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Discourse Analysis of Environmental Regulations and Technological Innovation for Corporate Competitiveness

Won-Seok KIM[1], Choongik CHOI[2]

1 First Author Graduate Student, Department of Public Administration, Kangwon National University, Korea.
E-mail: tensi0081@kangwon.ac.kr

2 Corresponding Author Professor, Department of Public Administration, Kangwon National University, Korea.
E-mail: choich@kangwon.ac.kr

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Abstract

Purpose **–** This article aims to explore the mechanism in which environmental regulations have positive effects on corporate competitiveness through technological innovation. This study also attempts to examine the relationship between environmental regulation and corporate competitiveness from a technological innovation perspective and explore a desirable relationship between those two.
Research design, data, and methodology **–** Discourse analysis and SWOT analysis is used in terms of methodology, and this study is based on literature review theoretically. The methodology is employed in various ways to describe a variety of environmental issues.
Result **–** The results support that technological innovation is able to play a role in coordinating relationship between environmental regulations and corporate competitiveness. The uncertainty and time lag problems innate to technological innovation function as disturbing factors for individual companies to actively increase R&D investment in response to environmental regulations. Environmental regulations may be considered to be working as a factor consolidating corporate competitiveness through technological innovation to respond to the environmental regulations including climate change issue.
Conclusion **–** This study proposes that to achieve two goals of environmental protection and corporate competitiveness consolidation, policy support from various aspects is implied to be required. This implies that environmental regulations and technical innovation must be harmoniously balanced for future corporate success.

Keywords: Environmental Regulations, Research & Development, Technological Innovation, Corporate Competitiveness, SWOT Analysis, Climate Change

JEL Classification Code: G38, O1, O33, G18

1. Introduction

Disputes on the relationship between environmental regulations and corporate competitiveness have continued for a long time. The viewpoint of traditional economists on environmental regulations is that environmental regulations decrease corporate productivity and weaken competitiveness. However, some scholars including Porter presented a theory that environmental regulations may reinforce corporate competitiveness for the long-term, not always weakening corporate competitiveness (Kang, 2014). Porter insisted that strict environmental regulations provide an opportunity to have a strategic advantage to companies in the Market Failure Approach and that companies that conducted higher level of investment to respond to environmental regulations may have an advantage compared to competitors (Kim, 2011). Existing studies have shown that companies are less competitive due to environmental regulations. This research is different from existing research in that it describes technological innovation as a catalyst for strengthening corporate competitiveness due to environmental regulations.

The definition of environmental regulation is diverse and extensive. The impact of environmental regulations is also expected to be different because they are so diverse and wide, including climate change, fisheries, agriculture and food. Depending on the nature of environmental regulations, the impact on technological innovation and strengthening corporate competitiveness may also vary. This study manipulates the definition of environmental laws and policies established for national health and environmental conservation and sustainable economic development.

Environmental regulations have the nature of control out of two essences, namely science and technology policy from the aspect of restricting or prohibiting the use of embodied product (Hong, 2016). From this aspect, the science and technology policy and environmental regulations can be viewed as having the characteristics of regulatory policy. From another aspect, environmental regulations can be regarded as having the nature of another essence of science and technology policy, which is promotion in that environmental regulations promote new science and technology R&D and the commercialization of products to respond to them. From the science and technology policy perspective, environmental regulations may be viewed as a complex science and technology policy simultaneously having the characteristics for national science and technology's promotion and control.

The science and technology policy aims to promote technological innovation through national level investment in science and technology and consequently to consolidate corporate competitiveness. However the science and technology policy is changing to the direction of regretting causing problems such as the global environmental pollution and resource depletion, because science and technology development has focused on the goal of economic development, and pursuing the improvement of social welfare and quality of life (OECD, 1971). Environmental regulations are a policy instrument to realize government's intention to lead society to a desirable direction by ensuring a comfortable living environment (Jeong, 1991). Therefore the goals of a science and technology policy and environmental regulations are consistent.

This study examines existing discussions on relationship between environmental regulations and technological innovation and corporate competitiveness reinforcement. This study aims to present the basic discourse to establish policies to consolidate corporate competitiveness by protecting the natural environment, improving people's welfare, and innovating science and technology through environmental regulations.

2. Theoretical Discussion

2.1. Technological Innovation

Schumpeter divided the process of technological change into three phases – invention, technological innovation, and technology diffusion processes. Technological innovation is the second phase process in which the development of new ideas is realized with new products having market value and production process (Jo, 2003). In the theory of Schumpeter on the process of technological change, technological innovation means the intermediate process that spreads to the market in which the creation of new ideas and the product embedded with the ideas are disseminated to the market. However, recent technological innovation is not only used as a term indicating the entire process of technological change including the diffusion of embodied products, but also means business fluctuations due to the adoption and diffusion of technological innovation. Technological innovation changes to a concept on the entire social process of technology.

As for the sources and determinants of technological innovation, a technology push theory asserting that progress in science and technology is the main factor in innovation and a market pull theory insisting that market demand affects innovation activities the most have been conflicting. From the science and technology policy perspective, there

are huge differences between the technology push theory that emphasizes the need for government support for science and technology development and the market pull theory that requests policies that stimulate market demand for new technologies (Hong, 2016). The technology push theory is in line with the Solow-Swan model that pointed out technological progress as a driving force for economic growth and the endogenous growth theory looking for the driving force of technological progress from investment in human resources. Meanwhile, the market pull theory looks for a driving force promoting new idea creation from consumer demand and the technology push theory adequately explains the influence of market on technological innovation that is underestimated Because the technology push theory and the market pull theory partially explain the driving force and determinants of technological innovation, respectively, an interaction theory insisting that technological innovation is carried out through continuous interactions between science and technology and the market is recently becoming a leading theory (Hong, 2016).

2.2. Relationship between Environmental Regulations, Technology Innovation, and Corporate Competitiveness

The traditional view of economists is that environmental regulations weaken corporate and national competitiveness. They say that production decreases because input resources required for production should be converted into pollution reduction resources due to environmental regulations and consequently productivity falls, and so corporate competitiveness weakens. The reasons why environmental regulations decrease productivity can be summarized into the four reasons (Jo, 2006): First, not only goods, but products related to quality of the environment should be produced using the factors of production because of environmental regulations. Second, productivity may decline, if restrictions are imposed upon production process or management methods in response to environmental regulations consolidation. Third, investment in pollution prevention facilities due to environmental regulations offset productive investment. Fourth, the cost of investment pollution prevention facilities is required whenever the best available technology is developed, as environmental regulations make companies mandatorily adopt the best available technology.

Porter considered environmental regulations as an opportunity to consolidate corporate competitiveness as opposed to the conventional point of view. The point of view on the relationship between environmental regulations and competitiveness is called Porter Hypothesis, which consists of an assertion that environmental regulations work as technological innovation's driving force and an assertion that technological innovation makes the company concerned have comparative advantage compared to competitors due to cost savings due to the result of technological innovation (Jo, 2006). According to Porter Hypothesis, if the environmental regulations are to work as a factor that can enhance competitiveness, technological innovation should occur as an intermediate stage. Jaffe Palmer (1996) classified an assertion that there is a positive relationship between environmental regulations and technological innovation as weak Porter Hypothesis and an assertion that there is a positive relationship between environmental regulations and industrial competitiveness as strong Porter Hypothesis. The empirical studies on Porter Hypothesis have fully or partially verified two points, namely whether environmental regulations give an impetus to technological innovation and whether the environmental regulations consolidate competitiveness via technological innovation.

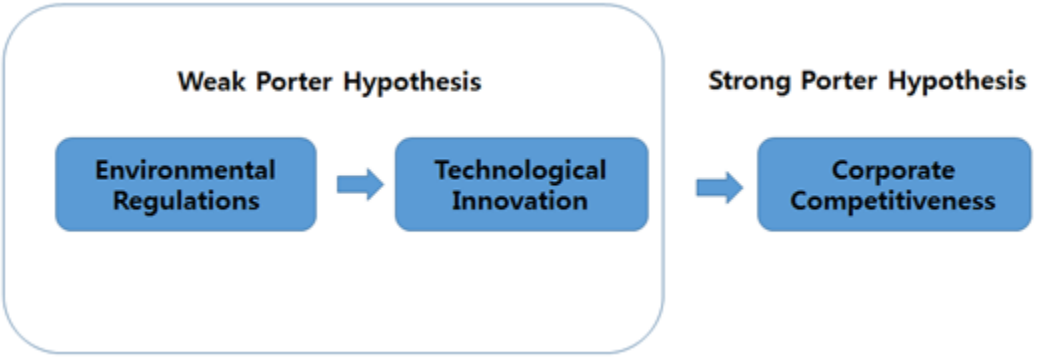

Figure 1: Weak Porter Hypothesis & Strong Porter Hypothesis

Kang and Lee (2006) empirically analyzed the effects of environmental regulations reinforcement on technological innovation from 1982 until 2001. As the proxy variable of environmental regulations, pollution abatement and control

expenditure was used and as the proxy variable of technological innovation, domestic manufacturing R&D expenditure was used. Also the panel fixed effects model was used to analyze the effects of environmental regulations reinforcement on technological innovation by dividing into the period until 1991 when environmental regulations were relatively weak and the period after 1992 when environmental regulations were consolidated and environmental budget sharply increased. As the pollution abatement and control expenditure increased, R&D expenditure also increased and so it was verified that environmental regulations consolidation has an attraction effect of technological innovation for pollution and cost reduction. The effect was revealed more during 1992 and 2001 and so it was ascertained that weak Porter Hypothesis was adopted well.

Jo (2003) investigated whether increase/decrease in the capital ratio of pollution prevention facilities has an effect on R&D expenditure increase rate and the number of patent applications form 1983 until 1997. As an analysis result, only the model setting R&D expenditure as a dependent variable was significant and the model setting the number of patent applications as a dependent variable was not significant. However, it is difficult to insist that there is no relationship with environment-related patent applications as a result of environmental regulations and technological innovation to which an impetus is given by the environmental regulations, because patent data was not collected by limiting to environment-related patents in this study.

Lee et al. (2020) examined the factors affecting Chinese companies' green technological innovation by dividing them into corporate internal factors and external factors based on the Porter Hypothesis and resource-based theory. For green technological innovation, which is a dependent variable, the number of environment-related patent applications, and for corporate internal factor, which is an independent variable, R&D expenditure, and for an external factor, fines due to Chinese government's environmental regulations were used as the proxy variable, respectively. According to the analysis result, it was identified that independent variables had positive correlations with dependent variables and that the correlations between the independent and dependent variables were stronger in Eastern region of China where environmental regulations were stronger than other regions, when regional difference was input as a moderating variable. Therefore it was confirmed that the weak Porter Hypothesis was adopted well.

Kim and Ha (2012) empirically analyzed what effects the changes in environmental investment had on the growth rate of productivity by each industry from 1991 until 2009. As the proxy variable of environmental regulations, the ratio of environmental investment was used and total factor productivity was used as a measurement tool for productivity by industry. As a result of the analysis, a productivity improvement effect was proved to be significant after two years from the time when the ratio of environmental investment increased. According to result of difference checking by industry that was classified into 20 types of industries, the productivity improvement effect was larger and faster, as an industry's environmental pollution emissions were more and so the strong Porter Hypothesis was adopted.

Lee and Ji (2011) empirically analyzed relationship between environmental regulations, technological innovation, and productivity using various economic statistics from 1992 until 2007. As the proxy variable of economic regulations, technological innovation, and productivity, the pollution abatement and control expenditure (PACE), R&D expenditure by one's own burden out of the total R&D expenditure, and value-added amount deducting the cost of production from the value of production were used, respectively. By analyzing and modeling the theoretic model that the Porter Hypothesis takes, an analysis was made sequentially, and the panel data 2-SLS was used. According to the analysis result, as environmental regulations were consolidated and so the pollution abatement and control expenditure increased, there were more positive effects on technological innovation. It was confirmed that positive effects were revealed as R&D expenditure increased and thus as technological innovation was carried out. Therefore the strong Porter Hypothesis was adopted.

Kang (2015) empirically analyzed the data from 2003 until 2012 by adopting the panel data 2-SLS sequential model of Lee and Ji (2011), and using total factor productivity used by Kim and Ha (2012) as the proxy variable of competitiveness, which is the last dependent variable. According to the analysis result, the strong Porter Hypothesis was adopted and so the prior researches using an econometrics approach after 2000 consistently showed positive relationship between environmental regulations and productivity competitiveness.

Another common result shown from those researches is that time lag exists in each stage when environmental regulations are connected to technological innovation and then the technological innovation is connected to productivity improvement and competitiveness consolidation. Kang (2015) made a conclusion that it would take one year for environmental regulations to be connected to technological innovation, two years for technological innovation to be connected to productivity increase, and so it would take three years in total for environmental regulations to improve productivity and consolidate competitiveness. The conformation of time lag is in line with the prior researches on relationship between R&D investment and technological innovation (Choi & Kim, 2015; Choi & Kim, 2016). This partially explains the reason why the results of initial stage empirical studies not considering time lag did not adopt the Porter Hypothesis.

The empirical studies of Porter Hypothesis by the econometrics approach above have an important meaning in that they checked relationship between environmental regulations and productivity competitiveness. However the analysis level was set at industrial level, and there is a limitation that whether technological innovation is made and competitiveness can be consolidated through additional R&D investment at individual corporate level was not verified.

Table 1: Empirical Studies on the Proxy Variables of Porter Hypothesis

Prior Research	Environmental Regulations	Technological Innovation	Competitiveness
Hamamoto (2006)	Pollution abatement and control expenditure	R&D expenditure	-
Kang & Lee (2006)	Pollution abatement and control expenditure	R&D expenditure	-
Jaffe & Palmer (1996)	Increase/decrease in the capital ratio of pollution prevention facilities	① R&D increase/decrease rate ② Number of patent applications	-
Jo (2003)	Increase/decrease in the capital ratio of pollution prevention facilities	① R&D increase/decrease rate ② Number of patent applications	-
Lee et al. (2020)	Fines on environmental regulations	Number of environmental patent applications	-
Kim & Ha (2012)	Environment-related investment amount	-	Total factor productivity
Lee & Ji(2011)	Pollution abatement and control expenditure	R&D expenditure (company's own burden)	Added value
Kang (2015)	Pollution abatement and control expenditure	R&D expenditure (company's own burden)	Total factor productivity

2.3. Technological Innovation as a Moderating Variable of Corporate Competitiveness Consolidation

The basic assumption of theories on technological innovation is that capital accumulation and an increase in population and labor force that mainstream Economics perspective noted as key factors cannot fully explain economic growth and development. When the effect of the input of capital and labor approaches 0 due to diminishing marginal utility, an assertation that the factor which can give an impetus to economic growth and development is technological innovation is widely accepted now. Meanwhile, environmental regulations can be regarded as a policy restricting production and consumption activities, due to a result of recognition that environmental regulations are huge social cost incurred by a side effect of devoting all energy to only economic growth and development.

From this perspective, environmental regulations can be also understood to have an opposite direction from science and technology development giving an impetus to economic growth and development through technological innovation. However, when dynamic relationship between science and technology development and economic growth is not assumed as unilineal, but the possible future economic state occurring, if no policy intervention, namely no environmental regulations exist, and the future economic future to occur as a result of environmental regulations intervened are imaged as alternative futures competing with each other, the environmental regulations may be regarded as playing a role in modulating the direction of science and technology development. Environmental regulations do not control scientific and technology development, but changes its direction. From the market pull theory on technological innovation, environmental regulations can be considered as the factors that create new market and consumer demand that could not exist, if environmental regulations did not exist. From this perspective, environmental regulations can be understood as demand from the market to promote science and technology development.

However it is difficult to assure that technological innovation brings a corporate competitiveness consolidation effect unconditionally. From corporate position, they judge corporate competitiveness has been consolidated only if profits increasing through technological innovation are larger than costs for technological innovation. If companies do not carry out technological innovation that may respond to environmental regulations, costs increase and the resulting competitiveness decline occur due to environmental regulations as main Economics assert from the time when the environmental regulations intervene. As for companies that performed technological innovation that may respond to environmental regulations, their competitiveness decreases due to a cost increase from R&D investment until the time when technological innovation is completed. Their competitiveness becomes consolidated due to R&D investment outcome after the completion of the technological innovation. Time lag exists in each stage of the process and the time lag may work as a factor hindering R&D investment for technological innovation.

When it comes to how to respond to the policy intervention through environmental regulations from corporate position, the uncertainty of technological innovation works as obstacles in decision making to increase R&D investment. The uncertainty to consider first is that the period between the time when R&D started and the time when technological innovation is performed cannot be exactly predicted. Therefore relationship between technological innovation and corporate competitiveness may greatly differ depending on the status of technological innovation's success and the time lag between the success time of the technological innovation and the intervention of environmental regulations. The time when environmental regulations intervene is notified by the government in advance and the companies trying to respond to the regulations need to make the technological innovation succeed, until the environmental regulations intervention start, and complete the development of the embodied products and the establishment of mass production system to maximize a comparative advantage. If the time of technological innovation success is later than the time of environmental regulations intervention, more R&D expenditure should be burdened than those not performing R&D investment between the period and so the company's competitiveness weakens more and should pay higher cost expenditure. The company should go through the transition period until it can recover corporate competitiveness by collecting the additional cost spent in between the period through the comparative advantage gained from technological innovation.

Uncertainty to consider secondly is that the success of technological innovation cannot be assured. If a company fails in technological innovation, the corporate competitiveness weakens as much as R&D expenditure. Uncertainty to consider lastly is that a comparison issue between the cost incurred from technological innovation and profit through technological innovation. Although a company succeeds in technological innovation, if profits do not increase more than input costs, the corporate competitiveness weakens. An attempt to consolidate corporate competitiveness through environmental regulations may fail, if uncertainties innate to technological innovation and the time lag problem are not adequately considered.

3. Methodology

As examined thus far, it is true that the corporate and industrial sector strongly recognize that environmental regulations are a factor that increases costs and weaken competitiveness from direct and indirect aspects, although positive relationship between environmental regulations and competitiveness are observed in many cases. From a company's perspective to perform technological innovation through R&D investment, the uncertainties of technological innovation become a factor to make companies hesitate active R&D investment. There is no guarantee that technological innovation success is connected to corporate competitiveness consolidation.

Environmental regulations consolidation is an unavoidable change and flow of times and is expected to be more reinforced internationally. In consideration of uncertainty of technological innovation and corporate competitiveness consolidation, a need for strategic planning at the national level emerges in order to make corporate competitiveness be consolidated as a result of the environmental regulations. A policy to encourage individual companies increase R&D investment and carry out technological innovation and so strengthen competitiveness by actively responding to environmental regulations and to support technological innovation to be connected to competitiveness consolidation is needed. This study aims to draw policy direction required to analyze internal factors and external environment on relationship between environmental regulations and corporate competitiveness through literature review, create technological innovation and strengthen competitiveness through a SWOT analysis.

A SWOT analysis is a sort of strategic planning approach. As the internal factors of analysis subjects, the strength, weakness, external environment, opportunity, and threat are drawn, making each factor and environment match, and a response strategy is produced, and organizations can be mainly analysis subjects. The SWOT analysis is much used

to draw development strategies of local governments or organizations (Kim & Kang 2020; Ryu, 2010; Ryu, 2011), and it is also used for an industry promotion policy (Kim et al, 2020; Lee & Kim, 2004; Jeon & Seo, 2012).

4. SWOT Analysis

4.1. Internal Factors and External Environment

This study extensively explores the factors and environment having important effects on the relationship between environmental regulations and competitiveness consolidation so that environmental regulations can be connected to competitiveness consolidation. As examined above, technological innovation plays a pivotal role to do so, there is a need to analyze influencing factors and therefore the components of the technological innovation system approached from the systems perspective on technological innovation are referred to. The technological innovation system encompasses the following: technological innovation's main players, namely companies, universities, research institutes; individual researchers; actors including research support institutions, government ministries managing and supervising the research support institutions; macroeconomy affecting R&D and technological innovation effects; environmental factors including changes in institutions, regulations and basic education/training system. The technological innovation system is suitable as a theoretic framework to analyze and find the factors of the SWOT analysis. The factors related to technological innovation's main players (companies, universities, research institutes) and the factors related to technological innovation's nature are defined as internal factors here. In addition, the factors of support system, policy, and macroeconomy affecting the technological innovation main players are defined as the external environment.

4.1.1. Strength

4.1.1.1. High Prior Technology Level

If world top level is set at 100%, Korea's environmental technology has relatively high level in various fields: high efficiency and eco-friendly non-CO2 green gas reduction technology - 88.5%, smart water circulation and water resource securing and management technology - 85%, soil and underground environmental pollution management technology - 84%, environmental and human risk assessment technology of harmful factors - 82.5%, waste resource recycling technology - 80%, climate change monitoring/prediction/adaptation technology - 80% (KISTEP, 2020b). There are many technologies having 2~3 years of skills gap, compared to world top level technologies. If the group is classified, there are many technologies that can be classified as a chase group. However the six technologies to reduce greenhouse gas except CO2 can be evaluated as close to leading level technologically.

Korea has many world top level technologies in the energy resource technology related to the environment including the following: high-capacity, long-life secondary battery technology - 96%, high-efficiency solar cell technology - 90%, nuclear energy technology - 88%, marine energy technology - 81%. Therefore a high synergy effect can be expected with the environmental technologies. Overall, Korea's technology level improved 3.2%p in 2019, compared to 2018, and skills gap was reduced to 0.5 year. If this trend is maintained, Korea is expected to reach the world top level within 5~6 years. Especially Korea's paper growth rate and patent influence in 120 key science and technologies ranks the second in comparison with China, Japan, EU, and the U.S.A. and so Korea can be evaluated as having high technological level.

4.1.1.2. Excellent R&D Manpower

The number of full time equivalent researchers indicating the number of researchers estimated by reflecting the rate focusing on R&D work was 430,000 based on 2019, which ranks fifth in the world following China, the U.S.A., Japan, and Germany. The number of researchers per 1,000 domestic economically active population was 15.4, which ranks the highest level in comparison with major developed countries. France, Japan, and Germany have 10 researchers, and the U.K., and the U.S.A. have 9 researchers, and Korea has 1.5 times higher researchers per 1,000 domestic economically active population than major developed countries. The increase trend is 0.5%p annually on average in view of a 3.0%p increase in 2019 from 12.4% in 2013.

4.1.2. Weakness

4.1.2.1. Uncertainty of Technological Innovation

The uncertainty of technological innovation is a weakness factor making companies hesitate investing in environmental technologies. In the chase phase, the aimed technology can be recognized to be developed in advance, because there is a subject to imitate technological innovation. However the subject to imitate becomes obscure or no subject to imitate exists in the phase beyond the chase phase and also it becomes difficult to assure whether the technology can be developed (Song & Lee, 2007). Another uncertainty of technological innovation is about a question on whether the newly developed technology can be connected to commercialization phase. If the developed technology falls behind in a competition between developed technologies, the outcome cannot be enjoyed, despite success in technological innovation. In an opposite case, if a competitor can imitate the technology or more innovated technology is developed, despite success in leading technological innovation, there is a problem that adequate profits may be difficult to be enjoyed from the technological innovation.

4.1.2.2. Time Lag in Technological Innovation

The time lag in technological innovation can be an important weakness factor. As stated above, it will take 2~3 years for R&D investment to produce outcome connected to technological innovation. The time lag is the same level as the skills gap required for Korean environmental technologies to catch up with world top level technologies. This may be connected to a pessimistic outlook that gap with leading technologies cannot narrow down, despite R&D investment.

4.1.3. Opportunity

4.1.3.1. National R&D Support System

Because the result of R&D is very uncertain and its effect is revealed for the long-term, government support is accepted as inevitable (Hong, 2015). Korea established the R&D support system, centered on science and technology societies by setting national innovation system theory as a core idea in the Roh Administration. Since 2006, Korea has continuously made efforts to make a support system rational and efficient by establishing the Act on the Performance Evaluation and Management of National Research and Development Projects, etc. The R&D policy is a policy field very difficult to diagnose policy effectiveness due to the uncertainties of technological innovation and the time lag problem in terms of outcome generation and diffusion. Dependence on experts' opinions is very strong, but policy change may easily occur depending on the change of political power (Cheon & Ha, 2013). Korea's R&D policy has experienced a great deal of changes from the Kim (Dae-jung) Administration that greatly emphasized the importance of science and technology policy to the current Moon Administration. As the 4th industrial society comes to maturity, the importance of science and technology is generally recognized, and R&D investment size expands, and the R&D support and evaluation system is also persistently reorganized.

Another important factor comparable to the construction of the R&D support system is R&D investment size. Korea's R&D investment has continuously increased and it stands at KRW 27.4 trillion according to the joint briefing session with ministries on R&D in 2021. When the private sector R&D expenses was summed up, the R&D investment was KRW 100 trillion and ranked fifth based on OECD data in 2019 and the ratio of R&D expenses to gross domestic product ranked second, following Israel. The ratio of R&D expenses in environmental technology out of the total R&D size in 2019 was 8.7%, and it ranked third, following IT and NT (nano technology) (OECD, 2020; KISTEP, 2020a – requoted).

4.1.3.2. Social Consensus on Environmental Values

As the importance of governance in administration and policy is emphasized, social consensus is emerging as an important resource to ensure policy effectiveness and feasibility. A perception survey is a typical method to investigate social consensus on specific problems or themes. Korea Environmental Policy Evaluation Institute (KEITI) that carries out a national environmental awareness survey each year in order to enhance environmental policy effectiveness and preemptive and strategic policy promotion, namely KEITI surveys people's awareness on the environment and practical volition (Jeon et al., 2020). According to the survey result, 71.9% of Korean people have interest in overall environmental issues. 91.4% of Korean people recognize that severity of climate change is serious in overall society and also 70% recognize that it is also serious to each respondent. 65% of the respondents said they already receive negative effects of climate change and so the respondents stood at 2/3 of the total respondents recognizing environmental problems are the problems at present, instead of the far future or the next generation.

What is required to note is the response on environmental attitude. 68% said they prioritize environmentally-friendly behaviors, putting up with inconveniences on the question about which they prefer between environmentally friendly behaviors and conveniences in life. In a question about efforts to respond to climate change, 77% of the total respondents answered that they would make more efforts, if companies make more efforts to respond to climate change,

and 75% said they have an intention to endeavor more, if the government endeavors more to respond to climate change. Concerning reinforcement of punishment for inducing environmental damage to solve environmental problems, 20% of the total respondents said so, 14% said the standard consolidation of environmental regulations, and 13% said the expansion of investment in the development of environmental pollutant reduction technology. Consequently, recognition on reinforcement of environmental regulations and expansion of R&D for environmental problems is high, and therefore it can be inferred that overall social consensus on environmental values has been made.

4.1.4. Threat

4.1.4.1. Technological Chase of Latecomers

Although Korea changes world top level in diverse environmental technology field, Korea is in a position1 to be chased from latecomers. China is closely chasing Korea in the air pollution response technology including particulate matters, ultra-advanced treatment and control technology for aquatic pollutants. China is rather more advanced than Korea in the climate change monitoring/prediction/adaptation technology and waste resource recycling technology.

4.1.4.2. Advancement, Diversification, and Complication of Environmental

When environmental regulations are understood as a request in the market and if environmental technologies are viewed as a corporate activity to actively respond to market needs, the environmental regulations' advancement, diversification, and complication mean that a request for companies to invest in R&D increases and more difficult situation appears in response to the environmental regulations.

The comprehensive plan for particulate matter management announced in November 2019 is a court plan presenting a policy direction and promotional tasks by 2024. Compared to existing measures, which were a separate administrative plan, the abovementioned comprehensive plan shows differences in that it has binding force of the state and administrative institutions (KEITI, 2020b). According to the comprehensive plan, environmental regulations have been reinforced gradually including the adoption of Total Maximum Daily Loads (TMDL) and emission standard consolidation. Also an emission impact analysis that was exempted for the workplaces targeted for TMDL was abolished in 2020. Consequently, environmental regulations show the advancement, diversification, and complication from diverse aspects.

4.2. Policy Response Strategy to Reinforce Technological Innovation and Corporate Competitiveness

In SWOT analysis, the distinction criterion is what role technology innovation plays in order to strengthen corporate competitiveness. Through matching of internal factors classified through the SWOT analysis and external environment, the policy response strategy to induce technological innovation and competitiveness reinforcement was drawn as follows:

4.2.1. S-O (Strategy-Opportunity) Strategy

A strategy to reinforce technological innovation using the following opportunity is necessary: an advantage of high level of prior technology and excellent R&D manpower, nationally well-established R&D support system, and the social consensus on environmental values.

4.2.2. W-O (Weakness- Opportunity) Strategy

The uncertainties and time lag of technological innovation are the factors that make companies unwilling to invest in the R&D of environmental technology. Therefore policy support that can reduce uncertainties by using the well-equipped R&D support system and reduce problems caused by time lag is required.

For development cost spent for R&D investment, help should be offered for companies to easily receive financial support and incentives need to be provided so that technological innovation's outcome can be hugely enjoyed.

4.2.3. S-T (Strength-Threat) Strategy

Even though technological chase of latecomers such as China is intense, there is a need to maintain existing skills lag through active R&D investment. In a situation that environmental regulations become advanced, diversified, and complicated, it is difficult to evenly develop technologies in all sectors. Consequently, there is a need to select sectors having a higher possibility for technological innovation outcomes to be enjoyed, and intensively invest in and nurture them. Among already secured prior technologies, excellent R&D manpower should be more efficiently used for technologies having huge potential that can strategically lead technology.

4.2.4. W-T (Weakness-Threat) Strategy

By adequately considering more advanced and diversified environmental regulations trend and time lag of technological innovation, preemptive R&D investment predicting future marked demand is necessary. It is very difficult to adequately perform such a thing by individual companies, and so a strategy should be established at overall national level and government ministries and companies need to vigorously cooperate to make it possible.

Table 2: SWOT Matrix and Strategies

Internal factors / External environments	Strengths	Weaknesses
	● High prior technology level ● Excellent R&D manpower	● Uncertainties of technological innovation ● Time lag of technological innovation
Opportunities	S-O strategy	W-O strategy
● National R&D support system ● Social consensus on environmental values	▶ Technological consolidation	▶ Reinforcement of financial support for R&D investments and fortification of technological incentives
Threats	S-T strategy	W-T strategy
● Technological chase of latecomers ● Environmental regulations' advancement, diversification, and complication	▶ Maintaining skills lag through preemptive technology development	▶ Preemptive R&D investment considering time lag and the trends of environmental regulations

5. Conclusion

Environmental regulations are likely to increase production costs and weaken corporate competitiveness. This study explores the possibility that environmental regulations can positively affect technological innovation and strengthen corporate competitiveness. The reality is that most companies do not welcome the environmental regulations introduced by the government.

This study has examined the relationship between technological innovation and environmental regulations, delved into the internal factors and external environments related to reinforcement of corporate competitiveness to respond to environmental regulations, and presented suitable response strategies at basic discourse level. Korea has strengths of high level prior technologies and excellent R&D manpower and opportunities of the well-established national R&D support system and social consensus on environmental values. However there are problems on how to respond to such weaknesses including fundamental uncertainties and time lag innate to technological innovation and threats including latecomers' technological chase and environmental regulations' advancement, diversification, and complication. It can be also noted that to better overcome weakness and threat factors relies on how efficiently strengths and

opportunities are maximized. The reality is that most companies do not welcome the environmental regulations introduced by the government.

Eventually, companies have no choice but to think about the costs of regulation and prevent regulatory costs from leading to a sharp rise in corporate production costs. It is technological innovation that plays an important role in this process, and the key point is to reduce the increase in production costs caused by regulation through technological innovation. In this respect, environmental regulations can provide a natural response for an entity to increase R&D costs.

It can be noted that there may be limitations in the study or verification of whether important variables are missing or not in the derivation of sub-elements for SWOT analysis. When it comes to research method, it would be better to present a methodology that can be more objectively demonstrated through the use of SWOT as well as AHP analysis methods as an additional research task for further studies. In the future, empirical research and methodology improvements that can support Potter's theory that environmental regulations have a positive impact on technological innovation and that technological innovation eventually enhances corporate competitiveness should be accompanied.

The world companies are now in the middle of energy transformation involving industrial, technological, economic and social innovation. The sustainable development and carbon neutrality is increasingly referred to by many organizations as a necessary basis for achieving their strategies. The leading companies are collaborating and making every effort to increase renewable electricity demand for reaching RE100 membership requirements. It has become an important era for companies as well as governments to be compatible with each other through the harmonious balance between environmental regulations and technological innovation.

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