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How Do the Measures of Global Warming Drive Innovation?: An Empirical Study of Japanese SMEs in the Manufacturing Industry

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Abstract

This study aims to identify the factors affecting innovation in Japanese SMEs from the global warming perspective, focusing on the manufacturing industry firms in Osaka prefecture. Statistical analysis methods are extended ordered probit regression and SEM (Structural Equation Modeling). As a result, the innovation of new products for new markets is most likely affected by implementing a new operation of global warming measures of renewable energy, storage of batteries, and recycling, and the reduction of electricity consumption, waste, and carbon dioxide emission. This study also finds that adopting ICT and customer alliance relatively affect global warming. Our empirical evidence supports the importance of customers as information resources indicated by many previous studies. This study contributes to showing that ICT impacts global warming measures.

Keywords: *global warming, eco-innovation, ICT, alliances with stakeholders*

1. INTRODUCTION

This study aims to examine the hypotheses: (1) global warming measures can lead to innovation, (2) ICT and alliance with other stakeholders can promote global warming measures in the Japanese SMEs of the manufacturing industry.

Today, firms worldwide face environmental challenges such as global warming. We attempt to identify the factors affecting innovation in Japanese SMEs from the view of global warming. The international community has discussed the necessity to undertake this issue for several decades, and therefore Japanese firms must overcome it. To learn about the situation surrounding Japanese companies in the context of global warming. We overview the international agreement in which the Japanese government has participated.

The Kyoto Protocol was adopted on 11 December 1997, which set forth binding targets and timetables for greenhouse gas (GHG) emission reductions for developed countries. It excluded developing countries from binding targets, and the United States withdrew from the Kyoto Protocol. The United States, one of the world's largest greenhouse gas emitters, did not ratify the Kyoto

Protocol. China and India, which have since become significant emitters, were not required to reduce their emissions under the agreement. The protocol aimed for a 5% reduction in emissions from 1990 levels by 2012, deemed too low to impact global warming significantly. The Kyoto Protocol heavily relied on market-based mechanisms, such as emissions trading and the Clean Development Mechanism, to help countries meet their targets. These mechanisms were criticized for being prone to fraud and manipulation and not necessarily leading to emission reductions. While a significant step towards addressing climate change, the Kyoto Protocol faced several challenges that could have improved its effectiveness.

The new international framework in place of the Kyoto Protocol for GHG emission reductions, namely, the Paris Agreement, was set up. It is a legally binding international treaty on climate change. It entered into force on 4 November 2016. Its goal is to limit global warming to below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. By providing financial services to developing countries to mitigate climate change and enhance their abilities to adapt to climate change, developing countries can easily sign in the Paris Agreement. The Kyoto Protocol contained legally binding targets and compliance mechanisms, such as a carbon market and penalties for non-compliance. On the other hand, the Paris Agreement relies on voluntary commitments and does not include penalties for non-compliance. However, the Paris Agreement does have a transparent framework for tracking progress. The Paris Agreement recognizes the importance of technology transfer and finance to support climate action in developing countries. It aims to provide financial resources to help developing countries mitigate and adapt to climate change.

The Japanese government has made a policy to mitigate global warming. Society 5.0, proposed by the Cabinet Office in the Japanese government, will perform a high degree of convergence between virtual and real space, supported by AI. New technologies such as IoT, robotics, AI, and big data are thought to achieve economic development and reduce GHG emissions in Society 5.0. Considering the policy of Society 5.0, we investigate the effects of ICT on innovation. Japanese firms are involved in this worldwide trend. Innovation is necessary for a firm to grow and become profitable. The regulation by the government may be a burden for a firm, particularly in the case of small and medium enterprises. However, firms that challenge environmental regulation may find a new market through innovations. The firms which have the corporate image of eco-friendly can build the brand. It is one of the main drivers of adopting environmental measures for firms to improve their corporate image. Eco-labels enable firms to use their environmental performance in their marketing strategies, differentiating their products in order to gain competitive advantages (Rennings, 2000).

A widespread definition states, "Environmental innovation consists of new or modified processes, techniques, systems and products to avoid or reduce environmental damage" (Kemp et al., 2001). Many studies have investigated eco-innovation. According to Kemp and Foxon (2007), Eco-innovation is the production, application, or exploitation of a good, service, production process, organizational structure, or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and the negative impacts of resources use (including energy use) compared to relevant alternatives.

Determinants of eco-innovation are categorized as (1) technology push, (2) management capabilities, (3) market pull, (4) collaboration or alliance with research institutions, including universities, suppliers, and customers, and (5) regulation or government policy.

Horbach (2008) categorizes determinants of eco-innovation as technological and management capabilities, collaboration with research institutions, agencies, and universities, access to external information and knowledge, size, material prices, energy prices, market share market demand for green products, existing regulations, expected future regulations, and access to existing subsidies and fiscal incentive. The supply-side and demand-side factors determine the price factor. Horbach (2008) shows that improving technological capabilities by R&D triggers eco-innovation.

Diego Augusto et al. (2017) indicates the determinant of eco-innovation: governmental policy supporting eco-innovation, availability of resources, perception of the strategic relevance of eco-innovation, technological advisory oriented to environment, product, and process eco-innovation oriented methods, and cooperation and partnership within supply networks.

The characteristics of determinants of eco-innovation are various, as seen above. It is necessary to arrange the previous empirical studies and focus on the points which should be discussed. This paper aims to investigate the relationship between innovation and measures of global warming statistically. In the next section, we survey the previous studies to focus on researching Japanese SMEs.

2. PREVIOUS STUDIES

We introduce the representative previous empirical studies of researching eco-innovation summarized in Table 1. By comparing those studies, we found the points to be discussed.

2.1. Environmental regulations, including self-regulation or environmental policies

Environmental regulations, including self-regulation or environmental policies, have an essential role in driving eco-innovations (Demirel et al., 2018; Doran & Ryan, 2016; Frondel et al., 2007; Horbach, 2008; Horbach et al., 2012; Kesidou & Demirel, 2012; Rehfeld et al., 2007; Wagner, 2008).

Horbach (2008) concludes that environmental regulation is a significant outcome. Government regulation is crucial in pushing firms to reduce air (CO_2, SO_2, NOx) as well as water or noise emissions, avoid hazardous substances, and increase the recyclability of products (Horbach et al., 2012). Regulatory measures and the stringency of environmental policies are positively correlated with end-of-pipe technologies (Frondel et al., 2007). Traditional environmental policy is effective; existing regulations (stick incentives) drive innovation significantly (Doran & Ryan, 2016).

EMS (Environmental management systems) is considered the factor of policy or corporate strategy (Rehfeld et al., 2007). Environmental management systems are not associated with product innovations (Wagner, 2008). An Environmental Management System (EMS) is a framework that helps an organization achieve its environmental goals through consistent review, evaluation, and improvement of its environmental performance. By implementing EMS, firms can gain effective guidance to establish and review their business practice. Soft environmental policy instruments, such as activities regarding voluntary agreements or the certification of EMS, may stimulate environmental product innovations to a certain extent (Rehfeld et al., 2007). Rehfeld et al. (2007) note that the EMS certification by ISO14001 significantly positively affects environmental product innovations. Firms can review their procedures from the view of environmental product innovations using certificated EMS. Demirel et al. (2018) illustrates that the requirements to comply with direct environmental regulations encourage the adoption of EMS to reduce firms' environmental impact but detract from EMS certification.ISO14001 certification effectively strengthens the positive impact of environmental management systems on End-of-Pipeline technologies, while CSR policies do not significantly motivate any of the eco-innovations (Demirel & Kesidou, 2011).

Many previous studies introduced above mentioned countries in the EU that are advanced cases of environmental challenges. The importance of regulations and policies could vary by country. We should consider it in analyzing the Japanese case.

2.2. R&D activity (supply-side factor)

R&D is one of the supply-side determinants in eco-innovation (Cainelli et al., 2015; Demirel & Kesidou, 2011; Horbach, 2008; Kammerer, 2009; Mazzanti & Zoboli, 2009; Rennings et al., 2006). Technologically, R&D investment is considered the fundamental factor.

Horbach (2008) indicates that the improvement of technological capabilities ("knowledge capital") by R&D triggers environmental innovations. Demirel & Kesidou (2011) shows that R&D has the highest environmental and technological impact. Its results suggest that regulations can play an essential role in combating pollution not only in the short run by stimulating investments in process innovations such as end-of-pipeline technologies but also in the long run by driving investments in process and product innovations through environmental

R&D. In terms of internal innovation resources, the presence of R&D structure is even more critical than for other innovations in spurring the development of EIs (Environment Innovations) (Cainelli et al., 2015). On the other hand, R&D activities are less important than consumer benefit and regulation in EP (Environmental Product) innovation of German manufacturers (Kammerer, 2009). There are conflicting arguments on the importance of R&D in the environmental field. The effectiveness of regulations versus the market mechanism in addressing environmental issues varies by country. To make definitive statements, further accumulation of research in this field is required.

Japanese SMEs might not invest enough in environmental R&D activities. Our field survey has confirmed that Japanese SMEs have limited financial resources and are reluctant to do more than meet the demands of larger companies with which they have business relationships, and therefore we do not focus on this issue.

2.3. External factor and demand side factor

Due to the relationship with the client, business partner, and customer, firms are thought to often cope with environmental problems. According to Cainelli et al. (2015), External resources are more relevant for EIs (environmental innovations) than for developing other innovations. Cainelli et al. (2012) notes that EIs are stimulated by the firms' interaction with "qualified partners" such as universities and business suppliers.

Also, Aboelmaged (2018), Borghesi et al. (2015), Burki (2019), Doran & Ryan (2016), Horbach et al. (2012), Triguero et al. (2013), and Wagner (2008) focus on the external stakeholders such as research institutes, customers, and other firms.

Doran & Ryan (2016) presents that customer pressure is a variable mechanism through which firms can be encouraged to eco-inovate. Consumer demand for environmentally friendly products, public procurement requirements, and exports all play a part in the market for eco-innovation (Doran & Ryan, 2016). Kammerer (2009) emphasizes market pull factors as determinants of eco-innovations by introducing the concept of customer benefit. According to Wagner (2008), for product innovations, mainly information on consumers and eco-labeling activities show a positive association. If a firm already has positive experiences with eco-labeling, then its incentive to develop environmentally-sound products which are suitable for labeling should increase, and this can explain the observed positive effect of eco-labeling on environmental product innovations (Wagner, 2008). Customer requirements are another important source of eco-innovations, particularly with regard to products with improved environmental performance and process innovations that increase material efficiency and reduce energy consumption, waste, and the use of dangerous substances (Horbach et al., 2012).

On the other hand, Rehfeld et al. (2007) indicates no strong stimulus for eco-innovation from the demand side since eco-friendly products are still too expensive. Companies do not care about environmental labeling, so a positive effect on environmental innovations cannot be verified. The relationship with customers (consumers) can be considered a demand-side factor and an external factor if the firm activates customer information. Either way, the factor of customers (consumers) must be considered arguable, and therefore we examine it in the next section.

Hofmann et al. (2012) testifies the hypothesis that firms collaborating with customers and suppliers are likely to adopt environmental management practices. As a result of statistical analysis, this hypothesis is firmly proven. It is noted that firms maintain stronger relations with their customers, and suppliers adopt environmental management practices to a larger extent (Hofmann et al., 2012).

Triguero et al. (2013) shows that collaborative networks with research institutes, agencies, and universities are essential to driving all types of eco-innovation. Therefore, managers must be conscious of the possibility of using these collaboration networks to enhance their environmental innovation strategy. Further, the significance of innovation–cooperation with universities confirms the importance that basic research has for this kind of EI (environmental innovations), for which an important part of the underlying knowledge is actually codified (Cainelli et al., 2012).

Contrary to Cainelli et al. (2012) and Triguero et al. (2013), Doran & Ryan (2016) demonstrates that

Table 1: Comparable table among

article	Triguero et al. (2013)	Horbach et al. (2012)	Demirel et al. (2018)	Doran & Ryan (2016)	Hofmann et al. (2012)	
statistical method	Multivariate probit regression	Probit regression	Probit with sample selection estimation	Multivariate probit regression	OLS regression	
object	European SMEs	German	UK	Irish Community Innovation Survey	Small and medium-sized manufacturers	
sample size	4947	4929	2076	2148	294	
Result	Entrepreneurs who give importance to collaboration with research institutes, agencies and universities, and to the increase of market demand for green products are more active in all types of eco-innovations. Supply-side factors seem to be a more important driver for environmental processes and organizational innovations than for environmental product innovations.	Government regulation is particularly important with regard to pushing firms to reduce air (CO_2, SO_2, NOx) as well as water or noise emissions, avoid hazardous substances, and increase recyclability of products. Cost savings are an important motivation for reducing energy and material use, pointing to the role of energy and raw material prices as well as taxation as drivers for ecoinnovation. Customer requirements are another important source of eco-innovations, particularly with regard to products with improved environmental performance and process innovations that increase material efficiency, and reduce energy consumption, waste and the use of dangerous substances.	Effective environmental protection entails collaboration between environmental state regulation and in-house adoption of EMS(Environmental Management System). Results also reveal that externally certified EMS substitutes for state environmental regulation, filling the void that results from weakening state regulation in the context of neoliberalism.	While the results indicate that the impact of demand-side, supply-side, and regulatory drivers vary across the different types of eco-innovation, it is consistently observed that existing regulations, customer expectations, and voluntary agreements have a positive effect on the likelihood of firms' introducing each of the nine types of eco-innovation.	Based on regression analysis, the authors provide evidence for a relationship between the underlying capabilities and environmental management practices. Consequently, the results point to additional benefits of known strategic capabilities and suggest how firms should approach sustainability initiatives by developing certain competencies.	
article	Cainelli et al. (2012)	Frondel et al. (2007)	Rehfeld et al. (2007)	Rennings et al.(2006)	Horbach (2008)	
statistical method	probit model with using instrumental variable	Multinomial logit	Binary and multinomial logit	Binary probit model	Mutlinomial logit model by using panel data	
object	Firms in the Emilia–Romagna (ER) region (North-East Italy)	Seven OECD countries(none South European	Germany	Germany	Germany	
sample size	555	3699	371	1277	1485	
Result	Cooperating with a certain kind of local actors—i.e. suppliers and universities—is the most important EI driver for the investigated firms, along with their training coverage and their adoption of information and communication technologies. Networking effects and agglomeration economies are instead found to strongly promote the adoption of EIs by multinational firms, thus highlighting the importance of local–global interactions. Interesting specifications for these results are found for particular kinds of EIs, in such fields as CO_2 abatement and ISO labelling, generally extending the analysis of EI drivers by joining local and international factors.	Regulatory measures and the stringency of environmental policies are positively correlated with end-of-pipe technologies, while cost savings, general management systems, and specific environmental management tools tend to favor clean production.	The certification of environmental management systems has a significantly positive effect on environmental product innovations. Measures concerning waste disposal or take-back systems of products seem to be an even more important driver for environmental product innovations. Other factors that have been suggested in the literature, such as environmental policy, technology push and market pull as well as specific other firm characteristics have a significant positive influence on environmental product innovations.	A positive impact of the maturity of environmental management systems on environmental process innovations is shown. Another important determinant of environmental process innovations is the strong participation of specific departments in the further development of EMAS, such as the R&D department. For environmental product innovations, learning processes by environmental management systems have a positive impact.	The econometric estimations show that the improvement of the technological capabilities ("knowledge capital") by R&D is very important for environmental innovation. General and environmental innovative firms in the past are also more likely to innovate in the present.	

previous empirical studies

Demirel and Kesidou (2011)	Kesidou and Demirel (2012)	Kammerer (2009)	Mazzanti and Zoboli (2009)	Cainelli et al. (2015)
Tobit	Heckman selection	Ordered logit analysis	OLS corrected for heteroskedasticity Probit corrected for heteroskedasticity	probit model
UK	UK	the electrical and electronic appliances industry in Germany	Itary	Spanish manufacturing firms
289	1566	92	140	4829
Our findings indicate that End of Pipeline Technologies and Integrated Cleaner Production Technologies are mainly driven by equipment upgrade motives with a view of improving efficiency while environmental regulations are effective in stimulating the End-of-Pipeline technologies and Environmental R&D. Interestingly, alongside government induced regulations, we find that market factors, mainly motivated by cost savings, are effective in driving Environmental R&D. Finally, ISO14001 certification is effective in strengthening the positive impact of environmental management systems on both End-of-Pipeline technologies and Environmental R&D while CSR policies have no significant impact on motivating any of the eco-innovations.	Our findings indicate that demand factors affect the decision of the firm to undertake eco-innovations whilst these factors exhibit no impact upon the level of investments in eco-innovations. Hence, we suggest that firms initiate eco-innovations to satisfy the minimum customer and societal requirements, yet, increased investments in eco-innovations are stimulated by other factors such as cost savings, firms' organisational capabilities, and stricter regulations.	The impact of customer benefit and regulation on EP(Environmental Product)-innovation is analyzed with logit regression and the results clearly show that both customer benefit and regulation play a key role for EP-innovation. They not only foster the implementation of EP-innovations but also their broad application and their level of novelty.	Environmental auditing schemes also show some relevant correlation to innovation adoptions. R&D efforts appear to be associated to networking activities, which substitute for size - related economies of scale.	In terms of internal innovation resources, the presence of a R&D structure is even more important than for other innovations in spurring the development of Eis(Environment Innovations). External resources are more relevant for EIs than for the development of other innovations: green innovators fuel their innovation efforts through inter-organizational relationships more intensively than other innovators, considering both the co-development of innovation through networking (external resources) and the acquisition of externally developed resources (hybrid resources).
Wagner (2008)	Borghesi et al. (2015)	Aboelmaged (2018)	Burki et al.(2019)	Chiou et al. (2011)
Multivariate probit model/ Multinomial logit model	Probit regression	PLS-SEM	SEM	SEM
Belgium,France,Germany,Hungary,Netherlands,Norway,Sweden, Switzerland,UK	Italy	UAE	Turkish exporting firms,located in the Izmir region(Turkey)	Taiwan
849	6483	182	181	124
Environmental management systems are associated with process innovations. However, the study does not find that environmental management systems are associated with product innovations. For product innovations, mainly information about consumers and eco-labelling activities show a positive association. Market research on the potential of environmental innovations positively relates to both process and product innovations. Importantly, firm size is not found to have any effect on the probability of a firm carrying out environmental product or process innovations.	A few factors emerge as particularly relevant such as relationships with other firms and institutions, sectoral energy expenditure intensity, and current and future expected environmental regulation. On the one hand, ETS(Emissions Trading Scheme) sectors are more likely to innovate than non-ETS sectors, but on the other hand, that sector's specific policy stringency is negatively associated with EI(Environmental Innovations).	The findings demonstrated the significant effects of a hotel's environmental orientation on eco-innovation practices, environmental supplier collaboration, and hotel performance. The results also confirmed the direct and mediating effect of eco-innovation practices on hotel performance.	Customer cooperation positively mediates the relationship between top management commitment and process innovation. However, customer cooperation fails to mediate the relationship between top management commitment and managerial innovation. The magnitude of customer cooperation increases the adoption of green innovations between supply chain partners to mitigate the negative impact on the environment. Furthermore, customer cooperation enforces a sense of mutuality between supply chain partners to diminish the impact of carbon footprint.	Greening the supplier through green innovation contributes significant benefits to the environmental performance and competitive advantage of the firm.

public linkages with universities, research centers, and agencies have no impact on eco-innovation. The issue of the linkage with research institutes is arguable.

Collaborative alliance with external stakeholders is one of the essential particularities in eco-innovation. Previous empirical studies argue about external stakeholders such as customers, suppliers, and research institutes such as universities and research centers; their empirical results are not coincident. Hence, we exploit this point in Japanese SMEs in our empirical study.

Turning attention to methodology, we classify previous studies (shown in Table 1) into two groups: first, the econometric model in Borghesi et al. (2015), Cainelli et al. (2012), Cainelli et al. (2015), Demirel and Kesidou (2011), Demirel et al. (2018), Doran & Ryan (2016), Frondel et al. (2007), Hofmann et al. (2012), Horbach (2008), Horbach et al. (2012), Kammerer (2009), Kesidou & Demirel (2012), Mazzanti & Zoboli (2009), Rehfeld et al. (2007), Rennings et al. (2006), Triguero et al. (2013), and Wagner (2008), and second, SEM (Structural Equation Model) in Burki et al. (2019), Burki et al. (2019) and Chiou et al. (2011). Econometric models such as logit and probit models are more likely if the number of observations is relatively large and the theoretical framework is more rigid. We select the statistical methods with reference to those previous studies.

3. CONCEPTUAL FRAMEWORK

As aforementioned, environmental problems must be tackled globally, and at the same time, we should consider the difference among countries, especially in regulations and policies. Firms of participating nations in the Paris Agreement are likely to follow the government policy. On the other hand, considering that Japanese firms face a difficult situation, such as the economic stagnation caused by COVID-19 and a hike in energy prices triggered by Russia's invasion of Ukraine, it seems complicated for Japanese SMEs to bear the environmental investment heavily.

Recently, the Japanese government has vigorously promoted Society 5.0. In Society 5.0, much information from sensors in physical space is accumulated in cyberspace. AI analyzes this big data in cyberspace, and the results are fed back to humans in physical space in various forms. Society 5.0. aims for sustainability, allowing economic growth and reducing greenhouse gas (GHG) emissions. According to the concept of Society 5.0., Firms should achieve the optimum as a whole, not the partial optimum within a firm.

Therefore, alliances and networks with other firms, such as suppliers, customers, and research institutions, become more critical for grappling with environmental challenges. Utilizing AI, IoT, and robotics is necessary for firms to survive in Society 5.0.

The information source from external stakeholders promotes innovation, as aforementioned. A number of specific 'information sources' are relevant for increasing innovation capabilities (Borghesi et al., 2015). The external networks are supported efficiently by ICT. Thus, we should consider the environmental measures and utilization of ICT at the same time. The most relevant "internal" drivers of EI (environmental innovation) are firm cooperation with suppliers and universities and firm exploitation of ICT (Cainelli et al., 2012).

This study highlights the relationship between the measures of ICT and global warming. ICT and alliances with external stakeholders are the main factors for statistical analysis in the next section.

Also, the Japanese government has actively contributed to discussing SDGs (Sustainable Development Goals). The Japanese government demonstrates leadership in 7 areas: quality infrastructure, disaster risk reduction, marine plastic litter, climate change, women empowerment, health, and education. Society 5.0. is linked with SDGs and has the same directions.

This study examines two hypotheses; (1) global warming measures can lead to innovation, (2) ICT and alliance with other stakeholders can promote global warming measures in the Japanese SMEs of the manufacturing industry.

4. EMPIRICAL STUDY

4.1. Dataset and variables

The dataset this study investigated was collected

Table 2: Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
new products for new markets	366	0.2869	0.4529	0	1
new products for existing markets	366	0.4563	0.4988	0	1
improvement in quality, price, and the deadline for delivery	366	0.2213	0.4157	0	1
renewable energy	366	1.3333	0.7278	1	3
storage of battery	364	1.0879	0.3681	1	3
recycling	361	1.5706	0.8731	1	3
reduction of electricity consumption	365	0.7918	0.4066	0	1
reduction of waste	358	0.6508	0.4774	0	1
reduction of carbon dioxide emission	366	0.3279	0.4701	0	1
initiative for SDGs	363	0.4242	0.4949	0	1
service online	364	0.2445	0.4304	0	1
ordering online	359	0.3148	0.4651	0	1
groupware	363	0.1901	0.3929	0	1
digitalization of administrative processes in the firm	364	0.4011	0.4908	0	1
alliance with customer	360	0.0472	0.2124	0	1
alliance with supplier	359	0.3148	0.4651	0	1
alliance with research institute	360	0.0944	0.2929	0	1
improvement of production method	366	0.3470	0.4767	0	1
SDGs by reduction, energy, and waste	364	0.3984	0.4902	0	1
number of employees	366	3.3033	1.6178	1	7
industry dummy for food and beverage	366	0.0683	0.2526	0	1
industry dummy for textile	366	0.0656	0.2479	0	1
industry dummy for wood and furniture	366	0.0164	0.1272	0	1
industry dummy for paper and printing	366	0.1175	0.3224	0	1
industry dummy for chemical	366	0.0519	0.2222	0	1
industry dummy for plastics	366	0.1120	0.3158	0	1
industry dummy for clay	366	0.0246	0.1551	0	1
industry dummy for steel and non-steel metal	366	0.0738	0.2618	0	1
industry dummy for metalworking	366	0.2814	0.4503	0	1
industry dummy for electronic components and equipment	366	0.0656	0.2479	0	1
industry dummy for transport machinery	366	0.0137	0.1162	0	1
industry dummy for machinery instruments	366	0.0874	0.2829	0	1

in August 2022 by the Creative Management and Innovation Research Institute of Kindai University and the Osaka Prefectural Government. The data were collected from SMEs of the manufacturing industry in Osaka prefecture by mail survey, and the number of respondents was 607 (the response rate was 17.9%). After eliminating missing values of the main variables, the sample size became 366.

The questionnaire consisted of essential attributes, business, organization, innovation, the initiative for SDGs, measures of global warming, ICT, alliances, etc. The questions related to global warming used in this research were of two types; (1) implementation or a new operation of global warming measures which were renewable energy, storage of batteries, and recycling, and (2) reduction of electricity, waste, and carbon dioxide emission. The questions related to ICT were about sales online, ordering online, implementation of groupware, and digitalization of the administration process in firms. The questions related to alliances were with suppliers, customers, and research institutes, including universities.

Innovations were threefold in this study; new products for new markets, products for existing markets, and improvements in quality, price, and the deadline for delivery. The concept of eco-innovations in previous studies corresponded to (1) implementation or a new operation of global warming measures which were renewable energy, storage of batteries, and recycling, and (2) reduction of electricity consumption, waste, and carbon dioxide emission. Strictly to state, the three innovations mentioned above included eco-innovations and others. We did not separate eco-innovation from others in our questionnaire by considering that parts of both innovations were affected by implementing renewable energy, storage of batteries, recycling, and reducing electricity consumption, waste, and carbon dioxide emission.

Descriptive statistics are shown in Table 2 mentioned above. The variables of implementation or a new operation of global warming measures renewable energy, storage of batteries, and recycling were the three-point Likert scale, and the number of employees for the control variable was the seven-point Likert scale. Other variables were binary.

4.2. Statistical analysis

We conducted extended ordered probit regression and SEM (Structured Equation Model) used in many previous studies. Extended ordered probit regression accommodates endogenous covariates. Binary and ordinal endogenous covariates are allowed in the extended probit model. SEM can analyze causalities among lots of variables, including latent variables.

The results of ordered probit regression were summarized in Tables 3–8. The effects of grappling with global warming measures were summarized in Tables 3–5, and the cases of reduction of energy, waste, and carbon dioxide emission were summarized in Tables 6–8. The results where the dependent variable was the innovation of new products for new markets are in Table 3. [1], [2], [3] were renewable energy, storage battery, and recycling, which were the measures of global warming. Table 4 and Table 5 showed the results of new products for existing markets, and improvements in quality, price, and delivery deadline, respectively, for dependent variables. [4]-[9] of Table 4 and Table 5 correspond to renewable energy, storage battery, and recycling, which were the measures of global warming, as well as [1]-[3] in Table 3.

[1]-[9] were estimated by main explanatory variables of renewable energy, storage battery, and recycling and controlled by industry and size[1)] of firms. At the same time, renewable energy, storage battery, and recycling were estimated by the initiative for SDGs, ICT variables, and alliances, controlled by industry and size of the firm. [10]-[18] were the cases that were reductions of electricity consumption, waste, and carbon dioxide emission as the same as [1]-[9].

The estimation results (Table 3) of the implementation or a new operation of global warming measures indicated that [1] renewable energy, [2] storage of batteries, and [3] recycling impacted the innovation of new products for new markets ($p<.01$). Renewable energy was affected by the initiative for SDGs, service online, ordering online, groupware, and alliance with the customer (respectively $p<.1$, $p<.05$, $p<.1$, $p<.05$). Storage of batteries was affected by ordering online, and alliance with the customer (respectively $p<.1$, $p<.05$). Recycling was affected by ordering online ($p<.05$).

The estimation results (Table 4 and Table 5) showed that all variables of global warming measures were insignificant to innovations.

In the cases of (Table 6-Table 8), innovations of the new products for new markets, and new products for existing markets were affected by the reductions of electricity consumption, waste, and carbon dioxide emission($p<.01$). Initiative for SDGs was significant in [11] and [12]. Service online was comparatively significant in ICT. Alliance with a customer was significant in [11] and [14] ($p<.05$), and alliance with research institutes was significant weakly in only [14] ($p<.1$).

The results of SEM were illustrated in Figure 1-Figure 3 for (1) implementation or a new operation of global warming measures which were renewable energy, storage of batteries, and recycling, and Figure 4-Figure 6 for (2) reduction of electricity consumption, waste, and carbon dioxide emission. Latent variables named as the initiative for global warming and reduction were made, respectively (1) and (2). Variables of innovations were the same

Table 3: Estimation result by extended ordered probit regression
The measures of global warming: new products for new markets

	[1]		[2]		[3]	
dependent variable: new products for new markets						
renewable energy	1.3375	***				
	(0.0989)					
storage of battery			2.7243	***		
			(0.3653)			
recycling					1.1530	***
					(0.1021)	
dependent variable:	renewable energy		storage of battery		recycling	
initiative for SDGs	0.1081	*	0.0447		0.1113	
	(0.0596)		(0.0402)		(0.1202)	
service online	0.1186	**	0.0559		0.0957	
	(0.0601)		(0.0359)		(0.0675)	
ordering online	0.1346	**	0.0650	*	0.1058	**
	(0.0522)		(0.0375)		(0.0538)	
groupware	0.1261	*	0.0327		0.0566	
	(0.0712)		(0.0259)		(0.0581)	
digitalization of administrative processes in the firm	0.0236		0.0043		0.0382	
	(0.0518)		(0.0219)		(0.0671)	
alliance with customer	0.2941	**	0.0955	**	0.2694	
	(0.1243)		(0.0416)		(0.1959)	
alliance with research institute	-0.0217		-0.0016		0.0376	
	(0.0910)		(0.0343)		(0.1101)	
constant term	0.8076	***	0.8765	***	1.3999	***
	(0.1736)		(0.0597)		(0.3180)	
Number of obs	353		351		348	
Wald chi2	305.61		200.75		390.91	
Prob > chi2	0.00		0.00		0.00	

*: p<0.1, **: p<0.05, ***: p<0.01, (): robust standard error, Table 4-8 are the same.

Table 4: Estimation result by extended ordered probit regression
The measures of global warming: new products for existing markets

	[4]		[5]		[6]	
dependent variable: new products for existing markets						
renewable energy	0.6270					
	(0.7487)					
storage battery			-0.277407			
			(3.1890)			
recycling					0.1375	
					(0.8083)	
dependent variable:	renewable energy		storage of battery		recycling	
initiative for SDGs	0.1368		0.1179	*	0.2966	**
	(0.1347)		(0.0645)		(0.1338)	
service online	0.1087		0.0615		0.0340	
	(0.0905)		(0.0649)		(0.1257)	
ordering online	0.0796		0.0637		-0.0416	
	(0.0800)		(0.0508)		(0.1038)	
groupware	0.1188		-0.0272		-0.1711	
	(0.1187)		(0.0599)		(0.1272)	
digitalization of administrative processes in the firm	0.0851		0.0134		0.1404	
	(0.0934)		(0.0763)		(0.1282)	
alliance with customer	0.3380	**	-0.0143		0.2981	
	(0.1672)		(0.1661)		(0.3393)	
alliance with research institute	-0.0748		0.0164		0.2041	
	(0.1164)		(0.0886)		(0.1835)	
constant term	0.8040	***	0.8417	***	1.3558	***
	(0.1855)		(0.0635)		(0.3154)	
Number of obs	353		351		348	
Wald chi2	825.87		1575.27		1840.9	
Prob > chi2	0.00		0.00		0.00	

Table 5: Estimation result by extended ordered probit regression
The measures of global warming: Improvement of quality, price, and the deadline for delivery

	[7]	[8]	[9]
dependent variable: improvement of quality, price, and the deadline for delivery			
renewable energy	0.6270		
	(0.7487)		
storage battery		-0.277407	
		(3.1890)	
recycling			0.1375
			(0.8083)
dependent variable:	renewable energy	storage of battery	recycling
initiative for SDGs	0.1368	0.1179 *	0.2966 **
	(0.1347)	(0.0645)	(0.1338)
service online	0.1087	0.0615	0.0340
	(0.0905)	(0.0649)	(0.1257)
ordering online	0.0796	0.0637	-0.0416
	(0.0800)	(0.0508)	(0.1038)
groupware	0.1188	-0.0272	-0.1711
	(0.1187)	(0.0599)	(0.1272)
digitalization of administrative processes in the firm	0.0851	0.0134	0.1404
	(0.0934)	(0.0763)	(0.1282)
alliance with customer	0.3380 **	-0.0143	0.2981
	(0.1672)	(0.1661)	(0.3393)
alliance with research institute	-0.0748	0.0164	0.2041
	(0.1164)	(0.0886)	(0.1835)
constant term	0.8040 ***	0.8417 ***	1.3558 ***
	(0.1855)	(0.0635)	(0.3154)
Number of obs	353	351	348
Wald chi2	825.87	1575.27	1840.9
Prob > chi2	0.00	0.00	0.00

Table 6: Estimation result by extended ordered probit regression
The reduction of energy, waste, and carbon dioxide emission: new products for new markets

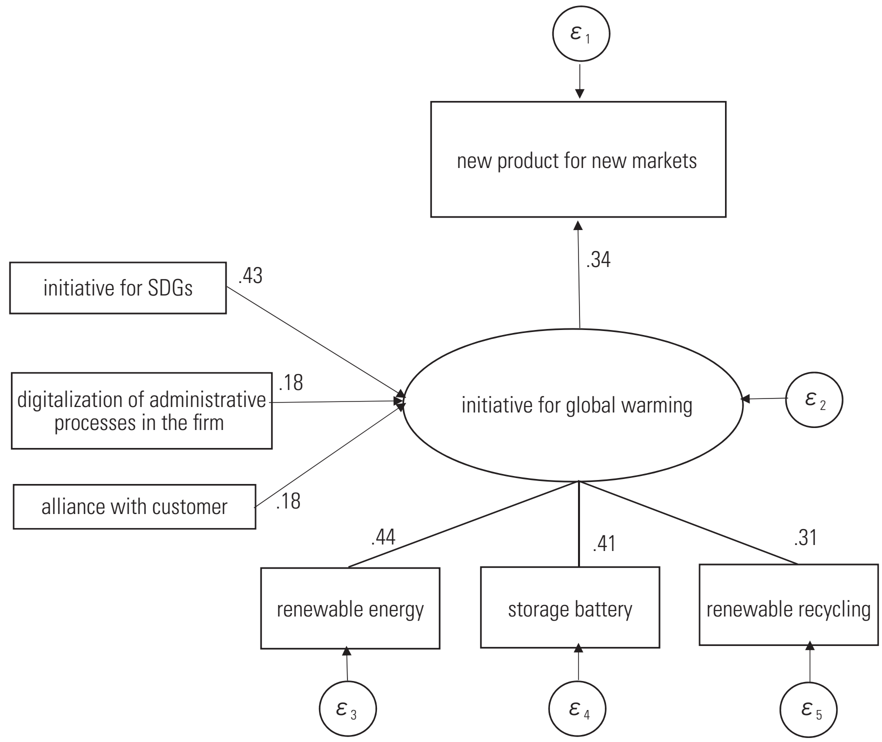
	[10]	[11]	[12]
dependent variable: new products for new market			
reduction of electricity consumption	2.4269 ***		
	(0.1685)		
reduction of waste		1.9828 ***	
		(0.1764)	
reduction of carbon dioxide emission			1.8528 ***
			(0.4278)
dependent variable:	reduction of electricity consumption	reduction of waste	reduction of carbon dioxide emission
initiative for SDGs	0.0380	0.0818 *	0.1525 **
	(0.0393)	(0.0422)	(0.0722)
service online	0.0416	0.0899 **	0.0592
	(0.0368)	(0.0422)	(0.0458)
ordering online	0.0414	0.0781 **	0.0699 *
	(0.0351)	(0.0343)	(0.0389)
groupware	0.0240	0.0375	0.0186
	(0.0228)	(0.0385)	(0.0575)
digitalization of administrative processes in the firm	-0.0006	-0.0056	0.0360
	(0.0172)	(0.0319)	(0.0414)
alliance with customer	0.0546	0.1348 **	0.0798
	(0.0357)	(0.0543)	(0.0742)
alliance with research institute	-0.0058	0.0198	0.0400
	(0.0266)	(0.0538)	(0.0788)
constant term	0.0232	0.0656	0.1025
	(0.0351)	(0.0475)	(0.0637)
Number of obs	353	347	354
Wald chi2	382.94	286.22	99.01
Prob > chi2	0.00	0.00	0.00

Table 7: Estimation result by extended ordered probit regression
The reduction of energy, waste, and carbon dioxide emission: new products for existing markets

	[13]	[14]	[15]
dependent variable: new products for existing market			
reduction of electricity consumption	2.5093 ***		
	(0.0977)		
reduction of waste		2.0676 ***	
		(0.1120)	
reduction of carbon dioxide emission			2.1831 ***
			(0.2585)
dependent variable:	reduction of electricity consumption	reduction of waste	reduction of carbon dioxide emission
initiative for SDGs	0.0064	0.0407	0.0655
	(0.0137)	(0.0342)	(0.0868)
service online	0.0254	0.0866 **	0.0722 **
	(0.0301)	(0.0392)	(0.0347)
ordering online	0.0155	0.0477 *	0.0474
	(0.0193)	(0.0282)	(0.0307)
groupware	0.0088	0.0182	0.0137
	(0.0124)	(0.0292)	(0.0357)
digitalization of administrative processes in the firm	0.0051	0.0174	0.0330
	(0.0080)	(0.0237)	(0.0390)
alliance with customer	0.0300	0.1103 **	0.0844
	(0.0314)	(0.0498)	(0.0519)
alliance with research institute	0.0267	0.0928 *	0.1031
	(0.0343)	(0.0509)	(0.0728)
constant term	0.5478 ***	0.2518	-0.1720
	(0.1741)	(0.1651)	(0.1114)
Number of obs	353	347	354
Wald chi2	674.27	614.59	447.83
Prob > chi2	0.00	0.00	0.00

Table 8: Estimation result by extended ordered probit regression
The reduction of energy, waste, and carbon dioxide emission: Improvement of quality, price, and the deadline for delivery

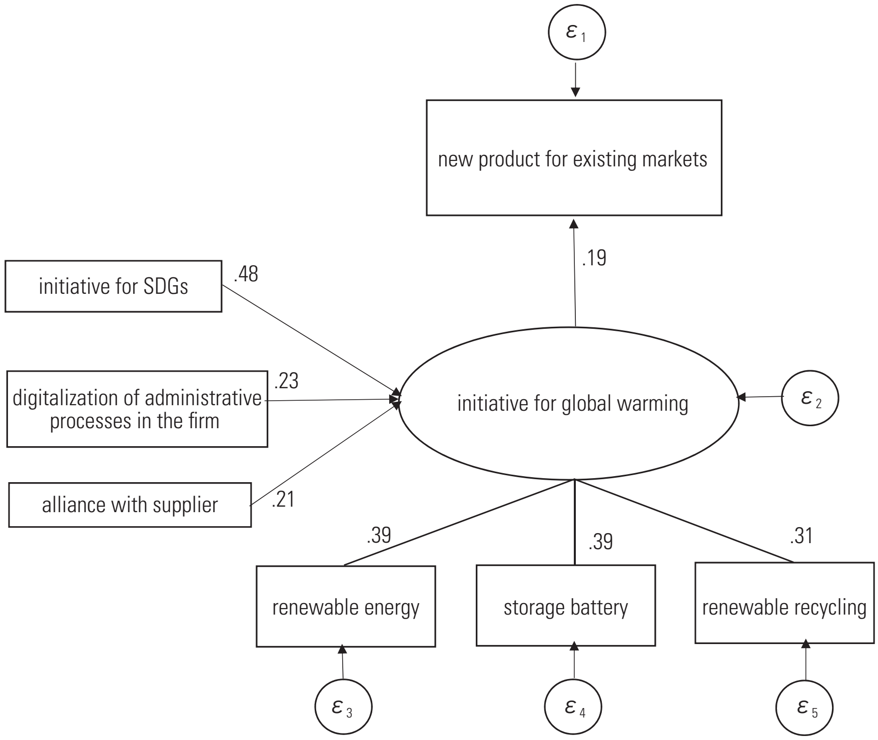
	[16]	[17]	[18]
dependent variable: improvement of quality, price, and the deadline for delivery			
reduction of electricity consumption	-1.6648		
	(1.6053)		
reduction of waste		0.9016	
		(1.3068)	
reduction of carbon dioxide emission			0.2182
			(0.9295)
dependent variable:	reduction of electricity consumption	reduction of waste	reduction of carbon dioxide emission
initiative for SDGs	0.0725	0.1194 *	0.2135 ***
	(0.0951)	(0.0721)	(0.0517)
service online	0.0136	0.0893 *	-0.0068
	(0.0749)	(0.0529)	(0.0596)
ordering online	0.0132	0.0310	0.0079
	(0.0470)	(0.0533)	(0.0510)
groupware	-0.0109	-0.0459	-0.0573
	(0.0604)	(0.0650)	(0.0698)
digitalization of administrative processes in the firm	-0.0545	0.0016	0.0589
	(0.0401)	(0.0734)	(0.0606)
alliance with customer	-0.1343	0.1429	-0.0167
	(0.0853)	(0.1254)	(0.1361)
alliance with research institute	0.0261	0.1013	0.1132
	(0.0673)	(0.0771)	(0.0861)
constant term	0.5255 ***	0.2243	-0.2023 **
	(0.1756)	(0.1642)	(0.0970)
Number of obs	353	347	354
Wald chi2	276.34	313.7	1347.2
Prob > chi2	0.00	0.00	0.00



Standardized	Coef.	OIM Std. Err.	z	P>z
Structural				
initiative for global warming				
digitalization of administrative processes in the firm	0.1830649	0.0801842	2.28	0.022
alliance with customer	0.1839006	0.0832439	2.21	0.027
initiative for SDGs	0.4292969	0.0806051	5.33	0
Measurement				
renewable energy				
initiative for global warming	0.4354216	0.0762464	5.71	0
constant	1.595388	0.1054043	15.14	0
storage battery				
initiative for global warming	0.4145336	0.0776768	5.34	0
constant	2.689844	0.1383424	19.44	0
recycling				
initiative for global warming	0.3146947	0.074372	4.23	0
constant	1.621904	0.1066048	15.21	0
new product for new markets				
initiative for global warming	0.3360819	0.0738077	4.55	0
constant	0.4308559	0.0779985	5.52	0
Number of obs		348		

Likelihood ratio p > chi2	0.132
RMSEA	0.037
AIC	3233.301
CFI	0.932
TLI	0.889
SRMR	0.036

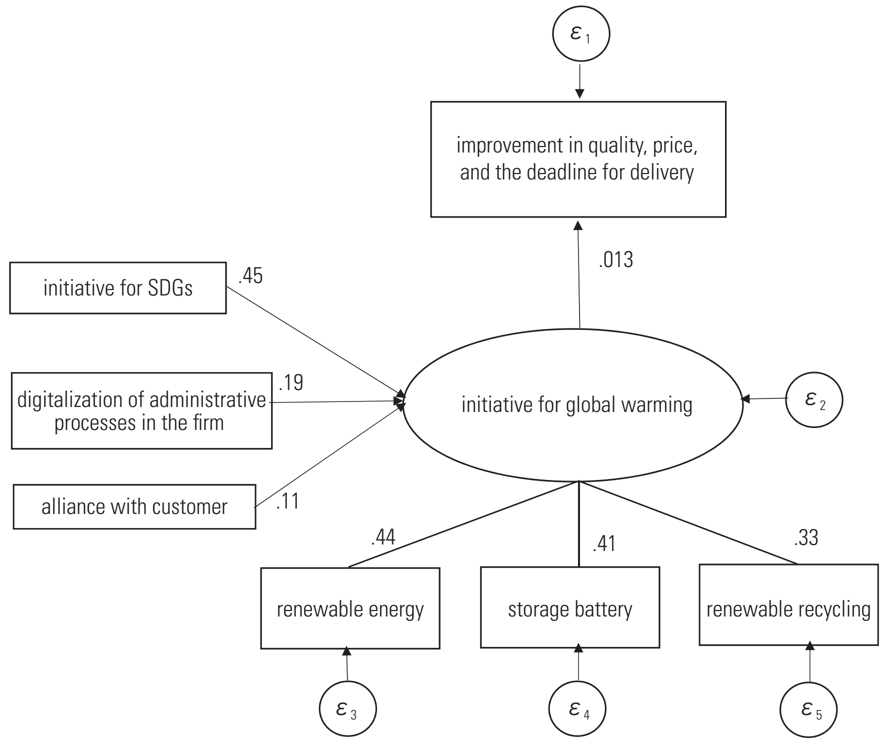
Figure 1: The structured model
The measures of global warming: new products for new markets



Standardized	OIM Coef.	Std. Err.	z	P>z
Structural				
initiative for global warming				
digitalization of administrative processes in the firm	0.2306217	0.0928342	2.48	0.013
alliance with supplier	0.2057788	0.0900883	2.28	0.022
initiative for SDGs	0.4784027	0.0982207	4.87	0
Measurement				
renewable energy				
initiative for global warming	0.3948326	0.0888225	4.45	0
constant	1.54584	0.1101469	14.03	0
storage battery				
initiative for global warming	0.3922487	0.0860958	4.56	0
constant	2.62789	0.1428579	18.4	0
recycling				
initiative for global warming	0.307014	0.0730468	4.2	0
constant	1.570844	0.1152306	13.63	0
new product for existing markets				
initiative for global warming	0.193358	0.0766039	2.52	0.012
constant	0.769385	0.0956894	8.04	0
Number of obs		347		

Likelihood ratio p > chi2	0.156
RMSEA	0.035
AIC	3845.583
CFI	0.93
TLI	0.885
SRMR	0.036

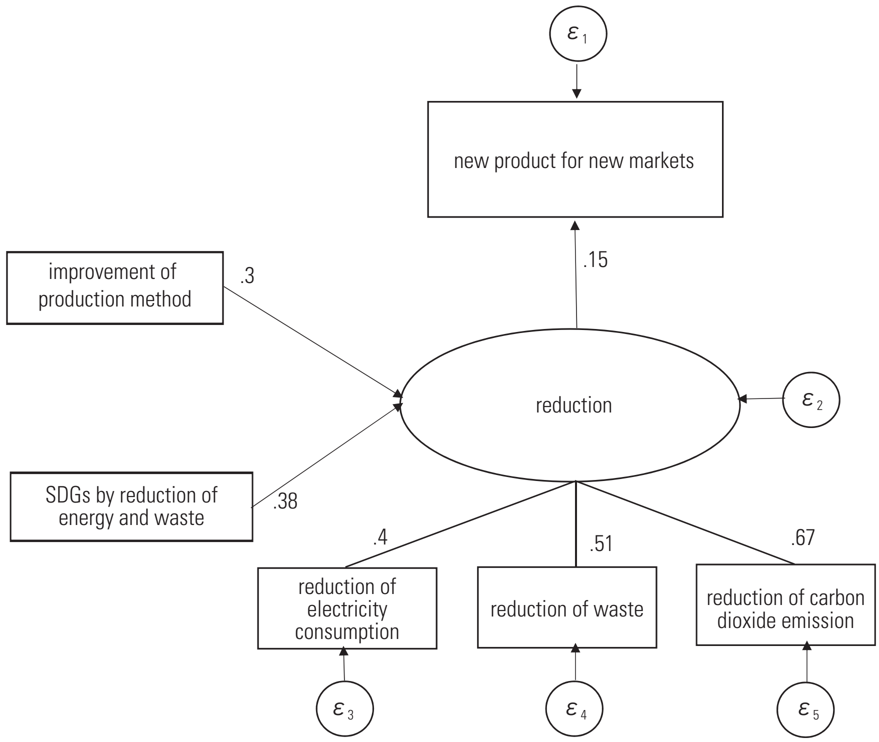
Figure 2: The measures of global warming: new products for existing markets



Standardized	OIM Coef.	Std. Err.	z	P>z
Structural				
initiative for global warming				
digitalization of administrative processes in the firm	0.1919398	0.0876253	2.19	0.028
alliance with customer	0.1089695	0.0866113	1.26	0.208
initiative for SDGs	0.4463474	0.0939871	4.75	0
Measurement				
renewable energy				
initiative for global warming	0.4428496	0.0884763	5.01	0
constant	1.588856	0.1061709	14.97	0
storage battery				
initiative for global warming	0.4081883	0.0846276	4.82	0
constant	2.691312	0.1392252	19.33	0
recycling				
initiative for global warming	0.3324284	0.0803284	4.14	0
constant	1.610098	0.1117748	14.4	0
improvement of quality, price, and the deadline for delivery				
initiative for global warming	0.013342	0.079782	0.17	0.867
constant	0.5342786	0.073483	7.27	0
Number of obs		348		

Likelihood ratio p > chi2	0.063
RMSEA	0.046
AIC	3204.764
CFI	0.872
TLI	0.79
SRMR	0.04

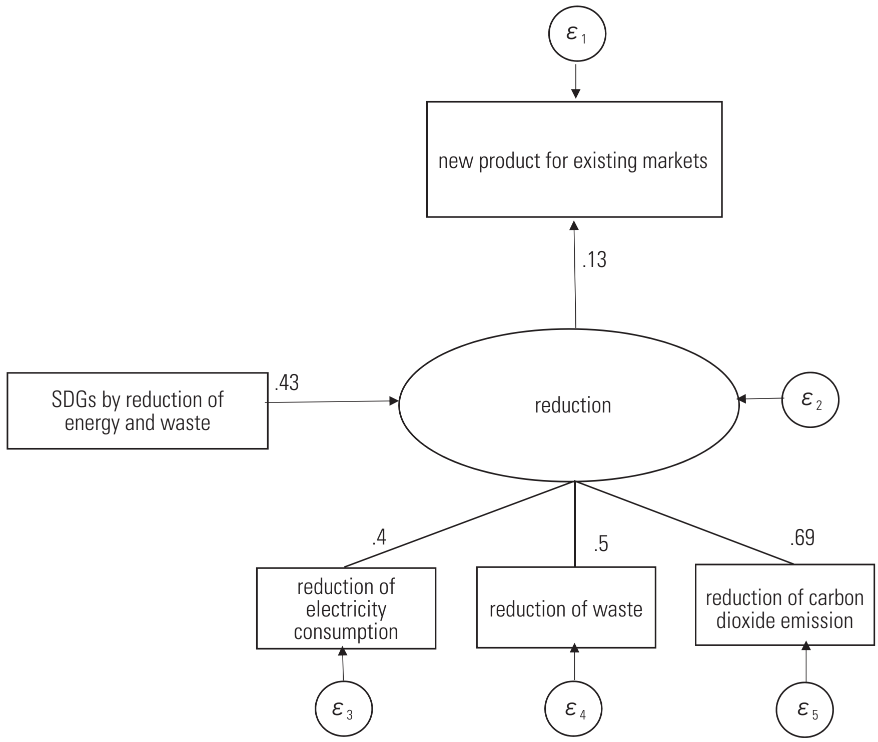
Figure 3: The measures of global warming: Improvement of quality, price, and the deadline for delivery



Standardized	OIM Coef.	Std. Err.	z	P>z
Structural				
reduction				
improvement of production method	0.3022656	0.0631411	4.79	0
SDGs by reduction of energy and waste	0.379624	0.0612772	6.2	0
Measurement				
reduction of electricity consumption				
reduction	0.4013079	0.0616405	6.51	0
constant	1.784901	0.1049317	17.01	0
reduction of waste				
reduction	0.5130649	0.0594314	8.63	0
constant	1.089882	0.0886074	12.3	0
reduction of carbon dioxide				
reduction	0.6683873	0.0596694	11.2	0
constant	0.3473615	0.0765511	4.54	0
new product for new markets				
reduction	0.1536762	0.0658654	2.33	0.02
constant	0.5569505	0.0700449	7.95	0
Number of obs		355		

Likelihood ratio p > chi2	0.312
RMSEA	0.022
AIC	2615.802
CFI	0.99
TLI	0.983
SRMR	0.029

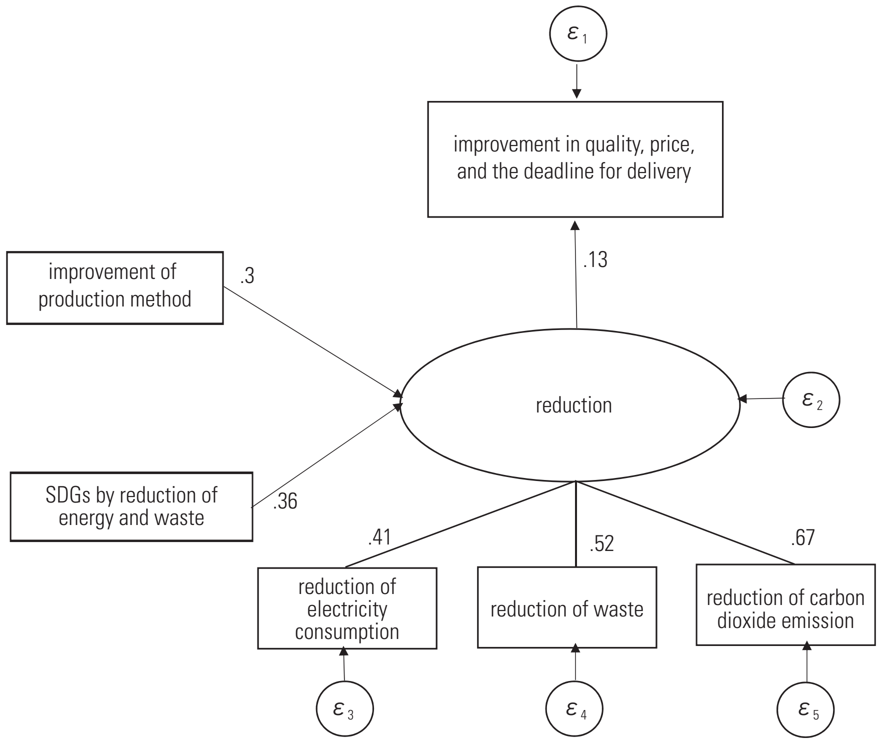
Figure 4: The reduction of energy, waste, and carbon dioxide emission: new products for new markets



Standardized	Coef.	OIM Std. Err.	z	P>z
Structural				
reduction				
SDGs by reduction of energy and waste	0.4313054	0.0593308	7.27	0
Measurement				
reduction of electricity consumption				
reduction	0.3974193	0.0655755	6.06	0
constant	1.859222	0.1001412	18.57	0
reduction of waste				
reduction	0.4956358	0.0637091	7.78	0
constant	1.189313	0.0834042	14.26	0
reduction of carbon dioxide				
reduction	0.6923875	0.0687223	10.08	0
constant	0.4603492	0.0726428	6.34	0
new product for new markets				
reduction	0.1281955	0.06662	1.92	0.054
constant	0.8864805	0.0690288	12.84	0
Number of obs		355		

Likelihood ratio p > chi2	0.157
RMSEA	0.041
AIC	2230.653
CFI	0.975
TLI	0.95
SRMR	0.032

Figure 5: The reduction of energy, waste, and carbon dioxide emission: new products for existing markets



Standardized	OIM Coef.	Std. Err.	z	P>z
Structural				
reduction				
improvement of production method	0.3031742	0.0632302	4.79	0
SDGs by reduction of energy and waste	0.3628079	0.0615244	5.9	0
Measurement				
reduction of electricity consumption				
reduction	0.4095868	0.0620023	6.61	0
constant	1.785844	0.1048537	17.03	0
reduction of waste				
reduction	0.5165903	0.0599263	8.62	0
constant	1.094779	0.0885861	12.36	0
reduction of carbon dioxide				
reduction	0.6713918	0.0608872	11.03	0
constant	0.3545711	0.0772548	4.59	0
improvement in quality, price, and the deadline for delivery				
reduction	0.1265398	0.0659813	1.92	0.055
constant	0.4775476	0.0675381	7.07	0
Number of obs	355			

Likelihood ratio p > chi2	0.372
RMSEA	0.015
AIC	2561.909
CFI	0.995
TLI	0.992
SRMR	0.027

Figure 6: The reduction of energy, waste, and carbon dioxide emission: improvement in quality, price, and the deadline for delivery

(new products for new markets in Figure 1 and Figure 4, products for existing markets in Figure 2 and Figure 5, and improvements in quality, price, and the deadline for delivery in Figure 3 and Figure 6) in analysis by Extended ordered probit regression. Variables were selected by Goodness of fit in all cases.

Variables of SDGs affected the latent variables in all cases. Digitalization of the administration process in firms in variables of ICT affected the latent variable of initiative for global warming. Alliance with customer affected initiative for global warming in Figure 1 and Figure 3 and alliance with supplier affected it in Figure 2. In replacement of ICT and alliances, the improvement of production method affected the latent variable of reduction, which consisted of electricity consumption, waste, and carbon dioxide emission in Figure 4 and Figure 6.

5. CONCLUSIONS

This study verified two hypotheses: (1) global warming measures can lead to innovation, (2) ICT and alliance with other stakeholders can promote global warming measures in the Japanese SMEs of the manufacturing industry. We summarize the results of our statistical analysis focusing on the innovation of new products for a new market because it is the most challenging.

On the results of testifying hypothesis (1), the innovation of new products for new markets is the most likely affected by the implementation and new operation of global warming measures of renewable energy, storage of batteries, and recycling, and the reduction of electricity consumption, waste, and carbon dioxide emission in both extended ordered probit regression and SEM (Structured Equation Model).

On the results of testifying hypothesis (2), online ordering related to ICT impacts global warming measures of renewable energy, storage of batteries, and recycling, and alliance with customers affects global warming measures of renewable energy and storage of batteries in extended ordered probit regression. Also, online ordering promotes the reduction of waste and carbon dioxide emission, and alliance with customers promotes the reduction of waste in extended ordered probit regression. Digitalization of administrative processes related to ICT and alliance with customers affect global warming measures in SEM (Structured Equation Model).

ICT adoptions, such as online ordering and digitalization of administrative processes, are found which to be critical factors in promoting global warming measures. ICT saves resources through improved operational efficiency. Telework reduces the need for commuting and saves resources such as fuel and energy. By using electronic documents and communication tools, businesses can reduce their paper usage and save resources. Our study indicates that ICT impacts global warming measures in the case of SMEs. The Japanese government has been keen on promoting Society 5.0. It is meaningful that we can demonstrate the positive relationship between ICT and eco-innovation for policy-making in Japan.

Also, our empirical evidence supports the importance of customers as an information resource indicated by many previous studies. This result indicates that customers are becoming more aware of the impact of their consumption on the environment and are increasingly seeking sustainable products and services in Japan. Firms and customers can work together to share resources and reduce waste. For example, firms can collaborate with customers to implement recycling programs.

Only some SMEs have successfully linked measures to address global warming with innovation. However, our results suggest that SMEs can reconcile measures to address global warming and growth by leveraging ICT and collaborating with customers.

Concerning the limitations of this study, it is necessary to point out that the object of this study is the SMEs of the manufacturing industry in Osaka prefecture. We must be cautious about extending the interpretation of the empirical results. Further evidence is needed to indicate the impact of ICT on eco-innovation in Japan.

NOTE

1) The number of employees was the proxy for the

size of firms.

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