The Dynamic Relationships between Technology, Business Model and Market in Autonomous Car and Intelligent Robot Industries

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Abstract

This study develops a new dynamic innovation model based on three elements — Technology–Business Model(BM)–Market — for characterizing the knowledge-based economy and open innovation. It identifies the relationship dynamics between technology, business model, and market through analysis of in-depth interviews with Korean firms that belong to the autonomous car and intelligent robot industries, the analysis of technologies worldwide as well as business model patent applications of both industries, and the analysis of the reference and citation networks among these patents.

It develops the Casual Loop Model and System Dynamics Model based on the dynamic relationships between Technology-BM-Market. In developing these models, the regulations, the standards, and the leading firm effects were considered. The Technology–BM–Market System Dynamics Model was validated through analysis of interviews with each firm, analysis of group meetings with experts from each industry, and analysis of technologies, and business model patent citations statistics and networks.

It identifies the importance of the business model in addition to 3 conditions identified in this research, the leading effect, standardization, and regulation. The research suggests new market increase strategies and policies which are based on Technology-BM-Market model in technology intensive industries such as autonomous car and intelligent robot industries.

Keywords: Technology–BM–Market System Dynamics Model, Open Innovation, Autonomous Car, Intelligent Robot.

1. Research questions

1.1. Research questions

Many IT-related industries are emerging in the second information revolution based on mobile information technology, sometimes called the third industrial revolution (Rifkin, 2011, p. 14). In particular, IT-based autonomous vehicles and intelligent robots are the most prominent areas of the newly emerging sector. In these newly emerging industries, the relationship between technology and market as well as their combination are expected to become the key drivers for establishing future corporate strategies and industrial policies.

This study attempts to obtain answers to the following research questions with respect to the autonomous vehicle and intelligent robot areas: 1.) What are the relationships between technologies and markets? 2.) How are technologies and markets combined? Additional questions to be answered include: 1.) During the growth process of the two industries, what is the driving force of the growth, technology or market, and business model and what are the reasons? 2.) Where are the bottlenecks of growth in the growth process of the two industries and what are the reasons? 3.) As the determining factor for the growth process of the two industries, where is the delay phenomenon taking place and how? 4.) How is the growth process being developed in the short, medium, and long term?

1.2. Scope and methods of research

The technology sectors that serve as the research subject of this study are the autonomous vehicle (or car) and intelligent (autonomous) robot industries. The two industries have not yet fully matured, and so come under the category of emerging industry or growing industry. At present, there are no definitions of the two industries that the main industry, academic world, and research communities can agree on. Wikipedia (2014) notes that the autonomous car, also known as a driverless car, self-driving car, or robot car, is an autonomous vehicle capable of fulfilling the human transportation capabilities of a traditional car (Göhring, Latotzky, Wang, & Rojas, 2013; Milanés, Llorca, Vinagre, González, & Sotelo, 2010). Also according to the Wikipedia (2014), an autonomous (intelligent) robot performs behaviors or tasks with a high degree of autonomy, and is particularly desirable in fields such as space exploration, floor cleaning, lawn mowing, and waste water treatment (Hsu & Fu, 2000; Schöner, Dose, & Engels, 1995).

As a research method, this study first establishes the Dynamic Innovation Model, which is used in analyzing the dynamic technology-innovation process of specific industries through the analysis of research papers. This is used to establish a conceptual model of the relationships of the technology and the market of the two industries.

Second, this study randomly selected five firms, each from Korea's autonomous car and intelligent robot industries. An examination was conducted of the manufacturing of their representative mass-produced products (products that are being manufactured now or will be in the not so distant future) and the relationships between relevant technology, market, and business model. This was accomplished through an analysis of interviews in both industries, analysis of media materials, and analysis of Web sites. The interviews were conducted for 1 – 1.5 hours using the half-structured questionnaire, with firms in Taegu and Seoul between February and March, 2014. The findings of the interviews are posted on the Google blog, Korea Open Innovation Center <Appendix 1>.

Third, based on the causal loop diagram's key variables, and the relationships of the two industries that were revealed through the interview results, the final causal loop diagrams and the System Dynamics Models of the two industries were set by brainstorming with focus groups. These groups included experts, researchers, and developers from relevant industries, and many others. The SD model was validated by analysis of the technologies of major countries in line with the two industries (the U.S., Europe, International, Japan, France, Germany, Canada, China, and Korea) and business model patent applications. The validation of the two industries' causal model and System Dynamics Model was secured by analyzing the number of technology patents and business model patents pertaining to G06Q, and search results using the names of the two industries as keywords, namely, autonomous vehicle (or car) and intelligent (autonomous) robot.

Lastly, using the changes in the values of the key determining factors that were revealed during the interviews and focus group meetings with experts, the future market changes of the two industries were simulated, after considering the proposed strategies and policy directions for firms belonging to the two industries.

2. Review of existing research and establishing the research model

2.1. Review of existing research: technology push, demand pull, and business model

Lotti and Santarelli analyzed the industry dynamics and the distribution of firm sizes, trying to assess the empirical implications of different models of industry dynamics. These included the model of passive learning, the model of active learning, and the evolutionary model (Lotti & Santarelli, 2001). In the model of industry evolution, the dynamics are driven by the process of endogenous innovations followed by subsequent embodiments in physical capital (Lach & Rob, 1996). The field of innovation studies finally came to the conclusion that both were important for the innovation and development of product (Dosi, 1988; Mowery & Rosenberg, 1979; Van den Ende & Dolfsma, 2005).

However, the field of innovation studies has gained renewed attention with the emergence of the solar industry, wind power generation industry, the electric car industry, home intelligent robot industry and many others. Such industries have not yet been able to develop their business models or mature because of market factors, but are attracting the attention of the market despite their technological immaturity.

One of the traditional theories on technological innovation is the Technology Push Theory (Nemet, 2009). The core of the science and technology push argument is that advances in scientific understanding determine the rate and direction of innovation (Nemet, 2009). The theory focuses on technology as the source of innovation, or as the motivation for innovators. Thus, this theory, as the starting point of technology innovation is an enterprise had been the main logic of the closed innovation until the 1990s during which the importance of enterprises' own technological developments were emphasized (Almirall & Casadesus-Masanell, 2010; Henry Chesbrough, 2004; Henry W Chesbrough, 2006).

Another traditional technological innovation theory is the Demand Pull Theory. The concept of the theory can be illustrated by what happened during the Middle East Energy Crisis of the 1970s: the price changes of the traditional energy sources triggered technology innovations in new energy sources, which are today's alternative energy sectors (Popp, 2001). The theory stipulates that demand steers firms to work on certain problems (N. Rosenberg, 1969). However, while the Demand Pull Theory is adequate when explaining incremental innovation, it has limitations when explaining destructive and radical innovation (Abernathy & Utterback, 1978; Dewar & Dutton, 1986).

The traditional innovation theories above have been developed into an integrated technology innovation theory that takes both technology and market into consideration (Pinch & Bijker, 1987; Williams & Edge, 1996). Recently, in addition to that integrated technology innovation theory, numerous further discussions and analyses have been appearing which also take the integration of technology and market into consideration. Such is the case with biosensors, which have been expected to play a significant analytical role in medicine, agriculture, food safety, homeland security, and environmental and industrial monitoring. The technology's commercialization has significantly lagged behind research output because of rising costs and some key technical barriers (Luong, Male, & Glennon, 2008). In other words, a significant portion of biosensor technology commercialization is being delayed by both technology and market factors.

In another example, a case study on one of Germany's biggest and most successful software development and information technology service providers revealed how market pull and technology push activities within the corporate technology and innovation management can be integrated (Brem & Voigt, 2009). That particular case demonstrated how technological innovation and the commercialization of enterprises can succeed through the integration of technology and market.

Another study (Nemet, 2009), investigated how a strong government policy that stimulates demand pull can fail if non-incremental technological changes don't accompany it. It was determined that such failure can occur for the following reasons: (1) when the rapid convergence on a single dominant design limits the market opportunity for non-incremental technical improvements; (2) when implemented policies stimulate demand, but uncertainty in their longevity dampens the incentives for inventions that were likely to take several years to pay off; and (3) as a result of declining R&D funding, weakening presidential engagement on energy, and other circumstantial reasons. In other words, even a government policy based on demand pull cannot succeed unless sufficient consideration is paid to the technology push aspect. Policies that maximize the effects of both technology and market integration are required.

Examples of integrated technology innovation cases that are determinants of eco-innovations include technology, market, firm specific factors, and regulations (Horbach, Rammer, & Rennings, 2012). In the cases of regulations, as they are materialized in the market, they can be substituted by the market. In the cases of firm-specific factors, they correspond to the integration of the technology pertaining to the manufacturing of specific products of different firms and the market.

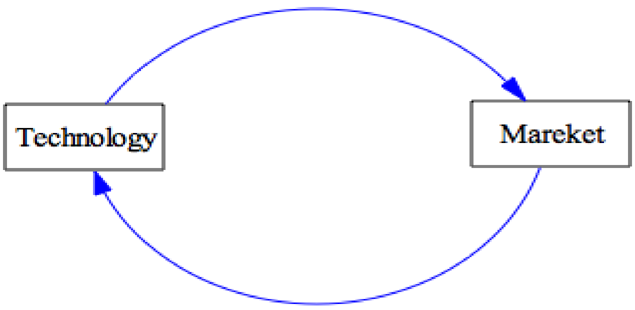


Fig 1. Technology — Market Relation in Traditional Innovation Theory

Figure 1 summarizes the integrated theory of technology push, demand pull, and technology demand. In brief, technology innovations are taking place continuously through a circulation loop in which technologies affect markets and markets again affect technologies.

However, a new theory, which proposes a business model that combines technologies and markets, suggests that business models as well as technologies and markets are emerging as the new factors in enterprise-level innovations (Henry Chesbrough, 2007). The business model provides a coherent framework that takes technological characteristics and potentials as inputs and converts them through customers and markets into economic outputs (Henry Chesbrough & Rosenbloom, 2002). The same idea or technology taken to market through two different business models will yield two different economic outcomes (Henry Chesbrough, 2010). A business model is a mediating construct between technology and economic value. It is what every company employs to perform two important functions: value creation and value capture. The role of the business model in innovation is to connect the captured value (Henry Chesbrough & Rosenbloom, 2002).

Table 1
Theories on Technology Innovation

Theory	Main Factors for Innovation	Sample Literatures
Technology Push Theory	Technology	Bush (1960)

Demand Pull Theory	Market	Rosenberg (1965, 1982) Vernon (1966)
Joining of Technology and Market for Innovation Theory	Concurrence of Technology and Market	Popp (2001) Luong et al., (2008) Brem & Voigt (2009) Nemet (2009) Horbach et al., (2012)
Business Model Theory	Business Model	Chesbrough and Rosenbloom (2002) Chesbrough (2010) Chesbrough (2007) Chesbrough and Schwartz (2007)

Source: (Brem & Voigt, 2009; Bush, 1960; Henry Chesbrough, 2010; Henry Chesbrough & Rosenbloom, 2002; Henry Chesbrough & Schwartz, 2007; Horbach et al., 2012; Luong et al., 2008; Nemet, 2009; Popp, 2001; M. Rosenberg, 1965; N. Rosenberg, 1982; Vernon, 1966)

The technology innovation theories above provide significant value in explaining the main aspects of technology innovation. However, with the advent of the knowledge-based economy, the amount of skills and knowledge has increased exponentially and a new paradigm of innovation has emerged, one of open innovation, that utilizes technologies and knowledge without corporate boundaries. As a result, the validities of the existing individual innovative theories have been significantly reduced (Brem & Tidd, 2012; Henry William Chesbrough, 2003, p. 24; Henry W Chesbrough, 2006; Foray & Lundvall, 1998; JIN-HYO & MOHAN; J.-H. J. Yun, Avvari, & Jung; J. H. J. Yun & Mohan, 2012; J. J. Yun, Nadhiroh, & Jung, 2013). Currently, nonlinear dynamics, not linear, are increasingly used with the feedback loop for opportunities and methods by which new technologies meet the markets (Warren, 2008, p. 51; Zajac, Kraatz, & Bresser, 2000). In other words, the increasing speed of feedback from technologies and markets due to the development of the mobile Internet, in addition to the online Internet, has produced a rapid increase in the speed of technology innovation. Thus, the importance of the business model as a means of innovation is rising steadily (Henry Chesbrough, 2010; Johnson, Christensen, & Kagermann, 2008; Teece, 2010). As a consequence, it is necessary to formulate new corporate innovation theories or models that reflect the rapid increase in the importance of all factors - the knowledge-based economy, open innovation paradigm, steadily rising innovation dynamics as well as the feedback loop - and business models are required more than ever.

2.2. Composition of research model: Technology–Business Model–Market Causal Model

Basically, the model is a configuration of feedback loop and time lag center around the relationships between technology, business model (BM), market, and additional explanatory variables, which affect these main variables. The main elements of the model are presented along with existing research which established the corresponding elements. In the model, technologies do not affect markets directly but rather affect the markets through the business model (Henry Chesbrough, 2010). In addition, a separate positive feedback loop structure exists between the technologies and business model, as well as between the business model and markets (Abdel-Rahim & Quaicoe, 1996; Henry Chesbrough, 2007; Henry Chesbrough & Schwartz, 2007; Leeson, 1966).

While these two small loops exhibit relatively short-time delays, a relatively long-time delay exists in the direct loop between technologies and markets (Davenport & Short, 1990; Hagedoorn & Schakenraad, 1994; Kokko, 1994; Narver & Slater, 1990; Osterwalder & Pigneur, 2005; Reich & Benbasat, 2000; Sterman, 2000, p. 409; Zott & Amit, 2008). While the long-time delay existing in this model tends to be a material delay in nature, the short-time delay tends to be an information delay (Sturges, 1972). Also, each technology and business model exhibits different degrees of openness to any new technology and business model, according to the open innovation index of each (Henry Chesbrough, 2004, 2007, 2010; H Chesbrough, 2012; Henry Chesbrough, 2013; Henry William Chesbrough, 2003; Henry W Chesbrough, 2006; Enkel, Gassmann, & Chesbrough, 2009). A business model could become the new driving force of innovation but usually receives negative effects (Grabowski, 1976; Jaffe & Palmer, 1997). In addition, as the roles of the leading firm grow bigger, the regulation index itself receives bigger negative effects (Admati & Pfleiderer, 2000; Harris, 2002; Rahman, Perera, & Ganesh, 2002)(Jaffe & Palmer, 1997). Markets also receive positive effects from the standardization index (Banz, 1981; Gallagher & Park, 2002; Oum, Oren, & Deng, 2006). In other words, the larger the standardization, the bigger the markets will grow.

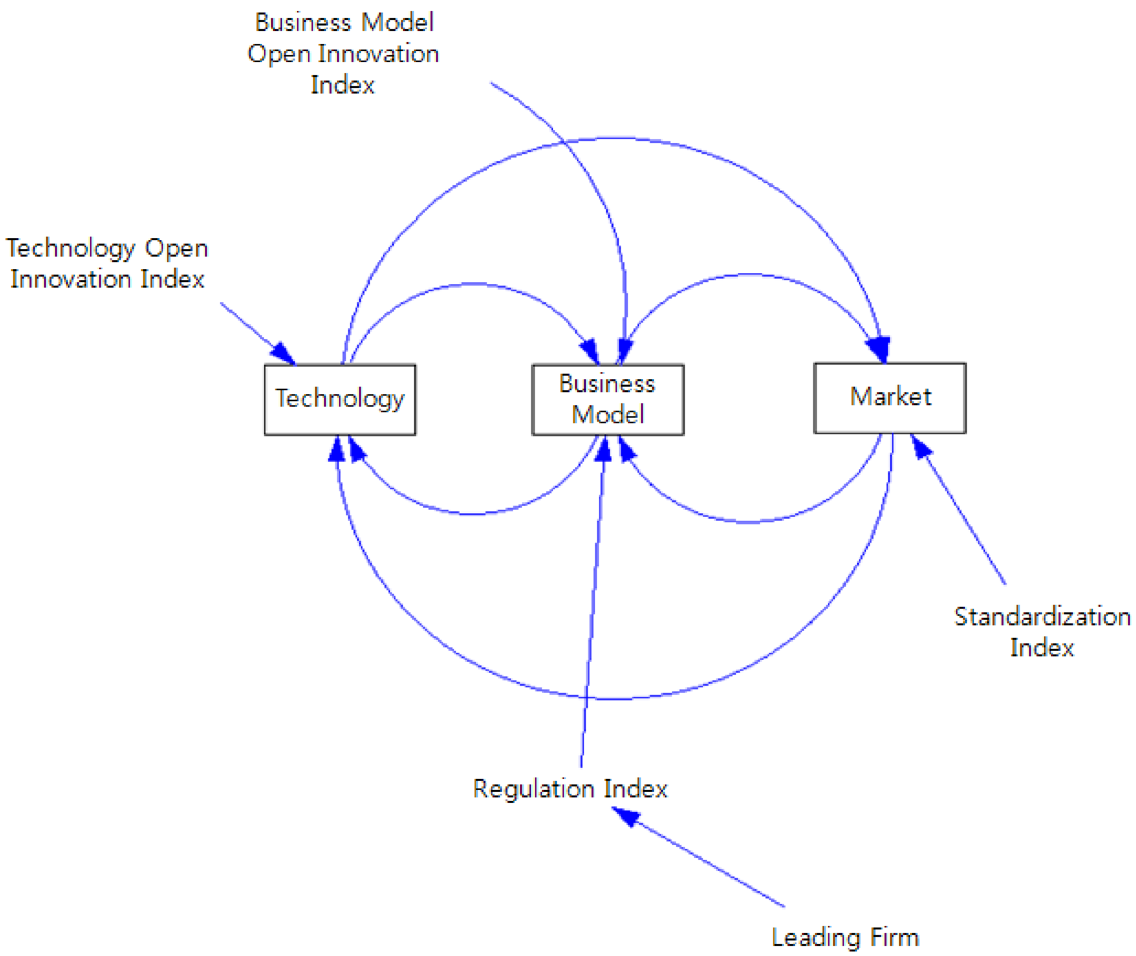


Fig 2. Technology–BM–Market Causal Model

3. Case study and advanced validation of T-BM-B System Dynamics Model

3.1. Autonomous car

Table 2
Summary of Interview Results About the Autonomous Car-related Firms

	Technology		Business Model		Market	
	Level	Example	Level	Example	Level	Example

Contela	2	UMTS small cell solution -> LTE small cell solution -> M2M solution	1	Autonomous car Government approvals and standards on the interior small cell Solution has not been established	2	Emergence of smart solution markets for the control of car interior and communication inside a car
DiSen	2	BOARD-> LCD module ASS'y F/P module ->Audio video network ->Etc.	1	Failed to come up with concrete business models because of the regulations concerning the LCD used to control the car interior or side view mirror substitute LCD	2	Incorporating various entertainment functions in the LCD for the GSP and addition of LCD in the rear passenger compartment
ATT R&D	2	Invita and completed electric car -> low-speed electric car ->autonomous car platform development	1	Electric car certification and resolutions concerning the completed unit are unresolved. Autonomous and test run are unresolved.	2	Low-speed electric car market High-speed electric car market Partial autonomous electric car, etc.
CammSys	2	Mobile camera module ->Car black box ->Vehicle-mounted camera vision and control system	1	Regulations concerning the camera vision and the control to achieve autonomous car are unresolved.	2	Smartphone camera module Car black box Car camera vision
Dong-Ah	2	Car heat controller ->HVAC control head ->Motor speed controller	1	Approvals and regulations concerning the controller and system for the autonomous run control are unresolved.	2	Car heating system Car audio and video Car speed system

The technology, business model, and market have two levels (high and low) based on AHP analysis by interviewee firms, author group, and focus group.

Interviews with small- and medium-sized firms and focus group meetings revealed that firms working in the autonomous car sector have amassed various and advanced technologies by accumulating experiences from existing complete unit manufacturing, especially IT-based machineries and engineering, which have been recently added. However, these technologies cannot be connected to the development of various autonomous car business models because of the absence of regulations, standards, and certification systems. Nonetheless, it was found that the small- and medium-sized firms are working actively to develop the autonomous car market within the framework of the existing automotive market.

Four out of five companies in Table 2 have been developing key technologies within the automotive industry to pursue market expansion within the existing automotive market. However, in spite of the efforts that firms have made in developing various business models for partial autonomous operation, there are no legal standards or criteria on autonomous driving available in Korea. Even Hyundai Motor Company, the leading car manufacturer in Korea, with its advanced research on autonomous operation and testing, has not been able to establish Korean autonomous car industry standards or play the leading role in abolishing existing regulations. This is in contrast to the efforts of Google regarding autonomous car operation in the U.S., which includes the abolition of regulations at the state level and leading the setting of new standards.

In Korea, numerous technologies have been developed for autonomous operations, such as Adaptive Cruise Control (ACC), Lane Departure Detection (LDD), Parking Assist, Remote Park Assist, and Blind Spot Information System (BLIS). However, these technologies cannot be established as business models as they cannot pass existing regulations, standards, and test certifications — the related components or systems are instead being adopted and used in foreign countries. The Korean domestic car industry cannot adopt various soft ware(SW)-related business models for autonomous operation because they do not conform to regulations, certification, and standards.

In spite of this, currently, a sizeable market involving partial autonomous operation has been adopted into the traditional car market and is being expanded in Korea. Firms are fully aware of the sizes of the SW-related markets in Korea which are presently dominated by foreign part markets business models, and are strategically focusing on developing various SW-based business models. It should be noted that CammSys, which is the world's leader in the development of the smartphone camera module, also leads the development of vision systems for the autonomous car, and the SW module business model for autonomous operation, and is strategically working to establish a new business model for the self-controlled car. Significantly, our other car manufacturers were optimistic about the future of the autonomous car market and are strategically focusing on the autonomous operation business model in spite of the difficult regulations and certification processes associated with it.

However, the business model of the Korean autonomous car market, like that for the electric car market, has not been properly established yet because of matters such as the leading car manufacturer's inability to lead on the global stage, unresolved regulations, absence of relevant standards, etc.

3.2. Intelligent robot

Table 3
Summary of Interview Results About Intelligent Robot-related Firms

	Technology		Business Model		Market	
	New Tech	Example	New BM	Example	New Market	Example

IDEAR System Co., LTD.	1	Agricultural products nondestructive testing equipment Grain rougher Moisture measurement device signal processing Container net system Pellet manufacturing method Rice hull carbonization system	2	CCD color sorter applying DPS Compact net system Coating drying system Bag filter Continuous dryer	1	Restricted to grain handling market: Grain processing, storage, post-processing (currently expanding into global market from the present southeast Asian market)
DaisoCell	1	Accumulation load cell of engineering to measure the load of large structures or power	2	BC type S type LC type RT type BS type BS type CC type and Various load cells such as special order	1	Limited to industrial load cell market. (At present, participating in research and development business of intelligent robot and manufacturing load cells)
YuJin Mechatronics	1	Mechanism design Motion control Intelligent robot-engineering sensor application software Programming	2	Industrial machinery Steel manufacturing equipment Automation -System Robot system Laser vision inspection Cutting robot Gantry robot Welding rail cars LNG spraying Safety fence	1	Limited markets, such as industrial equipment and industrial robot (Diversification strategy of source-technology based business model as markets for products are small because of the lack of standards.)

Samik Tech	1	Automated tool changer Goods transport assembly Uniformly distributing system and heating system	2	Automated tool changer Automated materials changer Wireless communication transporting robot AGV robot Distributed microwave drying and heating system	1	Restricted to individualized machine tool market, such as tools and machine tools, controller systems, and robots. (Focusing on the individualized market of tool or machine tool that controls its parts automatically)
Creative Space	1	Training program logic Logic circuit control circuit and may others — Basic circuit and sensor system	2	Educational robot DODDEE DARO TRS UCR Hands-on professional training materials Eco-navigation Creative personality, integrated science, engineering educational program, etc.	1	Restricted to educational market products, such as robots and science education related devices (simple robotic systems included) (Related market is fragmented into separate markets so there is a need to expand into various business models from the educational market.)

Technology, business model, and market have two levels (high and low) based on AHP analysis by interviewee firm, author group, and focus group.

Based on the interviews with the case study firms in Table 3 and the focus group meetings, it can be understood that Korean intelligent robot firms are striving to survive through the diversification of business models, while focusing on the limited technology base. Also, in this small market, it is a reality that most small- and medium-sized robot firms are faced with individual markets of small quantity batch production.

As shown in Table 3, the activities of the Korean firms in the intelligent robot industry are restricted to industrial machine equipment automation or robotic industry automation support. It is also true that the domestic robot market targeting various household activities is very limited, apart from its floor vacuuming application. Nonetheless, the Korean government has expanded investments in research and development in robotic industrial sectors to approximately KRW 1 trillion during the past five years, and many small- and medium-sized machine equipment firms have been able to accumulate technologies in the mechatronics fields by adding SW and control capabilities to their own existing technologies. However, they have not been able to acquire original technologies.

At present, domestic robot firms are not trying to advance the technologies they have accumulated in existing business fields, but are trying to diversify their business models into different areas. As the results of the interviews show, they have developed their business models into various areas while their technologies are limited.

However, in the case of industrial robots, which was the target of this interview, participants revealed that the market is not sufficiently big because of the concentration in the limited and nonstandardized markets. In addition, according to the results of the focus group, the market for professional and specialized robots, such as domestic household robots, medical equipment, and many others, has not been standardized and has not matured, hence remains limited. However, this is not the case with the household robot: the market for cleaning robots, where standardization is possible, continues to expand. It has also secured sizable markets at home and abroad.

Despite the immaturity of the Korean intelligent robot industry, leading firms have emerged because of the involvement of several large corporations, and the results of the robot industry development policy of the Korean government. Hyundai Heavy Industries, Doosan Heavy Industries, and a few other large corporations are leading industrial robot production. However, even growth in the industrial robot sector is not being developed sufficiently, as it is restricted to an import substitution market. It supplies industries whose finished products are sold globally, such as cars, integrated circuits, and home appliance industries, to fulfill their manufacturing needs. In other words, it is not leading the global market in intelligent robot technology development. It is not able to forecast demand for intelligent robots in the global market, in either the industrial or household sectors. Thus, the progress of several major domestic firms is stagnant and they are only able to supply the Korean market, which is a small and individual market.

The household robot industry of Japan as well as the medical and specialty robot industries of Germany lead the development of newly conceptualized robots, standards setting, regulations maintenance, and certification globally. Samsung Electronics and LG Electronics are emerging as the global leaders in the household robot sector because of expanding demand for robot vacuum cleaners and a limited number of household application robots in the global marketplace. However, even in the household robot market, these firms are not able to play leading roles among other firms in the global marketplace.

3.3 Minor conclusions

First, through the case analyses of small- and medium-sized firms, which are the incomplete unit firms of Korea’s autonomous car and intelligent robot industries, actual cases have been identified where technologies are being led to the markets through business models. By identifying that small- and medium-sized firms connect technologies to markets through business models, the validity of the Technology–Business Model–Market model adopted in this study is ensured.

Second, it has been identified that regulations and standards have significant impact in determining the business model, the scope, and the scale of the market. Although the effects of regulations on business models and standards on markets could not be divided precisely, case study analyses confirmed that regulations and standards greatly affect the business models and market expansions of the two industries.

Third, it has been identified that the leading firms of the two industries play very important roles, as confirmed by interviews with small- and medium-sized firms. It was revealed that Google’s effect on the autonomous car industry is not limited to the simplification of regulations, establishment of a certification system, and formulation of standards. However, such activities leverage the development of new business models and technologies. The interviews with firms, expert-focused group meetings, and questionnaire surveys have revealed that in Japan, the leading firms in the industrial robot, specialty robot, and household robot sectors play the same roles that Google plays in the autonomous car industry.

Table 4 shows the results of AHP analysis conducted during interviews with firms and seminars with experts. In the case of Korea’s autonomous car industry, it has been revealed that the firms leading roles are very meager: the industry is excessively regulated in the absence of relevant laws and is relatively well standardized within the framework of the existing car industry. On the other hand, the situation with the intelligent robot industry is somewhat different. Hyundai Heavy Industries and Doosan Heavy Industries, the leading firms of the industrial robot sector, and Samsung Electronics and LG Electronics, the leaders of the household robot sector, play strong roles. The industry is loosely regulated in the absence of relevant laws as it has not had chance to mature yet. The standards are not well established as the markets are relatively small.

Table 4
The Characteristics of Korea Autonomous Car and Intelligent Robot Industry

Subject	Autonomous Car	Intelligent Robot
Leading firm	Weak	Strong
Regulation	Strong	Weak
Standardization	Strong	Weak

4. Technology-BM-Market System Dynamics Model building and validation

4. 1. System Dynamics Model building

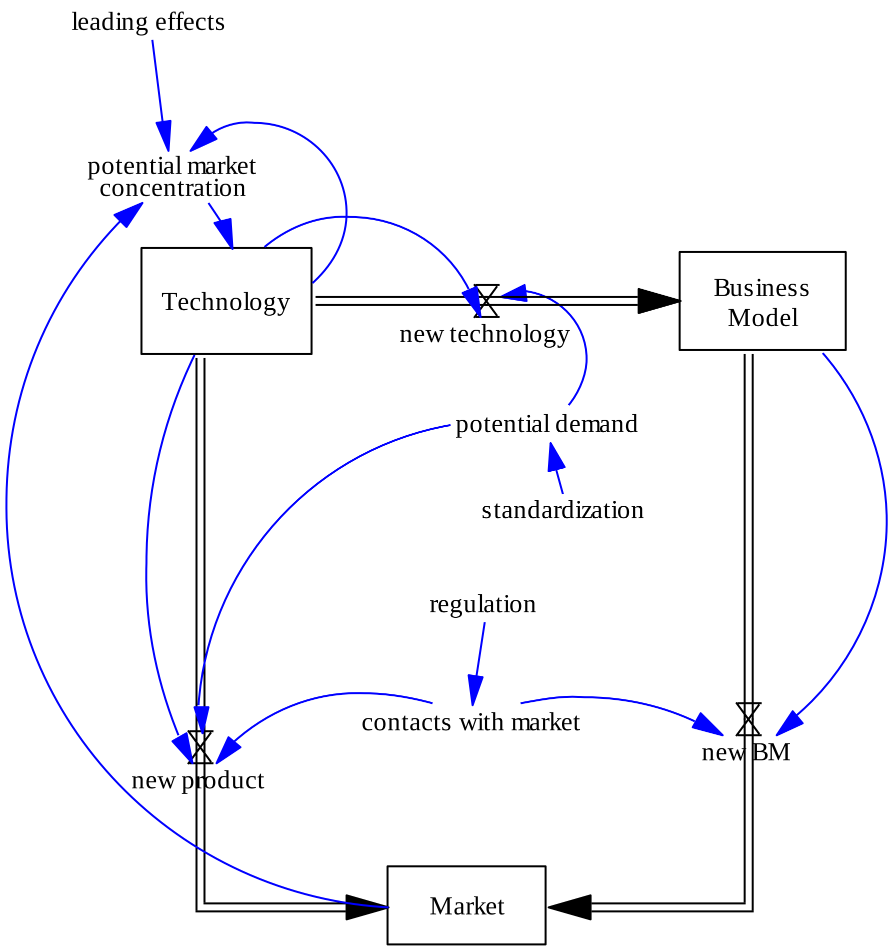


Fig 3. Technology–BM–Market System Dynamics Model

In this study, the causal loop relationship model of Technology–BM–Market was established through a review of theoretical discussions (Barlas, 1989, 1994). As a part of the structural assessment, the main variables and their relationships were identified theoretically and they form the basis of the System Dynamics Model Configuration (Sterman, 2000, p. 859).

In addition, through the case analyses of autonomous car and intelligent robot industries, it has been confirmed that leading firms, regulations, and standardization are the main explanatory variables of marketing. Securing validation of the main variable of the Corporate System Dynamics Model through the use of business activities case studies corresponds to a typical structure-oriented behavior test (Barlas, 1994; Forrester & Senge, 1978). The model is configured with leading runners, i.e. the leading firms are responsible for the feedback from markets to technologies. In the autonomous car and intelligent robot industries, the basis was secured from the consistent findings of interviews with individual firms. The leading firms of the autonomous car and intelligent robot industries use technology development as a means of feedback to the market's current potential needs — open innovation leading roles. It has been identified through the meetings with experts that Google and the robot firms of Japan actually form the pattern of markets and reversely lead the scope and directions of technology development.

Also, the equation was set as "Business Model = new technology-new business model". As was expressed in the definition and function of business model, a lot of new technologies go to market through business models (Chesbrough 2007; 2010; 2012). The ex-ante structure verification was secured by organizing the deduced results from the process of making the business models in 10 case firms (Coyle & Exelby, 2000; Forrester & Senge, 1978). In addition, according to Appendix 2, and 3, if we control indices such as leading firm, regulation, and standardization for optimal condition of market, markets increase consistently. This also shows the system dynamic model's validation.

4.2 Validation from patents citation network analysis of two industries

The G-Pass (http://gpass.kisti.re.kr) (LexisNexis) is a worldwide patent database built by the Korea Institute of Science and Technology Information (KISTI) based on a database provided by LexisNexis. Through an analysis of each keyword in the G-Pass, the patents of the two industries were extracted, centering on autonomous car or autonomous vehicle and intelligent robot or autonomous robot from 1960 to 2013. The totals are shown in Tables 5 and 6 below. This patent DB coverage includes all major countries, such as the U.S. (United States), EP (Europe), WO (International), CN (China), JP (Japan), KR (Korea), DE (Germany), FR (France), GB (Great Britain), and CA (Canada).

Table 5
Technology Patents in Autonomous Car and Intelligent Robot

Field	Number of Reference à (Record)	Number of à Technology Patents	Number of Citation (Record)
Autonomous Car	13,047	5,557	11,180
Intelligent Robot	8,708	2,994	7,404

Through Table 5, it has been found that more technologies have been quantitatively developed in the autonomous car industry than in the intelligent robot industry. In addition, even in the areas of citations and references, which are indicators of the spread of technologies, it has been identified that the activities in the autonomous car industry are progressing much more vigorously. As shown in Table 2 and Table 3, this also coincides with the results of interviews with the two industries of Korea. Basically citation and reference show us open innovation level of technologies and business models in 2 industries. Technology open innovation index and business model open innovation index in Figure 2 are decided by market.

Table 6
Business Model Patents in Autonomous Car and Intelligent Robot

Field	Number of Reference à (Record)	Number of à Technology Patents	Number of Citation (Record)
Autonomous Car	322	42	52
Intelligent Robot	240	74	414

In Table 6, showing the business model patents of the two industries, the citation and referencing of the business model patents are very few, at only 2–5 each. In other words, the analysis indicates that the citation and referencing activities mostly involve technology patents: in the intelligent robot sector, 74 intelligent robot business model patents referred to 240 intelligent robot business model patents out of many more. Those 74 intelligent robot business model patents were in turn cited by 414 intelligent robot technology patents.

Table 6, in the System Dynamics Model, substantiates the existence of the feedback loop by which technology is passed to a business model to form the initial process loop, moves to market, and back to technology. However, in the case of the autonomous vehicle, where 42 business model patents refer to 322 technology patents, the number of autonomous vehicle business model patent citations was very low, at 52. This is because the leading firms' roles as a whole are still quite weak. This also coincides with the Korean phenomena shown in Table 4. Tables 5 and 6 substantiate the existence of the forward loop of Technology–BM–Market System Dynamics of Table 3, and the feedback loop, directly and indirectly. In addition, on average 7.7 technology patents are referenced by each autonomous vehicle business model patent, and 3.2 technology patents are referenced by each intelligent robot business model patent: this provides manifest and concrete evidence about the role of the business model as a bridge between technology and markets (Chesbrough, 2010).

In addition, autonomous car technology patents are referring nearly half themselves according to Appendix 2. It is opposite to intelligent robot technology patents which are referring outside than themselves 5 times according to Appendix 3. These mean directly that autonomous cars are strongly standardized than intelligent robot like Table 4.

Citation of business model patents of intelligent robot is much bigger and diverse than that of autonomous car according to Appendix 2, and 3. Maybe intelligent robot industry has leading firms which are appearing as triggering identities of new technologies from business models opposite to autonomous car industry.

The volume and diversity of business model patents of autonomous car industry is smaller than intelligent robot industry according to Appendix 2, and 3 even though those of technology patents of autonomous car industry is larger nearly 1.5 times than intelligent robot industry. This means that regulation in autonomous car industry is much higher than that intelligent robot industry objectively.

5. Simulation and implication

5.1. Simulation results and discussion

First, for the autonomous car industry, the technology and business model patent values resulting from the patent analysis were calculated as the initial values of each simulation. In addition, the conditions of leading firm, standardization, and regulations have 2 different modules, namely, the real conditions in Korea, shown in Table 2, and optimal conditions. The simulation results are shown in Appendix 4, and 5. According to this simulation, first, optimal conditions can produce bigger markets than present conditions. If the Korean government motivates the leading firms and decreases regulation in the autonomous car industry, markets will increase very much in this industry. Second, and importantly, if the business model level for the modern condition increases, the market will increase more than the increase of business model without the level of technology and 3 conditions such as leading firm, standardization, and regulation. These simulation results converge with the reality, and provide a significant implication. In the open innovation paradigm, and knowledge based economy, if you develop a creative business model, you can increase market volume. If you develop technology, it will also increase the market. Increases in technology require larger investment than increases in business model because the development of a new business model does not require costly experiments.

Next, for the intelligent robot industry, the initial value of technology was set at 2,994. In the results of the patent analysis, the initial value of business model was set at 74. The simulation results differ for the 3 conditions and the modern level of business model, as shown in Appendix 3. In this industry, the optimal conditions also show bigger markets than the real conditions of the Korean robot industry shown in Table 2. In this industry, the increases in market size that accompany the increase of modern size of business model shows the same pattern as the autonomous car industry. But, the robot industry simulation results also show us another possibility. Market increase is limited by the highly increase such as 5,000 units of modern business model level in real conditions. This means that a high business model condition can overcome limiting conditions, such as scarce leading firm effect, high level of regulation, and low level of standardization.

5.2. Implications and future research topics

Through this study, it has been confirmed that the technology innovations of the autonomous car and intelligent robot industries are being progressed as a part of a dynamic feedback process between technology, business model, and market. Through specific case studies, the relationships between the three partial factors have been confirmed. Through the patent analysis, the existence of the three-factor feedback loop has been indirectly confirmed. Lastly, through the simulation analysis, changes in the dynamic relationships of the three-factors could be estimated.

In addition, through simulation, it has been estimated that the pattern and size of market growth could be different depending on the levels of regulation, standards, and role of leading firm. Furthermore, through the simulation results, it appears that if we increase the business model level, even though the technology level is not high, the market size increases much more than when the level of modern business model condition is low.

Therefore, firms should consider that their own technology innovation strategies are the results of the dynamic interactions of three factors, which include technology, business model, and market, and so should establish strategies that include both technology and business model together. Also, the government should not restrict its involvement to either technology- or market-driven approaches, or a combined two-approach strategy, but should definitely consider adopting the results of the business model analysis.

Furthermore, corporate strategies and national policies are required which take the levels of standards, regulations, and the role of leading firms into consideration as the main determining factors of market growth. According to the results of this study's simulation, one should keep mind that strategies or policies that are based on the dynamic feedback interaction between technology, business model, and market can result in markets that are vastly different from existing technology innovation strategies or technology innovation policies.

Most of all business model developing strategies and policies with technology increase strategy and policy can result in bigger increase in market. So, companies should keep in mind that developing a business model is one way to increase markets without the large investment required to increase the state of technology. Governments also motivate an increase in business models when they trigger new industries, such as autonomous car or intelligent robots industries.

In future, it will be necessary to refine the System Dynamics Model and conduct additional simulation research on the pattern and size of market growth through additional interviews with expert focus groups. Such research should further explore how market growth is dependent on the specific level of open innovation of the technology and business model selected by firms in the market. The ultimate goal of this study is to apply the technology innovation situation of an individual firm to this model, to enhance the value of this study's results. Lastly, the operation of national technology innovation systems based on the feedback model that depicts the interaction between Technology, BM and Market should be analyzed and applied to new concept innovation policy development. In order to significantly improve the validation of this study, we intend to shortly carry out the analyses of the two industries' technology and business model patent citation network as deeply as possible.

References

Abdel-Rahim, N. M., & Quaicoe, J. E. (1996). Analysis and design of a multiple feedback loop control strategy for single-phase voltage-source UPS inverters. *Power Electronics, IEEE Transactions on, 11*(4), 532-541.

Abernathy, W. J., & Utterback, J. M. (1978). Patterns of industrial innovation. *Journal Title: Technology review. Ariel, 64*, 254.228.

Admati, A. R., & Pfleiderer, P. (2000). Forcing firms to talk: Financial disclosure regulation and externalities. *Review of Financial Studies, 13*(3), 479-519.

Almirall, E., & Casadesus-Masanell, R. (2010). Open versus closed innovation: A model of discovery and divergence. *Academy of management review, 35*(1), 27-47.

Banz, R. W. (1981). The relationship between return and market value of common stocks. *Journal of financial economics, 9*(1), 3-18.

Barlas, Y. (1989). Multiple tests for validation of system dynamics type of simulation models. *European journal of operational research, 42*(1), 59-87.

Barlas, Y. (1994). *Model validation in system dynamics.* Paper presented at the Proceedings of the 1994 International System Dynamics Conference.

Brem, A., & Tidd, J. (2012). *Perspectives on Supplier Innovation: Theories, Concepts and Empirical Insights on Open Innovation and the Integration of Suppliers* (Vol. 18): World Scientific.

Brem, A., & Voigt, K.-I. (2009). Integration of market pull and technology push in the corporate front end and innovation management—Insights from the German software industry. *Technovation, 29*(5), 351-367.

Bush, V. (1960). *Science, the endless frontier*: National Science Foundation Washington, DC.

Chesbrough, H. (2004). MANAGING OPEN INNOVATION. *Research Technology Management, 47*(1).

Chesbrough, H. (2007). Business model innovation: it's not just about technology anymore. *Strategy & leadership, 35*(6), 12-17.

Chesbrough, H. (2010). Business model innovation: opportunities and barriers. *Long range planning, 43*(2), 354-363.

Chesbrough, H. (2012). Why companies should have open business models. *MIT Sloan management review, 48*(2).

Chesbrough, H. (2013). *Open business models: How to thrive in the new innovation landscape*: Harvard Business Press.

Chesbrough, H., & Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and corporate change, 11*(3), 529-555.

Chesbrough, H., & Schwartz, K. (2007). INNOVATING BUSINESS MODELS WITH CO-DEVELOPMENT PARTNERSHIPS. *Research Technology Management, 50*(1).

Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*: Harvard Business Press.

Chesbrough, H. W. (2006). The era of open innovation. *Managing innovation and change, 127*(3), 34-41.

Coyle, G., & Exelby, D. (2000). The validation of commercial system dynamics models. *System dynamics review, 16*(1), 27-41.

Davenport, T. H., & Short, J. E. (1990). The new industrial engineering: information technology and business process redesign. *Sloan management review, 31*(4).

Dewar, R. D., & Dutton, J. E. (1986). The adoption of radical and incremental innovations: an empirical analysis. *Management science, 32*(11), 1422-1433.

Dosi, G. (1988). Sources, procedures, and microeconomic effects of innovation. *Journal of economic literature*, 1120-1171.

Enkel, E., Gassmann, O., & Chesbrough, H. (2009). Open R&D and open innovation: exploring the phenomenon. *R&d Management, 39*(4), 311-316.

Foray, D., & Lundvall, B.-A. (1998). The knowledge-based economy: from the economics of knowledge to the learning economy. *The economic impact of knowledge*, 115-121.

Forrester, J. W., & Senge, P. M. (1978). *Tests for building confidence in system dynamics models*: System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology.

Göhring, D., Latotzky, D., Wang, M., & Rojas, R. (2013). Semi-autonomous car control using brain computer interfaces *Intelligent Autonomous Systems 12* (pp. 393-408): Springer.

Gallagher, S., & Park, S. H. (2002). Innovation and competition in standard-based industries: a historical analysis of the US home video game market. *Engineering Management, IEEE Transactions on, 49*(1), 67-82.

Grabowski, H. G. (1976). *Drug Regulation and Innovation: Empirical Evidence and Policy Options*: American Enterprise Institute for Public Policy Research Washington DC.

Hagedoorn, J., & Schakenraad, J. (1994). The effect of strategic technology alliances on company performance. *Strategic management journal, 15*(4), 291-309.

Harris, L. (2002). Small firm responses to employment regulation. *Journal of Small Business and Enterprise Development, 9*(3), 296-306.

Horbach, J., Rammer, C., & Rennings, K. (2012). Determinants of eco-innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull. *Ecological Economics, 78*, 112-122.

Hsu, F.-Y., & Fu, L.-C. (2000). Intelligent robot deburring using adaptive fuzzy hybrid position/force control. *Robotics and Automation, IEEE Transactions on, 16*(4), 325-335.

Jaffe, A. B., & Palmer, K. (1997). Environmental regulation and innovation: a panel data study. *Review of economics and statistics, 79*(4), 610-619.

JIN-HYO, J. Y., & MOHAN, A. V. A Study on the Difference of Open Innovation Effect according to Technology Life Cycle.

Johnson, M. W., Christensen, C. M., & Kagermann, H. (2008). Reinventing your business model. *Harvard business review, 86*(12), 57-68.

Kokko, A. (1994). Technology, market characteristics, and spillovers. *Journal of development economics, 43*(2), 279-293.

Lach, S., & Rob, R. (1996). R&D, investment, and industry dynamics. *Journal of Economics & Management Strategy, 5*(2), 217-249.

Leeson, D. B. (1966). A simple model of feedback oscillator noise spectrum. *Proceedings of the IEEE, 54*(2), 329-330.

Lotti, F., & Santarelli, E. (2001). Industry dynamics and the distribution of firm sizes: A non-parametric approach.
Luong, J. H., Male, K. B., & Glennon, J. D. (2008). Biosensor technology: technology push versus market pull. *Biotechnology advances, 26*(5), 492-500.
Milanés, V., Llorca, D. F., Vinagre, B. M., González, C., & Sotelo, M. A. (2010). *Clavileño: Evolution of an autonomous car.* Paper presented at the Intelligent Transportation Systems (ITSC), 2010 13th International IEEE Conference on.
Mowery, D., & Rosenberg, N. (1979). The influence of market demand upon innovation: a critical review of some recent empirical studies. *Research Policy, 8*(2), 102-153.
Narver, J. C., & Slater, S. F. (1990). The effect of a market orientation on business profitability. *Journal of marketing, 54*(4).
Nemet, G. F. (2009). Demand-pull, technology-push, and government-led incentives for non-incremental technical change. *Research Policy, 38*(5), 700-709.
Osterwalder, A., & Pigneur, Y. (2005). Clarifying business models: Origins, present, and future of the concept. *Communications of the association for Information Systems, 16*.
Oum, Y., Oren, S., & Deng, S. (2006). Hedging quantity risks with standard power options in a competitive wholesale electricity market. *Naval Research Logistics (NRL), 53*(7), 697-712.
Pinch, T. J., & Bijker, W. E. (1987). The Social Construction of Facts and Artifacts: Or How the Sociology of. *The social construction of technological systems: New directions in the sociology and history of technology, 17*.
Popp, D. (2001). Induced innovation and energy prices: National Bureau of Economic Research.
Rahman, A., Perera, H., & Ganesh, S. (2002). Accounting practice harmony, accounting regulation and firm characteristics. *Abacus, 38*(1), 46-77.
Reich, B. H., & Benbasat, I. (2000). Factors that influence the social dimension of alignment between business and information technology objectives. *MIS quarterly*, 81-113.
Rifkin, J. (2011). *The third industrial revolution: how lateral power is transforming energy, the economy, and the world*: Macmillan.
Rosenberg, M. (1965). Society and the adolescent self-image.
Rosenberg, N. (1969). The direction of technological change: inducement mechanisms and focusing devices. *Economic Development and Cultural Change*, 1-24.
Rosenberg, N. (1982). *Inside the black box: technology and economics*: Cambridge University Press.
Schöner, G., Dose, M., & Engels, C. (1995). Dynamics of behavior: Theory and applications for autonomous robot architectures. *Robotics and autonomous systems, 16*(2), 213-245.
Sterman, J. D. (2000). Business dynamics.
Sturges, P. T. (1972). Information delay and retention: Effect of information in feedback and tests. *Journal of Educational Psychology, 63*(1), 32.
Teece, D. J. (2010). Business models, business strategy and innovation. *Long range planning, 43*(2), 172-194.
Van den Ende, J., & Dolfsma, W. (2005). Technology-push, demand-pull and the shaping of technological paradigms-Patterns in the development of computing technology. *Journal of Evolutionary Economics, 15*(1), 83-99.
Vernon, R. (1966). International investment and international trade in the product cycle.
Warren, K. (2008). *Competitive strategy dynamics*: John Wiley & Sons.
Williams, R., & Edge, D. (1996). The social shaping of technology. *Research Policy, 25*(6), 865-899.
Yun, J.-H. J., Avvari, M. V., & Jung, W. Y. Unraveling the relationship between entrepreneurship and open innovation: A Study on one of Modern Technology Evolution Channel.

Yun, J. H. J., & Mohan, A. V. (2012). Exploring open innovation approaches adopted by small and medium firms in emerging/growth industries: case studies from Daegu–Gyeongbuk region of South Korea. *International Journal of Technology, Policy and Management, 12*(1), 1-19.

Yun, J. J., Nadhiroh, I. M., & Jung, W. Y. (2013). The relationship between open innovation, entrepreneurship, and introduction of new business models in Korean and Indonesian information technology enterprises. *Korean Social Science Journal, 40*(2), 81-99.

Zajac, E. J., Kraatz, M. S., & Bresser, R. K. (2000). Modeling the dynamics of strategic fit: A normative approach to strategic change. *Strategic management journal, 21*(4), 429-453.

Zott, C., & Amit, R. (2008). The fit between product market strategy and business model: implications for firm performance. *Strategic management journal, 29*(1), 1-26.

Appendix 1
Half-structured questionnaire and interviewers list

1. Half-structured questionnaire

This interview is to check the current state of technology development and market formations of new industry sectors, and to figure out what the firms' understandings of the markets are, and the characteristics of technologies.

1) Industry overview
- Achievement history
- Sales
- Main products
- Investments in patent and research and development, research staff, etc.
2) Changes in your firm's main products or diversification history and agents
3) Sources of new products and process innovation of firms
(Own R&D, collaboration with universities, collaboration with institutions, cooperation with firms that purchase products from you, firms that sell products to you, etc.)
4) Market trends and outlook of this industry sector and requirements for market vitalization
5) Status and prospects of technologies of this industry sector and requirements for technology development
6) The biggest obstacle to the development of this industry sector
7) Policy changes the government has to make to develop this industry
8) Characteristics of entrepreneurship, corporate culture, etc.
9) The value and potential of your firm's current business model

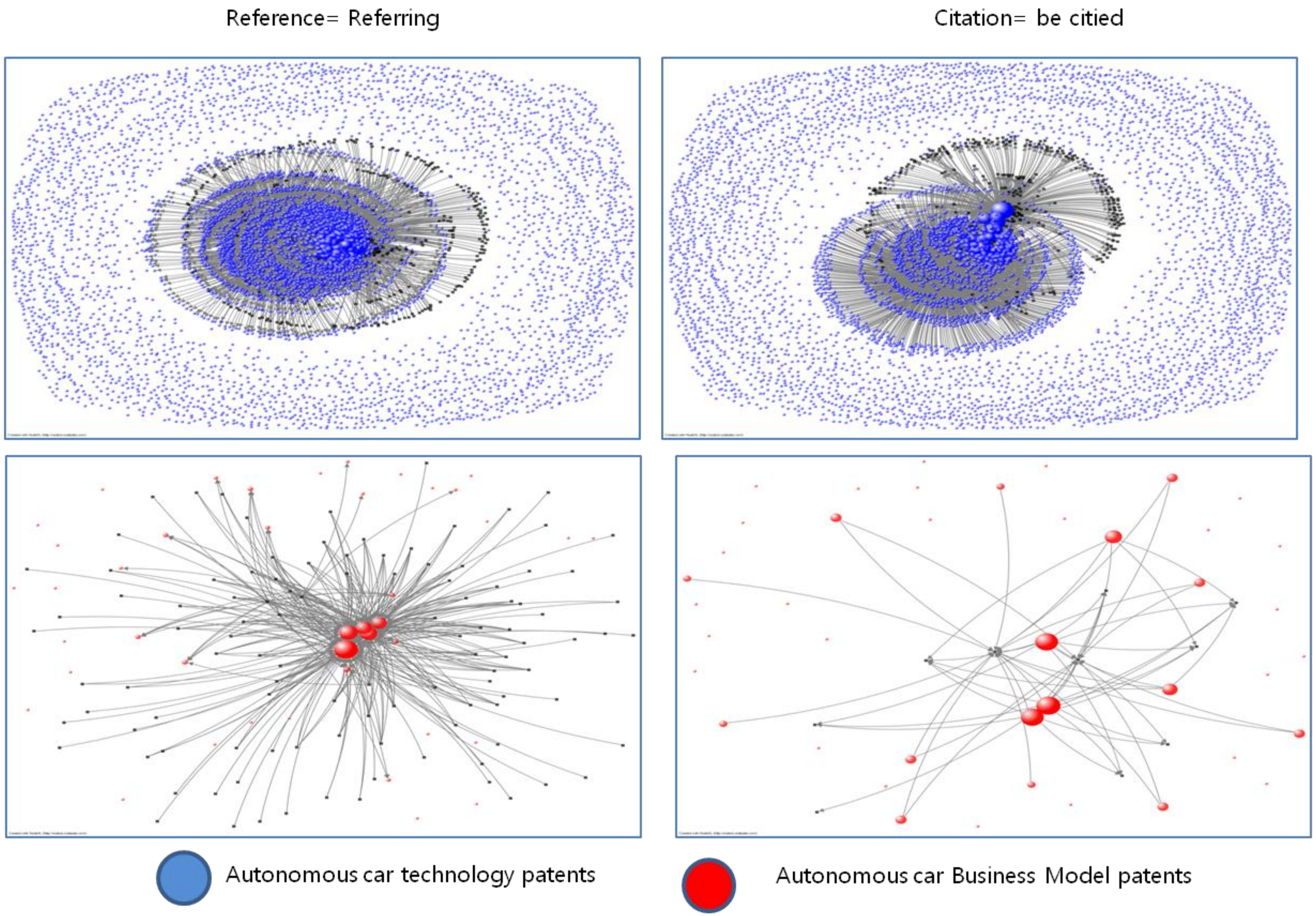
2. Interviewee list

Sector	Date	Firm's name	Interviewee	Characteristics
Autonomous car	2014.2.13	Contela	Kim Jungmin, Managing Director	Gateway system Management system Evolved into small cell system, Pursuing autonomous car small cell system
	2014.2.14	DiSen	Lee Hun, Research Center Director	Car LCD module localization, the first in Korea Expanding into audio video navigation system technology business Expanding into AVN for autonomous car
	2014.2.24	ATT R&D	Kim Mansik, CEO	Production of electric vehicles as well as slow speed and hybrid electric car electric vehicle consulting Expansion into autonomous car platform

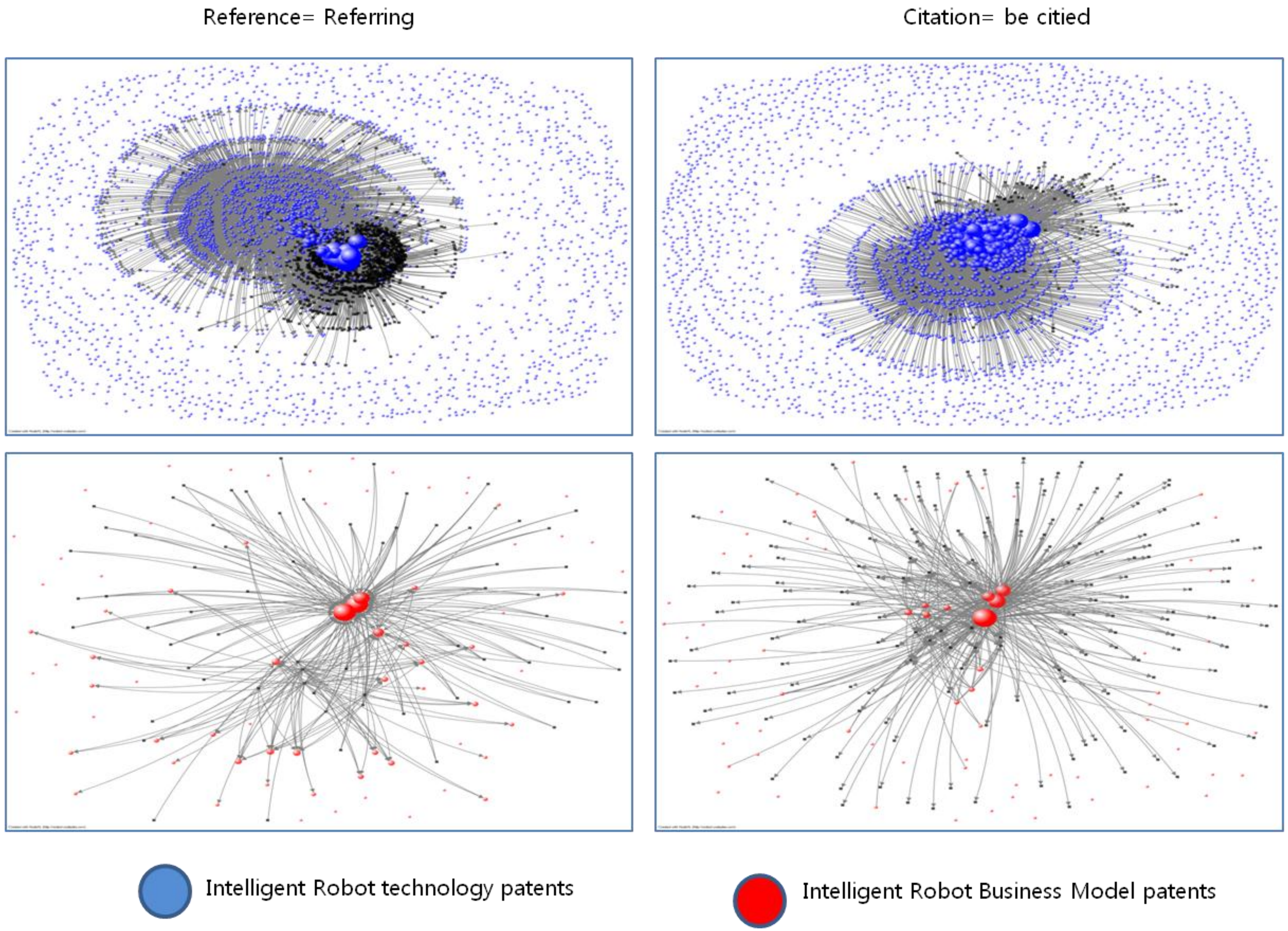
	2014.2.25	CammSys	Sung Sungu, General Manager	Mobile camera module Intelligent black box Developed camera for autonomous car and expanding to control sensor
	2014.2.28	Dong-Ah	Cho Bongnam, Managing Director	Car heater and air conditioner controller Motor speed controller Real view system Expand into controller for audio equipment
Intelligent robot	2014.03.05	IDEAR System Co., LTD. (Manufacturing of crop processing equipment)	Choi Byeongjo, CEO	Grain dryer, processor, and storage facilities Color sorter Rice processing complex Expand into eco-energy facilities
	2014.03.05	Diaos Cell (Manufacturing of industrial load cells)	Cho Heedong, CEO	Concentrate on various industrial load cells, such as BC type S type LC type
	2014.03.06	YuJin Mechatronics (Industrial robots)	Eun Jongok, CEO	Submission equipment Industrial robots Sense application Expand soft programing
	2014.03.07	SamIk Tech (Robot machine tool)	Choi Kyeongsu, CEO	Tower-automated tool changer Wireless communication transport robot Expand into distributed microwave drying and heating system
	2014.03.07	Creative Space (Robot education and teaching materials)	Lee Eunkyeong, CEO	Educational robotics and intelligent robot R&D Develop integrated science programs
Focus Group	2014.03.03	ETRI Electronics and Telecommunications Research Institute Autonomous car industry specialist	Jeon Hwangsu, PhD	Pointed out that due regulations and business model development are blocked.
	2014.03.03	KIET Korea Institute for Industrial Economics and Technology Intelligent Robot Specialist	Jeong Mantae, PhD	Pointed out that due to immaturity of standards, industrial and household robot industry cannot be developed efficiently.

	2014.03.20	Korea Delpai	Park SangChul R&D Planner	Pointed out that there a not leading firms autonomous car industri and there are a lot technologies f autonomous car alread
	2014.04.11 (Scheduled)	DGIST Intelligent robot System research specialist	Lee SangChoul Ph.D.	Pointed out that there are not high standards in intelligent robots which ar becoming bottlenecks in this industry.
	2014.04.12. (Scheduled)	DGIST Autonomous car Vision research specialist	Son JunWou Ph.D.	Pointed out that there are high regulations in autonomous car and electronic car all together

Appendix 2 Autonomous car technology, and business model patents network of reference, and citation



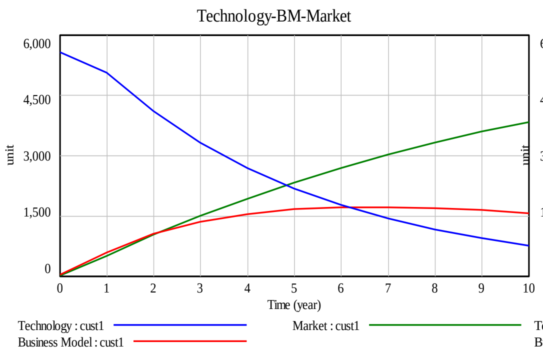
Appendix 3 Intelligent robot technology, and business model patents network of reference, and citation

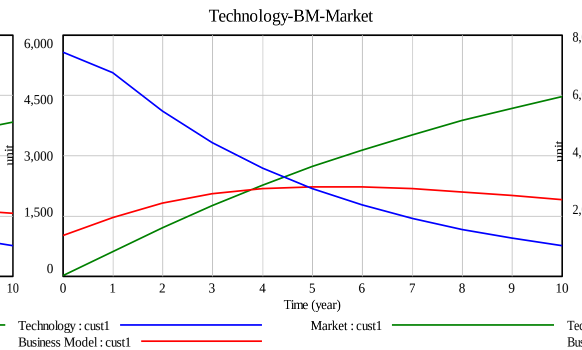


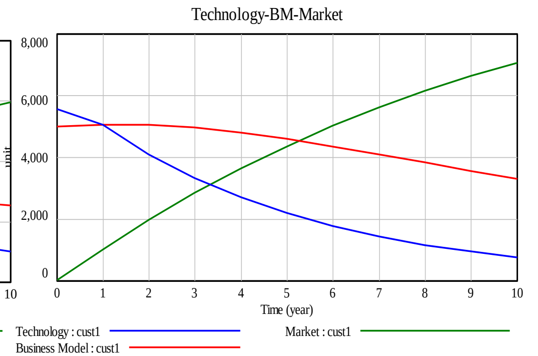
Appendix 4 Simulation results of autonomous car

Starting Level of BM=42 | Starting Level of BM=1000 | Starting Level of BM=5000

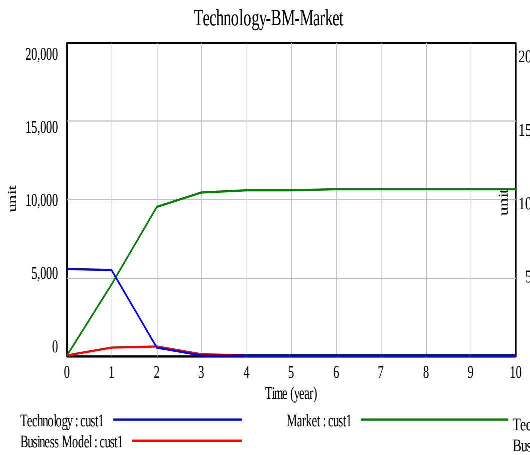
Autonomous Car: Leading Weak, Standardization Strong, Regulation Strong

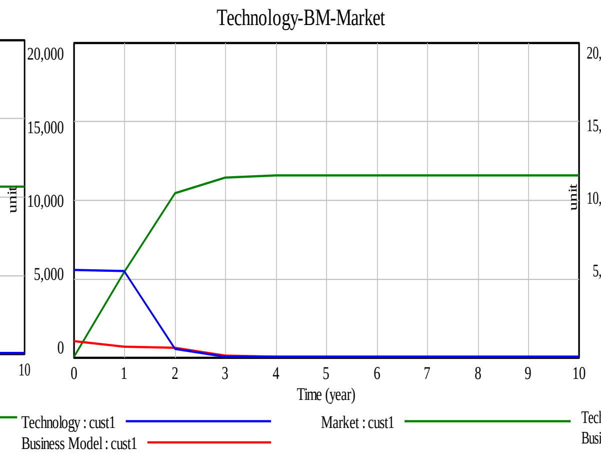


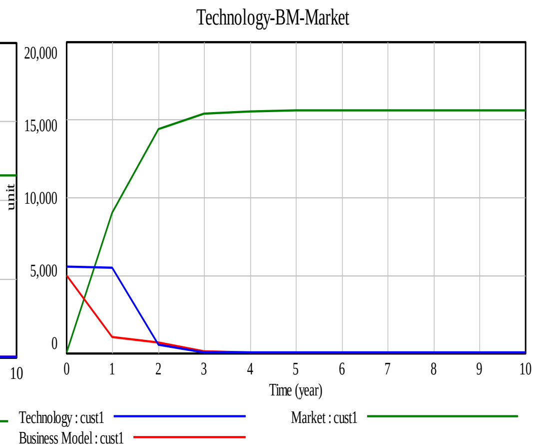




Autonomous Car: Leading Strong, Standardization Strong, Regulation Weak







Appendix 5 Simulation results of intelligent robot