Technological Forecasting & Social Change 146 (2019) 534–562

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

The role of a business model in market growth: The difference between the converted industry and the emerging industry

JinHyo Joseph Yun[a,*], DongKyu Won[b], KyungBae Park[c], EuiSeob Jeong[b], Xiaofei Zhao[a]

[a] Daegu Gyeongbuk Institute of Science and Technology (DGIST), 50-1, Sang-ri, Hyeonpung-myeon, Dalseong-gun, Daegu 711-873, Republic of Korea
[b] Korea Institute of Science and Technology Information (KISTI), Hoegi-ro, 66 Dongdaemun-gu, Seoul 130-741, Republic of Korea
[c] Sangji University, 660, Woosan-dong, Wonju, Kangwon-do 220-702, Republic of Korea

ARTICLE INFO

Keywords:
Business model
Open innovation
Converted industry
Emerging industry
Autonomous car
Intelligent robot
System dynamics
Simulation

ABSTRACT

This paper investigates the role of business models: What differences exist between the roles of an already-existing market-based converted industry and a newly appearing market-based emerging industry?

This study analyzed the status of the technologies and business models in the autonomous car and intelligent robot industries, as well as their recent two-year growth, using technology and business model patents. In addition, it investigated the current situation of the technologies, business models, and markets of the two industries based on literature reviews. This study then simulated the market growth of the autonomous car and intelligent robot industries using system dynamics. The simulations were established and verified by analyzing the references and citations of the technology patents and business model patents of the two industries. This study reached three conclusions. First, in the case of a converted industry such as autonomous cars, a strategy focused on a business model is useful in the early stage, whereas one focused on technology is efficient in the mature stage. Second, in the case of an emerging industry such as intelligent robots, a strategy focused on technology is somewhat more useful in the early stage than one focused on a business model; conversely, a strategy focused on technology is slightly more useful in the mature stage. Third, a business model is also important to supplement technology such as intelligent robots at a mature stage in Canada or autonomous cars at a mature stage in Japan.

1. Introduction

IT advances are producing innovative changes in all industries, leading to what many have called the Fourth Industrial Revolution. As the pace of these changes accelerates, creative combinations of technologies and markets are emerging in various segments of the economy. This Fourth Industrial Revolution is expected to produce revolutionary changes as industries and businesses start to adopt cyber-physical systems, which are combinations of physical systems and cyber systems (Bloem et al., 2014). Cyber-physical systems (CPSs) are based on the newest and foreseeable developments in computer science, information, and communication technologies combined with manufacturing science and technology. This confluence is frequently designated Industry 4.0 (Monostori, 2014).

More generally, the Fourth Industrial Revolution is characterized by the emergence of new business models, the disruption of existing systems, and the reorganization of production, consumption, transportation, and delivery systems (Schwab, 2017). One key feature is the emergence of creative business models, which involve a creative recombination of technologies and markets.

As a result, the Fourth Industrial Revolution has generated two types of new industries (see Fig. 1).

First are the converted industries replacing the existing market, such as the autonomous car industry, which is replacing the traditional car industry, or smart farm factories, which are replacing traditional agriculture. Second are the emerging industries, which do not have any precedent among similar industries. Examples include intelligent robots and 3-D printers.

Within this context, the goal of this study was to investigate the differences in the effects of business models on the growth and development of markets between the autonomous car as a converted industry and the intelligent robot as an emerging industry.

* Corresponding author.
E-mail addresses: jhyun@dgist.ac.kr (J.J. Yun), dkwon@kisti.re.kr (D. Won), kbpark@sangji.ac.kr (K. Park), esjng@kisti.re.kr (E. Jeong), qiaoke@dgist.ac.kr (X. Zhao).

https://doi.org/10.1016/j.techfore.2019.04.024
Received 5 June 2017; Received in revised form 17 April 2019; Accepted 21 April 2019
Available online 26 April 2019
0040-1625/ © 2019 Elsevier Inc. All rights reserved.

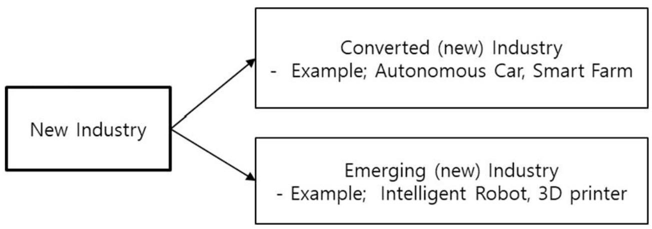


Fig. 1. Two types of new industries.

1.1. Research question

What differences exist in the role of the business model between an already-existing market-based converted industry, and a newly appearing market-based emerging industry?

We selected this research topic considering that the Fourth Industrial Revolution involves the creative recombination of technologies and markets as well as appropriate business models in various industries. The study aimed to identify the role of the business model in the market growth of two different sectors: the autonomous car and intelligent robot industries.

This study is a follow-up to the paper titled "The relationship between technology, business model, and market in the autonomous car and intelligent robot industries" (Yun et al., 2016b). The previous study analyzed the role of the business model in the autonomous car and intelligent robot industries. Extending research on this topic, this study aims to determine how the business models of the two industries affect their future market growth.

1.2. Research method and scope

To answer the research question, we examined two different industries—the autonomous car industry and the intelligent robot industry. We selected these two industries because both are new but comprehensively different market-based industries: one is an example of a converted industry (from the mechanical car industry to the electronic and computerized smart car industry), whereas the other is an emerging industry that is completely unlike any existing industries, such as the industrial robot industry.

This study used the system dynamics (SD) simulation method to determine the differences in the roles of the business models in the two industries. We used technology patents and business model patents as measures of the technology and business models of the two industries. We simulated 32 different conditions for each of the target industries. We then analyzed market data and information to validate our simulation models and to interpret the simulation results.

Next, we analyzed the technology patents and business model patents of the two target industries and set up simulation conditions based on the patents. We used G-Pas (http://gpass.kisti.re.kr), which is the worldwide patent database of the Korea Institute of Science and Technology Information (KISTI). The patents for the two industries were extracted using the keywords "autonomous car" or "autonomous vehicle," and "intelligent robot" or "autonomous robot," first from 1960 to 2014 and then from 1960 to 2016. This patent database includes all major countries, including the U.S., Europe, China, Japan, Korea, Germany, France, the United Kingdom, and Canada.

2. System dynamic modeling

2.1. Literature review and system dynamics model building

2.1.1. Literature review

Technologies do not affect markets directly, but do so through businesses, and a separate positive feedback loop structure exists between technologies and business models, as well as between business models and markets (Kodama and Shibata, 2015; Yun et al., 2016b). A business model serves as an intermediate construct that links the technical and economic domains (Chesbrough, 2006). As a combination of technologies and markets, a business model should cover strategies and resources to avoid miscombinations, such as technology overfitting or the Icarus paradox. However, new business models allow for potential additional innovations on top of product and process innovations (Gassmann et al., 2014).

What makes innovations disruptive? The root of tension is the conflict between business models established for existing technologies and those required to exploit emerging, disruptive technologies (Chesbrough, 2010). Thus, according to Chesbrough (2010), following "dominant logic" can lead to firms missing out on the potential valuable uses of technologies that do not fit their current business model. In addition, to offset increasing development costs and shorter product life cycles, companies must explore creative ways to expand their business models by using external ideas and technologies for internal product development, and by allowing commercialization of internal intellectual property (Chesbrough, 2007a, 2007b).

The same idea or technology marketed through two different business models will yield two different economic outcomes. Thus, a mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model. This is because technology, by itself, has no single objective value (Chesbrough, 2010).

In other words, a business model is a kind of articulated logic by which a business creates and delivers value to customers (Čirjevskis, 2016). A business model that creates and captures values for sustainable enterprise performance requires three key clusters of dynamic capabilities: (1) sensing (the identification and assessment of opportunities), (2) seizing (the mobilization of resources internally and externally to address opportunities and to capture value in doing so), and (3) transformation (the continual renewal of an organization) (Teece, 2007, 2010). Dynamic capabilities include the ability to not just sense new technologies and target markets, but also business models. Thus, the process of business model design includes selecting technologies and identifying markets in addition to determining benefits, confirming revenues, and designing mechanisms to capture value (Teece, 2010).

According to these studies, a conceptual model of technology, business, and market can be established as shown in Fig. 2. In addition, according to previous studies and the opinions of researchers in the autonomous car and intelligent robot fields, as well as those of other industry stakeholders, a technology is affected mainly by the appearance of leading firms, which includes the growth of markets. The business model is affected by regulations that cover environments, as shown at the bottom part of Fig. 2. Meanwhile, a market is affected mainly by the standardization status, which includes the price of products (Yun et al., 2016b).

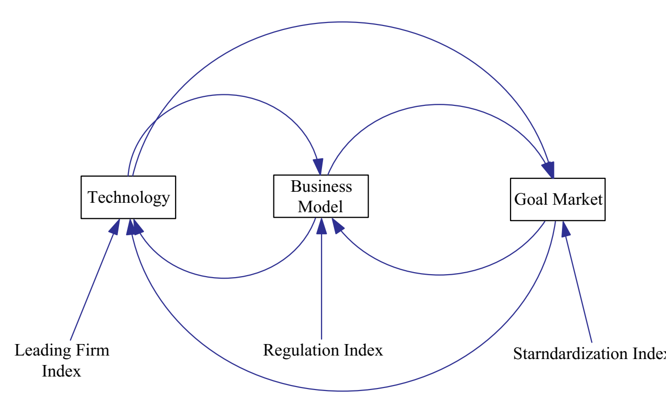


Fig. 2. Conceptual model.

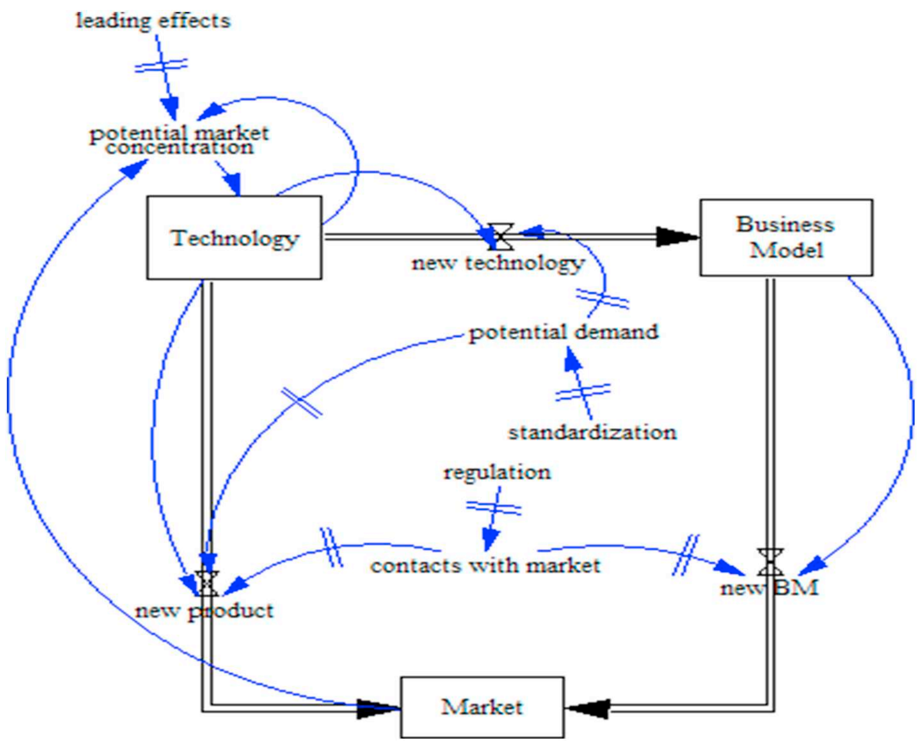


Fig. 3. System dynamics model.

2.1.2. Model building

The SD model, shown in Fig. 3, adopts a causal model of the relationships between technology, business, and market (Yun et al., 2016b). The cycle "nurturing leading firm → tech investment → technology innovation" in the causal loop is realized as "leading effects (time delay) → potential market concentration → technology" in the system dynamic model. In the system dynamic model, the interaction in the loop between deregulation and business model (BM), and new BM development is realized as "regulation (time delay) → contacts with market (time delay) → new BM" and "regulation (time delay) → contacts with market (time delay) → new product." Furthermore, the interaction and diffusion between "standardization and new BM development" and "standardization and economic efficiency" in the causal loop is realized as "standardization (time delay) → potential demand (time delay) → new technology" and "standardization (time delay) → potential demand (time delay) → new product." Technology variety and the cost of using alternative technologies are included in the system dynamic model.

2.2. Realities of the two industries

2.2.1. Autonomous car industry from the system dynamics model

An autonomous car is a self-driving vehicle that has the capacity to perceive the surrounding environment and navigate without human intervention (Jo et al., 2014). The functional components of the autonomous driving system consist of perception, control, planning, system management, and localization features, according to Jo et al. (2014), or of a GPS receiver, laser scanner, camera, radar, automated steering, automated braking, automated throttle, central processing unit, motion sensor, and speed sensor according to Beiker (2012).

Technologies and business models can be analyzed using technology patents and business model patents (Jaffe and Trajtenberg, 2002). Normally, patent applications or approvals specific to a business model are strictly constrained. However, as the knowledge-based economy gradually develops, the ratio of patents to the total amount of knowledge existing in the world continues to increase. As a result, the degree to which patents overlap with R&D and new products, including business models, is significantly expanding (Acs et al., 2004; Hagedoorn and Cloodt, 2003; Yun et al., 2016a, 2016b). Nonetheless, until recently, few business models were patented, either because the patented business model offered only weak protection, or because of the difficulties in getting such applications approved. With the open innovation paradigm, the value of business model patents and the business model itself has been steeply increasing in the fourth industrial era (Amit and Zott, 2012; Chesbrough, 2010; Johnson et al., 2008; Zott et al., 2011).

Using the relationship between a patent and its descendants, what we call the overall "importance" of a patent, we can directly determine the importance of any technology, and indirectly evaluate the future of related markets.

As shown in Table 1, according to patent searches using related keywords, technology patents for autonomous cars have increased by 1.73 times in the past 30 months. Simultaneously, business model patents for autonomous cars have grown by 3.36 times. However, there was a much larger difference in the rate by which references and citations for technology and business model patents increased. The references and citations of technology patents increased by 2.10 and 2.65

Table 1
Technology and business model patents of autonomous cars (June 3, 2014 → November 28, 2016).

Patent category	Number of references (record)	Number of technology patents	Number of citations (record)
Technology patents	13,047 → 27,479	**5557 → 9630**	11,180 → 29,578
Business model patents	322 → 2103	**42 → 141**	52 → 376

Bold values indicates pay attention to the increase of business model patent in short time.

times, respectively, while those of business model patents grew by 6.53 and 7.23 times, respectively.

It should be noted that, in the situation of regulation of the autonomous car industry, to maximize safety and consumer benefits, it is necessary to have a legal infrastructure that regulates public autonomous driving (Beiker, 2012). Autonomous driving involves many challenges in terms of individual mobility and purpose. Several methods can be used to prepare for the public use of autonomous vehicles, including the use of (1) pilot fleets evaluated through statistical comparisons, (2) extensive beta testing with "limited autonomy," (3) mock trials and focus groups, (4) special insurance policies for autonomous vehicles, and (5) mandatory data recorders for autonomous vehicles (Beiker, 2012). Autonomous cars face much stricter regulations than cars driven by humans, as they are affected by new regulations as well as the existing regulations that govern automobiles. It is also possible that U.S. states may develop their own regulations to guide the technology's development, in which case they might "create a crazy quilt of different, and perhaps incompatible requirements that could increase costs and make the technology uneconomical" (Anderson et al., 2014).

Autonomous vehicles have five levels of automation: Level 1, function-specific automation; Level 2, combined function automation; Level 3, limited self-driving automation; Level 4, self-driving under specified conditions; and Level 5, full self-driving automation (Litman, 2014).

In terms of the level of autonomous driving, the five levels of the Society of Automobile Engineers (SAE), the four stages of the National Highway Traffic Safety Administration (NHTSA), and the four stages of Bundesanstalt für Straßenwesen (Federal Highway Research Institute) (BASt) are comprehensively different from each other (Dokic et al., 2015). The ranges and levels of self-driving capacity announced by companies that are developing or already operating autonomous cars also vary. In other words, at present, there is no final or uniform standard for autonomous driving.

Companies from three different sectors are currently competing with each other in the autonomous car field. There are ICT firms such as Google, Apple, and Baidu; companies that manufacture finished cars such as Audi, Ford, Mercedes–Benz, Volkswagen, Volvo, Hyundai and Kia Motors, BMW, and GM; and electric car firms such as Tesla (Eng, 2016). The IT company segment of the self-driving car industry, including Apple, Amazon, Alibaba, Google, Uber, and Baidu, are promoting a radical change in the autonomous car industry (Dudenhöffer, 2016). Yet, self-driving car innovations have been gradually promoted by traditional automakers for the past 40 years. What is clear is that there is no leading firm in the autonomous car sector. In this light, there are not enough standards in the autonomous car industry to date.

Google and Apple aim to fully realize self-driving by 2020. Baidu intends to assist with the self-adjusting feature, that is, Level 2 self-driving. Audi is making efforts to resolve traffic congestion issues, while BMW aims to resolve traffic congestion issues and assist in developing emergency driving features in 2018. GM has strived to realize self-adjusting and lane-keeping functions since 2017, and Ford intends to assist in improving the self-adjusting feature by 2020. Mercedes–Benz and Volkswagen are working hard to achieve an ultimate solution to traffic congestion by 2019 and 2020, respectively. Volvo is trying to implement self-adjusting and lane-keeping features by 2016, and Hyundai and Kia Motors are working to develop an ultimate response to traffic congestion and lane keeping by 2020.

However, at present, there are no companies manufacturing fully self-driving cars. The market status of current self-driving automobiles is led by Tesla, an electric car firm, which has updated its car SW and has shown Level 2 autonomous driving.

Previous estimates expected the self-driving car market to become active in earnest after 2015, as shown in Table 2. The Institute of Electrical and Electronics Engineers (IEEE) forecast in 2012 that, by 2040, autonomous cars would account for 75% of all vehicles in the world. However, the 2013 data described in Table 2 predict that this will occur as early as by 2035. In general, such predictions suggest that autonomous cars will emerge earlier than expected.

Table 2
Market forecast for the autonomous car industry (unit: 1000 cars, %).

		2020	2025	2030	2035
All automobiles		98,103	106,917	116,221	127,170
Autonomous cars	Number	7.3	4756	47,113	95,444
	Ratio	0.01%	4.4%	40.5%	75.1%

Source: Autonomous Vehicles. Self-Driving Vehicles, Autonomous Parking, and Other Advanced Driver Assistance Systems: Global Market Analysis and Forecasts. Navigant Research, 2013.

In summary, when it comes to the sectoral innovation system of autonomous cars, the regulation level is high, but standardization has not yet been achieved nor leading firms established, and their statuses are low. This is in contrast to the opinions of industry experts as stated in interviews in 2015. According to such interviews, regulation and standardization levels were high, but the status of leading firms was low (Yun et al., 2016a, 2016b). The standardization status of the Korean self-driving car market was thought to be high because respondents confused the standards for driverless cars with those of existing vehicles. At the time, there were no global leading firms in Korea, nor concrete strategies for autonomous car makers in Korea. This was clarified through additional interviews.

2.2.2. *Intelligent robot industry from the system dynamics model*

An intelligent service robot perceives the surrounding environment and recognizes the situation independently, for autonomous mobility and manipulation. Such robots can provide intelligent services in various fields such as education, medical treatment, elderly care, defense, construction, undersea works, and agriculture. Its brain is a product of artificial intelligence (AI) combined with advanced sensors. With the convergence and performance of IT technologies, service robots are evolving into IT-based intelligent service robots that can function widely and operate in a virtual space using a network.

As shown in Table 3, technology patents in the intelligent robot industry have increased by approximately 2.98 times over the past 30 months. At the same time, the references and citations of the technology patents have grown by 1.93 and 3 times, respectively. Meanwhile, business model patents in the industry have increased by 2.2 times, which is relatively high, but still lower than the growth of technology patents. The references and citations of business patents increased by 2.33 and 2.82 times, respectively.

As shown in Table 4, the intelligent robot industry has already been extensively formed, and has grown with the manufacturing robot industry. Service robots are basically intelligent robots. Since 2009, the personal service robot industry has grown at an annual average rate of 29%, and leading firms are emerging in this field. Personal service robots are being widely developed, particularly for home cleaning, personal assistance, entertainment, and education. Several Japanese firms such as Yaskawa, Toyota, and Sony already lead the markets in cleaning, medical service, and emotional robots.

Professional service robots, on the other hand, are not designed for personal services. Possibly because they tend to be expensive, significant growth has not been achieved. However, their growth rate is not so small. For example, several robots are already outstanding in their industry, including Pepper, an artificial intelligent robot of SoftBank, Prime Air, a drone-based delivery robot of Amazon, and "THOR-MANG" at the DARPA Robotics Challenge.

In particular, in June 2015, SoftBank started selling Pepper to the public, intended for personal services. Using the Pepper app, it can recognize and learn human feelings through an "emotion engine," as well as perform diverse functions such as managing photos, saving a

Table 3
Technology and business patents of intelligent robots (June 3, 2014 → November 28, 2016).

Patent category	Number of references (record)	Number of technology patents	Number of citations (record)
Technology patents	8708 → 16,789	**2994 → 8924**	7404 → 22,218
Business model patents	240 → 558	**74 → 163**	414 → 1169

Table 4
Intelligent robot industry markets.

Category	2009	2010	2011	2012	2013	2014	Annual average
For manufacture	3976	5678	8278	8796	9507	10,737	22%
For service	2801	3890	4205	4860	5366	5965	16%
Professional	2200	3353	3569	3636	3662	3779	11%
Personal	601	537	363	1224	1704	2186	29%
Total	6777	9568	12,483	13,356	14,873	16,702	20%

Source: World Robotics, 2015.

diary, and playing voice games, as well as conducting formation acquisition through the Internet and message sending. In August 2014, Dr. Cynthia Breazeal from the Massachusetts Institute of Technology (MIT) launched JIBO, a personal interactive home service robot capable of communication with a user and photoshoots. Blue Frog Robotics, a French start-up dedicated to robots, developed Buddy, a social robot based on the Android open-source platform. Apple has acquired several intelligent robot companies, including Vocal Q, which is developing a self-learning conversation platform; Perceptio, which has enabled the operation of a smartphone AI system without sharing user data; Emotient, which handles an AI platform that reads human emotions; and Faceshift, which specializes in motion capture technology. Apple seeks to change the Apple OS to the SW platform for intelligent robots.

The U.S. invested intensively in the intelligent robot industry during Obama's presidency, focusing on health care, medical treatment, and defense as part of the "Advanced Manufacturing Partnership" (AMP). Japan is actively developing service robots based on its competitiveness in manufacturing robots and its global leadership in the manufacturing robot industry. Its targets are robots for medical rehabilitation and nursing—efforts led by Toyota and Yaskawa.

Meanwhile, European countries are focused on service robots, particularly those for welfare—such as medical treatment and rehabilitation—and for health care, traffic, and social security. Although China intensively promotes a policy for manufacturing robots, it does not separately pay attention to the intelligent robot industry. The Korean government has formulated an intelligent robot industry policy, including the manufacture of robots and network-based robots, as well as robots for personal and professional services.

However, despite this progress, there are presently no standards for intelligent robots, as shown by the differences in the target projects of the intelligent robot policies of each nation. In addition, physical standards, such as the range of components in intelligent robots, have not been actively discussed or fully developed. In addition, the establishment of an SW platform standard for intelligent robots is in an early stage of discussion.

Regulation of the intelligent robot field is not yet being actively discussed. This means that the various regulations in the hardware and software fields that must be faced once intelligent robots become a part of our lives have not been fully considered. These include the processing and security of personal information needed to offer personal robot services, data integration by connecting intelligent robots, and the cloud-based accumulation of knowledge and databases of the robots. Some of the world's greatest scholars, including Stephen Hawking, warned about the risks of AI. Because there is a possibility that the intelligent robot industry will employ AI, these warnings should motivate the establishment of industry regulations.

In summary, for the sectoral innovation system of intelligent robots, the regulation and standardization levels are low, but the leading firm status is high. This situation is identical to the results obtained from interviews with experts of the Korean intelligent robot industry in 2015 (Yun et al., 2016a, 2016b).

However, the interviews also indicated that Korean firms were considered leaders in the intelligent robot market, due to inaccurate knowledge of the leadership role of large Japanese companies and actual Korean conditions. There was also some confusion around Hubo, an AI robot that was developed for research by the Korea Advanced Institute of Science and Technology (KAIST). In fact, the Korean AI robot industry does not have leading firms. This situation was confirmed through additional interviews.

3. Simulating autonomous car industry market growth

Along with replacing the existing automobile industry, the autonomous car industry is also creating a never-seen-before market (Chesbrough and Teece, 1996; Jeong and Ko, 2016). With the appearance of a converted industry, the structure, content, and characteristics of existing markets are changed. Currently, the autonomous car industry does not have a leading firm (Litman, 2014). In addition, uniform standards have not been established (Markoff, 2010). However, because it is replacing an existing industry, newly formulated market regulations as well as the stringent regulations of the existing market need to be taken into consideration (Beiker, 2012; Nothdurft et al., 2011).

This study simulated the market size of the autonomous car industry under two different conditions, as well as technology and business model variables. First, under the current market conditions of a low leading-firm effect, a low standardization level, and high regulations, we simulated the growth of the market as it is, the growth of the future market when technologies were improved in proportion to the increase in technology patents in the industry for the past two years, and the growth of the future market when business models were enhanced as much as the increase in technology patents in the industry for the past two years. Second, under conditions of when the autonomous car market is completely developed, that is, under a high leading-firm effect, a high standardization level, and more sophisticated and established regulations, we simulated the growth of the future market as it is, the growth of the future market when technologies were improved proportionally to the increase in technology patents in the industry for the past two years, and the growth of the future market when business models were enhanced to the same degree as the increase in technology patents in the industry for the past two years.

In these scenarios, "technologies" was defined to included trade secrets and general knowledge, as well as patented technologies. The ratio and value of patented technologies have gradually increased with the development of a knowledge-based economy (Chesbrough, 2006; Yun et al., 2016a, 2016b). Thus, it is reasonable to use the number of patents to estimate the current technological level of autonomous cars and to simulate improvements in the technologies in the future.

It is noteworthy that a mediocre technology pursued with a great business model may become more valuable than a great technology exploited via a mediocre business model, even in the autonomous car industry (Chesbrough, 2010). In particular, with the acceleration of CPSs through the combination of physical systems and cyber systems during the Fourth Industrial Revolution, the importance of a new business model increases (Bloem et al., 2014; Schwab, 2017). However, in essence, a business model is a conceptual rather than a financial model, and involves a new combination of technologies and markets (Chesbrough, 2007a, 2007b; Teece, 2010). Thus, the business model itself needs to be researched and developed, although not to the same extent as technology development.

Because business models largely comprise conceptual characteristics, only a few can be protected by patents. Moreover, business models are typically combined with a corporate strategy and continuously developed, and as a result, the initial business model is frequently modified and supplemented. Thus, this study simulates the increase in business models based on the rising number of technology patents in the industry for the past two years. The reason for this is that the growth in business model patents for the past two years actually affects very few technologies, according to Table 1. In addition, simulating the increase in business models using growth similar to that of technologies takes into consideration that the increase in business models of the same size has a much smaller development cost, compared with the increase in technologies of the same size.

3.1. Simulation of current autonomous car industry conditions: leading, weak; standardization, weak; and regulation, strong

Fig. 4 shows the simulation of market growth created by a change in technologies and business models under the current conditions, that is, an infant or growing autonomous car industry with a converting market. The simulation results indicate that the development of business models leads to faster and higher market growth than the development of technologies in a converted industry. Carmakers and parts supply companies need to develop proper business models and strategies to prevent themselves from being squashed by swifter and stronger companies, such as the new service companies from the Internet industry, including Apple, Baidu, Google, Tesla, and Uber (Dudenhöffer, 2016).

The simulation results can be verified by the movements of these companies. They are newly entering or making attempts to enter the autonomous car industry by developing new business models, such as car sharing, unmanned delivery services, and diverse sharing-based automotive services.

Access-based consumption in the context of car sharing, such as Zipcar, is an example of a new business model for autonomous car industries (Bardhi and Eckhardt, 2012; Weikl and Bogenberger, 2013). The rise of the so-called “sharing economy” has created new competition between traditional taxies and car-sharing services (Wallsten, 2015). Uber and Lyft are trying to maximize the competitiveness of their car-sharing services by introducing autonomous car systems (Kanter, 2015; Viereckl et al., 2015). Amazon's autonomous car is also connected to a new business model, for example, the robot cargo car (Walch et al., 2015). The growth of diverse self-driving car projects is based on various business models. They support the validity of the simulation results shown in Fig. 4. In addition, in the early growth stage of a converted industry, the market-pull value generated by a business model can be estimated using these simulation results. In addition, the simulation results of the currently emerging infant autonomous car industry of eight individual countries show that business models motivate more market growth than technology growth without exception (see Appendix 1). Furthermore, the U.S., which has a high amount of technology, as well as business models for autonomous cars, shows the largest difference between business model-based market growth and technology-based market growth (see Appendix 1-1) when compared with Canada, which has a low amount of technology and business model patents in autonomous cars (see Appendix 1-8).

3.2. Simulation of after-growth autonomous car industry conditions: leading firm, strong; standardization, strong; and regulation, strong

Fig. 5 simulates the market size expansion caused by the increase in technologies and business models after the autonomous car industry has matured. Taking into consideration various conditions that were in place when the existing automobile industry developed and matured, it is estimated that leading global firms will strongly emerge and that related standards will be clearly established. In addition, related regulations will be formulated (Oltra and Saint Jean, 2009; Sturgeon et al., 2008; Xi et al., 2009).

According to the autonomous car market simulation results after market growth, the introduction of new technologies and business models does not lead to a large difference in market growth between them, even though technology spurs slightly more market growth than seen in the business model. In other words, according to Fig. 4, the expansion of the autonomous car market after the initial growth period does not show a large difference according to (a) the strategy of strengthening technical development, or (b) reinforcement of the business model. This simulation result is fully reasonable considering the current situation, in which strategies to develop technologies and business models in the existing maturing automobile market do not directly lead to the creation of an additional market difference (Bauner et al., 2009; Godoe, 2006).

Overall, new markets in the autonomous car industry are not generally created by technology introduction or business model development after their initial growth. However, new technology development has a relatively greater effect on creating additional markets, compared with new business model development.

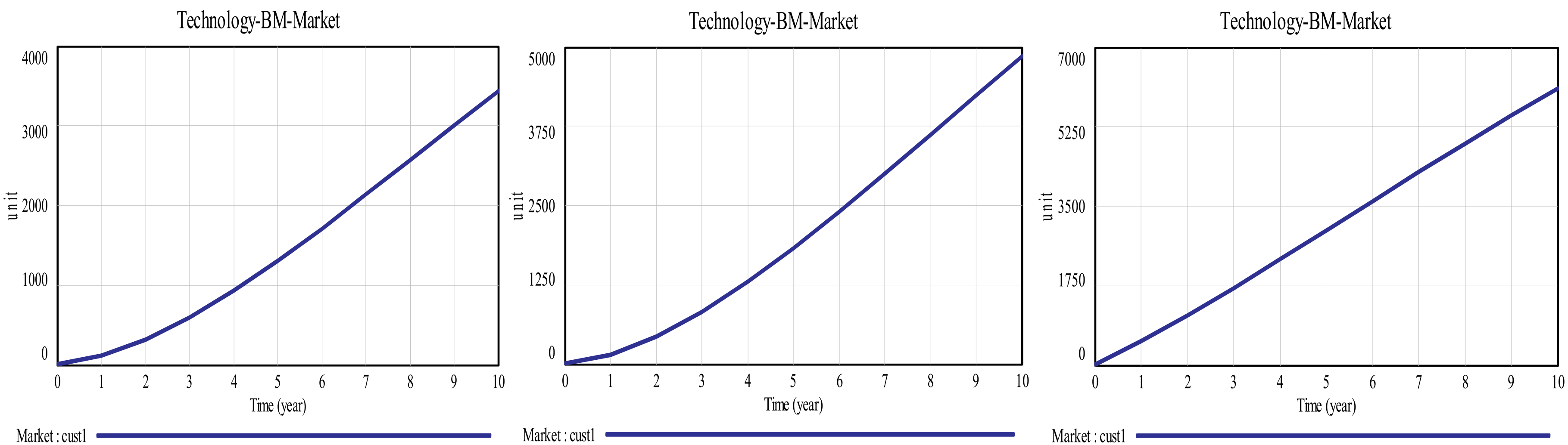
It can be assumed that the reason technical development plays a larger role in creating additional markets is related to the establishment of a dominant design. This is interpreted to mean that when a dominant design is established in an industry, technology development that effectively implements the existing business model will have a greater impact on securing additional markets than new business model development (Henderson and Clark, 1990; Tushman and Murmann, 2002).

After the growth of the autonomous car industry, the simulation results of eight individual countries are as shown in Fig. 5 (also see Appendix 2). The market growth gap between technology-based growth and business model-based growth in small market countries such as France (Appendix 2-6) and the U.K. (Appendix 2-7) is insignificant compared with larger market countries such as the U.S. (Appendix 2-1), Japan (Appendix 2-3), and China (Appendix 2-4).

4. Simulating market growth of the intelligent robot industry

The intelligent robot industry is newly emerging. Yet, while intelligent robots are being developed and improved at an unprecedented pace, the question of how these products should behave and interact with humans and act socially remains largely unanswered (Bartneck and Forlizzi, 2004a). The industrial robot industry began to grow following the introduction of the Mitsubishi PA-10 robot arm and Barrett WAM. The intelligent robot industry started with ASIMO of Honda, AIBO of Sony, and Wakamaru of Mitsubishi Heavy Industries in the 2000s. However, the intelligent robot industry has created a new market rather than replacing the industrial robot industry or another existing industry. An intelligent robot promotes user interaction and has the characteristics of a social robot, with partial autonomy (Bartneck and Forlizzi, 2004b). From this perspective, the intelligent robot industry is clearly creating a completely new market.

The present study simulated the market size of the intelligent robot industry under two different conditions and two variables—technology and business model. First, under current market conditions, with a relatively high leading-firm effect and low standardization and regulation, we simulated the growth of the future market as it is, and the

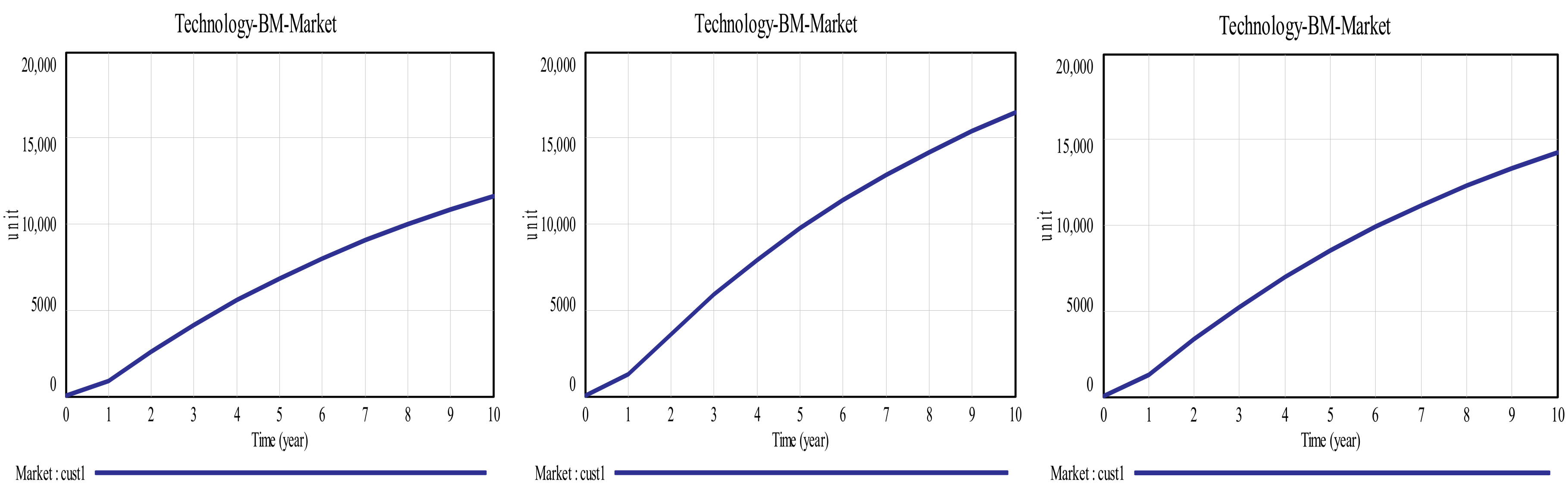


(a) Current Condition Simulation
Technology = 9,630, BM = 141

(b) Technology Increase Simulation
Technology = 9,630 + 4,073, BM = 141

(c) BM Increase Simulation
Technology = 9,630, BM = 141 + 4,073

Fig. 4. Simulation of currently emerging infant autonomous car industry.



(a) Now Condition Simulation
Technology = 9,630, BM = 141

(b) Technology Increase Simulation
Technology = 9,630 + 4,073, BM = 141

(c) BM Increase Simulation
Technology = 9,630, BM = 141 + 4,073

Fig. 5. After-growth autonomous Car industry simulation.

growth of the future market when technologies have improved on par with the increase in technology patents in the industry for the past two years. We also simulated the growth of the future market when business models were enhanced in proportion to the increase in technology patents in the industry for the past two years. If a weight is given to a system in the SD model from 0 to less than 1, the high leading-firm effect is 0.9, and the low standardization effect is 0.1. In addition, the low regulation effect is 0.1.

Second, considering that the intelligent robot market has been fully developed, that is, under a high leading-firm effect, a high standardization level, and established high regulations, we simulated the growth of the future market as it is, when the future market grows when technologies are improved in proportion to the increase in technology patents in the industry for the past two years, and when business models are enhanced as much as the increase in technology patents in the industry for the past two years. If there is a weight given to the system in the SD model from 0 to less than 1, the high leading-firm effect is 0.9, and the high standardization effect is 0.9. In addition, the high regulation effect is 0.9.

We simulated both technologies and business models. For the technologies, 8924 patents were analyzed in late November 2016 by searching for intelligent robot technology patents considered to be at the initial technology level. In terms of business models, 163 patents were searched for in the same period and at the same initial business model level.

For the simulation of the intelligent robot industry with a new emerging market, as the number of patented technologies increased, their ratio and value became more important. It was thus possible to estimate the current technology level of intelligent robots by considering the number of related patents, and to simulate the increase in related technologies in the future.

In addition, although there are more business model patents for intelligent robots than autonomous cars, few business models are patented, and most exist only as trade secrets or in combination with other strategies. Thus, we simulated the growth of the business models of intelligent robots by considering the increasing number of technology patents for the past two years, which totaled 5930.

4.1. Simulation of current intelligent robot industry conditions: leading firm, strong; standardization, weak; and regulation, weak

Fig. 6 indicates the simulation of market growth brought about by changes in technologies and business models under the current conditions of intelligent robots with a new market, that is, infant or growth industry conditions.

According to the simulation results, when the intelligent robot industry creates a new market, technology development-based market growth is faster and higher than business model-based market development. That can be interpreted as follows: technology innovation leads the business model in new market creation in the infant market conditions of an emerging industry, such as the intelligent robot industry.

The key to create intelligent robots is the expansion and development of the three main technological elements—perception, cognition, and mobility and manipulation—and the development of their business models. This explains the simulation results, which indicate that market creation led by technologies is greater than that led by business models, and is also consistent with the actual situation.

Although robots have been used in laboratories and factories for several years, their uses are changing rapidly. For instance, the sales of professional and personal service robots, or intelligent robots, have risen sharply, and it is estimated that the total number sold will reach 11.5 million by 2011 and USD 5282 by 2013, according to World Robotics 2014 (Sharkey, 2008). Although the intelligent robot industry developed later than the industrial robot industry and is still in its early growth period, its market is growing. That trend corresponds to the simulation results (Singer, 2011).

The intelligent robot industry is a new emerging industry, and the simulation results show that technology development leads market expansion in both the infant and after-growth stages of the industry. The technology sector, including AI, cognition, and response, may lead a market, and the post-development of corresponding business models may create a market. In addition, when the intelligent robot industry creates a new market, the simulation results show that investment in both technology development and business model development leads to massive market creation.

The simulation results correspond to actual conditions. For example, although AI technology development remained stagnant for long, it has recently begun to grow tremendously due to technical developments such as Google's Deep Learning. The technology market is expanding explosively with products such as Roomba, an autonomous robotic vacuum cleaner, and Pepper, SoftBank's social robot (Jones, 2006; LeCun et al., 2015; Sung et al., 2007).

The currently emerging infant intelligent robot industries of eight individual countries show similar results in Fig. 6 (see also Appendix 3). In Japan (Appendix 2-3) and the U.K. (Appendix 2-7), the gap between the technology-based and business model-based market growth simulation is not significant compared with the simulation results of the autonomous car industry of these countries presented in Appendix 1.

4.2. Simulation of after-growth intelligent robot industry conditions: leading firm, strong; standardization, strong; and regulation, strong

Fig. 7 simulates the market size expansion caused by an increase in technologies and business models after the intelligent robot industry has matured. Because this industry does not have an alternative market, it is not easy to estimate its maturity. However, taking existing mature industries into consideration, such as the mobile and computer sectors, it is estimated that global leading firms will emerge and that a standard will be set. In addition, regulations will be established.

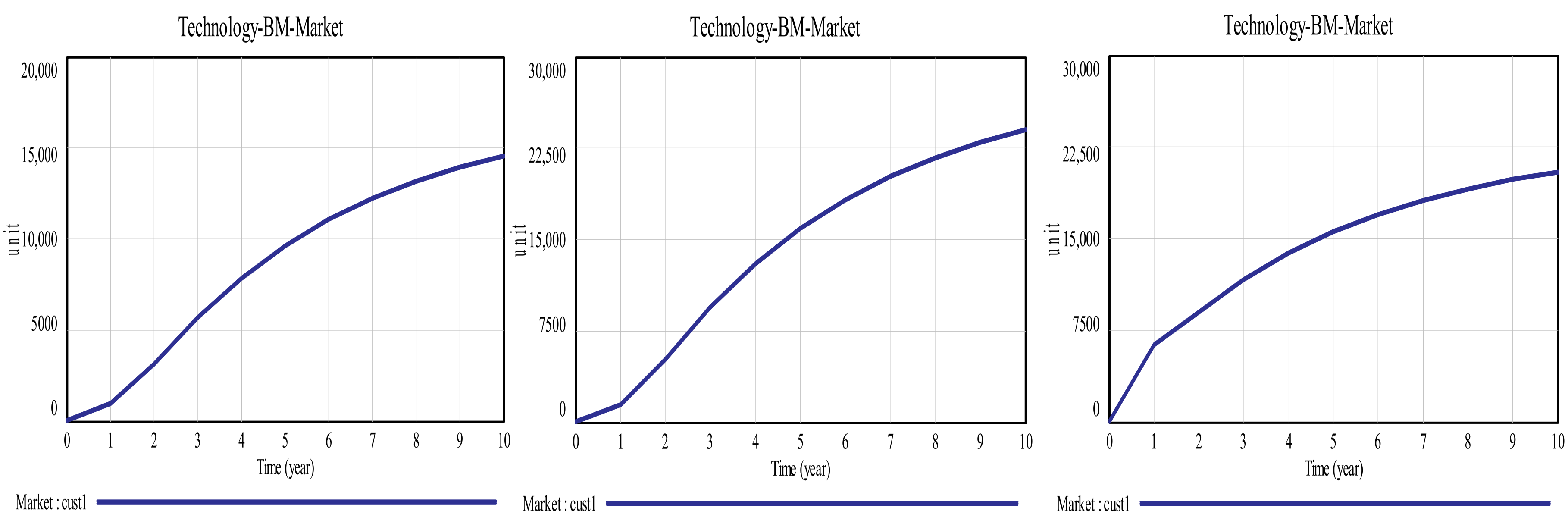
The simulation results for the intelligent robot market after its growth period show that the introduction of new technologies and business models leads to additional growth of the market. When the characteristics of a market are fully known or an alternative market does not exist, the development of new technologies and business models may lead to the creation of and an increase in new and diverse markets. Thus, the results are consistent with the actual conditions. In particular, with the introduction of intelligent robot products, such as cleaning robots, personal service robots, professional service robots, and personal AI service robots, technology development and a new business model introduced after its maturity period may lead to new market growth together (Gockley et al., 2007; Kim et al., 2013; Scassellati, 2007).

In other words, the simulation results depicted in Fig. 7, which shows the expansion of the intelligent robot market after a growth period without additional development of technologies and business models, clearly indicates that the strategy of strengthening technical development may lead to slightly more market growth than the strategy of reinforcing business models.

Overall, the effect of the development of new technologies on additional market creation is relatively higher than that of business models, after the growth of the intelligent robot industry. For an emerging industry that does not have a converting market, it is estimated that technology development will create a larger market than business model development, but that both will continuously create massive markets.

Because the intelligent robot industry is creating new markets in various ways, a dominant design has not been established even after the growth period, and diverse new markets and dominant designs will appear (Anderson and Tushman, 1990; Suàrez and Utterback, 1995; Teece, 2010).

After market growth, the simulation results of eight individual

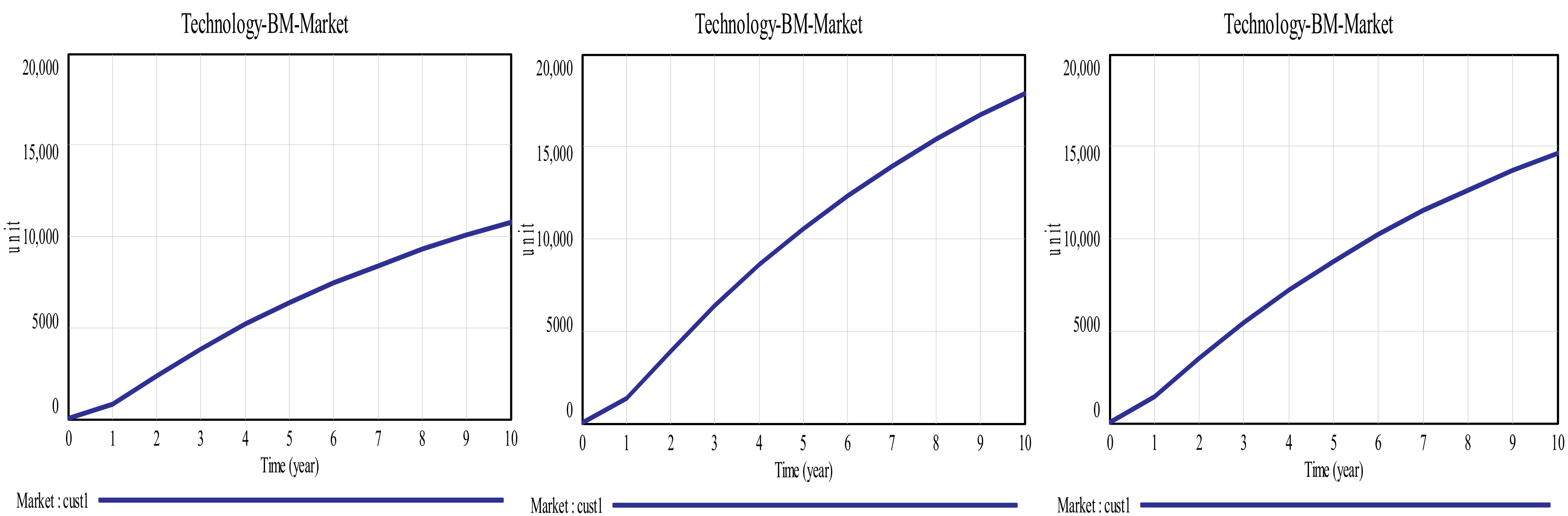


(a) Now Condition Simulation
Technology = 8,924, BM = 163

(b) Technology Increase Simulation
Technology = 8,924 + 5,930, BM = 163

(c) BM Increase Simulation
Technology = 8,924, BM = 163 + 5,930

Fig. 6. Currently emerging infant intelligent robot industry simulation.



(a) Current Condition Simulation
Technology = 8,924, BM = 163

(b) Technology Increase Simulation
Technology = 8,924 + 5,930, BM = 163

(c) BM Increase Simulation
Technology = 8,924, BM = 163 + 5,930

Fig. 7. After-growth intelligent robot industry simulation.

countries are similar to Fig. 7. In the case of insignificant technology conditions, such as in Canada (Appendix 4-8), a business model-based growth strategy of intelligent robots can create a larger market than a technology-based growth strategy.

5. Discussion and conclusion

5.1. Discussion

5.1.1. The high role of the business model in a converted industry

For a converted industry, a business model is highly important. The new business model itself leads to market growth, and technology development is required to implement the new business model in a sophisticated manner. We have clearly shown that the simulation results correspond to actual situations. Two examples are Apple's smartphones replacing Nokia's feature phones, as well as the growth of Samsung's smartphones and Chinese smartphone makers. Apple created the mobile music download business model, the App Store business model, and the Office mobile business model based on the existing mobile Internet, screen, and download music platform, and implemented them in the iPhone series. Thus, it became a leader in the smartphone market and replaced Nokia's feature phones. Samsung and Chinese smartphone makers then implemented business models introduced from or established in the smartphone industry with a more up-to-date camera, touch, authentication, and screen technologies, as well as additionally developed business models, to compete with Apple.

The greatest discovery of this study is that in the second IT era, or Fourth Industrial Revolution, the development of an advanced business model in a converted industry is important for fast and substantial growth of the initial market. Existing studies have not paid attention to the role of business models in converted industries because they misinterpret the development of a new business model as a new technology.

In particular, the open business model platform, which allows people to develop a new business model and create profits together, was mistaken for a technology; the role and function of the business model in converted industries thus were not properly evaluated. Open business model platforms, such as App Store, iBooks Author, GarageBand, and iTunes Radio, are business models that earn profits by themselves, and other companies can add a new business model to these platforms and share some of the profits.

To activate open business model platforms, Apple created the authoring tools that are used for the business models and offered them for free or at low cost. For example, anyone can create and upload a book in iBooks through Book Writer; easily make music and sell it by uploading it to iTunes through GarageBand; and develop and upload an app in Apple's App Store through Swift, Apple's easy application development program.

5.1.2. Post-catch-up by open innovation and new business model development

Instead of catching up with companies and targeting an existing market, post-catch-up replaces an existing market or establishes a new market. The open innovation strategy with a business model at post-catch-up is emerging as an important strategic means (Lee and Lim, 2001). The leapfrogging catch-up strategy that creates a path is a part of the post-catch-up strategy based on open innovation.

The open innovation for post-catch-up leads to the creation of a new business model that creatively recombines technologies and markets (Li and Kozhikode, 2009; Xielin, 2005). The post-catch-up strategy for creating a new industry requires the development of a business model that is continuously combined with a new market and secures external creative technology through an open innovation strategy (van Elkan, 1996). In other words, even for a new emerging industry, the development of a business model is no less important than technology.

5.2. Summary and limits, and future research agenda

5.2.1. Summary and limits

Fig. 4 shows that the effect of the business model is greater than the effect of technology in the currently converted infant autonomous car industry simulation. In contrast, Fig. 6 shows that the technology effect is larger than the business model effect in the currently emerging infant intelligent robot industry simulation. This means that in a currently converted infant industry, the business model has a larger effect on market growth than technology. Two different types of industries are currently appearing—a pure new market industry and a converted new market industry. In a pure new market industry such as AI, technology is important in the emerging period. In contrast, in a converted new market industry, such as the autonomous car industry, the business model is important in the emerging period.

This study used the changing trends in technology patents and business model patents in the autonomous car and intelligent robot industries of eight countries for the last two years as the actual measured value, and simulated and analyzed the market growth of the two industries based on preceding studies. In particular, the effect of the additional development of technologies and business models on market growth in the current infant industry, and on market growth after the growth period, was simulated and analyzed, and the simulation results were interpreted.

This study confirmed the qualitative validity of the simulation results using existing analytical results of the industry, as well as cases of similar industries. The results suggest implications of present and future strategies in the two industries. However, because there are insufficient industrial data on the autonomous car and intelligent robot industries, which are in their initial or growth stage, the validity of the present research results cannot be confirmed in a quantitative manner.

5.2.2. Future research agenda

First, we determined that the development of open innovation strategies and business models as well as the development and innovation of technologies of leading firms in the autonomous car and intelligent robot industries should be analyzed in depth. Detailed analyses of the practical realities of technology innovation and business model development in a converted industry and an emerging industry will enrich and broaden the implications of this study.

Second, a statistical analysis to enhance the content and implications of the present research results should be conducted through a massive survey, targeting autonomous car and intelligent robot companies, their market and technical data accumulation, and other sources.

Third, researchers should analyze and additionally validate why some new emerging or converted industries have more business models than other industries, and study the changing dynamics of the value of technology in maturing industries through additional research.

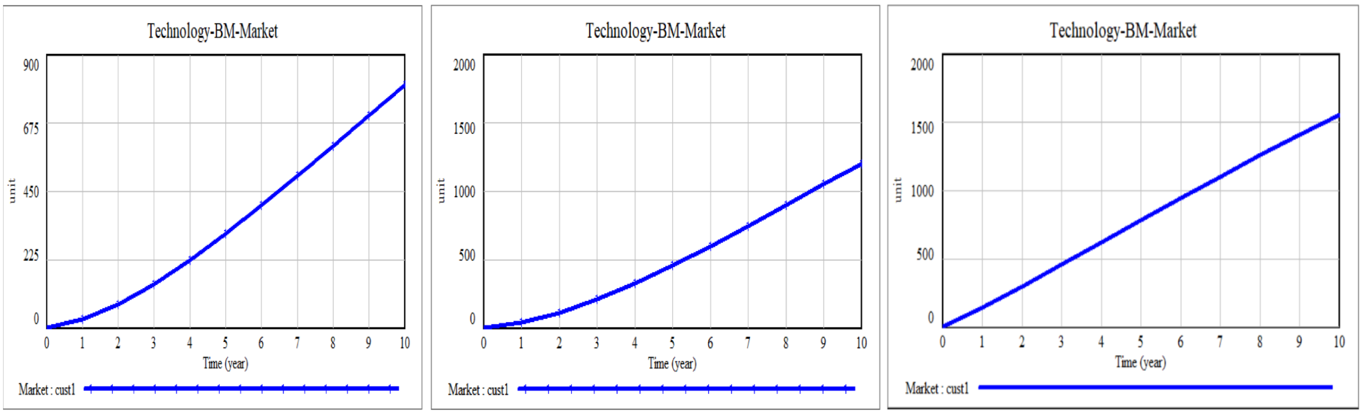
Fourth, as a separate future research agenda, scholars should analyze the real differences in the roles of technology and business models in these two industries in addition to performing simulation research of the eight individual countries of this study, using data by country, or by adding a fixed country effect based on different technological environments and economic growth across countries.

Acknowledgement

All authors thank the anonymous reviewers, and the Editor In Chief of TFSC, professor Fred Phillips for their valuable comments. This paper was funded by the research program of DGIST 2016-2019 IT-1 the budget of which was given from the Korean Department of Science, and ICT. First and corresponding author JinHyo Joseph Yun announces that professor DonKwu Won, and KyungBae Park did the role of co-corresponding authors when authors have been developing this paper last 4 years.

Appendix 1. Simulation of currently emerging infant autonomous car industry of eight countries

Appendix 1-1. U.S.

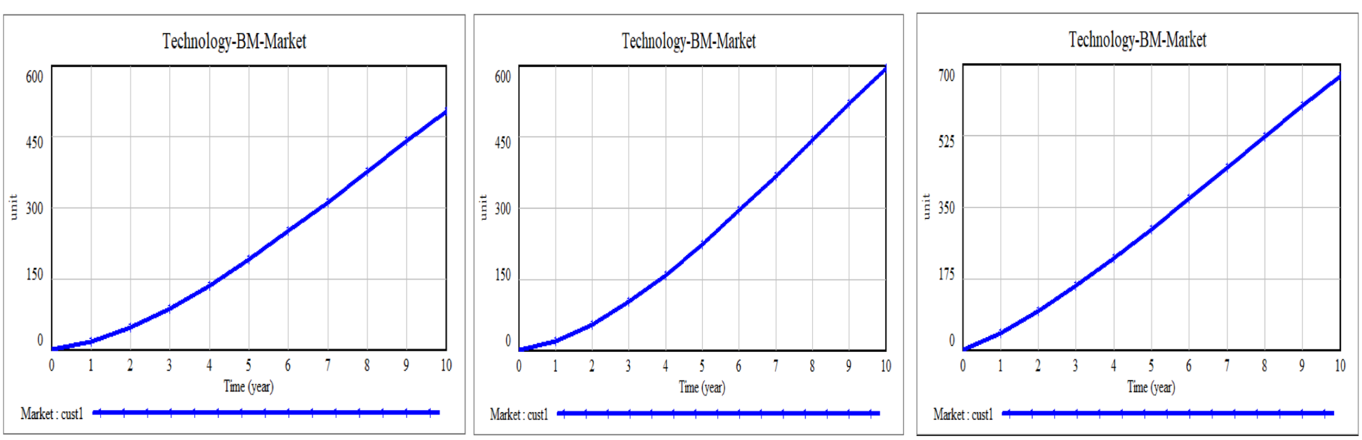


(a) Current Condition Simulation
Technology = 2171, BM = 67

(b) Technology Increase Simulation
Technology = 2171+1157, BM = 67

(c) BM Increase Simulation
Technology = 2171, BM = 67+1157

Appendix 1-2. Korea

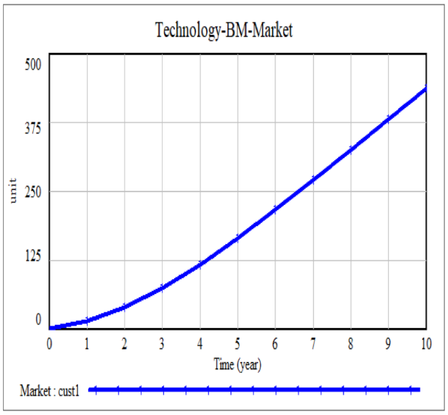


(a) Current Condition Simulation
Technology = 1408, BM = 18

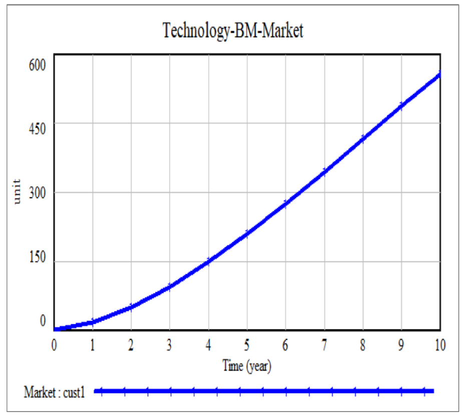
(b) Technology Increase Simulation
Technology = 1408+260, BM = 18

(c) BM Increase Simulation
Technology = 1408, BM = 18+260

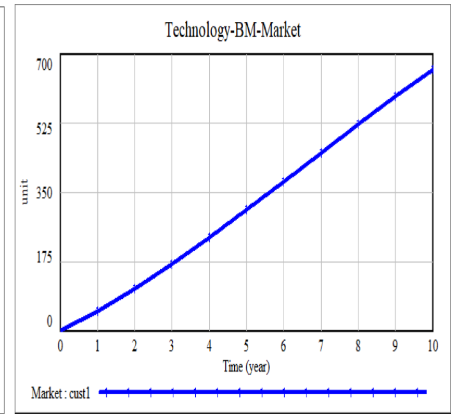
A endix 1-3. Ja an



(a) Current Condition Simulation
Technology = 1230, BM = 10

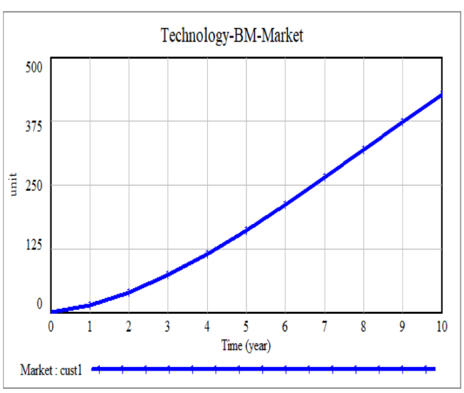


(b) Technology Increase Simulation
Technology = 1230+346, BM = 10

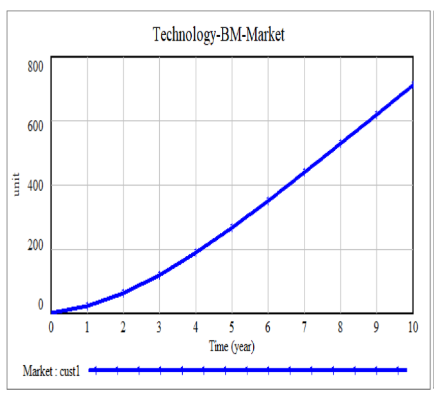


(c) BM Increase Simulation
Technology = 1230, BM = 10+346

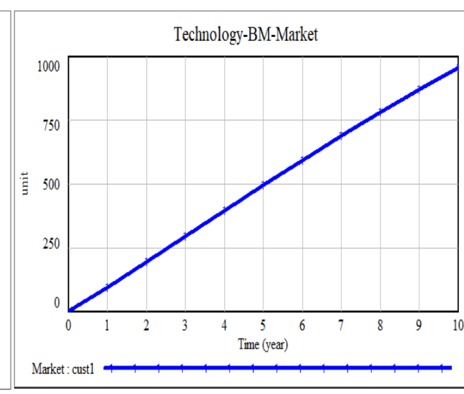
Appendix 1-4. China



(a) Current Condition Simulation
Technology = 1198, BM = 12



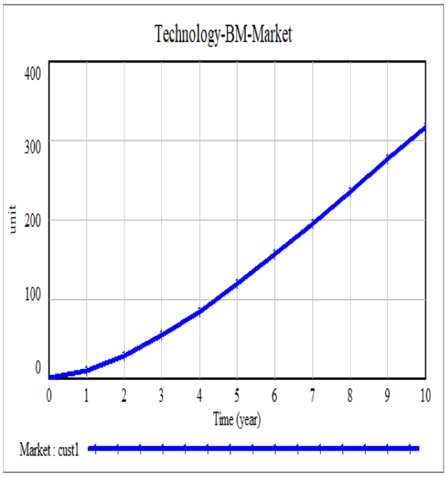
(b) Technology Increase Simulation
Technology = 1198+816, BM = 12



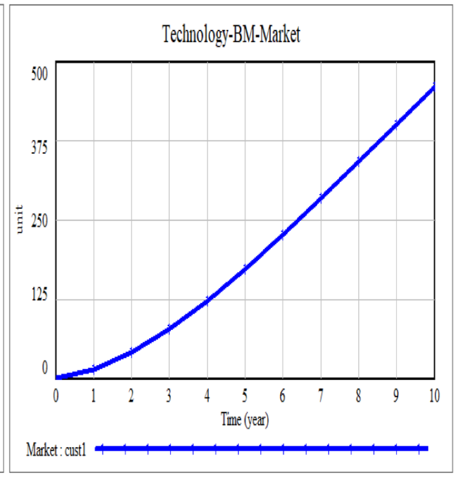
(c) BM Increase Simulation
Technology = 1198, BM = 12+816

Technological Forecasting & Social Change 146 (2019) 534–562

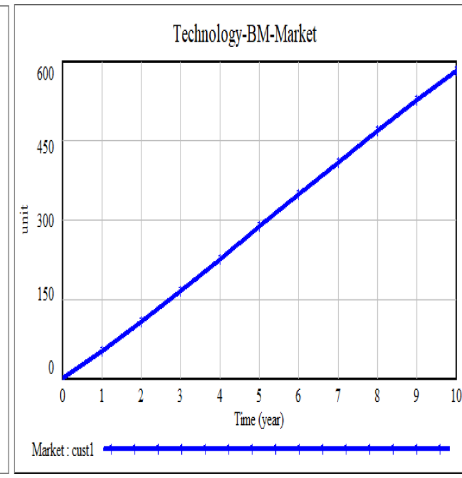
Appendix 1-5. Germany



(a) Current Condition Simulation
Technology = 886, BM = 8

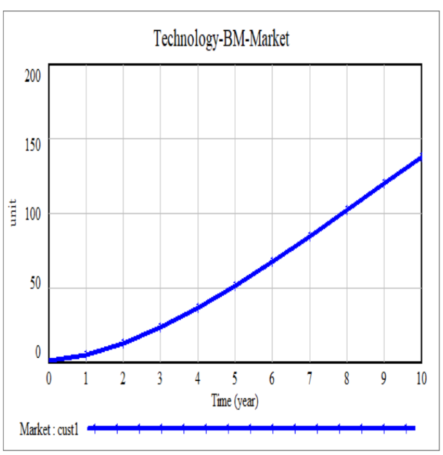


(b) Technology Increase Simulation
Technology = 886+412, BM = 8

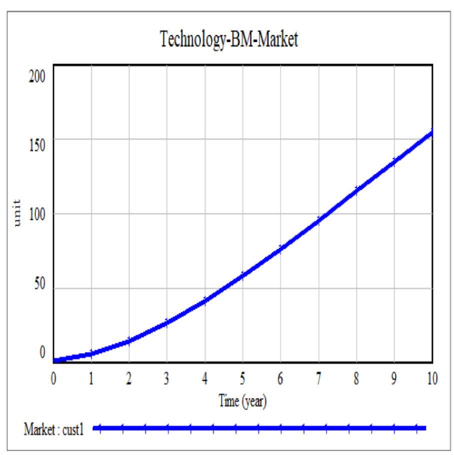


(c) BM Increase Simulation
Technology = 886, BM = 8+412

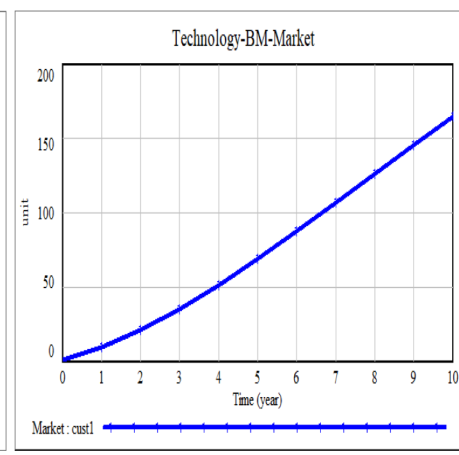
Appendix 1-6. France



(a) Current Condition Simulation
Technology = 383, BM = 1

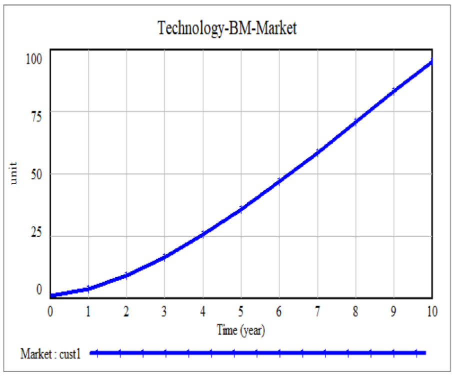


(b) Technology Increase Simulation
Technology = 383+44, BM = 1

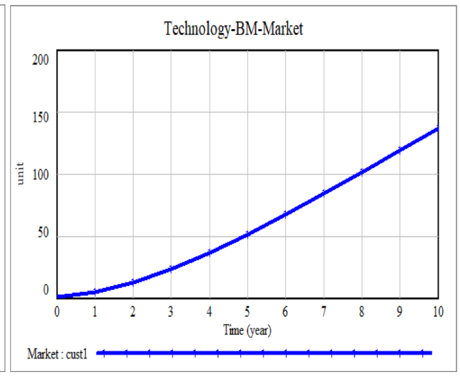


(c) BM Increase Simulation
Technology = 383, BM = 1+44

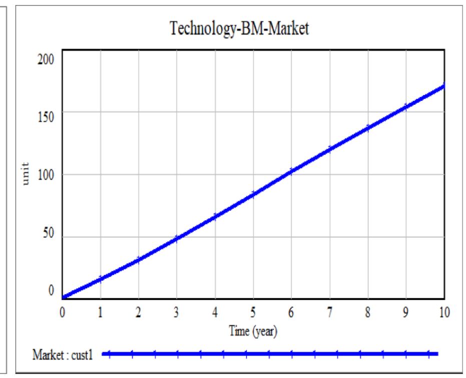
Appendix 1-7. U.K.



(a) Current Condition Simulation
Technology = 262, BM = 1

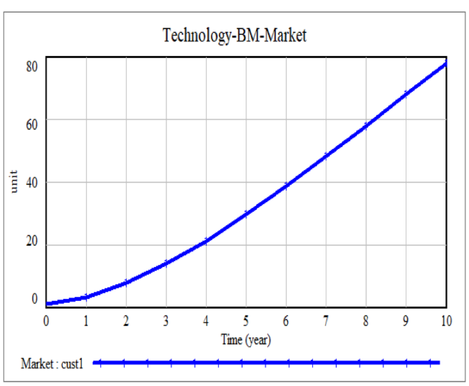


(b) Technology Increase Simulation
Technology = 262+119, BM = 1

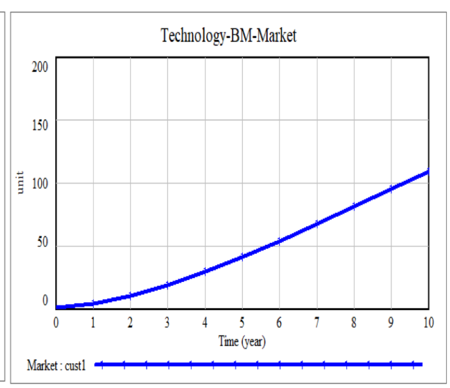


(c) BM Increase Simulation
Technology = 262, BM = 1+119

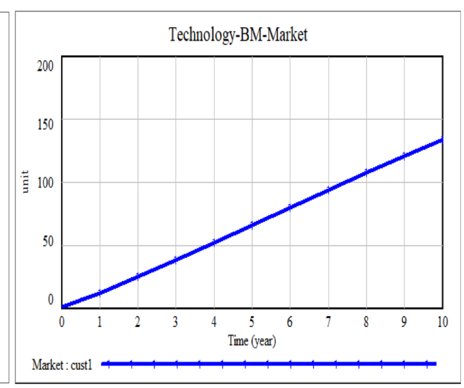
Appendix 1-8. Canada



(a) Current Condition Simulation
Technology = 209, BM = 3



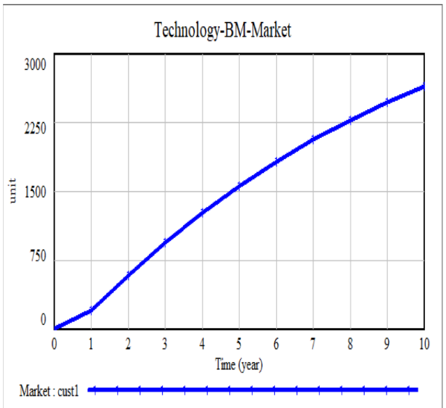
(b) Technology Increase Simulation
Technology = 209+89, BM = 3



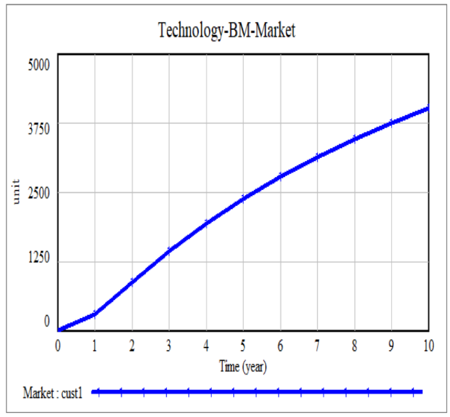
(c) BM Increase Simulation
Technology = 209, BM = 3+89

Appendix 2. After-growth autonomous car industry simulation of eight countries

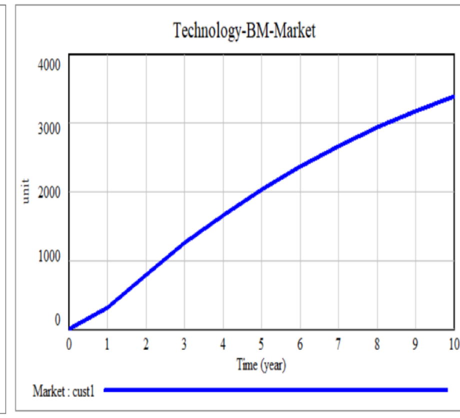
Appendix 2-1. U.S.



(a) Current Condition Simulation
Technology = 2171, BM = 67

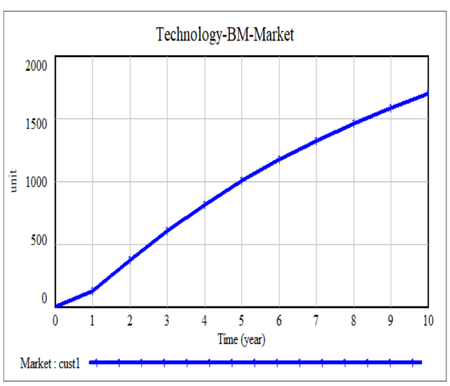


(b) Technology Increase Simulation
Technology = 2171+1157, BM = 67

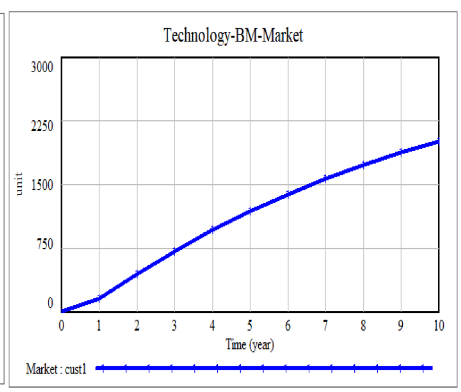


(c) BM Increase Simulation
Technology = 2171, BM = 67+1157

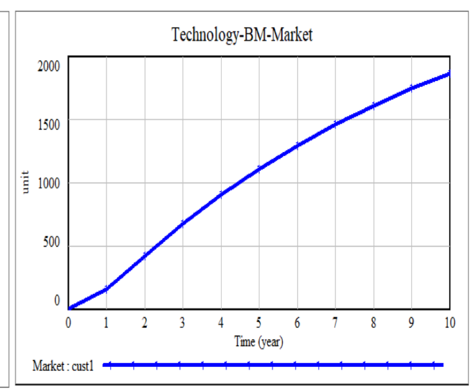
Appendix 2-2. Korea



(a) Current Condition Simulation
Technology = 1408, BM = 18

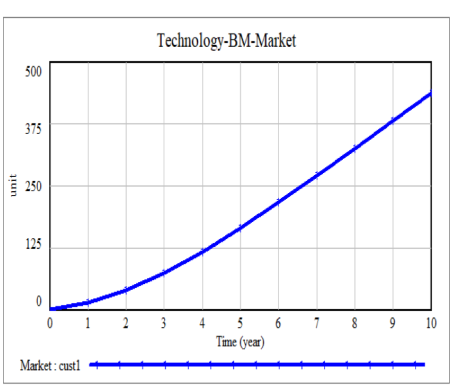


(b) Technology Increase Simulation
Technology = 1408+260, BM = 18

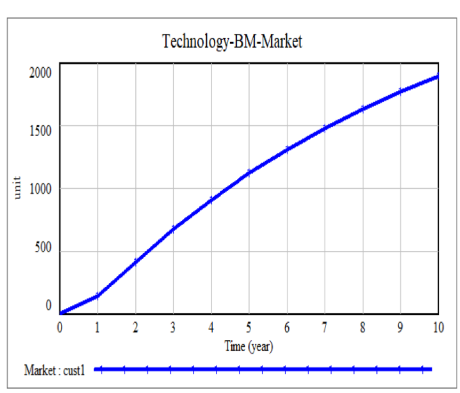


(c) BM Increase Simulation
Technology = 1408, BM = 18+260

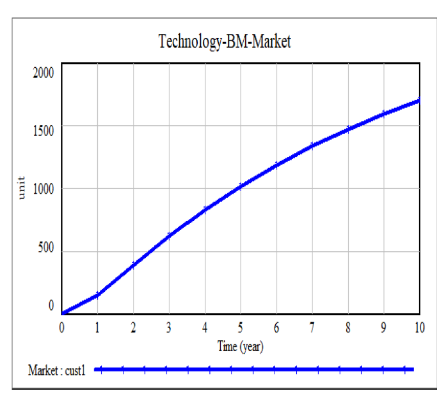
Appendix 2-3. Japan



(a) Current Condition Simulation
Technology = 1230, BM = 10

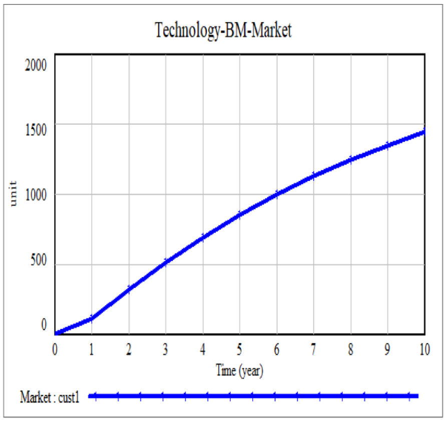


(b) Technology Increase Simulation
Technology = 1230+346, BM = 10

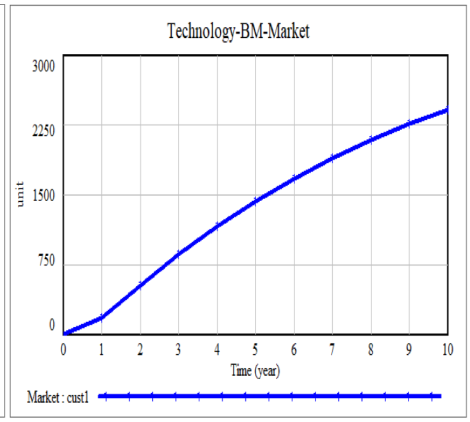


(c) BM Increase Simulation
Technology = 1230, BM = 10+346

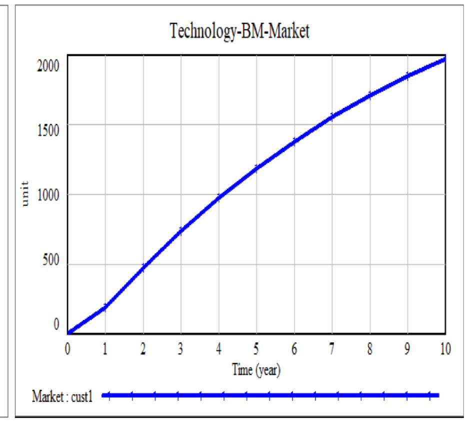
Appendix 2-4. China



(a) Current Condition Simulation
Technology = 1198, BM = 12

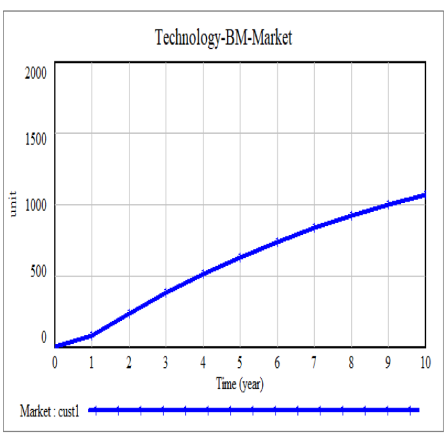


(b) Technology Increase Simulation
Technology = 1198+816, BM = 12

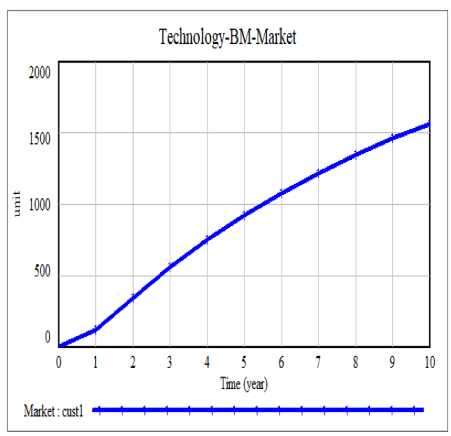


(c) BM Increase Simulation
Technology = 1198, BM = 12+816

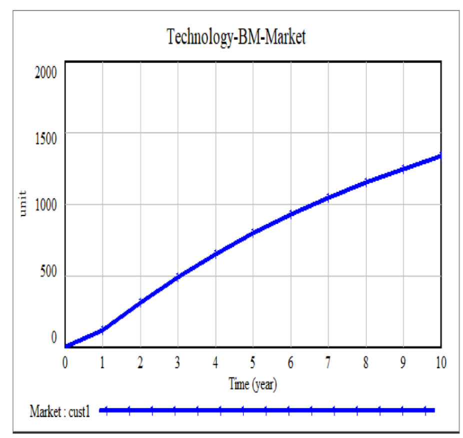
Appendix 2-5. Germany



(a) Current Condition Simulation
Technology = 886, BM = 8

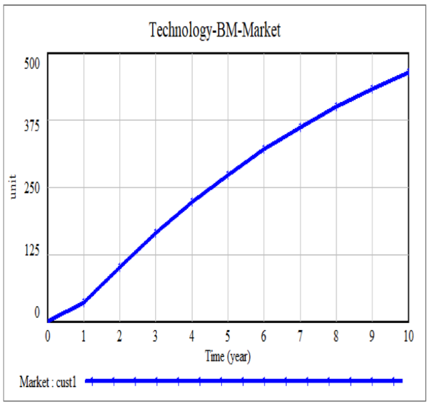


(b) Technology Increase Simulation
Technology = 886+412, BM = 8

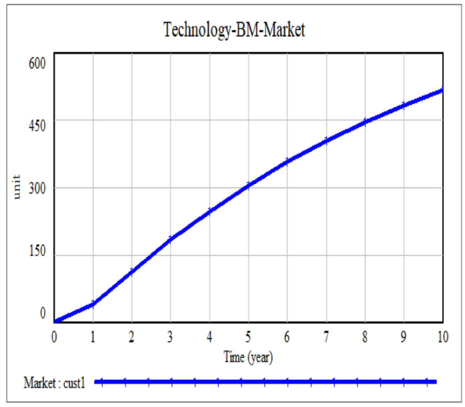


(c) BM Increase Simulation
Technology = 886, BM = 8+412

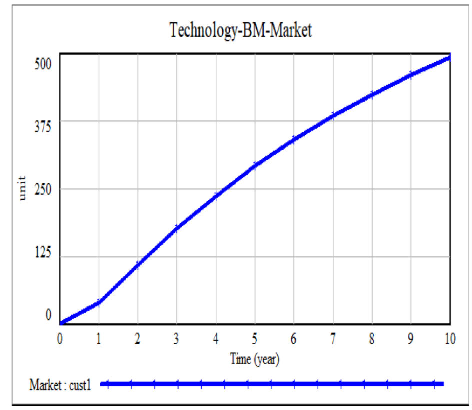
Appendix 2-6. France



(a) Current Condition Simulation
Technology = 383, BM = 1

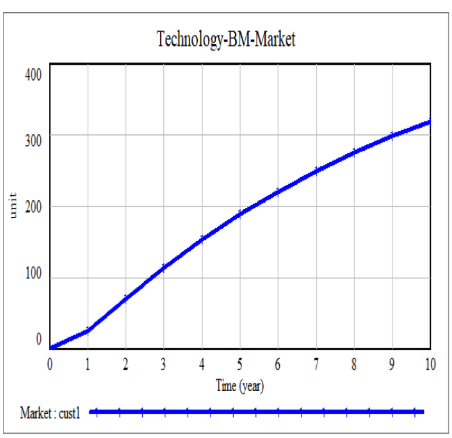


(b) Technology Increase Simulation
Technology = 383+44, BM = 1

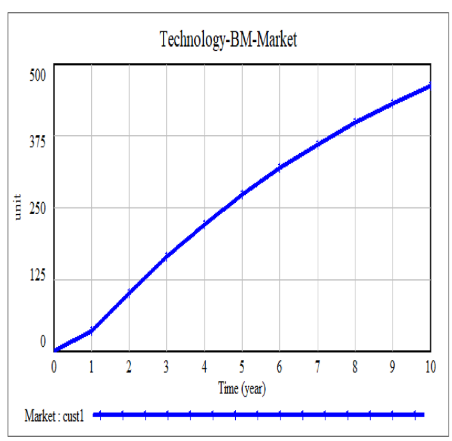


(c) BM Increase Simulation
Technology = 383, BM = 1+44

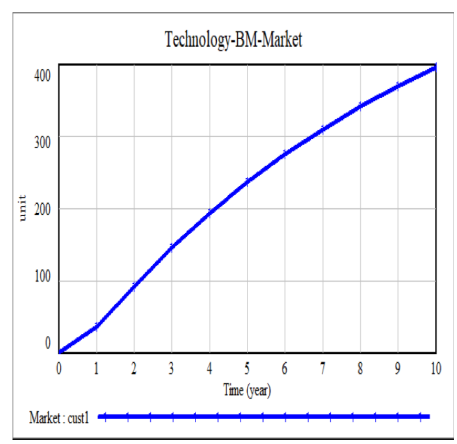
Appendix 2-7. U.K.



(a) Current Condition Simulation
Technology = 262, BM = 1

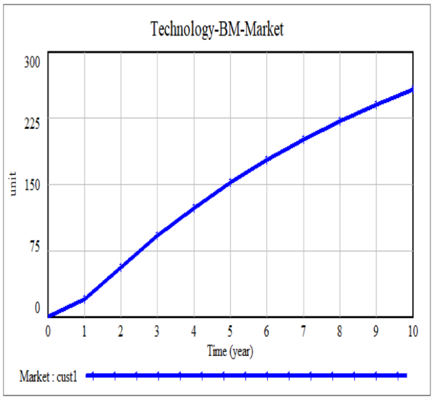


(b) Technology Increase Simulation
Technology = 262+119, BM = 1

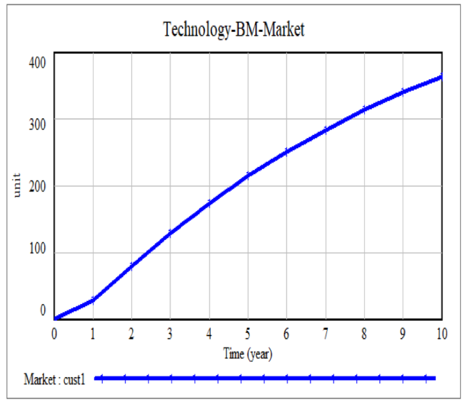


(c) BM Increase Simulation
Technology = 262, BM = 1+119

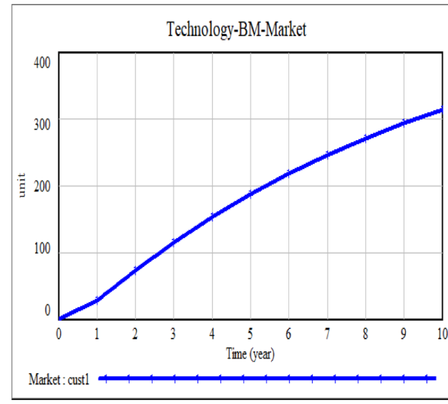
Appendix 2-8. Canada



(a) Current Condition Simulation
Technology = 209, BM = 3



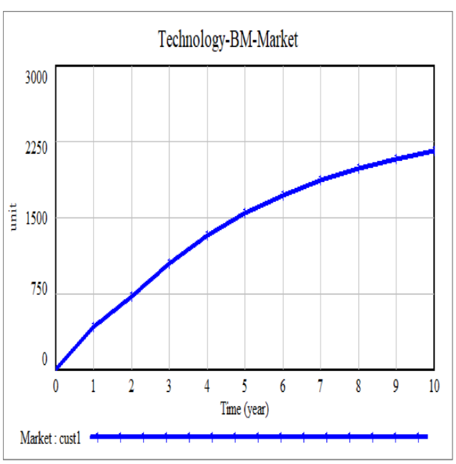
(b) Technology Increase Simulation
Technology = 209+89, BM = 3



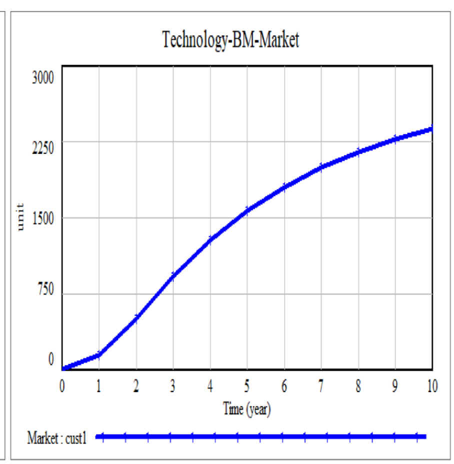
(c) BM Increase Simulation
Technology = 209, BM = 3+89

Appendix 3. Currently emerging infant intelligent robot industry simulation of eight countries

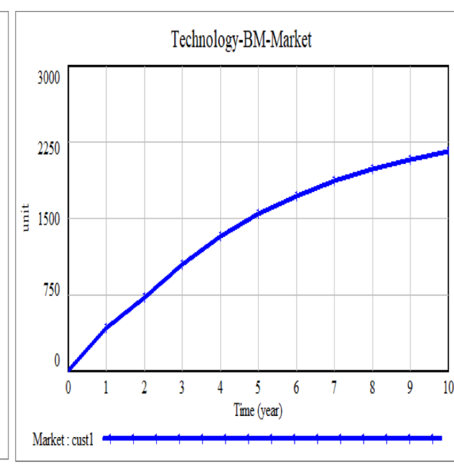
Appendix 3-1. U.S.



(a) Current Condition Simulation
Technology = 1119, BM = 19

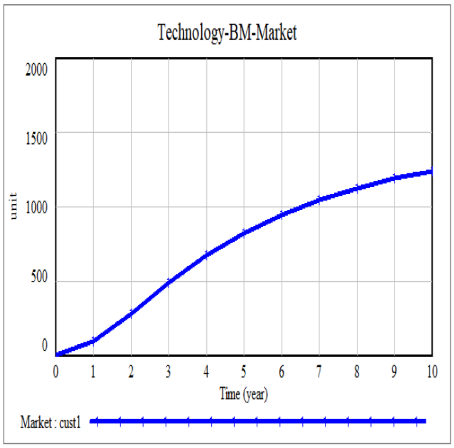


(b) Technology Increase Simulation
Technology = 1119+337, BM = 19

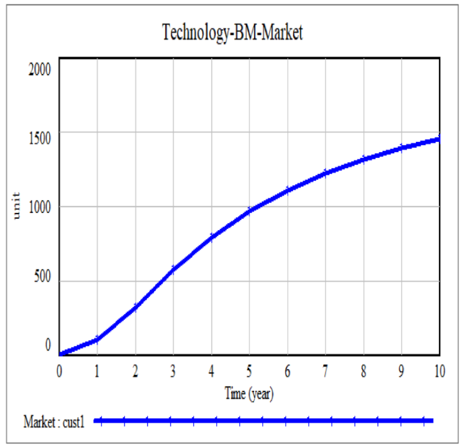


(c) BM Increase Simulation
Technology = 1119, BM = 19+337

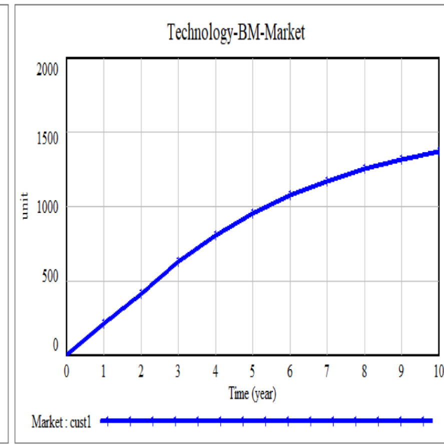
Appendix 3-2. Korea



(a) Current Condition Simulation
Technology = 746, BM = 28

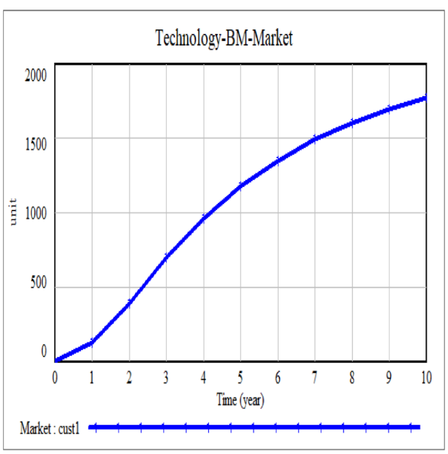


(b) Technology Increase Simulation
Technology = 746+133, BM = 28

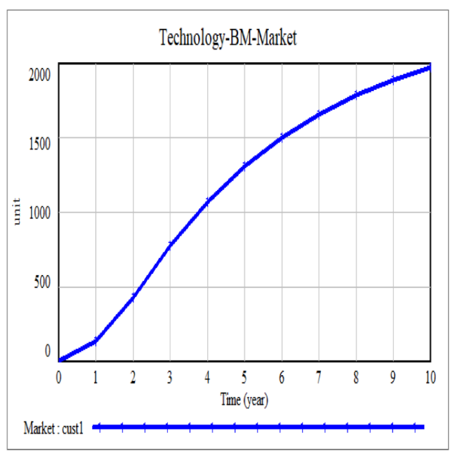


(c) BM Increase Simulation
Technology = 746, BM = 28+133

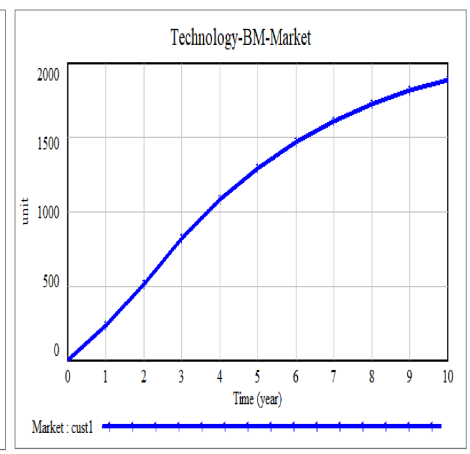
Appendix 3-3. Japan



(a) Current Condition Simulation
Technology = 1075, BM = 29

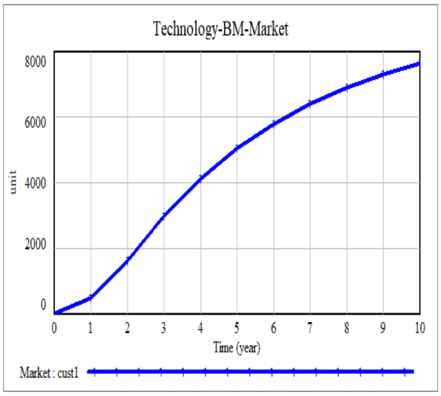


(b) Technology Increase Simulation
Technology = 1075+123, BM = 29

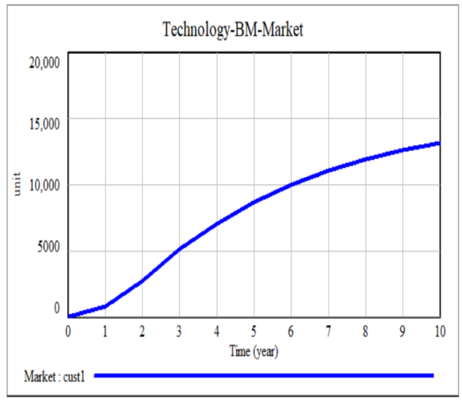


(c) BM Increase Simulation
Technology = 1075, BM = 29+123

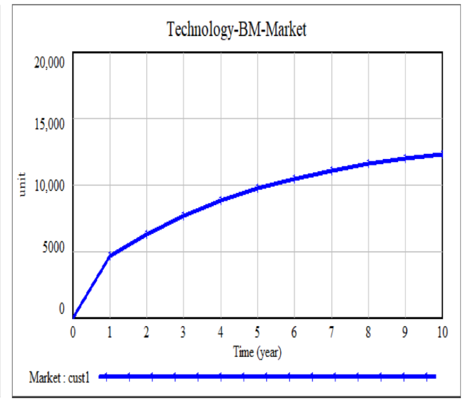
Appendix 3-4. China



(a) Current Condition Simulation
Technology = 4076, BM = 48

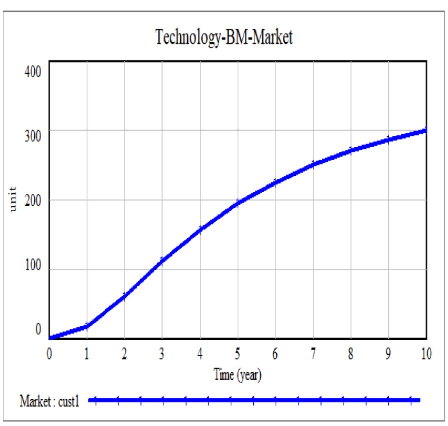


(b) Technology Increase Simulation
Technology = 4076+4076, BM = 48

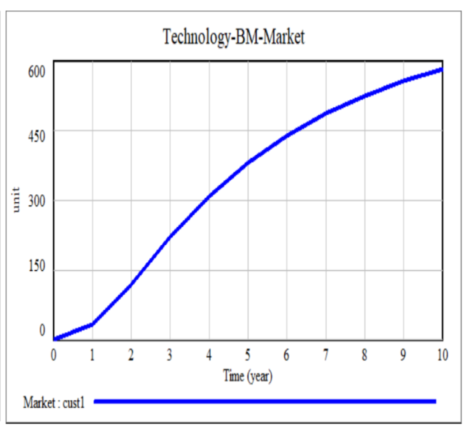


(c) BM Increase Simulation
Technology = 4076, BM = 48+4076

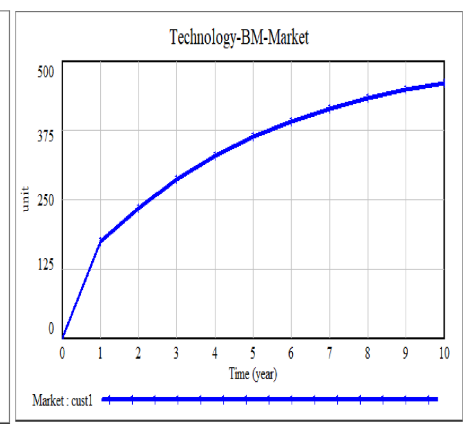
Appendix 3-5. Germany



(a) Current Condition Simulation
Technology = 175, BM = 1

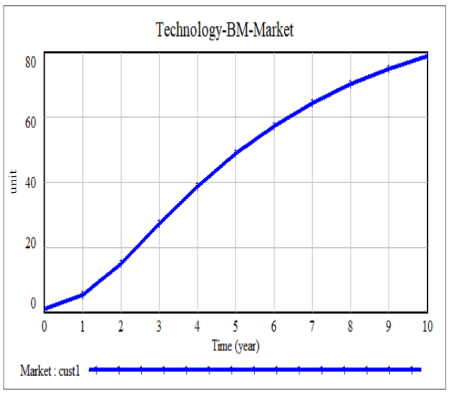


(b) Technology Increase Simulation
Technology = 175+175, BM = 1

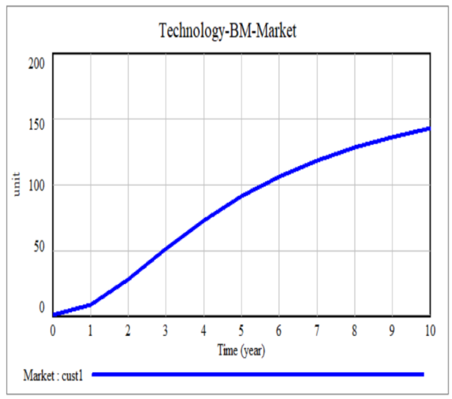


(c) BM Increase Simulation
Technology = 175, BM = 1+175

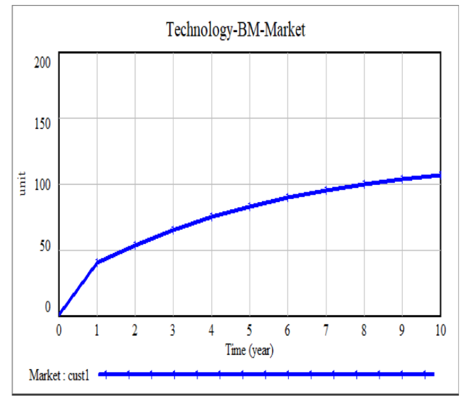
Appendix 3-6. France



(a) Current Condition Simulation
Technology = 39, BM = 1

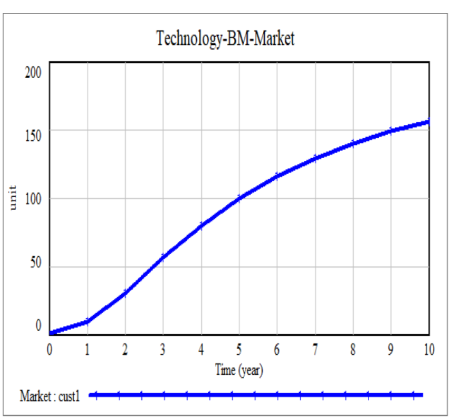


(b) Technology Increase Simulation
Technology = 39+39, BM = 1

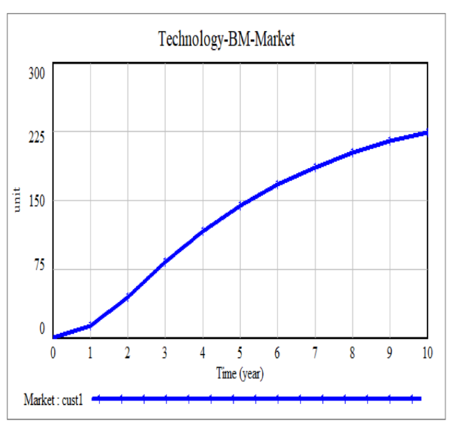


(c) BM Increase Simulation
Technology = 39, BM = 1+39

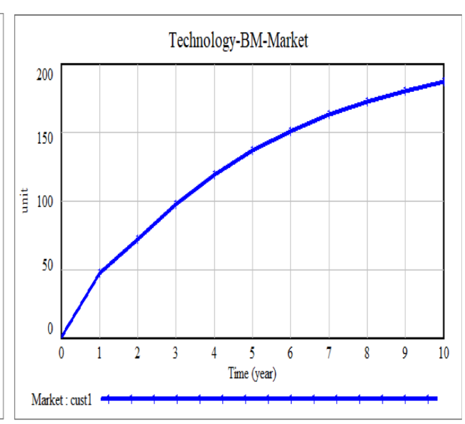
Appendix 3-7. U.K.



(a) Current Condition Simulation
Technology = 86, BM = 1

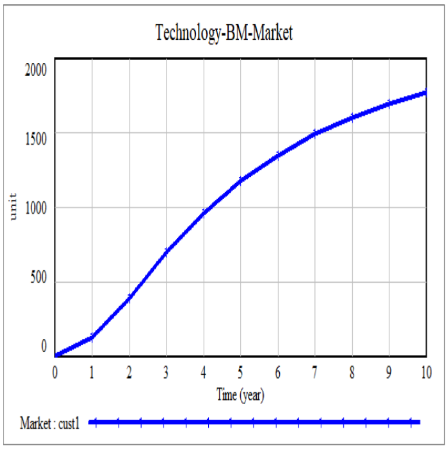


(b) Technology Increase Simulation
Technology = 86+42, BM = 1

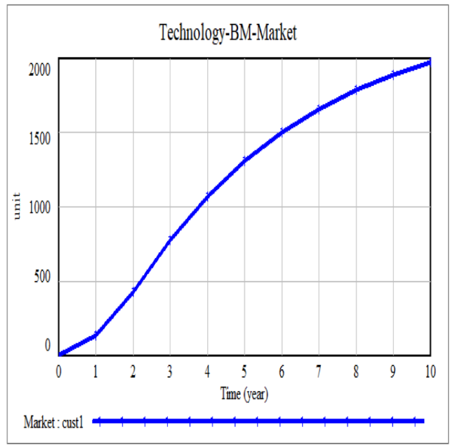


(c) BM Increase Simulation
Technology = 86, BM = 1+42

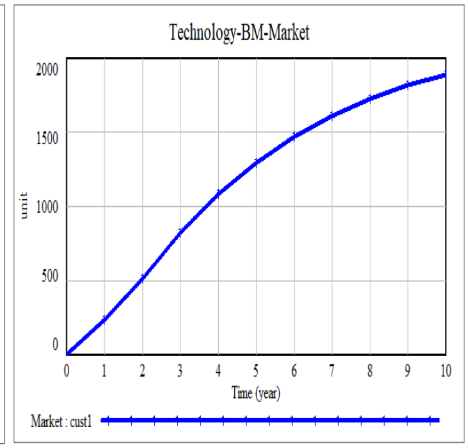
Appendix 3-3. Japan



(a) Current Condition Simulation
Technology = 1075, BM = 29



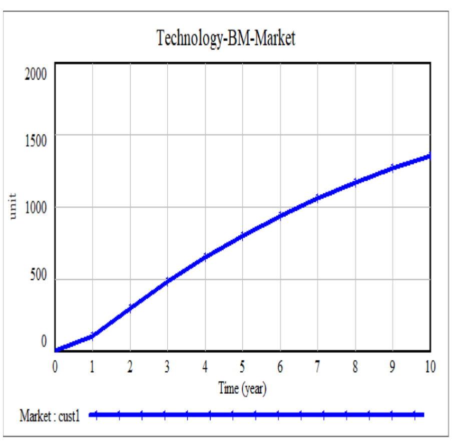
(b) Technology Increase Simulation
Technology = 1075+123, BM = 29



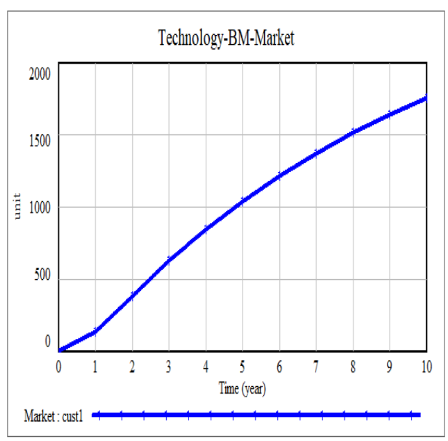
(c) BM Increase Simulation
Technology = 1075, BM = 29+123

Appendix 4. After-growth intelligent robot industry simulation of eight countries

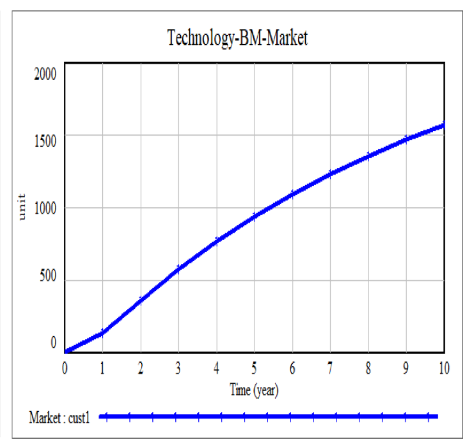
Appendix 4-1. U.S.



(a) Current Condition Simulation
Technology = 1119, BM = 19

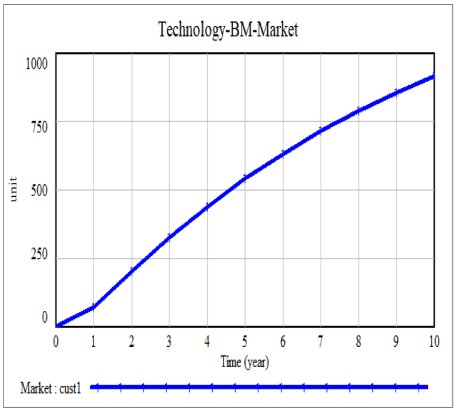


(b) Technology Increase Simulation
Technology = 1119+337, BM = 19

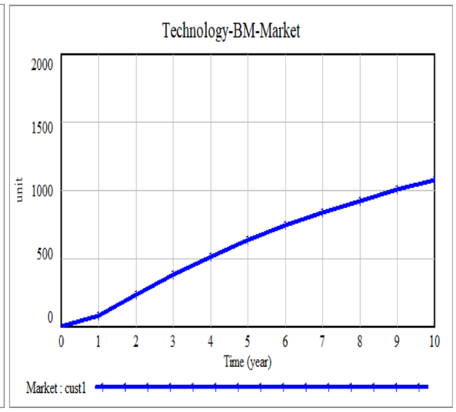


(c) BM Increase Simulation
Technology = 1119, BM = 19+337

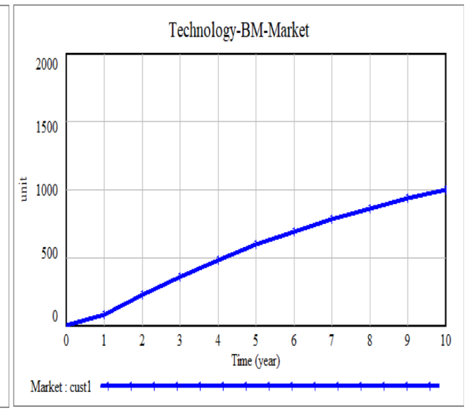
Appendix 4-2. Korea



(a) Current Condition Simulation
Technology = 746, BM = 28

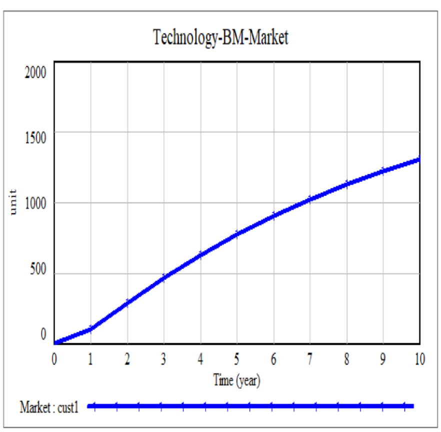


(b) Technology Increase Simulation
Technology = 746+133, BM = 28

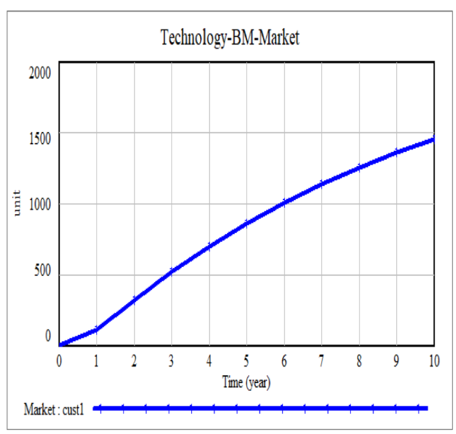


(c) BM Increase Simulation
Technology = 746, BM = 28+133

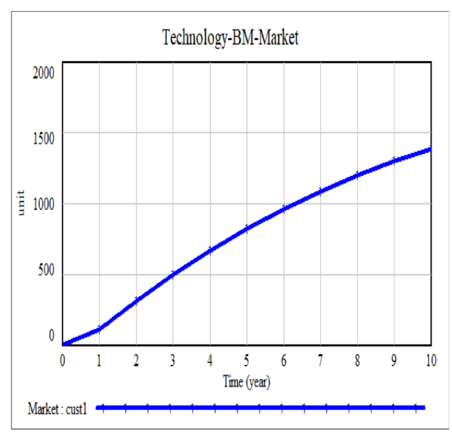
Appendix 4-3. Japan



(a) Current Condition Simulation
Technology = 1075, BM = 29

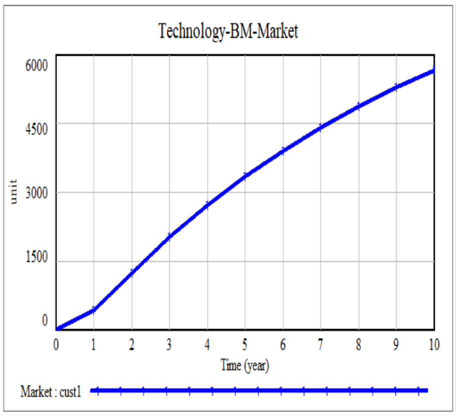


(b) Technology Increase Simulation
Technology = 1075+123, BM = 29

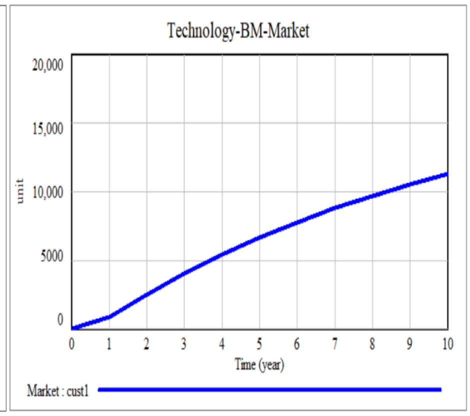


(c) BM Increase Simulation
Technology = 1075, BM = 29+123

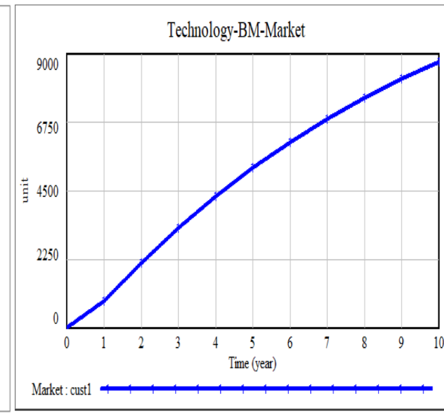
Appendix 4-4. China



(a) Current Condition Simulation
Technology = 4076, BM = 48

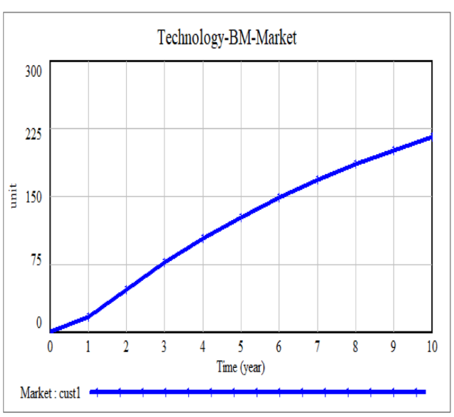


(b) Technology Increase Simulation
Technology = 4076+4076, BM = 48

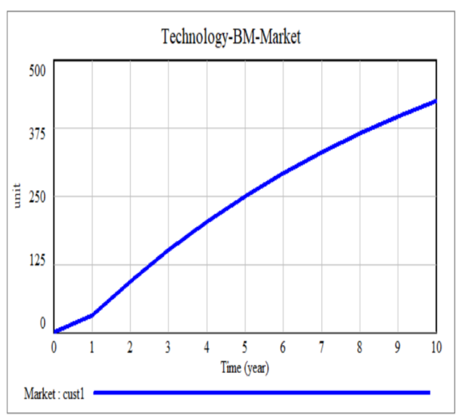


(c) BM Increase Simulation
Technology = 4076, BM = 48+4076

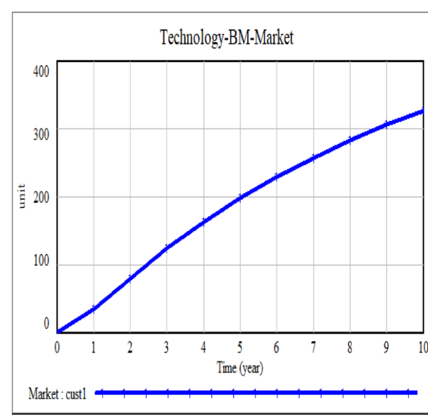
Appendix 4-5. Germany



(a) Current Condition Simulation
Technology = 175, BM = 1

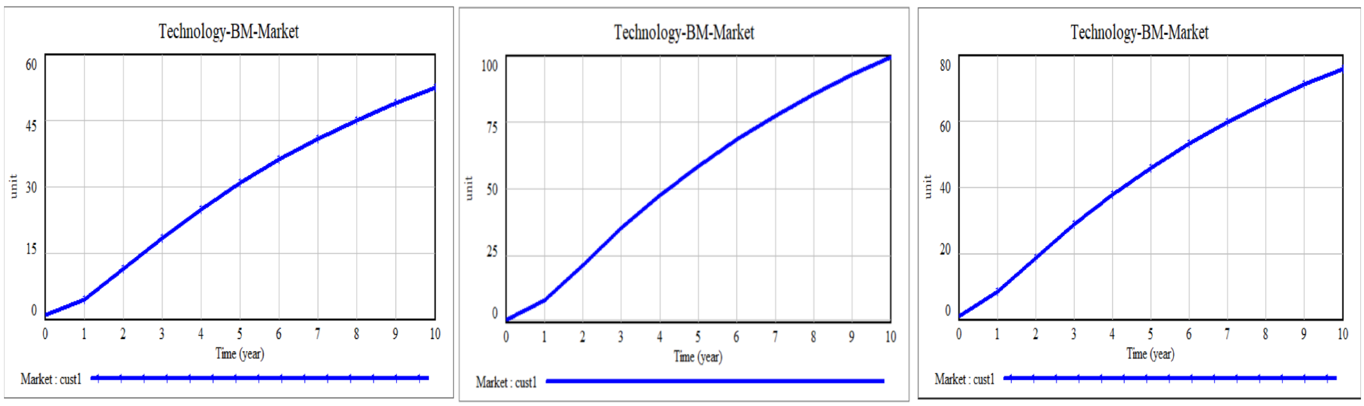


(b) Technology Increase Simulation
Technology = 175+175, BM = 1



(c) BM Increase Simulation
Technology = 175, BM = 1+175

Appendix 4-6. France

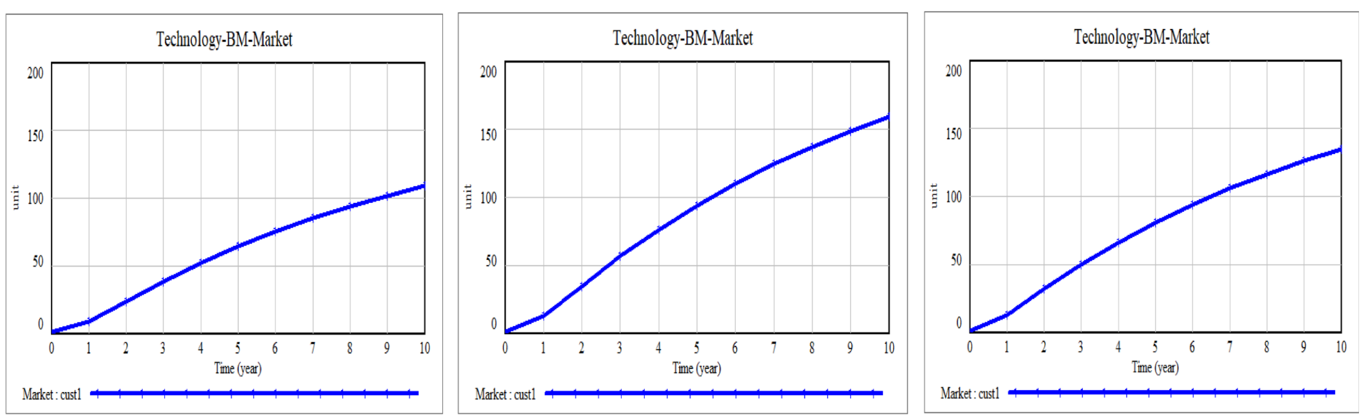


(a) Current Condition Simulation
Technology = 39, BM = 1

(b) Technology Increase Simulation
Technology = 39+39, BM = 1

(c) BM Increase Simulation
Technology = 39, BM = 1+39

Appendix 4-7. U.K.

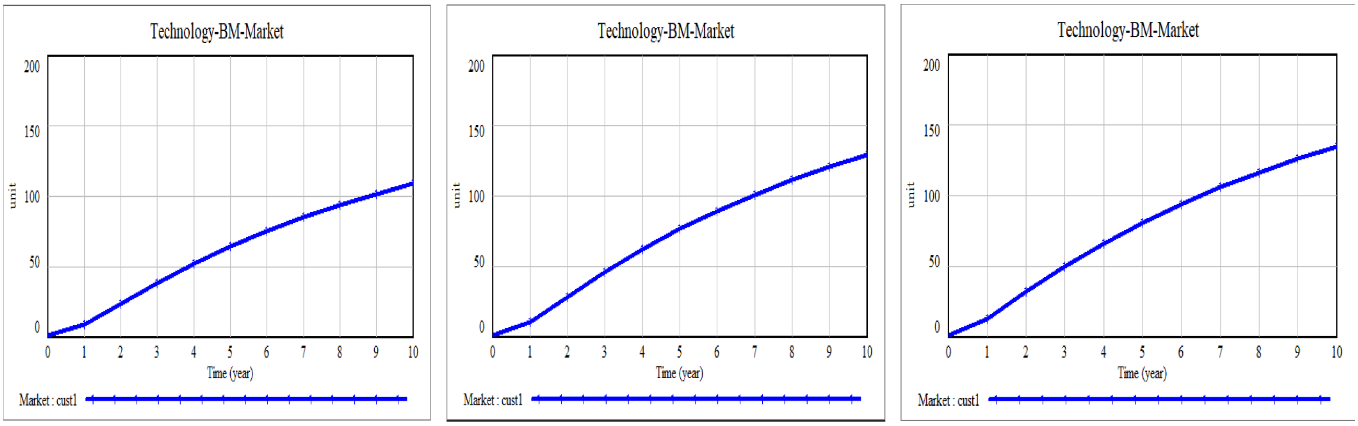


(a) Current Condition Simulation
Technology = 86, BM = 1

(b) Technology Increase Simulation
Technology = 86+42, BM = 1

(c) BM Increase Simulation
Technology = 86, BM = 1+42

Appendix 4-8. Canada



(a) Current Condition Simulation
Technology = 100, BM = 7

(b) Technology Increase Simulation
Technology = 100+100, BM = 1

(c) BM Increase Simulation
Technology = 100, BM = 1+100

References

Z.J. Acs, L. Anselin, L., A. Varga, Patents and innovation counts as measures of regional production of new knowledge. Res. Policy, 31(7) (2004)1069–1085.

Amit, R., Zott, C., 2012. Creating value through business model innovation. MIT Sloan Manag. Rev. 53 (3), 41.

Anderson, P., Tushman, M.L., 1990. Technological discontinuities and dominant designs: a cyclical model of technological change. Admin. Sci. Quart. 35 (1), 604–633. https://doi.org/10.2307/2393511.

J.M. Anderson, N. Kalra, K.D. Stanley, P. Sorensen, C. Samaras, O.A. Oluwatola, Autonomous Vehicle Technology: A Guide for Policymakers, Rand Corporation, Santa Monica, CA, 2014.

Bardhi, F., Eckhardt, G.M., 2012. Access-based consumption: the case of car sharing. J. Consum. Res. 39 (4), 881–898. https://doi.org/10.1086/666376.

Bartneck, C., Forlizzi, J., 2004a. A Design-centred Framework for Social Human–robot Interaction, RO-MAN 2004: 13th IEEE International Workshop on Robot and Human Interactive Communication. IEEE. https://doi.org/10.1109/roman.2004.1374827.

Bartneck, C., Forlizzi, J., 2004b. Shaping Human–robot Interaction: Understanding the Social Aspects of Intelligent Robotic Products, CHI '04: Extended Abstracts on Human Factors in Computing Systems. ACMhttps://doi.org/10.1145/985921.986205.

Bauner, D., Laestadius, S., Iida, N., 2009. Evolving technological systems for diesel engine emission control: balancing GHG and local emissions. Clean Techn. Environ. Policy 11 (3), 339–365. https://doi.org/10.1007/s10098-008-0151-x.

Beiker, S.A., 2012. Legal aspects of autonomous driving. Santa Clara Law Rev. 52 (4), 1145. https://doi.org/10.2139/ssrn.2767899.

Bloem, J., van Doorn, M., Duivestein, S., Excoffier, D., Maas, R., van Ommeren, E., 2014. The Fourth Industrial Revolution, Sogeti VINT.

Chesbrough, H.W., 2006. Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business School Press, Boston, MA.

Chesbrough, H., 2007a. Business model innovation: it's not just about technology anymore. Strateg. Leadersh. 35 (6), 12–17. https://doi.org/10.1108/10878570710833714.

H.. Chesbrough, Why companies should have open business models, MIT Sloan Manage. Rev. 48(2) (2007b) 22.

Chesbrough, H., 2010. Business model innovation: opportunities and barriers. Long Range Plan. 43 (2–3), 354–363. https://doi.org/10.1016/j.lrp.2009.07.010.

Chesbrough, H.W., Teece, D.J., 1996. When is virtual virtuous? Harv. Bus. Rev. 74 (1), 65–73.

Čirjevskis, A., 2016. Designing dynamically "signature business model" that support durable competitive advantage. Journal of Open Innovation: Technology, Market, and Complexity 2 (1), 15.

Dokic, J., Müller, B., Meyer, G., 2015. European roadmap smart systems for automated driving. Eur. Technol. Platform Smart Syst. Integr.

Dudenhöffer, F., 2016. Wer kriegt die Kurve?: Zeitenwende in der Autoindustrie, Campus Verlag. Frankfurt, Germany.

Eng, H., 2016. Embracing the Future of Land Transportation: Valuing Flexibility in Design and Technology Options for Autonomous Vehicle Developments in Singapore. Massachusetts Institute of Technology, Cambridge, MA.

Gassmann, O., Frankenberger, K., Csik, M., 2014. The Business Model Navigator: 55 models that Will Revolutionise your Business, Pearson UK. United Kingdom, London.

Gockley, R., Forlizzi, J., Simmons, R.G., 2007. Natural Person-Following Behavior for Social Robots, Proceedings of the 2nd ACM SIGCHI/SIGART International Conference on Human–Robot Interaction. ACMhttps://doi.org/10.1145/1228716.1228720.

Godoe, H., 2006. The role of innovation regimes and policy for creating radical innovations: comparing some aspects of fuel cells and hydrogen technology development with the development of internet and GSM. Bull. Sci. Technol. Soc. 26 (4), 328–338. https://doi.org/10.1177/0270467606290303.

Hagedoorn, J., Cloodt, J., 2003. Measuring innovative performance: is there an advantage in using multiple indicators? Res. Policy 32 (8), 1365–1379.

Henderson, R.M., Clark, K.B., 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Admin. Sci. Quart. 35 (1), 9–30. https://doi.org/10.2307/2393549.

Jaffe, A.B., Trajtenberg, M., 2002. Patents, Citations, and Innovations: A Window on the Knowledge Economy. MIT Press, Cambridge, MA.

Jeong, H.J., Ko, Y., 2016. Configuring an alliance portfolio for eco-friendly innovation in the car industry: Hyundai and Toyota. Journal of Open Innovation: Technology, Market, and Complexity 2 (1), 24.

Jo, K., Kim, J., Kim, D., Sunwoo, M., 2014. Development of autonomous car—part I. distributed system architecture and development process. IEEE Trans. Ind. Electron. 61 (12), 7131–7140.

Johnson, M.W., Christensen, C.M., Kagermann, H., 2008. Reinventing your business model. Harv. Bus. Rev. 86 (12), 57–68.

Jones, J.L., 2006. Robots at the tipping point: the road to iRobot Roomba. IEEE Robot. Autom. Mag. 13 (1), 76–78. https://doi.org/10.1109/mra.2006.1598056.

Z. Kanter, How Uber's autonomous cars will destroy 10 million jobs and reshape the economy by 2025, Accessed September 1, 2015, URL: http://zackkanter.com/2015/01/23/how-ubers-autonomous-cars-will-destroy-10-million-jobs-by-2025/.

Kim, E.S., Berkovits, L.D., Bernier, E.P., Leyzberg, D., Shic, F., Paul, R., Scassellati, B., 2013. Social robots as embedded reinforcers of social behavior in children with autism. J. Autism Dev. Disord. 43 (5), 1038–1049. https://doi.org/10.1007/s10803-012-1645-2.

Kodama, F., Shibata, T., 2015. Demand articulation in the open-innovation paradigm. Journal of Open Innovation: Technology, Market. Complexity 1 (1), 2.

LeCun, Y., Bengio, Y., Hinton, G., 2015. Deep learning. Nature 521 (7553), 436–444. https://doi.org/10.1038/nature14539.

Lee, K., Lim, C., 2001. Technological regimes, catching-up and leapfrogging: findings from the Korean industries. Res. Pol. 30 (3), 459–483. https://doi.org/10.1016/s0048-7333(00)00088-3.

Li, J., Kozhikode, R.K., 2009. Developing new innovation models: shifts in the innovation landscapes in emerging economies and implications for global R&D management. J. Int. Manag. 15 (3), 328–339. https://doi.org/10.1016/j.intman.2008.12.005.

Litman, T., 2014. Autonomous vehicle implementation predictions. Victoria Transport Policy Institute 28.

Markoff, J., 2010. Google cars drive themselves, in traffic. The New York Times 10 (A1), 9.

Monostori, L., 2014. Cyber-physical production systems: roots, expectations and R&D challenges. Procedia CIRP 17, 9–13. https://doi.org/10.1016/j.procir.2014.03.115.

Nothdurft, T., Hecker, P., Ohl, S., 2011. Stadtpilot: first fully autonomous test drives in urban traffic. 14th International IEEE Conference on Intelligent Transportation Systems (ITSC), IEEE. https://doi.org/10.1109/ITSC.2011.6082883.

Oltra, V., Saint Jean, M., 2009. Sectoral systems of environmental innovation: an

application to the French automotive industry. Technol. Forecast. Soc. Change 76 (4), 567–583. https://doi.org/10.1016/j.techfore.2008.03.025.
Scassellati, B., 2007. How social robots will help us to diagnose, treat, and understand autism. In: Thrun, S., Brooks, R., Durrant-Whyte, H. (Eds.), Robotics Research: Results of the 12th International Symposium ISRR. Springer, pp. 552–563. https://doi.org/10.1007/978-3-540-48113-3_47.
Schwab, K., 2017. The Fourth Industrial Revolution, Penguin UK.
Sharkey, N., 2008. The ethical frontiers of robotics. Science 322 (5909), 1800–1801. https://doi.org/10.1126/science.1164582.
Singer, P.W., 2011. Military robotics and ethics: a world of killer apps. Nature 477 (7365), 399–401. https://doi.org/10.1038/477399a.
Sturgeon, T., van Biesebroeck, J., Gereffi, G., 2008. Value chains, networks and clusters: reframing the global automotive industry. J. Econ. Geogr. 8, 297–321. https://doi.org/10.1093/jeg/lbn007.
Suàrez, F.F., Utterback, J.M., 1995. Dominant designs and the survival of firms. Long Range Plan. 28 (6), 122. https://doi.org/10.1016/0024-6301(95)99957-2.
Sung, J.-Y., Guo, L., Grinter, R.E., Christensen, H.I., 2007. "My Roomba is Rambo": Intimate home appliances. In: International Conference on Ubiquitous Computing. Springer.
Teece, D.J., 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strategic Manage. J. 28 (13), 1319–1350. https://doi.org/10.1002/smj.640.
Teece, D.J., 2010. Business models, business strategy and innovation. Long Range Plan. 43 (2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003.
Tushman, M.L., Murmann, J.P., 2002. Dominant designs, technology cycles, and organizational outcomes. In: Garud, R., Kumaraswamy, A., Langlois, R. (Eds.), Managing in the Modular Age: Architectures, Networks, and Organizations, Blackwell Publishing, Oxford, United Kingdom, pp. 316–348.
van Elkan, R., 1996. Catching up and slowing down: learning and growth patterns in an open economy. J. Int. Econ. 41 (1–2), 95–111. https://doi.org/10.1016/s0022-1996(96)01433-x.
Viereckl, R., Ahlemann, D., Koster, A., Hirsh, E., Kuhnert, F., Mohs, J., Fischer, M., Gerling, W., Gnanasekaran, K., Kusber, J., Stephan, J., Crusius, D., Kerstan, H., Warnke, T., Schulte, M., Seyfferth, J., Baker, E.H., 2015. Connected Car Study 2015: Racing Ahead with Autonomous Cars and Digital Innovation. http://www.strategyand.pwc.com/reports/connected-car-2015-study.
Walch, M., Lange, K., Baumann, M., Weber, M., 2015. Autonomous driving: Investigating the feasibility of car-driver handover assistance. In: Automotive UI '15: Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications. ACM, pp. 11–18. https://doi.org/10.1145/2799250.2799268.
Wallsten, S., 2015. The competitive effects of the sharing economy: how is Uber changing taxis. Technology Policy Institute 22.
Weikl, S., Bogenberger, K., 2013. Relocation strategies and algorithms for free-floating car sharing systems. IEEE Intell. Transp. Syst. Mag. 5 (4), 100–111. https://doi.org/10.1109/mits.2013.2267810.
Xi, L., Lei, L., Guisheng, W., 2009. Evolution of the Chinese automobile industry from a sectoral system of innovation perspective. Ind. Innov. 16 (4–5), 463–478. https://doi.org/10.1080/13662710903053755.
Xielin, L., 2005. China's Development Model: An Alternative Strategy for Technological Catch-up. Research Institute of Economy, Trade and Industry.
Yun, J.J., Jeong, E.S., Park, J.S., 2016a. Network analysis of open innovation. Sustainability 8 (8), 729. https://doi.org/10.3390/su8080729.
Yun, J.J., Won, D.K., Jeong, E.S., Park, J.Y., 2016b. The relationship between technology, business model, and market in autonomous car and intelligent robot industries. Technol. Forecast. Soc. Change 103 (6), 142–155. https://doi.org/10.1016/j.techfore.2015.11.016.
Zott, C., Amit, R., Massa, L., 2011. The business model: recent developments and future research. J. Manag. 37 (4), 1019–1042.