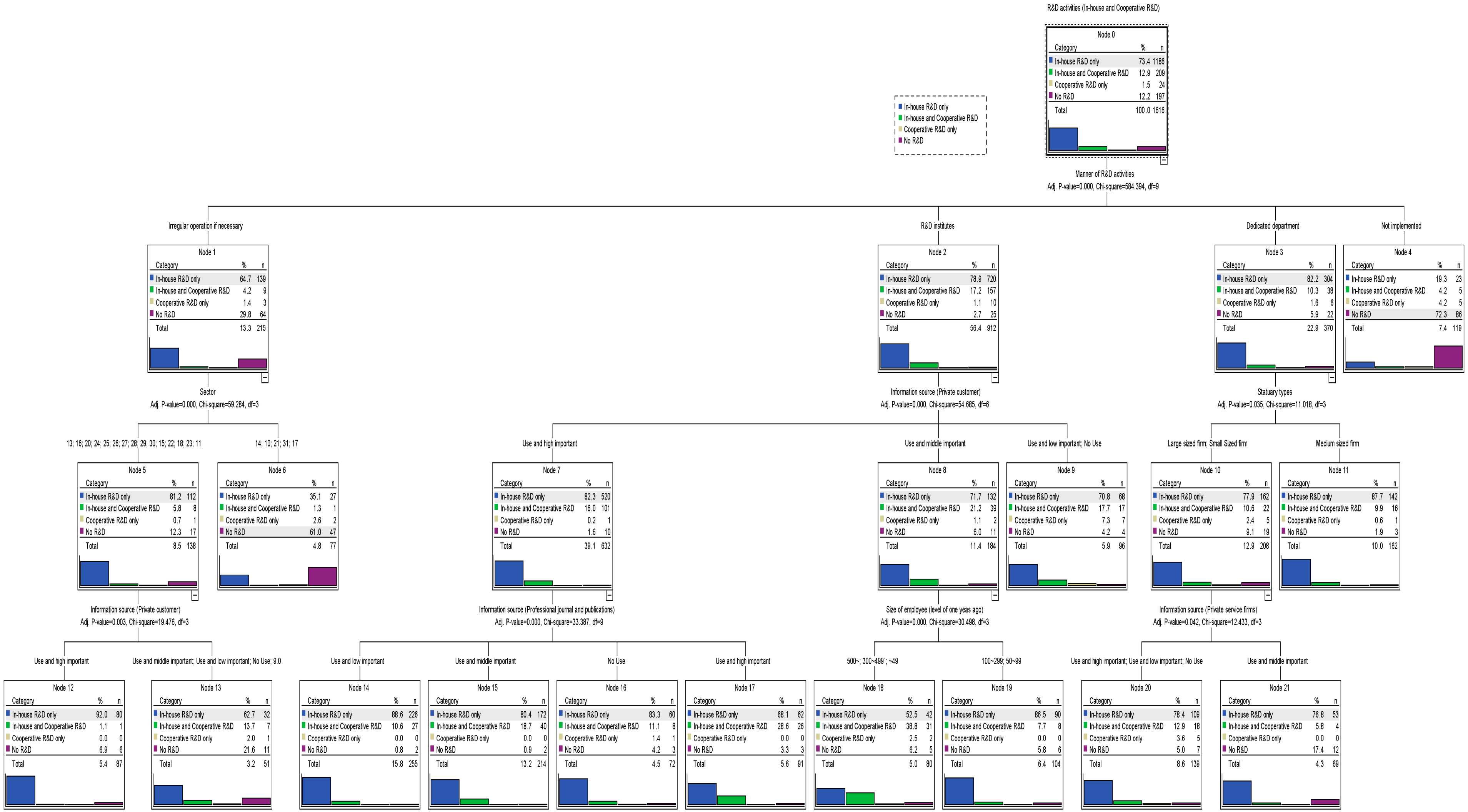


Figure A7. DT result of an R&D activities model in 2016.

Appendix D

Table A4. Cross-tabulation between sectors and innovation success and failure in KIS 2014.

Sectors	Innovation										Total				
	Failure					Success									
	Count	Expected Count	% Within Innovation	% Within Sector	% of Total	Count	Expected Count	% Within Innovation	% Within Sector	% of Total	Count	Expected Count	% Within Innovation	% Within Sector	% of Total
10	158	183.0	5.1%	65.8%	3.9%	82	57.0	8.5%	34.2%	2.0%	240	240.0	5.9%	100.0%	5.9%
11	12	13.7	0.4%	66.7%	0.3%	6	4.3	0.6%	33.3%	0.1%	18	18.0	0.4%	100.0%	0.4%
13	145	128.1	4.7%	86.3%	3.6%	23	39.9	2.4%	13.7%	0.6%	168	168.0	4.1%	100.0%	4.1%
14	97	83.9	3.1%	88.2%	2.4%	13	26.1	1.3%	11.8%	0.3%	110	110.0	2.7%	100.0%	2.7%
15	27	27.5	0.9%	75.0%	0.7%	9	8.5	0.9%	25.0%	0.2%	36	36.0	0.9%	100.0%	0.9%
16	33	30.5	1.1%	82.5%	0.8%	7	9.5	0.7%	17.5%	0.2%	40	40.0	1.0%	100.0%	1.0%
17	81	70.9	2.6%	87.1%	2.0%	12	22.1	1.2%	12.9%	0.3%	93	93.0	2.3%	100.0%	2.3%
18	55	48.1	1.8%	87.3%	1.3%	8	14.9	0.8%	12.7%	0.2%	63	63.0	1.5%	100.0%	1.5%
19	16	13.0	0.5%	94.1%	0.4%	1	4.0	0.1%	5.9%	0.0%	17	17.0	0.4%	100.0%	0.4%
20	109	131.9	3.5%	63.0%	2.7%	64	41.1	6.6%	37.0%	1.6%	173	173.0	4.2%	100.0%	4.2%
21	25	41.9	0.8%	45.5%	0.6%	30	13.1	3.1%	54.5%	0.7%	55	55.0	1.3%	100.0%	1.3%
22	237	228.8	7.6%	79.0%	5.8%	63	71.2	6.5%	21.0%	1.5%	300	300.0	7.4%	100.0%	7.4%
23	136	125.8	4.4%	82.4%	3.3%	29	39.2	3.0%	17.6%	0.7%	165	165.0	4.0%	100.0%	4.0%
24	154	137.3	5.0%	85.6%	3.8%	26	42.7	2.7%	14.4%	0.6%	180	180.0	4.4%	100.0%	4.4%
25	424	386.7	13.6%	83.6%	10.4%	83	120.3	8.6%	16.4%	2.0%	507	507.0	12.4%	100.0%	12.4%
26	218	254.0	7.0%	65.5%	5.3%	115	79.0	11.9%	34.5%	2.8%	333	333.0	8.2%	100.0%	8.2%
27	86	109.1	2.8%	60.1%	2.1%	57	33.9	5.9%	39.9%	1.4%	143	143.0	3.5%	100.0%	3.5%
28	165	199.8	5.3%	63.0%	4.0%	97	62.2	10.0%	37.0%	2.4%	262	262.0	6.4%	100.0%	6.4%
29	436	435.5	14.0%	76.4%	10.7%	135	135.5	14.0%	23.6%	3.3%	571	571.0	14.0%	100.0%	14.0%
30	249	244.8	8.0%	77.6%	6.1%	72	76.2	7.4%	22.4%	1.8%	321	321.0	7.9%	100.0%	7.9%
31	144	117.5	4.6%	93.5%	3.5%	10	36.5	1.0%	6.5%	0.2%	154	154.0	3.8%	100.0%	3.8%
32	45	45.0	1.4%	76.3%	1.1%	14	14.0	1.4%	23.7%	0.3%	59	59.0	1.4%	100.0%	1.4%
33	56	51.1	1.8%	83.6%	1.4%	11	15.9	1.1%	16.4%	0.3%	67	67.0	1.6%	100.0%	1.6%
Total	3108	3108.0	100.0%	76.3%	76.3%	967	967.0	100.0%	23.7%	23.7%	4075	4075.0	100.0%	100.0%	100.0%

Table A5. Cross-tabulation between sectors and innovation success and failure in KIS 2016.

Sectors	Innovation										Total				
	Failure					Success									
	Count	Expected Count	% Within Innovation	% Within Sector	% of Total	Count	Expected Count	% Within Innovation	% Within Sector	% of Total	Count	Expected Count	% Within Innovation	% Within Sector	% of Total
10	98	124.6	4.1%	46.9%	2.5%	111	84.4	6.9%	53.1%	2.8%	209	209.0	5.2%	100.0%	5.2%
11	14	11.9	0.6%	70.0%	0.4%	6	8.1	0.4%	30.0%	0.2%	20	20.0	0.5%	100.0%	0.5%
13	109	74.5	4.6%	87.2%	2.7%	16	50.5	1.0%	12.8%	0.4%	125	125.0	3.1%	100.0%	3.1%
14	78	68.5	3.3%	67.8%	2.0%	37	46.5	2.3%	32.2%	0.9%	115	115.0	2.9%	100.0%	2.9%
15	16	16.1	0.7%	59.3%	0.4%	11	10.9	0.7%	40.7%	0.3%	27	27.0	0.7%	100.0%	0.7%
16	16	19.7	0.7%	48.5%	0.4%	17	13.3	1.1%	51.5%	0.4%	33	33.0	0.8%	100.0%	0.8%
17	56	54.8	2.3%	60.9%	1.4%	36	37.2	2.2%	39.1%	0.9%	92	92.0	2.3%	100.0%	2.3%
18	34	25.0	1.4%	81.0%	0.9%	8	17.0	0.5%	19.0%	0.2%	42	42.0	1.1%	100.0%	1.1%
19	16	11.3	0.7%	84.2%	0.4%	3	7.7	0.2%	15.8%	0.1%	19	19.0	0.5%	100.0%	0.5%
20	99	97.7	4.2%	60.4%	2.5%	65	66.3	4.0%	39.6%	1.6%	164	164.0	4.1%	100.0%	4.1%
21	6	17.3	0.3%	20.7%	0.2%	23	11.7	1.4%	79.3%	0.6%	29	29.0	0.7%	100.0%	0.7%
22	226	217.5	9.5%	61.9%	5.7%	139	147.5	8.6%	38.1%	3.5%	365	365.0	9.1%	100.0%	9.1%
23	96	78.7	4.0%	72.7%	2.4%	36	53.3	2.2%	27.3%	0.9%	132	132.0	3.3%	100.0%	3.3%
24	158	123.4	6.6%	76.3%	4.0%	49	83.6	3.0%	23.7%	1.2%	207	207.0	5.2%	100.0%	5.2%
25	314	240.8	13.2%	77.7%	7.9%	90	163.2	5.6%	22.3%	2.3%	404	404.0	10.1%	100.0%	10.1%
26	154	214.6	6.5%	42.8%	3.9%	206	145.4	12.7%	57.2%	5.2%	360	360.0	9.0%	100.0%	9.0%
27	94	99.5	3.9%	56.3%	2.4%	73	67.5	4.5%	43.7%	1.8%	167	167.0	4.2%	100.0%	4.2%
28	152	170.5	6.4%	53.1%	3.8%	134	115.5	8.3%	46.9%	3.4%	286	286.0	7.2%	100.0%	7.2%
29	258	340.3	10.8%	45.2%	6.5%	313	230.7	19.4%	54.8%	7.8%	571	571.0	14.3%	100.0%	14.3%
30	200	238.4	8.4%	50.0%	5.0%	200	161.6	12.4%	50.0%	5.0%	400	400.0	10.0%	100.0%	10.0%
31	108	76.9	4.5%	83.7%	2.7%	21	52.1	1.3%	16.3%	0.5%	129	129.0	3.2%	100.0%	3.2%
32	51	40.5	2.1%	75.0%	1.3%	17	27.5	1.1%	25.0%	0.4%	68	68.0	1.7%	100.0%	1.7%
33	31	21.5	1.3%	86.1%	0.8%	5	14.5	0.3%	13.9%	0.1%	36	36.0	0.9%	100.0%	0.9%
Total	2384	2384.0	100.0%	59.6%	59.6%	1616	1616.0	100.0%	40.4%	40.4%	4000	4000.0	100.0%	100.0%	100.0%

Table A6. Cross-tabulation between regions and innovation success and failure in KIS 2014.

Region	Innovation										Total				
	Failure					Success									
	Count	Expected Count	% Within Innovation	% Within Region	% of Total	Count	Expected Count	% Within Innovation	% Within Region	% of Total	Count	Expected Count	% Within Innovation	% Within Region	% of Total
Busan	303	289.1	79.9%	9.7%	7.4%	76	89.9	20.1%	7.9%	1.9%	379	379.0	100.0%	9.3%	9.3%
Chungcheongbuk	133	135.0	75.1%	4.3%	3.3%	44	42.0	24.9%	4.6%	1.1%	177	177.0	100.0%	4.3%	4.3%
ChungCheongnam	162	159.4	77.5%	5.2%	4.0%	47	49.6	22.5%	4.9%	1.2%	209	209.0	100.0%	5.1%	5.1%
Daegu	146	144.9	76.8%	4.7%	3.6%	44	45.1	23.2%	4.6%	1.1%	190	190.0	100.0%	4.7%	4.7%
Daejeon	69	77.8	67.6%	2.2%	1.7%	33	24.2	32.4%	3.4%	0.8%	102	102.0	100.0%	2.5%	2.5%
Ganwon	43	42.7	76.8%	1.4%	1.1%	13	13.3	23.2%	1.3%	0.3%	56	56.0	100.0%	1.4%	1.4%
Gwangju	77	72.5	81.1%	2.5%	1.9%	18	22.5	18.9%	1.9%	0.4%	95	95.0	100.0%	2.3%	2.3%
Gyeongbuk	232	212.8	83.2%	7.5%	5.7%	47	66.2	16.8%	4.9%	1.2%	279	279.0	100.0%	6.8%	6.8%
Gyeonggi	874	900.0	74.1%	28.1%	21.4%	306	280.0	25.9%	31.6%	7.5%	1180	1180.0	100.0%	29.0%	29.0%
Gyeonnam	283	264.7	81.6%	9.1%	6.9%	64	82.3	18.4%	6.6%	1.6%	347	347.0	100.0%	8.5%	8.5%
Incheon	139	149.5	70.9%	4.5%	3.4%	57	46.5	29.1%	5.9%	1.4%	196	196.0	100.0%	4.8%	4.8%
Jeju	3	5.3	42.9%	0.1%	0.1%	4	1.7	57.1%	.4%	0.1%	7	7.0	100.0%	0.2%	0.2%
Jeollabuk	110	96.1	87.3%	3.5%	2.7%	16	29.9	12.7%	1.7%	0.4%	126	126.0	100.0%	3.1%	3.1%
Jeollnam	86	79.3	82.7%	2.8%	2.1%	18	24.7	17.3%	1.9%	0.4%	104	104.0	100.0%	2.6%	2.6%
Sejong	5	5.3	71.4%	0.2%	0.1%	2	1.7	28.6%	.2%	0.0%	7	7.0	100.0%	0.2%	0.2%
Seoul	315	363.8	66.0%	10.1%	7.7%	162	113.2	34.0%	16.8%	4.0%	477	477.0	100.0%	11.7%	11.7%
Ulsan	128	109.8	88.9%	4.1%	3.1%	16	34.2	11.1%	1.7%	0.4%	144	144.0	100.0%	3.5%	3.5%
Total	3108	3108.0	76.3%	100.0%	76.3%	967	967.0	23.7%	100.0%	23.7%	4075	4075.0	100.0%	100.0%	100.0%

Table A7. Cross-tabulation between regions and innovation success and failure in KIS 2016.

Region	Innovation										Total				
	Failure					Success									
	Count	Expected Count	% Within Innovation	% Within Region	% of Total	Count	Expected Count	% Within Innovation	% Within Region	% of Total	Count	Expected Count	% Within Innovation	% Within Region	% of Total
Busan	128	147.8	5.4%	51.6%	3.2%	120	100.2	7.4%	48.4%	3.0%	248	248.0	6.2%	100.0%	6.2%
Chungcheongbuk	87	103.1	3.6%	50.3%	2.2%	86	69.9	5.3%	49.7%	2.2%	173	173.0	4.3%	100.0%	4.3%
ChungCheongnam	114	133.5	4.8%	50.9%	2.9%	110	90.5	6.8%	49.1%	2.8%	224	224.0	5.6%	100.0%	5.6%
Daegu	87	118.0	3.6%	43.9%	2.2%	111	80.0	6.9%	56.1%	2.8%	198	198.0	5.0%	100.0%	5.0%
Daejeon	33	46.5	1.4%	42.3%	0.8%	45	31.5	2.8%	57.7%	1.1%	78	78.0	2.0%	100.0%	2.0%
Ganwon	39	32.8	1.6%	70.9%	1.0%	16	22.2	1.0%	29.1%	0.4%	55	55.0	1.4%	100.0%	1.4%
Gwangju	55	53.6	2.3%	61.1%	1.4%	35	36.4	2.2%	38.9%	0.9%	90	90.0	2.3%	100.0%	2.3%
Gyeongbuk	197	187.7	8.3%	62.5%	4.9%	118	127.3	7.3%	37.5%	3.0%	315	315.0	7.9%	100.0%	7.9%
Gyeonggi	887	770.6	37.2%	68.6%	22.2%	406	522.4	25.1%	31.4%	10.2%	1293	1293.0	32.3%	100.0%	32.3%
Gyeonnam	272	243.2	11.4%	66.7%	6.8%	136	164.8	8.4%	33.3%	3.4%	408	408.0	10.2%	100.0%	10.2%
Incheon	149	193.7	6.3%	45.8%	3.7%	176	131.3	10.9%	54.2%	4.4%	325	325.0	8.1%	100.0%	8.1%
Jeju	2	2.4	0.1%	50.0%	0.1%	2	1.6	0.1%	50.0%	0.1%	4	4.0	0.1%	100.0%	0.1%
Jeollabuk	60	53.0	2.5%	67.4%	1.5%	29	36.0	1.8%	32.6%	0.7%	89	89.0	2.2%	100.0%	2.2%
Jeollnam	62	54.2	2.6%	68.1%	1.6%	29	36.8	1.8%	31.9%	0.7%	91	91.0	2.3%	100.0%	2.3%
Sejong	7	12.5	0.3%	33.3%	0.2%	14	8.5	0.9%	66.7%	0.4%	21	21.0	0.5%	100.0%	0.5%
Seoul	115	152.6	4.8%	44.9%	2.9%	141	103.4	8.7%	55.1%	3.5%	256	256.0	6.4%	100.0%	6.4%
Ulsan	90	78.7	3.8%	68.2%	2.3%	42	53.3	2.6%	31.8%	1.1%	132	132.0	3.3%	100.0%	3.3%
Total	2384	2384.0	100.0%	59.6%	59.6%	1616	1616.0	100.0%	40.4%	40.4%	4000	4000.0	100.0%	100.0%	100.0%

Table A8. Cross-tabulation between regions and sectors in KIS 2014.

			Sector																							Total
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Busan	Count	2	0	4	2	3	1	0	0	0	5	0	3	0	1	13	2	2	8	19	6	2	2	1	76
		Expected Count	6.4	0.5	1.8	1.0	0.7	0.6	0.9	0.6	0.1	5.0	2.4	5.0	2.3	2.0	6.5	9.0	4.5	7.6	10.6	5.7	.8	1.1	0.9	76.0
		% within region	2.6%	0.0%	5.3%	2.6%	3.9%	1.3%	0.0%	0.0%	0.0%	6.6%	0.0%	3.9%	0.0%	1.3%	17.1%	2.6%	2.6%	10.5%	25.0%	7.9%	2.6%	2.6%	1.3%	100.0%
		% within sector	2.4%	0.0%	17.4%	15.4%	33.3%	14.3%	0.0%	0.0%	0.0%	7.8%	0.0%	4.8%	0.0%	3.8%	15.7%	1.7%	3.5%	8.2%	14.1%	8.3%	20.0%	14.3%	9.1%	7.9%
		% of Total	0.2%	0.0%	0.4%	0.2%	0.3%	0.1%	0.0%	0.0%	0.0%	0.5%	0.0%	0.3%	0.0%	0.1%	1.3%	0.2%	0.2%	0.8%	2.0%	0.6%	0.2%	0.2%	0.1%	7.9%
	Chungcheongbuk	Count	12	0	0	0	0	0	0	0	0	7	3	4	2	1	3	5	0	0	4	3	0	0	0	44
		Expected Count	3.7	0.3	1.0	0.6	0.4	0.3	0.5	0.4	0.0	2.9	1.4	2.9	1.3	1.2	3.8	5.2	2.6	4.4	6.1	3.3	0.5	0.6	0.5	44.0
		% within region	27.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.9%	6.8%	9.1%	4.5%	2.3%	6.8%	11.4%	0.0%	0.0%	9.1%	6.8%	0.0%	0.0%	0.0%	100.0%
		% within sector	14.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.9%	10.0%	6.3%	6.9%	3.8%	3.6%	4.3%	0.0%	0.0%	3.0%	4.2%	0.0%	0.0%	0.0%	4.6%
		% of Total	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.3%	0.4%	0.2%	0.1%	0.3%	0.5%	0.0%	0.0%	0.4%	0.3%	0.0%	0.0%	0.0%	4.6%
	ChungCheongnam	Count	7	0	0	0	0	0	1	0	0	3	0	5	2	3	2	7	1	1	9	5	1	0	0	47
		Expected Count	4.0	0.3	1.1	0.6	0.4	0.3	0.6	0.4	0.0	3.1	1.5	3.1	1.4	1.3	4.0	5.6	2.8	4.7	6.6	3.5	0.5	0.7	0.5	47.0
		% within region	14.9%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	6.4%	0.0%	10.6%	4.3%	6.4%	4.3%	14.9%	2.1%	2.1%	19.1%	10.6%	2.1%	0.0%	0.0%	100.0%
		% within sector	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	8.3%	0.0%	0.0%	4.7%	0.0%	7.9%	6.9%	11.5%	2.4%	6.1%	1.8%	1.0%	6.7%	6.9%	10.0%	0.0%	0.0%	4.9%
		% of Total	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.3%	0.0%	0.5%	0.2%	0.3%	0.2%	0.7%	0.1%	0.1%	0.9%	0.5%	0.1%	0.0%	0.0%	4.9%
	Daegu	Count	1	0	4	1	0	0	1	2	0	0	0	3	2	0	7	0	3	5	8	7	0	0	0	44
		Expected Count	3.7	0.3	1.0	0.6	0.4	0.3	0.5	0.4	0.0	2.9	1.4	2.9	1.3	1.2	3.8	5.2	2.6	4.4	6.1	3.3	0.5	0.6	0.5	44.0
		% within region	2.3%	0.0%	9.1%	2.3%	0.0%	0.0%	2.3%	4.5%	0.0%	0.0%	0.0%	6.8%	4.5%	0.0%	15.9%	0.0%	6.8%	11.4%	18.2%	15.9%	0.0%	0.0%	0.0%	100.0%
		% within sector	1.2%	0.0%	17.4%	7.7%	0.0%	0.0%	8.3%	25.0%	0.0%	0.0%	0.0%	4.8%	6.9%	0.0%	8.4%	0.0%	5.3%	5.2%	5.9%	9.7%	0.0%	0.0%	0.0%	4.6%
		% of Total	0.1%	0.0%	0.4%	0.1%	0.0%	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%	0.3%	0.2%	0.0%	0.7%	0.0%	0.3%	0.5%	0.8%	0.7%	0.0%	0.0%	0.0%	4.6%
	Daejeon	Count	0	2	1	0	0	0	0	0	0	2	1	0	1	0	1	7	9	1	7	0	0	0	1	33
		Expected Count	2.8	0.2	0.8	0.4	0.3	0.2	0.4	0.3	0.0	2.2	1.0	2.1	1.0	0.9	2.8	3.9	1.9	3.3	4.6	2.5	0.3	0.5	0.4	33.0
		% within region	0.0%	6.1%	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.1%	3.0%	0.0%	3.0%	0.0%	3.0%	21.2%	27.3%	3.0%	21.2%	0.0%	0.0%	0.0%	3.0%	100.0%
		% within sector	0.0%	33.3%	4.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	3.3%	0.0%	3.4%	0.0%	1.2%	6.1%	15.8%	1.0%	5.2%	0.0%	0.0%	0.0%	9.1%	3.4%
		% of Total	0.0%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.0%	0.1%	0.0%	0.1%	0.7%	0.9%	0.1%	0.7%	0.0%	0.0%	0.0%	0.1%	3.4%

Table A8. *Cont.*

			Sector																							Total
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Ganwon	Count	2	0	0	0	0	0	0	0	0	1	1	2	2	0	0	0	3	0	1	1	0	0	0	13
		Expected Count	1.1	0.1	0.3	0.2	0.1	0.1	0.2	0.1	0.0	0.9	0.4	0.8	0.4	0.3	1.1	1.5	0.8	1.3	1.8	1.0	0.1	0.2	0.1	13.0
		% within region	15.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.7%	7.7%	15.4%	15.4%	0.0%	0.0%	0.0%	23.1%	0.0%	7.7%	7.7%	0.0%	0.0%	0.0%	100.0%
		% within sector	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	3.3%	3.2%	6.9%	0.0%	0.0%	0.0%	5.3%	0.0%	0.7%	1.4%	0.0%	0.0%	0.0%	1.3%
		% of Total	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.0%	0.0%	0.0%	0.3%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	1.3%
	Gwangju	Count	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	3	3	2	1	0	2	0	18
		Expected Count	1.5	0.1	0.4	0.2	0.2	0.1	0.2	0.1	0.0	1.2	0.6	1.2	0.5	0.5	1.5	2.1	1.1	1.8	2.5	1.3	0.2	0.3	0.2	18.0
		% within region	5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.1%	22.2%	16.7%	16.7%	11.1%	5.6%	0.0%	11.1%	0.0%	100.0%
		% within sector	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%	3.5%	5.3%	3.1%	1.5%	1.4%	0.0%	14.3%	0.0%	1.9%
		% of Total	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%	0.3%	0.3%	0.2%	0.1%	0.0%	0.2%	0.0%	1.9%
	Gyeongbuk	Count	6	1	1	0	0	1	1	0	0	4	0	6	5	1	2	5	0	0	4	9	0	1	0	47
		Expected Count	4.0	0.3	1.1	0.6	0.4	0.3	0.6	0.4	0.0	3.1	1.5	3.1	1.4	1.3	4.0	5.6	2.8	4.7	6.6	3.5	0.5	0.7	0.5	47.0
		% within region	12.8%	2.1%	2.1%	0.0%	0.0%	2.1%	2.1%	0.0%	0.0%	8.5%	0.0%	12.8%	10.6%	2.1%	4.3%	10.6%	0.0%	0.0%	8.5%	19.1%	0.0%	2.1%	0.0%	100.0%
		% within sector	7.3%	16.7%	4.3%	0.0%	0.0%	14.3%	8.3%	0.0%	0.0%	6.3%	0.0%	9.5%	17.2%	3.8%	2.4%	4.3%	0.0%	0.0%	3.0%	12.5%	0.0%	7.1%	0.0%	4.9%
		% of Total	0.6%	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.4%	0.0%	0.6%	0.5%	0.1%	0.2%	0.5%	0.0%	0.0%	0.4%	0.9%	0.0%	0.1%	0.0%	4.9%
	Gyeonggi	Count	12	0	3	3	2	2	7	4	0	17	5	22	9	7	23	54	21	43	39	24	1	7	1	306
		Expected Count	25.9	1.9	7.3	4.1	2.8	2.2	3.8	2.5	0.3	20.3	9.5	19.9	9.2	8.2	26.3	36.4	18.0	30.7	42.7	22.8	3.2	4.4	3.5	306.0
		% within region	3.9%	0.0%	1.0%	1.0%	0.7%	0.7%	2.3%	1.3%	0.0%	5.6%	1.6%	7.2%	2.9%	2.3%	7.5%	17.6%	6.9%	14.1%	12.7%	7.8%	0.3%	2.3%	0.3%	100.0%
		% within sector	14.6%	0.0%	13.0%	23.1%	22.2%	28.6%	58.3%	50.0%	0.0%	26.6%	16.7%	34.9%	31.0%	26.9%	27.7%	47.0%	36.8%	44.3%	28.9%	33.3%	10.0%	50.0%	9.1%	31.6%
		% of Total	1.2%	0.0%	0.3%	0.3%	0.2%	0.2%	0.7%	0.4%	0.0%	1.8%	0.5%	2.3%	0.9%	0.7%	2.4%	5.6%	2.2%	4.4%	4.0%	2.5%	0.1%	0.7%	0.1%	31.6%
	Gyeonnam	Count	7	0	2	0	3	0	0	0	0	5	0	8	1	4	8	1	0	4	12	6	3	0	0	64
		Expected Count	5.4	0.4	1.5	0.9	0.6	0.5	0.8	0.5	0.1	4.2	2.0	4.2	1.9	1.7	5.5	7.6	3.8	6.4	8.9	4.8	0.7	0.9	0.7	64.0
		% within region	10.9%	0.0%	3.1%	0.0%	4.7%	0.0%	0.0%	0.0%	0.0%	7.8%	0.0%	12.5%	1.6%	6.3%	12.5%	1.6%	0.0%	6.3%	18.8%	9.4%	4.7%	0.0%	0.0%	100.0%
		% within sector	8.5%	0.0%	8.7%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%	7.8%	0.0%	12.7%	3.4%	15.4%	9.6%	0.9%	0.0%	4.1%	8.9%	8.3%	30.0%	0.0%	0.0%	6.6%
		% of Total	0.7%	0.0%	0.2%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.8%	0.1%	0.4%	0.8%	0.1%	0.0%	0.4%	1.2%	0.6%	0.3%	0.0%	0.0%	6.6%

Table A8. *Cont.*

			Sector																							Total
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Incheon	Count	4	0	0	0	0	2	0	1	0	6	0	4	1	1	4	5	3	10	10	2	0	1	3	57
		Expected Count	4.8	0.4	1.4	0.8	0.5	0.4	0.7	0.5	0.1	3.8	1.8	3.7	1.7	1.5	4.9	6.8	3.4	5.7	8.0	4.2	0.6	0.8	0.6	57.0
		% within region	7.0%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	1.8%	0.0%	10.5%	0.0%	7.0%	1.8%	1.8%	7.0%	8.8%	5.3%	17.5%	17.5%	3.5%	0.0%	1.8%	5.3%	100.0%
		% within sector	4.9%	0.0%	0.0%	0.0%	0.0%	28.6%	0.0%	12.5%	0.0%	9.4%	0.0%	6.3%	3.4%	3.8%	4.8%	4.3%	5.3%	10.3%	7.4%	2.8%	0.0%	7.1%	27.3%	5.9%
		% of Total	0.4%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.6%	0.0%	0.4%	0.1%	0.1%	0.4%	0.5%	0.3%	1.0%	1.0%	0.2%	0.0%	0.1%	0.3%	5.9%
	Jeju	Count	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
		Expected Count	0.3	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.3	0.1	0.1	0.3	0.5	0.2	0.4	0.6	0.3	0.0	0.1	0.0	4.0
		% within region	75.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within sector	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
		% of Total	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
	Jeollabuk	Count	5	0	1	1	0	0	0	0	0	1	0	1	0	1	0	1	0	2	2	0	0	1	0	16
		Expected Count	1.4	0.1	0.4	0.2	0.1	0.1	0.2	0.1	0.0	1.1	0.5	1.0	0.5	0.4	1.4	1.9	0.9	1.6	2.2	1.2	0.2	0.2	0.2	16.0
		% within region	31.3%	0.0%	6.3%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	0.0%	6.3%	0.0%	6.3%	0.0%	6.3%	0.0%	12.5%	12.5%	0.0%	0.0%	6.3%	0.0%	100.0%
		% within sector	6.1%	0.0%	4.3%	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	1.6%	0.0%	3.8%	0.0%	0.9%	0.0%	2.1%	1.5%	0.0%	0.0%	7.1%	0.0%	1.7%
		% of Total	0.5%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.2%	0.2%	0.0%	0.0%	0.1%	0.0%	1.7%
	Jeollnam	Count	4	1	0	0	0	0	0	0	0	2	0	1	1	2	3	0	0	1	2	1	0	0	0	18
		Expected Count	1.5	0.1	0.4	0.2	0.2	0.1	0.2	0.1	0.0	1.2	0.6	1.2	0.5	0.5	1.5	2.1	1.1	1.8	2.5	1.3	0.2	0.3	0.2	18.0
		% within region	22.2%	5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.1%	0.0%	5.6%	5.6%	11.1%	16.7%	0.0%	0.0%	5.6%	11.1%	5.6%	0.0%	0.0%	0.0%	100.0%
		% within sector	4.9%	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	0.0%	1.6%	3.4%	7.7%	3.6%	0.0%	0.0%	1.0%	1.5%	1.4%	0.0%	0.0%	0.0%	1.9%
		% of Total	0.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.1%	0.1%	0.2%	0.3%	0.0%	0.0%	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%	1.9%
	Sejong	Count	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
		Expected Count	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.3	0.1	0.0	0.0	0.0	2.0
		% within region	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	100.0%
		% within sector	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.2%
		% of Total	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%

Table A8. *Cont.*

			Sector																							**Total**
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Seoul	Count	15	2	7	6	1	0	2	1	1	8	20	3	3	3	14	22	12	18	15	3	1	0	5	162
		Expected Count	13.7	1.0	3.9	2.2	1.5	1.2	2.0	1.3	0.2	10.7	5.0	10.6	4.9	4.4	13.9	19.3	9.5	16.3	22.6	12.1	1.7	2.3	1.8	162.0
		% within region	9.3%	1.2%	4.3%	3.7%	0.6%	0.0%	1.2%	0.6%	0.6%	4.9%	12.3%	1.9%	1.9%	1.9%	8.6%	13.6%	7.4%	11.1%	9.3%	1.9%	0.6%	0.0%	3.1%	100.0%
		% within sector	18.3%	33.3%	30.4%	46.2%	11.1%	0.0%	16.7%	12.5%	100.0%	12.5%	66.7%	4.8%	10.3%	11.5%	16.9%	19.1%	21.1%	18.6%	11.1%	4.2%	10.0%	0.0%	45.5%	16.8%
		% of Total	1.6%	0.2%	0.7%	0.6%	0.1%	0.0%	0.2%	0.1%	0.1%	0.8%	2.1%	0.3%	0.3%	0.3%	1.4%	2.3%	1.2%	1.9%	1.6%	0.3%	0.1%	0.0%	0.5%	16.8%
	Ulsan	Count	0	0	0	0	0	1	0	0	0	2	0	1	0	2	1	2	0	1	1	3	2	0	0	16
		Expected Count	1.4	0.1	0.4	0.2	0.1	0.1	0.2	0.1	0.0	1.1	0.5	1.0	0.5	0.4	1.4	1.9	0.9	1.6	2.2	1.2	0.2	0.2	0.2	16.0
		% within region	0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	0.0%	0.0%	0.0%	12.5%	0.0%	6.3%	0.0%	12.5%	6.3%	12.5%	0.0%	6.3%	6.3%	18.8%	12.5%	0.0%	0.0%	100.0%
		% within sector	0.0%	0.0%	0.0%	0.0%	0.0%	14.3%	0.0%	0.0%	0.0%	3.1%	0.0%	1.6%	0.0%	7.7%	1.2%	1.7%	0.0%	1.0%	0.7%	4.2%	20.0%	0.0%	0.0%	1.7%
		% of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.0%	0.1%	0.0%	0.2%	0.1%	0.2%	0.0%	0.1%	0.1%	0.3%	0.2%	0.0%	0.0%	1.7%
	Total	Count	82	6	23	13	9	7	12	8	1	64	30	63	29	26	83	115	57	97	135	72	10	14	11	967
		Expected Count	82.0	6.0	23.0	13.0	9.0	7.0	12.0	8.0	1.0	64.0	30.0	63.0	29.0	26.0	83.0	115.0	57.0	97.0	135.0	72.0	10.0	14.0	11.0	967.0
		% within region	8.5%	.6%	2.4%	1.3%	0.9%	0.7%	1.2%	0.8%	0.1%	6.6%	3.1%	6.5%	3.0%	2.7%	8.6%	11.9%	5.9%	10.0%	14.0%	7.4%	1.0%	1.4%	1.1%	100.0%
		% within sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	8.5%	0.6%	2.4%	1.3%	0.9%	0.7%	1.2%	0.8%	0.1%	6.6%	3.1%	6.5%	3.0%	2.7%	8.6%	11.9%	5.9%	10.0%	14.0%	7.4%	1.0%	1.4%	1.1%	100.0%

Table A9. Cross-tabulation between regions and sectors in KIS 2016.

			Sector																							**Total**
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Busan	Count	11	1	1	0	3	2	2	0	1	6	1	13	1	7	7	5	1	13	30	10	3	2	0	120
		Expected Count	8.2	.4	1.2	2.7	.8	1.3	2.7	.6	.2	4.8	1.7	10.3	2.7	3.6	6.7	15.3	5.4	10.0	23.2	14.9	1.6	1.3	.4	120.0
		% within region	9.2%	0.8%	0.8%	0.0%	2.5%	1.7%	1.7%	0.0%	0.8%	5.0%	0.8%	10.8%	0.8%	5.8%	5.8%	4.2%	0.8%	10.8%	25.0%	8.3%	2.5%	1.7%	0.0%	100.0%
		% within sector	9.9%	16.7%	6.3%	0.0%	27.3%	11.8%	5.6%	0.0%	33.3%	9.2%	4.3%	9.4%	2.8%	14.3%	7.8%	2.4%	1.4%	9.7%	9.6%	5.0%	14.3%	11.8%	0.0%	7.4%
		% of Total	0.7%	0.1%	0.1%	0.0%	0.2%	0.1%	0.1%	0.0%	0.1%	0.4%	0.1%	0.8%	0.1%	0.4%	0.4%	0.3%	0.1%	0.8%	1.9%	0.6%	0.2%	0.1%	0.0%	7.4%
	Chungcheongbuk	Count	11	1	2	0	1	0	2	0	0	7	3	14	2	1	4	9	3	7	11	7	0	1	0	86
		Expected Count	5.9	.3	.9	2.0	.6	.9	1.9	.4	.2	3.5	1.2	7.4	1.9	2.6	4.8	11.0	3.9	7.1	16.7	10.6	1.1	.9	.3	86.0
		% within region	12.8%	1.2%	2.3%	0.0%	1.2%	0.0%	2.3%	0.0%	0.0%	8.1%	3.5%	16.3%	2.3%	1.2%	4.7%	10.5%	3.5%	8.1%	12.8%	8.1%	0.0%	1.2%	0.0%	100.0%
		% within sector	9.9%	16.7%	12.5%	0.0%	9.1%	0.0%	5.6%	0.0%	0.0%	10.8%	13.0%	10.1%	5.6%	2.0%	4.4%	4.4%	4.1%	5.2%	3.5%	3.5%	0.0%	5.9%	0.0%	5.3%
		% of Total	0.7%	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.4%	0.2%	0.9%	0.1%	0.1%	0.2%	0.6%	0.2%	0.4%	0.7%	0.4%	0.0%	0.1%	0.0%	5.3%
	ChungCheongnam	Count	14	2	0	0	0	0	2	0	0	5	2	9	3	1	3	12	5	6	24	22	0	0	0	110
		Expected Count	7.6	.4	1.1	2.5	.7	1.2	2.5	.5	.2	4.4	1.6	9.5	2.5	3.3	6.1	14.0	5.0	9.1	21.3	13.6	1.4	1.2	.3	110.0
		% within region	12.7%	1.8%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%	0.0%	4.5%	1.8%	8.2%	2.7%	0.9%	2.7%	10.9%	4.5%	5.5%	21.8%	20.0%	0.0%	0.0%	0.0%	100.0%
		% within sector	12.6%	33.3%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	7.7%	8.7%	6.5%	8.3%	2.0%	3.3%	5.8%	6.8%	4.5%	7.7%	11.0%	0.0%	0.0%	0.0%	6.8%
		% of Total	0.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.3%	0.1%	0.6%	0.2%	0.1%	0.2%	0.7%	0.3%	0.4%	1.5%	1.4%	0.0%	0.0%	0.0%	6.8%
	Daegu	Count	4	0	2	0	0	1	2	3	0	2	0	8	0	1	17	13	7	4	24	22	0	1	0	111
		Expected Count	7.6	.4	1.1	2.5	.8	1.2	2.5	.5	.2	4.5	1.6	9.5	2.5	3.4	6.2	14.1	5.0	9.2	21.5	13.7	1.4	1.2	.3	111.0
		% within region	3.6%	0.0%	1.8%	0.0%	0.0%	0.9%	1.8%	2.7%	0.0%	1.8%	0.0%	7.2%	0.0%	0.9%	15.3%	11.7%	6.3%	3.6%	21.6%	19.8%	0.0%	0.9%	0.0%	100.0%
		% within sector	3.6%	0.0%	12.5%	0.0%	0.0%	5.9%	5.6%	37.5%	0.0%	3.1%	0.0%	5.8%	0.0%	2.0%	18.9%	6.3%	9.6%	3.0%	7.7%	11.0%	0.0%	5.9%	0.0%	6.9%
		% of Total	0.2%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.2%	0.0%	0.1%	0.0%	0.5%	0.0%	0.1%	1.1%	0.8%	0.4%	0.2%	1.5%	1.4%	0.0%	0.1%	0.0%	6.9%
	Daejeon	Count	2	0	0	0	0	0	1	0	0	3	2	3	2	3	2	8	10	2	5	2	0	0	0	45
		Expected Count	3.1	.2	.4	1.0	.3	.5	1.0	.2	.1	1.8	.6	3.9	1.0	1.4	2.5	5.7	2.0	3.7	8.7	5.6	.6	.5	.1	45.0
		% within region	4.4%	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	0.0%	6.7%	4.4%	6.7%	4.4%	6.7%	4.4%	17.8%	22.2%	4.4%	11.1%	4.4%	0.0%	0.0%	0.0%	100.0%
		% within sector	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	2.8%	0.0%	0.0%	4.6%	8.7%	2.2%	5.6%	6.1%	2.2%	3.9%	13.7%	1.5%	1.6%	1.0%	0.0%	0.0%	0.0%	2.8%
		% of Total	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.2%	0.1%	0.2%	0.1%	0.2%	0.1%	0.5%	0.6%	0.1%	0.3%	0.1%	0.0%	0.0%	0.0%	2.8%

Table A9. *Cont.*

			Sector																						Total
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Ganwon	Count	2	1	0	0	0	0	0	0	0	1	1	2	1	0	0	0	3	3	1	1	0	0	0	16
		Expected Count	1.1	.1	.2	.4	.1	.2	.4	.1	.0	.6	.2	1.4	.4	.5	.9	2.0	.7	1.3	3.1	2.0	.2	.2	.0	16.0
		% within region	12.5%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.3%	6.3%	12.5%	6.3%	0.0%	0.0%	0.0%	18.8%	18.8%	6.3%	6.3%	0.0%	0.0%	0.0%	100.0%
		% within sector	1.8%	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	4.3%	1.4%	2.8%	0.0%	0.0%	0.0%	4.1%	2.2%	0.3%	0.5%	0.0%	0.0%	0.0%	1.0%
		% of Total	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.2%	0.2%	0.1%	0.1%	0.0%	0.0%	0.0%	1.0%
	Gwangju	Count	2	0	0	0	0	0	1	0	0	0	1	2	0	1	2	3	2	2	7	11	0	0	1	35
		Expected Count	2.4	.1	.3	.8	.2	.4	.8	.2	.1	1.4	.5	3.0	.8	1.1	1.9	4.5	1.6	2.9	6.8	4.3	.5	.4	.1	35.0
		% within region	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	2.9%	5.7%	0.0%	2.9%	5.7%	8.6%	5.7%	5.7%	20.0%	31.4%	0.0%	0.0%	2.9%	100.0%
		% within sector	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	4.3%	1.4%	0.0%	2.0%	2.2%	1.5%	2.7%	1.5%	2.2%	5.5%	0.0%	0.0%	20.0%	2.2%
		% of Total	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.2%	0.1%	0.1%	0.4%	0.7%	0.0%	0.0%	0.1%	2.2%
	Gyeongbuk	Count	4	1	5	0	0	1	2	0	0	3	0	10	2	6	9	11	4	7	25	25	0	3	0	118
		Expected Count	8.1	.4	1.2	2.7	.8	1.2	2.6	.6	.2	4.7	1.7	10.1	2.6	3.6	6.6	15.0	5.3	9.8	22.9	14.6	1.5	1.2	.4	118.0
		% within region	3.4%	0.8%	4.2%	0.0%	0.0%	0.8%	1.7%	0.0%	0.0%	2.5%	0.0%	8.5%	1.7%	5.1%	7.6%	9.3%	3.4%	5.9%	21.2%	21.2%	0.0%	2.5%	0.0%	100.0%
		% within sector	3.6%	16.7%	31.3%	0.0%	0.0%	5.9%	5.6%	0.0%	0.0%	4.6%	0.0%	7.2%	5.6%	12.2%	10.0%	5.3%	5.5%	5.2%	8.0%	12.5%	0.0%	17.6%	0.0%	7.3%
		% of Total	0.2%	0.1%	0.3%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.2%	0.0%	0.6%	0.1%	0.4%	0.6%	0.7%	0.2%	0.4%	1.5%	1.5%	0.0%	0.2%	0.0%	7.3%
	Gyeonggi	Count	19	0	3	1	1	2	15	2	0	20	7	34	13	12	17	69	23	49	84	25	2	5	3	406
		Expected Count	27.9	1.5	4.0	9.3	2.8	4.3	9.0	2.0	.8	16.3	5.8	34.9	9.0	12.3	22.6	51.8	18.3	33.7	78.6	50.2	5.3	4.3	1.3	406.0
		% within region	4.7%	0.0%	0.7%	0.2%	0.2%	0.5%	3.7%	0.5%	0.0%	4.9%	1.7%	8.4%	3.2%	3.0%	4.2%	17.0%	5.7%	12.1%	20.7%	6.2%	0.5%	1.2%	0.7%	100.0%
		% within sector	17.1%	0.0%	18.8%	2.7%	9.1%	11.8%	41.7%	25.0%	0.0%	30.8%	30.4%	24.5%	36.1%	24.5%	18.9%	33.5%	31.5%	36.6%	26.8%	12.5%	9.5%	29.4%	60.0%	25.1%
		% of Total	1.2%	0.0%	0.2%	0.1%	0.1%	0.1%	0.9%	0.1%	0.0%	1.2%	0.4%	2.1%	0.8%	0.7%	1.1%	4.3%	1.4%	3.0%	5.2%	1.5%	0.1%	0.3%	0.2%	25.1%
	Gyeonnam	Count	14	0	0	0	0	0	0	0	1	2	0	13	2	1	8	6	4	8	35	33	9	0	0	136
		Expected Count	9.3	.5	1.3	3.1	.9	1.4	3.0	.7	.3	5.5	1.9	11.7	3.0	4.1	7.6	17.3	6.1	11.3	26.3	16.8	1.8	1.4	.4	136.0
		% within region	10.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	1.5%	0.0%	9.6%	1.5%	0.7%	5.9%	4.4%	2.9%	5.9%	25.7%	24.3%	6.6%	0.0%	0.0%	100.0%
		% within sector	12.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	3.1%	0.0%	9.4%	5.6%	2.0%	8.9%	2.9%	5.5%	6.0%	11.2%	16.5%	42.9%	0.0%	0.0%	8.4%
		% of Total	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.8%	0.1%	0.1%	0.5%	0.4%	0.2%	0.5%	2.2%	2.0%	0.6%	0.0%	0.0%	8.4%

Table A9. *Cont.*

			Sector																							Total
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Incheon	Count	7	0	1	0	0	9	0	0	0	6	2	20	3	7	11	32	2	15	40	17	0	4	0	176
		Expected Count	12.1	.7	1.7	4.0	1.2	1.9	3.9	.9	.3	7.1	2.5	15.1	3.9	5.3	9.8	22.4	8.0	14.6	34.1	21.8	2.3	1.9	.5	176.0
		% within region	4.0%	0.0%	0.6%	0.0%	0.0%	5.1%	0.0%	0.0%	0.0%	3.4%	1.1%	11.4%	1.7%	4.0%	6.3%	18.2%	1.1%	8.5%	22.7%	9.7%	0.0%	2.3%	0.0%	100.0%
		% within sector	6.3%	0.0%	6.3%	0.0%	0.0%	52.9%	0.0%	0.0%	0.0%	9.2%	8.7%	14.4%	8.3%	14.3%	12.2%	15.5%	2.7%	11.2%	12.8%	8.5%	0.0%	23.5%	0.0%	10.9%
		% of Total	0.4%	0.0%	0.1%	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.4%	0.1%	1.2%	0.2%	0.4%	0.7%	2.0%	0.1%	0.9%	2.5%	1.1%	0.0%	0.2%	0.0%	10.9%
	Jeju	Count	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
		Expected Count	.1	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.2	.0	.1	.1	.3	.1	.2	.4	.2	.0	.0	.0	2.0
		% within region	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within sector	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
		% of Total	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
	Jeollabuk	Count	8	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	2	5	8	2	0	0	29
		Expected Count	2.0	.1	.3	.7	.2	.3	.6	.1	.1	1.2	.4	2.5	.6	.9	1.6	3.7	1.3	2.4	5.6	3.6	.4	.3	.1	29.0
		% within region	27.6%	0.0%	0.0%	0.0%	0.0%	0.0%	3.4%	0.0%	0.0%	0.0%	0.0%	3.4%	0.0%	0.0%	3.4%	3.4%	0.0%	6.9%	17.2%	27.6%	6.9%	0.0%	0.0%	100.0%
		% within sector	7.2%	0.0%	0.0%	0.0%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	1.1%	0.5%	0.0%	1.5%	1.6%	4.0%	9.5%	0.0%	0.0%	1.8%
		% of Total	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.3%	0.5%	0.1%	0.0%	0.0%	1.8%
	Jeollnam	Count	5	0	0	0	0	1	0	0	0	3	1	2	0	2	2	1	0	3	5	1	2	1	0	29
		Expected Count	2.0	.1	.3	.7	.2	.3	.6	.1	.1	1.2	.4	2.5	.6	.9	1.6	3.7	1.3	2.4	5.6	3.6	.4	.3	.1	29.0
		% within region	17.2%	0.0%	0.0%	0.0%	0.0%	3.4%	0.0%	0.0%	0.0%	10.3%	3.4%	6.9%	0.0%	6.9%	6.9%	3.4%	0.0%	10.3%	17.2%	3.4%	6.9%	3.4%	0.0%	100.0%
		% within sector	4.5%	0.0%	0.0%	0.0%	0.0%	5.9%	0.0%	0.0%	0.0%	4.6%	4.3%	1.4%	0.0%	4.1%	2.2%	0.5%	0.0%	2.2%	1.6%	0.5%	9.5%	5.9%	0.0%	1.8%
		% of Total	0.3%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.2%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	0.2%	0.3%	0.1%	0.1%	0.1%	0.0%	1.8%
	Sejong	Count	0	0	0	0	0	0	2	0	0	1	1	0	3	0	0	2	1	2	0	2	0	0	0	14
		Expected Count	1.0	.1	.1	.3	.1	.1	.3	.1	.0	.6	.2	1.2	.3	.4	.8	1.8	.6	1.2	2.7	1.7	.2	.1	.0	14.0
		% within region	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	14.3%	0.0%	0.0%	7.1%	7.1%	0.0%	21.4%	0.0%	0.0%	14.3%	7.1%	14.3%	0.0%	14.3%	0.0%	0.0%	0.0%	100.0%
		% within sector	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	1.5%	4.3%	0.0%	8.3%	0.0%	0.0%	1.0%	1.4%	1.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.9%
		% of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.2%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.9%

Table A9. *Cont.*

			Sector																							Total
			10	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Region	Seoul	Count	6	0	2	36	6	1	6	3	0	5	2	4	2	1	4	33	6	10	12	1	0	0	1	141
		Expected Count	9.7	.5	1.4	3.2	1.0	1.5	3.1	.7	.3	5.7	2.0	12.1	3.1	4.3	7.9	18.0	6.4	11.7	27.3	17.5	1.8	1.5	.4	141.0
		% within region	4.3%	0.0%	1.4%	25.5%	4.3%	0.7%	4.3%	2.1%	0.0%	3.5%	1.4%	2.8%	1.4%	0.7%	2.8%	23.4%	4.3%	7.1%	8.5%	0.7%	0.0%	0.0%	0.7%	100.0%
		% within sector	5.4%	0.0%	12.5%	97.3%	54.5%	5.9%	16.7%	37.5%	0.0%	7.7%	8.7%	2.9%	5.6%	2.0%	4.4%	16.0%	8.2%	7.5%	3.8%	0.5%	0.0%	0.0%	20.0%	8.7%
		% of Total	0.4%	0.0%	0.1%	2.2%	0.4%	0.1%	0.4%	0.2%	0.0%	0.3%	0.1%	0.2%	0.1%	0.1%	0.2%	2.0%	0.4%	0.6%	0.7%	0.1%	0.0%	0.0%	0.1%	8.7%
	Ulsan	Count	1	0	0	0	0	0	0	0	1	1	0	4	1	6	3	1	2	1	5	13	3	0	0	42
		Expected Count	2.9	.2	.4	1.0	.3	.4	.9	.2	.1	1.7	.6	3.6	.9	1.3	2.3	5.4	1.9	3.5	8.1	5.2	.5	.4	.1	42.0
		% within region	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%	2.4%	0.0%	9.5%	2.4%	14.3%	7.1%	2.4%	4.8%	2.4%	11.9%	31.0%	7.1%	0.0%	0.0%	100.0%
		% within sector	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	1.5%	0.0%	2.9%	2.8%	12.2%	3.3%	0.5%	2.7%	0.7%	1.6%	6.5%	14.3%	0.0%	0.0%	2.6%
		% of Total	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.2%	0.1%	0.4%	0.2%	0.1%	0.1%	0.1%	0.3%	0.8%	0.2%	0.0%	0.0%	2.6%
	Total	Count	111	6	16	37	11	17	36	8	3	65	23	139	36	49	90	206	73	134	313	200	21	17	5	1616
		Expected Count	111.0	6.0	16.0	37.0	11.0	17.0	36.0	8.0	3.0	65.0	23.0	139.0	36.0	49.0	90.0	206.0	73.0	134.0	313.0	200.0	21.0	17.0	5.0	1616.0
		% within region	6.9%	0.4%	1.0%	2.3%	0.7%	1.1%	2.2%	0.5%	0.2%	4.0%	1.4%	8.6%	2.2%	3.0%	5.6%	12.7%	4.5%	8.3%	19.4%	12.4%	1.3%	1.1%	0.3%	100.0%
		% within sector	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	6.9%	0.4%	1.0%	2.3%	0.7%	1.1%	2.2%	0.5%	0.2%	4.0%	1.4%	8.6%	2.2%	3.0%	5.6%	12.7%	4.5%	8.3%	19.4%	12.4%	1.3%	1.1%	0.3%	100.0%

References

1. Cho, C.; Park, S.Y.; Son, J.K.; Lee, S. R&D support services for small and medium-sized enterprises: The different perspectives of clients and service providers, and the roles of intermediaries. *Sci. Public Policy* **2016**, *43*, 859–871.
2. Cho, C.; Park, S.Y.; Son, J.K.; Lee, S. Comparative analysis of R&D-based innovation capabilities in SMEs to design innovation policy. *Sci. Public Policy* **2017**, *44*, 403–416.
3. Radas, S.; Božić, L. The antecedents of SME innovativeness in an emerging transition economy. *Technovation* **2009**, *29*, 438–450. [CrossRef]
4. Zhang, Y.; Khan, U.; Lee, S.; Salik, M. The Influence of Management Innovation and Technological Innovation on Organization Performance. A Mediating Role of Sustainability. *Sustainability* **2019**, *11*, 495. [CrossRef]
5. Michelino, F.; Cammarano, A.; Celone, A.; Caputo, M. The Linkage between Sustainability and Innovation Performance in IT Hardware Sector. *Sustainability* **2019**, *11*, 4275. [CrossRef]
6. Wehnert, P.; Kollwitz, C.; Daiberl, C.; Dinter, B.; Beckmann, M. Capturing the Bigger Picture? Applying Text Analytics to Foster Open Innovation Processes for Sustainability-Oriented Innovation. *Sustainability* **2018**, *10*, 3710. [CrossRef]
7. Shin, J.; Kim, C.; Yang, H. The Effect of Sustainability as Innovation Objectives on Innovation Efficiency. *Sustainability* **2018**, *10*, 1966. [CrossRef]
8. Bessant, J.; Lamming, R.; Noke, H.; Phillips, W. Managing innovation beyond the steady state. *Technovation* **2005**, *25*, 1366–1376. [CrossRef]
9. Hall, L.A.; Bagchi-Sen, S. An analysis of firm-level innovation strategies in the US biotechnology industry. *Technovation* **2007**, *27*, 4–14. [CrossRef]
10. Kapsali, M. How to implement innovation policies through projects successfully. *Technovation* **2011**, *31*, 615–626. [CrossRef]
11. Hobday, M.; Boddington, A.; Grantham, A. Policies for design and policies for innovation: Contrasting perspectives and remaining challenges. *Technovation* **2012**, *32*, 272–281. [CrossRef]
12. Samara, E.; Georgiadis, P.; Bakouros, I. The impact of innovation policies on the performance of national innovation systems: A system dynamics analysis. *Technovation* **2012**, *32*, 624–638. [CrossRef]
13. Aubert, B.A.; Kishore, R.; Iriyama, A. Exploring and managing the "innovation through outsourcing" paradox. *J. Strateg. Inf. Syst.* **2015**, *24*, 255–269. [CrossRef]
14. Soetanto, D.; Jack, S. The impact of university-based incubation support on the innovation strategy of academic spin-offs. *Technovation* **2016**, *50*, 25–40. [CrossRef]
15. Curnow, R.C.; Moring, G.G. 'Project sappho': A study in industrial innovation. *Futures* **1968**, *1*, 82–90. [CrossRef]
16. Rothwell, R.; Freeman, C.; Horlsey, A.; Jervis, V.T.P.; Robertson, A.B.; Townsend, J. SAPPHO updated-project SAPPHO phase II. *Res. Policy* **1974**, *3*, 258–291. [CrossRef]
17. Freeman, C.; Soete, L. Success and Failure in Industrial Innovation. In *The Economics of Industrial Innovation*, 3rd ed.; MIT Press: Boston, MA, USA, 1997; pp. 197–226.
18. Dziallas, M.; Blind, K. Innovation indicators throughout the innovation process: An extensive literature analysis. *Technovation* **2019**, *80*, 3–29. [CrossRef]
19. Becheikh, N.; Landry, R.; Amara, N. Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993–2003. *Technovation* **2006**, *26*, 644–664. [CrossRef]
20. Rothwell, R. Successful industrial innovation: Critical factors for the 1990s. *R D Manag.* **1992**, *22*, 221–240. [CrossRef]
21. Coombs, R.; Narandren, P.; Richards, A. A literature-based innovation output indicator. *Res. Policy* **1996**, *25*, 403–413. [CrossRef]
22. Souitaris, V. External communication determinants of innovation in the context of a newly industrialised country: A comparison of objective and perceptual results from Greece. *Technovation* **2001**, *21*, 25–34. [CrossRef]
23. Wolfe, R.A. Organizational innovation: Review, critique and suggested research directions. *J. Manag. Stud.* **1994**, *31*, 405–431. [CrossRef]
24. Asheim, B.T.; Isaksen, A. Location, agglomeration and innovation: Towards regional innovation systems in Norway? *Eur. Plan. Stud.* **1997**, *5*, 299–330. [CrossRef]

25. Michie, J. Introduction. The Internationalisation of the Innovation Process. *Int. J. Econ. Bus.* **1998**, *5*, 261–277. [CrossRef]
26. Amitrano, C.C.; Tregua, M.; Russo Spena, T.; Bifulco, F. On Technology in Innovation Systems and Innovation-Ecosystem Perspectives: A Cross-Linking Analysis. *Sustainability* **2018**, *10*, 3744. [CrossRef]
27. Wang, C.-H.; Chin, Y.-C.; Tzeng, G.-H. Mining the R&D innovation performance processes for high-tech firms based on rough set theory. *Technovation* **2010**, *30*, 447–458.
28. Bastı, E.; Kuzey, C.; Delen, D. Analyzing initial public offerings' short-term performance using decision trees and SVMs. *Decis. Support Syst.* **2015**, *73*, 15–27. [CrossRef]
29. Evangelista, R.; Perani, G.; Rapiti, F.; Archibugi, D. Nature and impact of innovation in manufacturing industry: Some evidence from the Italian innovation survey. *Res. Policy* **1997**, *26*, 521–536. [CrossRef]
30. Roberts, E.B. Managing Invention and Innovation. *Res. Technol. Manag.* **2007**, *50*, 35–54. [CrossRef]
31. Dewangan, V.; Godse, M. Towards a holistic enterprise innovation performance measurement system. *Technovation* **2014**, *34*, 536–545. [CrossRef]
32. Freeman, C.; Soete, L. Developing science, technology and innovation indicators: What we can learn from the past. *Res. Policy* **2009**, *38*, 583–589. [CrossRef]
33. Evanschitzky, H.; Eisend, M.; Calantone, R.J.; Jiang, Y. Success factors of product innovation: An updated meta-analysis. *J. Prod. Innov. Manag.* **2012**, *29*, 21–37. [CrossRef]
34. Archibugi, D.; Planta, M. Measuring technological change through patents and innovation surveys. *Technovation* **1996**, *16*, 451–519. [CrossRef]
35. Adams, R.; Bessant, J.; Phelps, R. Innovation management measurement: A review. *Int. J. Manag. Rev.* **2006**, *8*, 21–47. [CrossRef]
36. Cruz-Cázares, C.; Bayona-Sáez, C.; García-Marco, T. You can't manage right what you can't measure well: Technological innovation efficiency. *Res. Policy* **2013**, *42*, 1239–1250. [CrossRef]
37. Dodgson, M.; Hinze, S. Indicators used to measure the innovation process: Defects and possible remedies. *Res. Eval.* **2000**, *9*, 101–114. [CrossRef]
38. OECD. *Oslo Manual: The Measurement of Scientific and Technological Activities: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, 3rd ed.; OECD: Paris, France, 2005; p. 46.
39. Kalantaridis, C. Processes of innovation among manufacturing SMEs: The experience of Bedfordshire. *Entrep. Reg. Dev.* **1999**, *11*, 57–78. [CrossRef]
40. Kam, W.P.; Kiese, M.; Singh, A.; Wong, F. The pattern of innovation in Singapore's manufacturing sector. *Singap. Manag. Rev.* **2003**, *25*, 1–34.
41. Quadros, R.; Furtado, A.; Bernardes, R.; Franco, E. Technological innovation in Brazilian industry: An assessment based on the São Paulo innovation survey. *Technol. Forecast. Soc. Chang.* **2001**, *67*, 203–219. [CrossRef]
42. Uzun, A. Technological innovation activities in Turkey: The case of manufacturing industry, 1995–1997. *Technovation* **2001**, *21*, 189–196. [CrossRef]
43. Baptista, R.; Swann, P. Do firms in clusters innovate more? *Res. Policy* **1998**, *27*, 525–540. [CrossRef]
44. Michie, J.; Sheehan, M. Labour market deregulation,'flexibility'and innovation. *Camb. J. Econ.* **2003**, *27*, 123–143. [CrossRef]
45. Zahra, S.A. Environment, corporate entrepreneurship, and financial performance: A taxonomic approach. *J. Bus. Ventur.* **1993**, *8*, 319–340. [CrossRef]
46. Blundell, R.; Griffith, R.; Van Reenen, J. Market share, market value and innovation in a panel of British manufacturing firms. *Rev. Econ. Stud.* **1999**, *66*, 529–554. [CrossRef]
47. Koeller, C.T. Innovation, market structure and firm size: A simultaneous equations model. *Manag. Decis. Econ.* **1995**, *16*, 259–269. [CrossRef]
48. Nielsen, A.O. Patenting, R&D and market structure: Manufacturing firms in Denmark. *Technol. Forecast. Soc. Chang.* **2001**, *66*, 47–58.
49. Smolny, W. Determinants of innovation behaviour and investment estimates for West-German manufacturing firms. *Econ. Innov. New Technol.* **2003**, *12*, 449–463. [CrossRef]
50. Debackere, K.; Clarysse, B.; Rappa, M.A. Dismantling the ivory tower: The influence of networks on innovative output in emerging technologies. *Technol. Forecast. Soc. Chang.* **1996**, *53*, 139–154. [CrossRef]
51. Beneito, P. Choosing among alternative technological strategies: An empirical analysis of formal sources of innovation. *Res. Policy* **2003**, *32*, 693–713. [CrossRef]

52. Love, J.H.; Ashcroft, B. Market versus corporate structure in plant-level innovation performance. *Small Bus. Econ.* **1999**, *13*, 97–109. [CrossRef]
53. González-Blanco, J.; Coca-Pérez, J.; Guisado-González, M. The Contribution of Technological and Non-Technological Innovation to Environmental Performance. An Analysis with a Complementary Approach. *Sustainability* **2018**, *10*, 4014. [CrossRef]
54. Brouwer, E.; Budil-Nadvornikova, H.; Kleinknecht, A. Are urban agglomerations a better breeding place for product innovation? An analysis of new product announcements. *Reg. Stud.* **2010**, *33*, 541–549. [CrossRef]
55. Kaufmann, A.; Tödtling, F. Science–industry interaction in the process of innovation: The importance of boundary-crossing between systems. *Res. Policy* **2001**, *30*, 791–804. [CrossRef]
56. Wang, L. A study on innovation performance measurement of college students' venture enterprise based on SFA model. *J. Comput.* **2012**, *7*, 1974–1981. [CrossRef]
57. De Fuentes, C.; Dutrenit, G.; Santiago, F.; Gras, N. Determinants of innovation and productivity in the service sector in Mexico. *Emerg. Mark. Financ. Trade* **2015**, *51*, 578–592. [CrossRef]
58. Kamasak, R. Determinants of innovation performance: A resource-based study. *Procedia-Soc. Behav. Sci.* **2015**, *195*, 1330–1337. [CrossRef]
59. Frey, M.; Iraldo, F.; Testa, F. The determinants of innovation in green supply chains: Evidence from an Italian sectoral study. *R D Manag.* **2013**, *43*, 352–364. [CrossRef]
60. MacPherson, A.D. Academic-industry linkages and small firm innovation: Evidence from the scientific instruments sector. *Entrep. Reg. Dev.* **1998**, *10*, 261–276. [CrossRef]
61. Romijn, H.; Albaladejo, M. Determinants of innovation capability in small electronics and software firms in southeast England. *Res. Policy* **2002**, *31*, 1053–1067. [CrossRef]
62. Keizer, J.A.; Dijkstra, L.; Halman, J.I. Explaining innovative efforts of SMEs. An exploratory survey among SMEs in the mechanical and electrical engineering sector in The Netherlands. *Technovation* **2002**, *22*, 1–13. [CrossRef]
63. Trąpczyński, P.; Puślecki, Ł.; Staszków, M. Determinants of Innovation Cooperation Performance: What Do We Know and What Should We Know? *Sustainability* **2018**, *10*, 4517. [CrossRef]
64. Cooke, P.; Uranga, M.G.; Etxebarria, G. Regional innovation systems: Institutional and organisational dimensions. *Res. Policy* **1997**, *26*, 475–491. [CrossRef]
65. Storper, M.; Harrison, B. Flexibility, hierarchy and regional development: The changing structure of industrial production systems and their forms of governance in the 1990s. *Res. Policy* **1991**, *20*, 407–422. [CrossRef]
66. Dicken, P.; Forsgren, M.; Malmberg, A. The local embeddness of transnational corporations. In *Globalization, Institutions, and Regional Development in Europe*; Amin, A., Thrift, N., Eds.; Oxford University Press: New York, NY, USA, 1995; pp. 23–45.
67. Landry, R.; Amara, N.; Lamari, M. Does social capital determine innovation? To what extent? *Technol. Forecast. Soc. Chang.* **2002**, *69*, 681–701. [CrossRef]
68. Ritter, T.; Gemünden, H.G. Network competence: Its impact on innovation success and its antecedents. *J. Bus. Res.* **2003**, *56*, 745–755. [CrossRef]
69. Souitaris, V. Technological trajectories as moderators of firm-level determinants of innovation. *Res. Policy* **2002**, *31*, 877–898. [CrossRef]
70. Beugelsdijk, S.; Cornet, M. 'A far friend is worth more than a good neighbour': Proximity and innovation in a small country. *J. Manag. Gov.* **2002**, *6*, 169–188. [CrossRef]
71. Coombs, R.; Tomlinson, M. Patterns in UK company innovation styles: New evidence from the CBI innovation trends survey. *Technol. Anal. Strateg. Manag.* **1998**, *10*, 295–310. [CrossRef]
72. Love, J.H.; Roper, S. Location and network effects on innovation success: Evidence for UK, German and Irish manufacturing plants. *Res. Policy* **2001**, *30*, 643–661. [CrossRef]
73. Avermaete, T.; Viaene, J.; Morgan, E.J.; Pitts, E.; Crawford, N.; Mahon, D. Determinants of product and process innovation in small food manufacturing firms. *Trends Food Sci. Technol.* **2004**, *15*, 474–483. [CrossRef]
74. Åstebro, T.; Michela, J.L. Predictors of the survival of innovations. *J. Prod. Innov. Manag.* **2005**, *22*, 322–335. [CrossRef]
75. Bullinger, H.-J.; Bannert, M.; Brunswicker, S. Managing innovation capability in SMEs. The Fraunhofer three-stage approach. *Tech Monit.* **2007**, *24*, 17–27.
76. Freeman, C. The economics of technical change. *Camb. J. Econ.* **1994**, *18*, 463–514. [CrossRef]

77. Griffin, A.; Page, A.L. An interim report on measuring product development success and failure. *J. Prod. Innov. Manag.* **1993**, *10*, 291–308. [CrossRef]
78. Hollenstein, H. Innovation modes in the Swiss service sector: A cluster analysis based on firm-level data. *Res. Policy* **2003**, *32*, 845–863. [CrossRef]
79. Thongsri, N.; Chang, A. Interactions Among Factors Influencing Product Innovation and Innovation Behaviour: Market Orientation, Managerial Ties, and Government Support. *Sustainability* **2019**, *11*, 2793. [CrossRef]
80. Darroch, J.; McNaughton, R. Examining the link between knowledge management practices and types of innovation. *J. Intell. Cap.* **2002**, *3*, 210–222. [CrossRef]
81. Koberg, C.S.; Uhlenbruck, N.; Sarason, Y. Facilitators of organizational innovation: The role of life-cycle stage. *J. Bus. Ventur.* **1996**, *11*, 133–149. [CrossRef]
82. Koschatzky, K.; Bross, U.; Stanovnik, P. Development and innovation potential in the Slovene manufacturing industry: Analysis of an industrial innovation survey. *Technovation* **2001**, *21*, 311–324. [CrossRef]
83. Koeller, C.T. Union membership, market structure, and the innovation output of large and small firms. *J. Labor Res.* **1996**, *17*, 683–699. [CrossRef]
84. Baldwin, J.R.; Johnson, J. Business strategies in more-and less-innovative firms in Canada. *Res. Policy* **1996**, *25*, 785–804. [CrossRef]
85. Bughin, J.; Jacques, J.-M. Managerial efficiency and the Schumpeterian link between size, market structure and innovation revisited. *Res. Policy* **1994**, *23*, 653–659. [CrossRef]
86. Damanpour, F. Organizational size and innovation. *Organ. Stud.* **1992**, *13*, 375–402. [CrossRef]
87. Majumdar, S.K. The determinants of investment in new technology: An examination of alternative hypotheses. *Technol. Forecast. Soc. Chang.* **1995**, *50*, 235–247. [CrossRef]
88. Tsai, W. Knowledge transfer in intraorganizational networks: Effects of network position and absorptive capacity on business unit innovation and performance. *Acad. Manag. J.* **2001**, *44*, 996–1004.
89. González-Benito, Ó.; Muñoz-Gallego, P.A.; García-Zamora, E. Entrepreneurship and market orientation as determinants of innovation: The role of business size. *Int. J. Innov. Manag.* **2015**, *19*, 1550035. [CrossRef]
90. Aldieri, L.; Vinci, C. Firm Size and Sustainable Innovation: A Theoretical and Empirical Analysis. *Sustainability* **2019**, *11*, 2775. [CrossRef]
91. Andries, P.; Stephan, U. Environmental Innovation and Firm Performance: How Firm Size and Motives Matter. *Sustainability* **2019**, *11*, 3585. [CrossRef]
92. Bertschek, I.; Entorf, H. On nonparametric estimation of the Schumpeterian link between innovation and firm size: Evidence from Belgium, France, and Germany. *Empir. Econ.* **1996**, *21*, 401–426. [CrossRef]
93. Schumpeter, J.A. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*; Harvard University Press: Cambridge, MA, USA, 1934.
94. Schumpeter, J.A. *Socialism, Capitalism and Democracy*; Harper and Brothers: New York, NY, USA, 1942.
95. Sørensen, J.B.; Stuart, T.E. Aging, obsolescence, and organizational innovation. *Adm. Sci. Q.* **2000**, *45*, 81–112. [CrossRef]
96. Krasniqi, B.A.; Kutllovci, E.A. Determinants of innovation: Evidence from Czech Republic, Poland and Hungary. *Int. J. Technoentrep.* **2008**, *1*, 378–404. [CrossRef]
97. Freel, M. External linkages and product innovation in small manufacturing firms. *Entrep. Reg. Dev.* **2000**, *12*, 245–266. [CrossRef]
98. Love, J.H.; Ashcroft, B.; Dunlop, S. Corporate structure, ownership and the likelihood of innovation. *Appl. Econ.* **1996**, *28*, 737–746. [CrossRef]
99. Martinez-Ros, E. Explaining the decisions to carry out product and process innovations: The Spanish case. *J. High Technol. Manag. Res.* **1999**, *10*, 223–242. [CrossRef]
100. Bishop, P.; Wiseman, N. External ownership and innovation in the United Kingdom. *Appl. Econ.* **1999**, *31*, 443–450. [CrossRef]
101. Propris, L.D. Innovation and inter-firm co-operation: The case of the West Midlands. *Econ. Innov. New Technol.* **2000**, *9*, 421–446. [CrossRef]
102. Song, C.; Oh, W. Determinants of innovation in energy intensive industry and implications for energy policy. *Energy Policy* **2015**, *81*, 122–130. [CrossRef]

103. Arvanitis, S.; Sydow, N.; Woerter, M. Is there any impact of university–industry knowledge transfer on innovation and productivity? An empirical analysis based on Swiss firm data. *Rev. Ind. Organ.* **2008**, *32*, 77–94. [CrossRef]
104. Jacobsson, S.; Oskarsson, C.; Philipson, J. Indicators of technological activities-comparing educational, patent and R&D statistics in the case of Sweden. *Res. Policy* **1996**, *25*, 573–585.
105. Flor, M.L.; Oltra, M.J. Identification of innovating firms through technological innovation indicators: An application to the Spanish ceramic tile industry. *Res. Policy* **2004**, *33*, 323–336. [CrossRef]
106. Sosnowski, J. Precipitating innovations by academia and industry feedback. *Procedia-Soc. Behav. Sci.* **2014**, *109*, 113–119. [CrossRef]
107. Kleinknecht, A. Why do we need new innovation output indicators? An introduction. In *New Concepts in Innovation Output Measurement*; Kleinknecht, A., Bain, D., Eds.; Palgrave Macmillan: London, UK, 1993; pp. 1–9.
108. Cavdar, S.C.; Aydin, A.D. An empirical analysis about technological development and innovation indicators. *Procedia-Soc. Behav. Sci.* **2015**, *195*, 1486–1495. [CrossRef]
109. Raymond, L.; St-Pierre, J. R&D as a determinant of innovation in manufacturing SMEs: An attempt at empirical clarification. *Technovation* **2010**, *30*, 48–56.
110. Sternberg, R.; Arndt, O. The firm or the region: What determines the innovation behavior of European firms? *Econ. Geogr.* **2001**, *77*, 364–382. [CrossRef]
111. Pekovic, S.; Lojpur, A.; Pejic-Bach, M. Determinants of innovation intensity in developed and in developing economies: The case of France and Croatia. *Int. J. Innov. Manag.* **2015**, *19*, 1550049. [CrossRef]
112. Cohen, W.M.; Levinthal, D.A. Innovation and learning: The two faces of R&D. *Econ. J.* **1989**, *99*, 569–596.
113. Graves, S.B.; Langowitz, N.S. R&D productivity: A global multi-industry comparison. *Technol. Forecast. Soc. Chang.* **1996**, *53*, 125–137.
114. Kim, C.Y.; Lim, M.S.; Yoo, J.W. Ambidexterity in External Knowledge Search Strategies and Innovation Performance: Mediating Role of Balanced Innovation and Moderating Role of Absorptive Capacity. *Sustainability* **2019**, *11*, 5111. [CrossRef]
115. Loredo, E.; Mielgo, N.; Pineiro-Villaverde, G.; García-Álvarez, M.T. Utilities: Innovation and Sustainability. *Sustainability* **2019**, *11*, 1085. [CrossRef]
116. Hastuti, W.; Mardani, A.; Streimikiene, D.; Sharifara, A.; Cavallaro, F. The Role of Process Innovation between Firm-Specific Capabilities and Sustainable Innovation in SMEs: Empirical Evidence from Indonesia. *Sustainability* **2018**, *10*, 2244. [CrossRef]
117. Pisano, G.P.; Shan, W.; Teece, D.J. Joint ventures and collaboration in the biotechnology industry. In *International Collaborative Ventures in US Manufacturing*; Mowery, D., Ed.; Ballinger Publishing Company: Cambridge, MA, USA, 1988.
118. Mohnen, P.; Hoareau, C. What type of enterprise forges close links with universities and government labs? Evidence from CIS 2. *Manag. Decis. Econ.* **2003**, *24*, 133–145. [CrossRef]
119. Miotti, L.; Sachwald, F. Co-operative R&D: Why and with whom?: An integrated framework of analysis. *Res. Policy* **2003**, *32*, 1481–1499.
120. Becker, W.; Dietz, J. R&D cooperation and innovation activities of firms-evidence for the German manufacturing industry. *Res. Policy* **2004**, *33*, 209–223.
121. Sampson, R.C. R&D alliances and firm performance: The impact of technological diversity and alliance organization on innovation. *Acad. Manag. J.* **2007**, *50*, 364–386.
122. Abramovsky, L.; Kremp, E.; López, A.; Schmidt, T.; Simpson, H. Understanding co-operative innovative activity: Evidence from four European countries. *Econ. Innov. New Technol.* **2009**, *18*, 243–265. [CrossRef]
123. Freel, M.S.; Harrison, R.T. Innovation and cooperation in the small firm sector: Evidence from 'Northern Britain'. *Reg. Stud.* **2006**, *40*, 289–305. [CrossRef]
124. Harrigan, K.R. Joint ventures and competitive strategy. *Strateg. Manag. J.* **1988**, *9*, 141–158. [CrossRef]
125. Kogut, B. Joint ventures: Theoretical and empirical perspectives. *Strateg. Manag. J.* **1988**, *9*, 319–332. [CrossRef]
126. Kesteloot, K.; Veugelers, R. Stable R&D cooperation with spillovers. *J. Econ. Manag. Strategy* **1995**, *4*, 651–672.
127. Barkema, H.G.; Vermeulen, F. What differences in the cultural backgrounds of partners are detrimental for international joint ventures? *J. Int. Bus. Stud.* **1997**, *28*, 845–864. [CrossRef]

128. Mora-Valentin, E.M.; Montoro-Sanchez, A.; Guerras-Martin, L.A. Determining factors in the success of R&D cooperative agreements between firms and research organizations. *Res. Policy* **2004**, *33*, 17–40.
129. Lhuillery, S.; Pfister, E. R&D cooperation and failures in innovation projects: Empirical evidence from French CIS data. *Res. Policy* **2009**, *38*, 45–57.
130. Mata, J.; Woerter, M. Risky innovation: The impact of internal and external R&D strategies upon the distribution of returns. *Res. Policy* **2013**, *42*, 495–501.
131. Ozman, M. Inter-firm networks and innovation: A survey of literature. *Econ. Innov. New Technol.* **2009**, *18*, 39–67. [CrossRef]
132. Oliver, C. Determinants of interorganizational relationships: Integration and future directions. *Acad. Manag. Rev.* **1990**, *15*, 241–265. [CrossRef]
133. Okamuro, H. Determinants of successful R&D cooperation in Japanese small businesses: The impact of organizational and contractual characteristics. *Res. Policy* **2007**, *36*, 1529–1544.
134. Cassiman, B.; Veugelers, R. In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Manag. Sci.* **2006**, *52*, 68–82.
135. Beneito, P. The innovative performance of in-house and contracted R&D in terms of patents and utility models. *Res. Policy* **2006**, *35*, 502–517.
136. Lokshin, B.; Belderbos, R.; Carree, M. The productivity effects of internal and external R&D: Evidence from a dynamic panel data model. *Oxf. Bull. Econ. Stat.* **2008**, *70*, 399–413.
137. Hagedoorn, J.; Wang, N. Is there complementarity or substitutability between internal and external R&D strategies? *Res. Policy* **2012**, *41*, 1072–1083.
138. Hou, J.; Chen, J.; Song, H.; Wang, G. Are Non-R&D Innovation Activities Actually Effective for Innovation Sustainability? Empirical Study from Chinese High-Tech Industry. *Sustainability* **2018**, *11*, 174.
139. Blind, K.; Edler, J.; Frietsch, R.; Schmoch, U. Motives to patent: Empirical evidence from Germany. *Res. Policy* **2006**, *35*, 655–672. [CrossRef]
140. Kleinknecht, A.; Van Montfort, K.; Brouwer, E. The non-trivial choice between innovation indicators. *Econ. Innov. New Technol.* **2002**, *11*, 109–121. [CrossRef]
141. Hagedoorn, J.; Cloodt, M. Measuring innovative performance: Is there an advantage in using multiple indicators? *Res. Policy* **2003**, *32*, 1365–1379. [CrossRef]
142. Acs, Z.J.; Audretsch, D.B. Patents as a measure of innovative activity. *Kyklos* **1989**, *42*, 171–180. [CrossRef]
143. Cooper, R.G.; Kleinschmidt, E.J. New-product success in the chemical industry. *Ind. Mark. Manag.* **1993**, *22*, 85–99. [CrossRef]
144. Chiesa, V.; Frattini, F.; Lazzarotti, V.; Manzini, R. Performance measurement in R&D: Exploring the interplay between measurement objectives, dimensions of performance and contextual factors. *R D Manag.* **2009**, *39*, 487–519.
145. Tohidi, H.; Jabbari, M.M. Providing a framework for measuring innovation within companies. *Procedia Technol.* **2012**, *1*, 583–585. [CrossRef]
146. Edison, H.; bin Ali, N.; Torkar, R. Towards innovation measurement in the software industry. *J. Syst. Softw.* **2013**, *86*, 1390–1407. [CrossRef]
147. Ivanov, C.-I.; Avasilcăi, S. Performance measurement models: An analysis for measuring innovation processes performance. *Procedia-Soc. Behav. Sci.* **2014**, *124*, 397–404. [CrossRef]
148. Griffin, A.; Page, A.L. PDMA success measurement project: Recommended measures for product development success and failure. *J. Prod. Innov. Manag.* **1996**, *13*, 478–496. [CrossRef]
149. Kaplan, R.S.; Norton, D.P. The balanced scorecard: Measures that drive performance. *Harv. Bus. Rev.* **1992**, *70*, 71–79. [PubMed]
150. Caird, S.; Hallett, S.; Potter, S. The Open2-Innova8ion Tool—A software tool for rating organisational innovation performance. *Technovation* **2013**, *33*, 381–385. [CrossRef]
151. Chiesa, V.; Frattini, F.; Lazzarotti, V.; Manzini, R. An exploratory study on R&D performance measurement practices: A survey of Italian R&D-intensive firms. *Int. J. Innov. Manag.* **2009**, *13*, 65–104.
152. Kim, S.-K. Explicit design of innovation performance metrics by using analytic hierarchy process expansion. *Int. J. Math. Math. Sci.* **2014**, *2014*, 125950. [CrossRef]
153. Seo, H.; Chung, Y.; Yoon, H. R&D cooperation and unintended innovation performance: Role of appropriability regimes and sectoral characteristics. *Technovation* **2017**, *66*, 28–42.

154. Eom, B.-Y.; Lee, K. Determinants of industry–academy linkages and, their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. *Res. Policy* **2010**, *39*, 625–639. [CrossRef]
155. Kang, K.H.; Kang, J. Do external knowledge sourcing modes matter for service innovation? Empirical evidence from South Korean service firms. *J. Prod. Innov. Manag.* **2014**, *31*, 176–191. [CrossRef]
156. Chun, H.; Mun, S.-B. Determinants of R&D cooperation in small and medium-sized enterprises. *Small Bus. Econ.* **2012**, *39*, 419–436.
157. Seo, H.; Chung, Y.; Chun, D.; Woo, C. Value capture mechanism: R&D productivity comparison of SMEs. *Manag. Decis.* **2015**, *53*, 318–337.
158. Bozkir, A.S.; Sezer, E.A. Predicting food demand in food courts by decision tree approaches. *Procedia Comput. Sci.* **2011**, *3*, 759–763. [CrossRef]
159. Delen, D.; Kuzey, C.; Uyar, A. Measuring firm performance using financial ratios: A decision tree approach. *Expert Syst. Appl.* **2013**, *40*, 3970–3983. [CrossRef]
160. Breiman, L. Statistical modeling: The two cultures. *Stat. Sci.* **2001**, *16*, 199–231. [CrossRef]
161. Horner, S.B.; Fireman, G.D.; Wang, E.W. The relation of student behavior, peer status, race, and gender to decisions about school discipline using CHAID decision trees and regression modeling. *J. Sch. Psychol.* **2010**, *48*, 135–161. [CrossRef] [PubMed]
162. You, Z.; Si, Y.-W.; Zhang, D.; Zeng, X.; Leung, S.C.; Li, T. A decision-making framework for precision marketing. *Expert Syst. Appl.* **2015**, *42*, 3357–3367. [CrossRef]
163. Kohavi, R. A study of cross-validation and bootstrap for accuracy estimation and model selection. In Proceedings of the 14th International Joint Conference on Artificial Intelligence (IJCAI), Montreal, QC, Canada, 20–25 August 1995; pp. 1137–1145.
164. Provost, F.; Kohavi, R. Glossary of terms. Editorial for the special issue on applications of machine learning and the knowledge discovery process. *J. Mach. Learn.* **1998**, *30*, 271–274. [CrossRef]
165. Veugelers, R.; Cassiman, B. Make and buy in innovation strategies: Evidence from Belgian manufacturing firms. *Res. Policy* **1999**, *28*, 63–80. [CrossRef]
166. Katz, R.; Allen, T.J. Investigating the Not Invented Here (NIH) syndrome: A look at the performance, tenure, and communication patterns of 50 R&D project groups. *R D Manag.* **1982**, *12*, 7–20.
167. Gopalakrishnan, S.; Bierly, P.; Kessler, E.H. A reexamination of product and process innovations using a knowledge-based view. *J. High Technol. Manag. Res.* **1999**, *1*, 147–166. [CrossRef]
168. Weber, K.M.; Schaper-Rinkel, P. European sectoral innovation foresight: Identifying emerging cross-sectoral patterns and policy issues. *Technol. Forecast. Soc. Chang.* **2017**, *115*, 240–250. [CrossRef]
169. Hansen, U.E.; Gregersen, C.; Lema, R.; Samoita, D.; Wandera, F. Technological shape and size: A disaggregated perspective on sectoral innovation systems in renewable electrification pathways. *Energy Res. Soc. Sci.* **2018**, *42*, 13–22. [CrossRef]
170. Huergo, E. The role of technological management as a source of innovation: Evidence from Spanish manufacturing firms. *Res. Policy* **2006**, *35*, 1377–1388. [CrossRef]
171. Lau, A.K.W.; Lo, W. Regional innovation system, absorptive capacity and innovation performance: An empirical study. *Technol. Forecast. Soc. Chang.* **2015**, *92*, 99–114. [CrossRef]
172. Kiuru, J.; Inkinen, T. Predicting innovative growth and demand with proximate human capital: A case study of the Helsinki metropolitan area. *Cities* **2017**, *64*, 9–17. [CrossRef]
173. Diez, J.R. Innovative networks in manufacturing: Some empirical evidence from the metropolitan area of Barcelona. *Technovation* **2000**, *20*, 139–150. [CrossRef]
174. Sable, M. The impact of the biotechnology industry on local economic development in the Boston and San Diego metropolitan areas. *Technol. Forecast. Soc. Chang.* **2007**, *74*, 36–60. [CrossRef]
175. Blind, K.; Grupp, H. Interdependencies Between the Science and Technology Infrastructure and Innovation Activities in German Regions. *Res. Policy* **1999**, *28*, 451–468. [CrossRef]
176. Chung, S. Building a national innovation system through regional innovation systems. *Technovation* **2002**, *22*, 485–491. [CrossRef]
177. Pavitt, K. Sectoral patterns of technical change: Towards a taxonomy and a theory. *Res. Policy* **1984**, *13*, 343–373. [CrossRef]
178. Castellacci, F. Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation. *Res. Policy* **2008**, *37*, 978–994. [CrossRef]

179. Malerba, F. Sectoral dynamics and structural change: Stylized facts and "system of innovation" approaches. In *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe*; Malerba, F., Ed.; Cambridge University Press: Cambridge, UK, 2004; pp. 42–70.
180. Malerba, F. Sectoral systems of innovation and production. *Res. Policy* **2002**, *31*, 247–264. [CrossRef]
181. Breschi, S.; Malerba, F.; Orsenigo, L. Technological Regimes and Schumpeterian Patterns of Innovation. *Econ. J.* **2000**, *110*, 388–410. [CrossRef]
182. Cooke, P. Regional innovation systems: Origin of the species. *Int. J. Technol. Learn. Innov. Dev.* **2008**, *1*, 393–409. [CrossRef]
183. Camagni, R.P. The concept of innovative milieu and its relevance for public policies in European lagging regions. *Pap. Reg. Sci.* **1995**, *74*, 317–340. [CrossRef]
184. Asheim, B.; Oughton, C.; Lawton Smith, H. Regional Innovation Systems: Theory, Empirics and Policy. *Reg. Stud.* **2011**, *45*, 875–891. [CrossRef]