

Empirical Assessment of Fourth-sector Social Innovation and Coastal Sustainability under a Shrinking Society

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In this study, we propose a data-driven analytical framework for detecting shrinking-society risk in coastal regions and examining the effect of social innovation activities undertaken by fourth-sector firms on corporate sustainability. To this end, we applied a multi-source data fusion approach that integrates unstructured textual signals with structured financial data. Specifically, domain-specific benchmark lexicons were constructed using natural language processing techniques, including term frequency–inverse document frequency (TF-IDF) and Word2Vec algorithms, and sustainability and social innovation indices were derived from corporate disclosure materials and news texts through cosine similarity analysis. With panel data from 159 coastal-region firms over the period 2016–2025, the empirical results showed that social innovation activities by fourth-sector firms have a significant positive effect on corporate sustainability. The findings further indicated that shrinking-society risk positively moderates this relationship, suggesting that social innovation becomes more important in regions with greater structural vulnerability. This study makes a methodological contribution by transforming social innovation and regional risk into measurable indicators through information processing techniques. It also provides a technical foundation for designing data-driven monitoring systems that support coastal economic self-reliance and evidence-based policy decision-making.

1. Introduction

In South Korea, the continued concentration of the population in major metropolitan areas has intensified the demographic and economic vulnerability of coastal regions. Population decline, the weakening of local industrial bases, and the outmigration of the working-age population have become key drivers accelerating shrinking-society risk in these regions.^(1,2) Coastal regions are strategically important to the national economy, as they host major marine industries such as port logistics, fisheries, and marine tourism.⁽³⁾ However, because these ocean-dependent industrial structures rely heavily on coastal infrastructure and marine resources, environmental change or industrial decline can rapidly lead to economic instability, employment

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loss, and the weakening of local community functions.⁽⁴⁾ Recognizing these challenges, the Korean government has sought to strengthen collaboration among the public sector, the private sector, and civil society, while exploring structural innovation to address the complex problems facing coastal regions.⁽⁵⁾

The structural vulnerability of coastal regions, in particular, cannot be effectively addressed through government-led or public-service-oriented interventions alone. At the same time, firm-led market approaches are also insufficient to fully address complex issues such as marine resource management, the maintenance of fishing communities, and coastal ecosystem conservation. For this reason, community-based organizations grounded in social innovation have recently attracted attention as important actors in coastal governance.⁽⁶⁾

Among these organizations, fourth-sector organizations are distinguished from conventional organizational forms by their hybrid structure, which combines the characteristics of the public sector, the private sector, and civil society. Because fourth-sector organizations are capable of addressing social, economic, and environmental problems in an integrated manner, they are highly relevant to the structural conditions of coastal regions.⁽⁷⁾ In particular, they can be regarded as suitable organizational forms for addressing ocean-based social problems, including marine waste management, coastal ecosystem restoration, the revitalization of sustainable fishing communities, and the development of environmentally friendly marine tourism.⁽⁸⁾ Since these organizations emphasize both economic viability and social value creation, they are closely aligned with the characteristics of coastal regions, where local economies, natural environments, and community life are deeply interdependent.⁽⁹⁾

Nevertheless, empirical evidence remains insufficient regarding how the social innovation activities of fourth-sector firms contribute to corporate sustainability in South Korea's coastal regions.^(10,11) Previous studies have examined social innovation primarily through subjective and qualitative methods, such as surveys and interviews.^(12,13) Although these studies have provided valuable insights into the meanings and processes of social innovation, they have often been limited to explaining general patterns without fully capturing how social innovation operates within specific industrial and regional contexts.^(14,15)

In particular, data-driven research remains underdeveloped in this area. Few studies have quantitatively measured the social innovation factors of fourth-sector firms or examined the relationship between social innovation activities and corporate performance using unstructured big data. To address this research gap, in this study, we focused on fourth-sector firms operating in coastal regions and empirically examined how their social innovation activities affect corporate sustainability. Moreover, we introduced a shrinking-society risk index, constructed through text-based big data processing, as a moderating variable to analyze whether regional structural vulnerability strengthens or constrains the effect of social innovation.⁽¹⁵⁾

This study makes an academic contribution by proposing an integrated analytical model that converts an abstract environmental condition, namely, social risk, into a quantitative indicator through information processing techniques and combines it with firm-level performance data. From this perspective, the data-driven approach adopted in this study provides a technical foundation for designing intelligent monitoring systems capable of detecting regional economic

vulnerability. It may also contribute to policy intervention and the design of regional economic revitalization measures.

2. Literature Review and Hypothesis

2.1 Definition and concept of the fourth sector

The fourth sector is generally defined as a hybrid organizational domain located at the boundaries of the public sector, the private for-profit sector, and civil society or nonprofit organizations.^(16–18) Unlike public organizations, which primarily pursue collective welfare, or private firms, which prioritize profit maximization, fourth-sector organizations combine economic activity with explicit social purposes. In this sense, they can be understood as organizational forms that integrate economic and social characteristics within a single institutional logic.⁽¹⁹⁾

From the perspective of organizational purpose, the fourth sector can be regarded as an organizational attempt to address social and public problems through entrepreneurial and market-oriented approaches. It includes a wide range of organizations, from for-profit firms actively engaged in social contribution activities to nonprofit organizations that adopt business-oriented operating models.⁽²⁰⁾ Their defining feature is the simultaneous pursuit of social value creation and economic sustainability.

The hybrid nature of fourth-sector organizations can be further explained through their economic and social characteristics. Economically, they continuously produce and provide goods and services, maintain a high degree of organizational autonomy, assume economic risk, and rely on a certain level of paid labor. Socially, they contribute to local communities, pursue public purposes, involve diverse stakeholders in decision-making, distribute profits in ways that reflect social objectives, and interact with public policy processes. These characteristics explain why fourth-sector organizations emerge in diverse forms that combine economic and social objectives.⁽²¹⁾ Consumer cooperatives, community-based social enterprises, village enterprises, and B Corps can be understood as representative fourth-sector firms because they integrate market activity with social value creation.

2.2 Social innovation in fourth-sector enterprises

Corporate social responsibility (CSR) and stakeholder theory have traditionally framed corporate social responsibility as an ethical and normative obligation. However, these approaches have been criticized for their limited sustainability and effectiveness because they rely heavily on voluntary corporate engagement beyond legal requirements. When CSR activities are not directly linked to a firm's core economic interests, they are likely to be implemented selectively and remain peripheral rather than being integrated into the core of corporate management.

This limitation becomes more pronounced in marine and coastal contexts. Ocean-based social problems, such as marine waste management, coastal ecosystem restoration, and the

maintenance of fishing communities, require long-term and continuous intervention. Short-term CSR activities alone are therefore unlikely to generate substantive and lasting changes in these areas. In response to these limitations, social innovation has increasingly emerged as an important concept in both academic and policy debates. Compared with conventional CSR, social innovation has a more proactive managerial orientation because it seeks to identify new market opportunities and strengthen corporate competitiveness while addressing social problems.⁽²²⁾

Social innovation is particularly important in marine and coastal sectors. Marine environmental problems require intergovernmental coordination, long-term investment, and local community participation, while marine resources often have common-pool resource characteristics.⁽²³⁾ For this reason, public-sector management alone may face fiscal and administrative burdens, whereas market-based approaches may fail to adequately address externalities and long-term sustainability.⁽²⁴⁾ Under these conditions, fourth-sector firms can be understood as organizational alternatives that combine publicness and economic viability, enabling them to address marine environmental problems and promote local economic revitalization simultaneously.⁽²⁵⁾

International cases illustrate this potential. In Japan, social innovation firms that transform marine plastic collection and recycling into locally embedded circular economy models have emerged, thereby addressing employment challenges in fishing communities and marine pollution at the same time. In Europe, fourth-sector organizations have developed sustainable tourism models based on marine protected areas, contributing to local income generation and ecosystem conservation.⁽²⁶⁾ These cases suggest that social innovation in the marine sector can function as a mechanism through which ecosystem conservation, community continuity, and industrial competitiveness mutually reinforce one another.

2.3 Governance-driven social innovation and sustainability

Traditional corporate governance has generally operated as a centralized system in which ownership and decision-making authority are concentrated among a small group of executives. However, this structure may weaken transparency in decision-making and limit the participation of diverse stakeholders, such as outside directors, employees, and operational-level actors, to formal procedures.⁽²⁷⁾ These limitations become particularly salient in coastal regions, where economic activities involve complex interactions among multiple stakeholders, including local governments, fishing communities, private firms, civil society organizations, tourists, and environmental agencies. Under these conditions, conventional centralized governance is insufficient to coordinate complex issues such as marine resource management, coastal ecosystem conservation, and local economic circulation.

To overcome these limitations, firms need to establish participatory governance mechanisms that extend beyond internal decision-making structures and connect them with local communities, government, and civil society. Fourth-sector firms are well positioned to perform this role because they are hybrid organizations that integrate public value, market-based

operations, and civic participation.⁽²⁸⁾ Governance-based social innovation enables community participation in coastal governance, negotiation over resource-use rules, and engagement in ecosystem-based management.⁽²⁹⁾ Through these processes, it can strengthen the foundation of trust and collaboration between firms and local communities. Prior studies also showed that participatory governance in the fourth sector can enhance organizational commitment and performance in marine economies characterized by high uncertainty and ecological risk.^(30,31) Galego showed that social innovation is closely linked to participatory and collaborative forms of governance, in which civil society organizations and public actors engage in collective action to develop alternative solutions to unmet social needs.⁽³²⁾ Therefore, governance-based social innovation in fourth-sector firms is expected to have a positive effect on corporate sustainability by institutionalizing stakeholder participation and strengthening organizational capacity to coordinate complex problems in coastal regions. On the basis of this discussion, the following hypothesis is proposed.

H1: Governance-based social innovation positively affects corporate sustainability.

2.4 Workforce-oriented social innovation and sustainability

Traditional business organizations have managed labor and operations primarily through manager-centered hierarchical systems. In recent years, however, participatory management models have emerged as important mechanisms for strengthening sustainability.⁽³³⁾ As inclusiveness has become a core value in management, organizational members are increasingly understood not merely as providers of labor but as co-responsible actors in organizational operations and decision-making.⁽³⁴⁾ This perspective is particularly relevant to coastal industries, where rapid responses to safety risks, seasonal volatility, and environmental change are essential. In such contexts, the active participation of frontline workers, locally embedded experts, and employees from local communities can enhance both operational efficiency and organizational sustainability.

Workforce-based social innovation has particular significance for fourth-sector firms operating in coastal regions. Coastal industries, including fisheries, port logistics, and marine tourism, are highly labor-intensive and face structural challenges such as the aging of fishing communities, shortages of young workers, and the intergenerational loss of industrial expertise. These challenges are difficult to address through rigid hierarchical structures alone. Under uncertain marine and coastal conditions, workforce autonomy and collaborative decision-making can reduce internal conflict, strengthen field-level responsiveness, and support stable organizational operations.

Therefore, by expanding workforce participation and empowerment, fourth-sector firms can strengthen their operational capabilities to respond to the uncertainty of coastal industries and the structural vulnerability of local communities.⁽³⁵⁾ Such workforce-based social innovation activities are expected to enhance internal collaboration and accountability, thereby contributing

to corporate sustainability over the long term. On the basis of this discussion, the following hypothesis is proposed.

H2: Workforce-based social innovation positively affects corporate sustainability.

2.5 Community-oriented social innovation and sustainability

Community represents a core socio-economic foundation in which diverse stakeholders interact. Traditional CSR approaches have often treated local communities merely as recipients of corporate support and positioned community engagement as a peripheral activity separated from core business management.⁽³⁶⁾ This limitation is particularly evident in coastal regions, where population decline, aging, the decline of fisheries, and marine ecosystem degradation simultaneously threaten both local communities and business foundations.

Fourth-sector firms can respond to these challenges by integrating community relationships into their core business models. Coastal regions often depend economically on a limited number of marine-related industries, making local employment, supply chains, and community capacity highly vulnerable to external shocks.⁽³⁷⁾ Under these conditions, fourth-sector firms can function as key actors in community-based social innovation by contributing to marine resource management, sustainable fisheries, environmentally friendly marine tourism, and the maintenance of coastal communities.⁽³⁸⁾

In the B Corp certification system, community is also treated as one of the core assessment dimensions. Major indicators include local inclusion, fair employment, the strengthening of local value chains, and the promotion of local economic circulation.⁽³⁹⁾ Fourth-sector firms operating in coastal regions are therefore likely to generate meaningful outcomes in the community dimension through activities such as building sustainable local seafood value chains, participating in marine ecosystem restoration, and operating resident-participatory projects. Prior studies also suggest that community-based social innovation contributes not only to external community engagement but also to the formation of local social capital, the strengthening of collaborative networks, and the development of long-term partnerships between firms and local communities.

Therefore, community-based social innovation may positively affect corporate sustainability by strengthening the interdependent relationship between firms and local communities and by stabilizing local resources and market foundations. In coastal regions, where the continuity of local communities is closely linked to the survival base of firms, community-based social innovation is expected to serve as an important factor in enhancing long-term corporate sustainability. On the basis of this discussion, the following hypothesis is proposed.

H3: Community-based social innovation positively affects corporate sustainability.

2.6 Customer-oriented social innovation and sustainability

Traditional production-oriented management has long emphasized efficiency and cost reduction as its core principles. However, the contemporary business environment is shifting toward customer-centered and value-based management, driven by changes in consumer values, growing environmental awareness, and heightened social sensitivity.⁽⁴⁰⁾ This shift is particularly important in coastal regions, where consumers increasingly evaluate products and services not only in terms of quality and price but also in terms of their impacts on marine ecosystems and local communities.

As consumers gain greater access to information, they have become more sensitive to whether firms fulfill their environmental and social responsibilities.⁽⁴¹⁾ This tendency is especially pronounced in marine-related markets, including seafood products, marine tourism services, and environmentally friendly marine consumer goods.⁽⁴²⁾ Customers evaluate a firm's sustainability and respond through purchase decisions, brand trust, and word-of-mouth communication, all of which directly affect economic performance and market competitiveness.^(43,44)

Customer-based social innovation refers to a structural shift in which consumers are transformed from passive buyers into co-creators of value.⁽⁴⁵⁾ In coastal regions, customers are increasingly likely to consider how products and services affect local fisheries, coastal livelihoods, and marine ecosystem conservation. This change increases the need for firms to develop collaborative models with customers and to align market relationships with social value creation and environmental responsibility. In this sense, customer-based social innovation can function as a mechanism that promotes marine environmental protection and community sustainability through responsible consumption. As a result, customer-based social innovation serves as an important catalyst that enables fourth-sector firms to generate economic performance while addressing social and environmental problems.

Therefore, customer-based social innovation activities are expected to enhance the sustainability of fourth-sector firms by strengthening customer trust, brand loyalty, and markets based on responsible consumption. On the basis of this discussion, the following hypothesis is proposed.

H4: Customer-based social innovation positively affects corporate sustainability.

2.7 Moderating role of shrinking-society risk in corporate sustainability

Shrinking-society risk should be understood not merely as population decline, but as a structural process through which the social and economic foundations of a region weaken over the long term. Previous studies have explained shrinking-society phenomena mainly in terms of demographic factors, such as declining fertility and population aging.⁽⁴⁶⁾ More recent research,

however, has interpreted shrinking-society risk as a complex regional crisis associated with the weakening of industrial bases, the contraction of living infrastructure, the outmigration of younger populations, and local economic stagnation.^(47,48)

Research on shrinking society has expanded beyond East Asia to include European contexts such as Spain, Portugal, and France. In these regions, population decline and local economic deterioration have occurred simultaneously, leading to policy discussions on regional infrastructure restructuring, the promotion of social enterprises, and the development of local circular economies.⁽⁴⁹⁾ These discussions suggest that shrinking-society risk cannot be addressed through demographic interventions alone, but requires institutional, economic, and community-based responses.

Under these conditions, the role of fourth-sector firms becomes increasingly important. In high-risk regions where population decline and the weakening of industrial bases are rapidly progressing, conventional government-led policies or market mechanisms may not function effectively. In such contexts, the social innovation capacity of fourth-sector firms can complement, or in some cases, substitute for functions that are insufficiently provided by the public sector and the market. Accordingly, corporate social innovation becomes more practically significant in regions exposed to severe shrinking-society risk.

This moderating logic is particularly important in coastal regions. Coastal regions are characterized by the simultaneous aging of fishing communities, the structural decline of coastal industries, and changes in the marine environment. Under these conditions, social innovation activities, such as developing sustainable fisheries models, forming marine resource-based circular economies, and creating local employment opportunities, may function as survival mechanisms that go beyond improving firm performance and help maintain the socio-economic foundations of vulnerable coastal communities.

Therefore, shrinking-society risk is expected to moderate the relationship between social innovation and corporate sustainability. Specifically, the positive effect of social innovation activities undertaken by fourth-sector firms on corporate sustainability is expected to become stronger as the level of shrinking-society risk increases. This is because the value and necessity of social innovation activities become greater in regions where public and market functions are weakened. On the basis of this discussion, the following hypothesis is proposed.

H5: Shrinking-society risk positively moderates the relationship between fourth-sector enterprises' social innovation and corporate sustainability, such that the positive effect of social innovation activities on corporate sustainability becomes stronger as shrinking-society risk increases.

3. Research Method

3.1 Data collection

For the empirical analysis, we constructed an integrated panel dataset by combining unstructured text-based signals, structured financial data, and the shrinking-society risk index,

as shown in Fig. 1. This data fusion approach was designed to examine fourth-sector firms' social innovation activities, corporate sustainability, and regional structural risk within a unified empirical framework.

The analytical sample consisted of firms headquartered in, or operating major business sites within, coastal municipalities in South Korea. To ensure time-series consistency between text-based indicators and financial data, we included only firms for which continuous data matching was available from 2016 to 2025. As a result, 159 firms were included in the final sample.

The dependent variable, sustainability, was measured using firms' annually disclosed non-financial and financial reports. These reports contain unstructured textual information related to environmental, social, and governance activities.^(50–52) To quantify this information, we constructed a sustainability benchmark lexicon by extracting key activity keywords from European Sustainability Reporting Standards.

The independent variables, representing firms' social innovation activities, were collected from Big Kinds, a major news database in South Korea. Specifically, media reports related to innovation and social value creation activities by firms in coastal regions were collected as daily text data based on publication dates. To classify social innovation activities by type, we constructed a social innovation lexicon based on the four core domains of the B Corporation certification system: governance, workforce, community, and customer.

Structured financial data were additionally collected from each firm's official fiscal-year-end disclosures. These data were used to construct control variables, including firm size, liquidity, leverage, growth, and firm age. The moderating variable, shrinking-society risk, was constructed on the basis of the local extinction risk index provided by the Korea Employment Information Service. Because lower values in the original index indicate higher levels of risk, we transformed

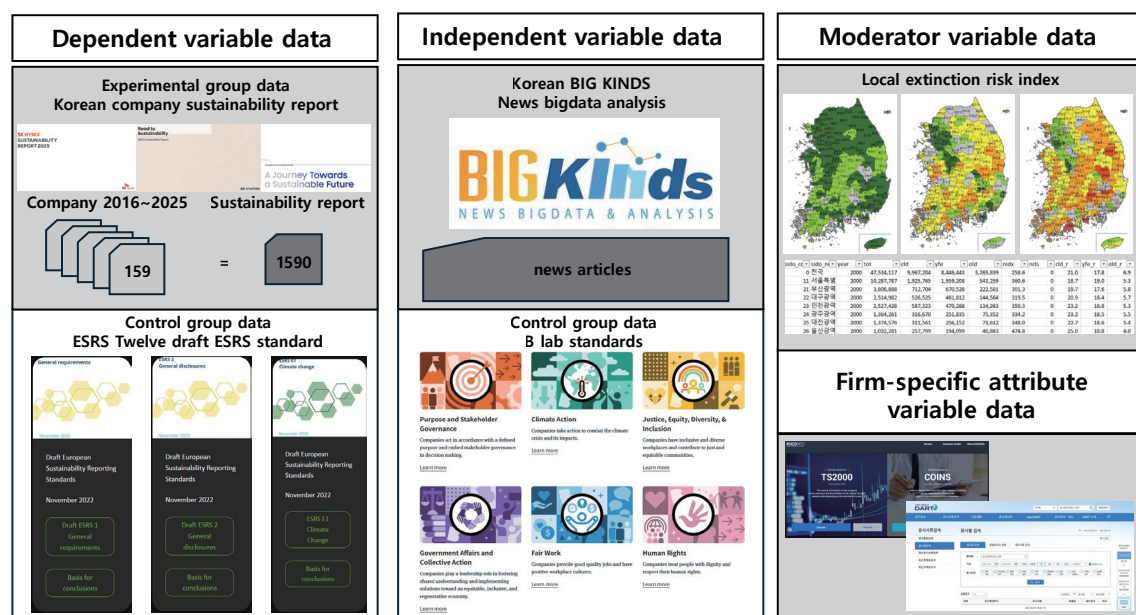


Fig. 1. (Color online) Data collection and variable construction framework.

the index so that higher values represent higher levels of shrinking-society risk. To ensure the industrial validity of the empirical analysis, the final sample was classified around coastal and marine-related industries.

3.2 Measurement of variables

We applied a sequential mechanism of sensing and transformation to derive the sustainability and social innovation indices from unstructured text data. In the sensing stage, unstructured text data were collected from corporate disclosure materials and news articles, and preprocessed into an analyzable form using natural language processing techniques. In the transformation stage, the refined textual signals were converted into document vectors, and cosine similarity was calculated between each document vector and the corresponding benchmark lexicon.⁽⁵³⁾ Through this process, qualitative information embedded in text was converted into the quantitative indicators as shown in Fig. 2.

The sustainability index, used as the dependent variable, was calculated by quantifying textual information that reflects firms' long-term value creation activities. The initial sustainability lexicon was constructed on the basis of European Sustainability Reporting Standards and key concepts identified in prior studies.⁽⁵⁴⁾ Term frequency–inverse document frequency (TF-IDF) analysis and Word2Vec-based semantic embedding were then jointly applied to derive approximately 300 key activity keywords associated with long-term sustainability performance. TF-IDF measures the relative importance of a specific term within a document corpus, whereas Word2Vec captures contextual semantic relationships among words.

After integrating the results of these two analytical procedures, only the core terms ranked within the top 20% in contextual importance were selected to construct the final sustainability benchmark lexicon. This multi-algorithm approach helps reduce the limitations of simple frequency-based analysis and strengthens the construct validity of the index. The final

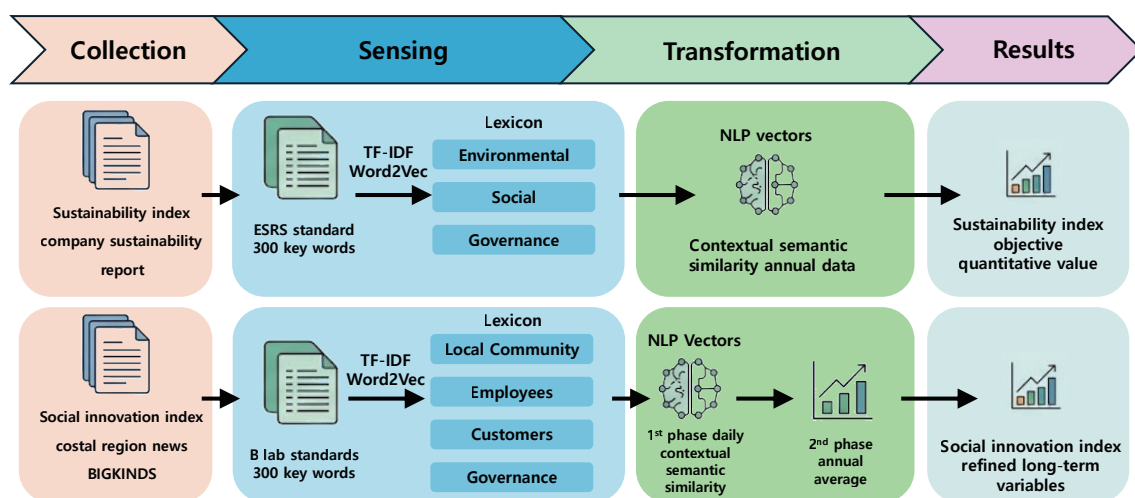


Fig. 2. (Color online) NLP-based transformation process from textual data to quantitative indices.

sustainability index was calculated by estimating the cosine similarity between the sustainability lexicon vector and each firm's sustainability report vector.

The main independent variable, social innovation, was measured using a social innovation lexicon constructed on the basis of B Lab's B Corporation Assessment Framework. This lexicon consists of four domains: community, workforce, customer, and governance. The community domain includes community engagement, social inclusion, fairness, and ethical supply chain development. The workforce domain includes employee welfare, working conditions, occupational safety, and employment stability. The customer domain reflects the social value created by products and services, consumer protection, and customer feedback systems. The governance domain includes the formal articulation of a social mission, stakeholder-oriented decision-making, transparency, and ethical management.⁽⁵⁵⁾

To measure actual social innovation activities, we used news data collected from Big Kinds. Search queries were designed by combining region-related keywords, such as coastal, shoreline, sea, and fishing village, with firm innovation-related keywords, such as social enterprise, fourth sector, social innovation, and sustainability. The collected news articles were cleaned by excluding duplicate articles, promotional articles, and articles with limited relevance to firm-level activities. The refined text data were then processed through tokenization, stop-word removal, morphological analysis, and vectorization.

A temporal smoothing process was applied to convert daily textual signals into stable annual indicators. Because news data may contain short-term outliers caused by specific events or promotional coverage, daily values were first converted into monthly averages. These monthly averages were then aggregated into annual averages to match the annual structure of firm-level financial data. Through this multi-stage aggregation process, the annual social innovation index was constructed.

The moderating variable, shrinking-society risk, was constructed using the local extinction risk index provided by the Korea Employment Information Service. The original index measures regional structural vulnerability by reflecting demographic reproduction capacity and population aging. Because lower values in the original index indicate higher extinction risk, we reverse-coded the index so that higher values represent higher levels of shrinking-society risk. The transformed index was then included in the regression model as the moderating variable.

We also included firm-level control variables to estimate the net effect of social innovation on sustainability. Firm size was measured as the natural logarithm of total assets.⁽⁵⁶⁾ Liquidity was measured using the current ratio.^(57,58) Leverage was measured using the debt-to-equity ratio.⁽⁵⁹⁾ Growth was measured as the annual sales growth rate.⁽⁶⁰⁾ Firm age was calculated as the number of years from the firm's founding year to the corresponding year of analysis.⁽⁶¹⁾ In addition, industry and year dummy variables were included to control for industry-specific conditions and macro-level changes over time.

3.3 Research model

We estimated panel regression models using firm-level panel data from 2016 to 2025 to analyze the effect of social innovation activities on corporate sustainability. Social innovation

activities were examined across four subdimensions: governance, workforce, community, and customer. A panel data approach was adopted because cross-sectional data alone cannot sufficiently control for unobserved heterogeneity across firms. Firms exhibit firm-specific and time-invariant characteristics that are difficult to observe directly, such as managerial culture, organizational structure, technological capabilities, and locally embedded networks. These characteristics may affect both social innovation activities and sustainability performance. If such unobserved factors are not controlled for, endogeneity problems may arise owing to correlations between the independent variables and the error term.

Accordingly, we employed a panel fixed-effect model to account for firm-specific unobserved heterogeneity. Year fixed effects were also included to account for exogenous shocks that may commonly affect firms in a given year, such as changes in the macroeconomic environment and policy conditions. In addition, the shrinking-society risk index was specified as a region-year-level variable constructed from the local extinction risk index of the coastal municipality in which each firm is located. This model specification allows the analysis to control for both firm-specific characteristics and temporal changes, thereby identifying the net effect of social innovation activities on corporate sustainability more precisely.

Panel analysis therefore provides an appropriate empirical framework for testing the moderating effect while simultaneously accounting for firm-level variation and changes over time. Finally, interaction terms between each subdimension of social innovation and shrinking-society risk were included to examine whether structural risk strengthens or weakens the relationship between social innovation and corporate sustainability.

$$\begin{aligned}
 &Sustainability_{it} \\
 &= \beta_0 + \beta_1 Governance_{it} + \beta_2 Workforce_{it} + \beta_3 Community_{it} \\
 &+ \beta_4 Customer_{it} + \beta_5 SSR_t + \beta_6 (Governance_{it} \times SSR_t) \\
 &+ \beta_7 (Workforce_{it} \times SSR_t) + \beta_8 (Community_{it} \times SSR_t) \\
 &+ \beta_9 (Customer_{it} \times SSR_t) + \gamma_1 Size_{it} + \gamma_2 Liquidity_{it} + \gamma_3 Leverage_{it} \\
 &+ \gamma_4 Growth_{it} + \gamma_5 FirmAge_{it}
 \end{aligned} \tag{1}$$

4. Empirical Results

4.1 Descriptive statistics and correlation

The descriptive statistics of the main variables are presented in Table 1. The dependent variable, corporate sustainability, has a mean value of 0.382 and a standard deviation of 0.094, with values ranging from 0.211 to 0.621. This indicates that there is a certain degree of variation in sustainability level among the sample firms. Regarding the subdimensions of social innovation, the community index shows the highest mean at 0.413, followed by governance at 0.398, workforce at 0.367, and customer at 0.352. In particular, the governance index has a relatively high standard deviation of 0.093, suggesting that firms differ in their organizational

Table 1
Descriptive statistics.

Variables	N	Mean	SD	Min	Max
Sustainability	1590	0.382	0.094	0.211	0.621
Governance	1590	0.398	0.093	0.171	0.654
Workforce	1590	0.367	0.089	0.144	0.588
Community	1590	0.413	0.102	0.185	0.691
Customer	1590	0.352	0.081	0.163	0.571
SSR	1590	0.539	0.058	0.658	0.459
Size	1590	22.41	1.52	19.03	26.87
Liquidity	1590	1.48	0.63	0.41	3.62
Leverage	1590	51.2	17.85	12.4	89.1
Growth	1590	4.82	8.91	−21.4	33.7
Firm age	1590	18.6	7.3	3	41.0

Notes: * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

operating systems and decision-making structures. The moderating variable, shrinking-society risk, has a mean of 0.539 and a standard deviation of 0.058, with values ranging from 0.459 to 0.658.

As shown in Table 2, the correlation analysis indicates that corporate sustainability is positively and significantly associated with all four subdimensions of social innovation. Specifically, the correlation coefficients are 0.44 for community, 0.42 for governance, 0.39 for workforce, and 0.37 for customer, all of which are statistically significant at the 1% level. These results suggest that the social innovation activities of fourth-sector firms are closely related to corporate sustainability.

By contrast, shrinking-society risk shows a negative and significant correlation with corporate sustainability (-0.21 , $p < 0.05$). This suggests that as regional structural crisis intensifies, corporate sustainability performance may be constrained. Therefore, shrinking-society risk can be understood not merely as an external environmental variable, but as an important structural condition that may moderate the relationship between social innovation activities and corporate sustainability. Some control variables also show significant correlations with sustainability.

4.2 Results of panel effect tests

To analyze the 10-year panel dataset of 159 firms, we conducted a series of panel effect tests to identify the most appropriate estimation method among pooled OLS, fixed effects, and random-effect models. The results are presented in Table 3. First, the F-test comparing the pooled OLS model with the fixed-effect model shows that firm fixed-effect are statistically significant ($F = 14.237$, $p < 0.0001$). This indicates the need to account for firm-specific characteristics in the estimation. The Breusch–Pagan LM test also confirms the presence of significant random effects ($\chi^2 = 211.584$, $p < 0.0001$), suggesting that a simple pooled OLS model is not appropriate.

Table 2
Correlation results.

Var	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	0.42***	1									
3	0.39***	0.36***	1								
4	0.44***	0.38***	0.35***	1							
5	0.37***	0.33***	0.30***	0.32***	1						
6	-0.21**	-0.10	-0.11*	-0.09	-0.08	1					
7	0.22***	0.18***	0.16***	0.18***	0.13**	-0.02	1				
8	0.09	0.06	0.05	0.07	0.04	-0.01	-0.14**	1			
9	-0.16**	-0.13**	-0.12**	-0.11**	-0.09**	0.03	-0.30**	-0.24**	1		
10	0.08*	0.06	0.05	0.072	0.04	0.02	0.09*	0.01	-0.02	1	
11	-0.14**	-0.1***	-0.11**	-0.13**	-0.08*	0.03	0.15**	-0.01	0.03	-0.01	1

Notes: 1 = Sustainability, 2 = Governance, 3 = Workforce, 4 = Community, 5 = Customer, 6 = Shrinking-society risk, 7 = Size, 8 = Liquidity, 9 = Leverage, 10 = Growth, 11 = Firm age. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3
Panel diagnostics test results.

Category	Test name	Null hypothesis (H_0)	Test statistic
Existence of fixed effects	F-test for fixed effects	Fixed effects do not exist	$F = 14.237$
Existence of random effects	Breusch–Pagan LM test	Random effects do not exist	$\chi^2 = 211.584$
FE vs RE model selection	Hausman specification test	Random-effect model is appropriate	$\chi^2 = 33.917$
Time effect test	F-test for time fixed effects	Time fixed effects do not exist	$F = 4.891$
Industry effect test	F-test for industry fixed effects	Industry fixed effects do not exist	$F = 6.742$

The Hausman test was then conducted to compare the suitability of the fixed-effect and random-effect models. The test result is statistically significant ($\chi^2 = 33.917$, $p = 0.0000$), leading to the rejection of the null hypothesis that the random-effect estimator is consistent. Accordingly, we adopted the fixed-effect model as the final estimation model, as it can control for unobserved firm-specific heterogeneity.

Additional tests were conducted to account for external shocks over time and structural differences across industries. The year effect test is statistically significant ($F = 4.891$, $p = 0.0002$) and the industry effect test is also significant ($F = 6.742$, $p < 0.0001$). Therefore, the final empirical model includes year fixed effects, while firm fixed effects control for time-invariant firm-level characteristics, including stable industry-related attributes, thereby strengthening the internal validity of the analysis.

4.3 Regression analysis results

We conducted panel fixed-effect regression analyses to examine the effects of the four subdimensions of social innovation on corporate sustainability and the moderating role of shrinking-society risk. To mitigate potential multicollinearity in models including interaction terms, all independent and moderating variables were mean-centered before estimation. The final results, controlling for firm and year fixed effects, are presented in Table 4.

Table 4
Regression results.

Sustainability	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Governance	0.153*** (0.049)	0.150*** (0.048)	0.159*** (0.051)	0.157*** (0.051)	0.154*** (0.051)	0.150*** (0.052)
Workforce	0.143*** (0.046)	0.142*** (0.046)	0.145*** (0.048)	0.150*** (0.047)	0.148*** (0.047)	0.141*** (0.048)
Community	0.158*** (0.051)	0.155*** (0.051)	0.175*** (0.053)	0.174*** (0.054)	0.176*** (0.054)	0.168*** (0.055)
Customer	0.112** (0.045)	0.110** (0.045)	0.116** (0.047)	0.113** (0.047)	0.115** (0.047)	0.109** (0.048)
Shrinking-Society risk	−0.248** (0.121)	−0.233** (0.121)	−0.241** (0.122)	−0.239** (0.121)	−0.230** (0.122)	−0.214** (0.123)
Governance × SSR	—	—	—	—	0.108** (0.054)	0.103** (0.055)
Workforce × SSR	—	—	0.112** (0.055)	—	—	0.104** (0.056)
Community × SSR	—	0.129** (0.062)	—	—	—	0.121** (0.063)
Customer × SSR	—	—	—	0.097* (0.052)	—	0.091* (0.053)
Size	0.062*** (0.019)	0.063*** (0.019)	0.064*** (0.020)	0.063*** (0.020)	0.062*** (0.020)	0.065*** (0.020)
Liquidity	0.018 (0.017)	0.017 (0.017)	0.017 (0.017)	0.018 (0.017)	0.016 (0.017)	0.017 (0.017)
Leverage	−0.051** (0.026)	−0.052** (0.026)	−0.051** (0.026)	−0.053** (0.026)	−0.050** (0.025)	−0.054** (0.026)
Growth	0.058** (0.029)	0.061** (0.029)	0.060** (0.029)	0.061** (0.029)	0.062** (0.029)	0.059** (0.029)
FirmAge	−0.015* (0.009)	−0.015* (0.009)	−0.015* (0.009)	−0.016* (0.009)	−0.015* (0.009)	−0.016* (0.009)
Firm year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1590	1590	1590	1590	1590	1590
R ²	0.359	0.366	0.371	0.364	0.358	0.362

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The baseline model shows that all four subdimensions of social innovation have significant positive effects on corporate sustainability. Governance has a coefficient of 0.153 ($p < 0.01$), supporting H1. Workforce has a coefficient of 0.143 ($p < 0.01$), supporting H2. Community shows the largest effect among the four dimensions, with a coefficient of 0.158 ($p < 0.01$), supporting H3. Customer is also positively associated with corporate sustainability, with a coefficient of 0.112 ($p < 0.05$), supporting H4. These main effects remain largely consistent across the extended models that include interaction terms.

The direct effect of shrinking-society risk is negative and significant across all models, with coefficients ranging from −0.214 to −0.248 ($p < 0.05$). This suggests that structural crises in coastal regions, such as population decline and industrial deterioration, may directly constrain corporate sustainability. Regarding the control variables, firm size and growth have positive effects on sustainability, whereas leverage and firm age show negative effects.

To test H5, interaction terms between each subdimension of social innovation and shrinking-society risk were included in the extended models. In the full model, the interaction terms show

positive directions across all four dimensions. The coefficient of Governance $\times$ Shrinking-society Risk is 0.103 ($p < 0.05$), that of Workforce $\times$ Shrinking-society Risk is 0.104 ($p < 0.05$), and that of Community $\times$ Shrinking-society Risk is 0.121 ($p < 0.05$). The Customer $\times$ Shrinking-society Risk interaction term is also positive, with a coefficient of 0.091, and is marginally significant at the 10% level ($p < 0.1$).

These results indicate that shrinking-society risk has a direct negative effect on corporate sustainability while simultaneously strengthening the positive relationship between social innovation and sustainability. In other words, social innovation activities become more important in structurally vulnerable regions where public and market functions are weakened. The findings suggest that the social innovation activities of fourth-sector firms are not merely supplementary practices, but may function as key mechanisms for sustaining both firms and local communities. Accordingly, H5 is supported.

5. Conclusion and Implications

5.1 Theoretical implications

This study contributes to the literature on social innovation by empirically examining the relationship between social innovation and sustainability in fourth-sector firms. The results show that community-, workforce-, customer-, and governance-based activities are significantly associated with corporate sustainability. This finding suggests that social innovation is not merely an ethical practice or a peripheral corporate activity, but can function as a core managerial component of corporate performance.⁽⁶²⁾ It also supports the existing theoretical argument that fourth-sector firms create value through organizational models that integrate economic and social objectives.

This study further shows that social innovation can be more closely linked to sustainability performance when it is embedded in organizational management systems. When social innovation is not limited to external reputation management or one-off philanthropic activities, but is integrated with decision-making structures, stakeholder participation systems, and internal motivational mechanisms, corporate sustainability can be strengthened. This finding can be interpreted as empirical support for the value creation mechanism proposed by the creating shared value perspective.

By focusing on firms operating in coastal regions, this study incorporates geographical and industrial specificity into social innovation research. Coastal regions are spaces in which marine industrial structures, demographic change, local economic foundations, and ecological risks interact in complex ways. The findings indicate that the effects of social innovation may become more salient in environments where ecological, economic, and demographic conditions are closely intertwined. This contributes to the development of a more context-sensitive theoretical model of fourth-sector firms and suggests that social innovation research should move beyond generalized national-level discussions toward place-based problem-solving processes.

Finally, by introducing shrinking-society risk as a moderating variable, this study confirms that the effect of social innovation may vary depending on regional structural conditions. The results show that the positive effect of social innovation on corporate sustainability becomes stronger in regions with higher levels of shrinking-society risk. This suggests that social innovation can function as a buffering mechanism that mitigates the negative effects of structural crises, such as population decline and industrial deterioration. In this respect, this study extends the understanding of fourth-sector firms as key actors in regional sustainability and place-based revitalization.

5.2 Practical implications

This study provides the following practical implications for managers and practitioners in coastal industries. First, managers need to redefine local communities not as passive recipients of CSR or philanthropic support, but as core business partners. The empirical results show that community-based activities have the strongest effect on corporate sustainability. Since population decline and the weakening of fishing communities directly threaten coastal supply chains and local business ecosystems, firms need to develop creating shared value-based business models that connect local economic circulation with corporate value creation. Examples include supporting young fishery workers, sharing fishing village infrastructure, and establishing local seafood processing ecosystems.

Second, firms need to move beyond traditional hierarchical structures and establish workforce-centered empowerment systems. Coastal industries are highly exposed to climate change, safety risks, and seasonal volatility; therefore, the crisis response capacity of internal human resources is closely linked to corporate performance. Participatory safety management committees and multi-skilled worker development programs can serve as practical tools for improving operational stability. In aging coastal communities where securing replacement labor is difficult, workforce-centered management can also contribute to reducing turnover and improving organizational continuity.

Third, firms need to recognize customers as participants in coastal social innovation. Contemporary customers increasingly evaluate whether products and services contribute to marine environmental conservation and local community sustainability. Practices such as marine eco-labeling, the transparent disclosure of seafood production histories, and tourism programs linked to local development can help coastal fourth-sector firms differentiate themselves from large competitors. Market approaches connected to responsible consumption can also help these firms strengthen their position in niche markets and enhance brand loyalty.

Finally, in regions with high levels of shrinking-society risk, firms need to consider proactive social innovation rather than withdrawal. In regions where public services and market actors retreat, fourth-sector firms can fill institutional and service gaps while securing local trust and influence. Through these activities, managers can build durable firm-community partnerships and develop relationship-based competitive advantages that are difficult for competitors to imitate.

5.3 Policy implications

On the basis of the empirical findings of this study, several policy directions can be proposed to enhance the sustainability of coastal regions. Policymakers need to consider linking coastal region-specific regulatory sandboxes with place-based innovation. Given that community- and governance-based activities have strong effects on corporate sustainability, designating selected coastal municipalities as coastal innovation priority zones may be a viable policy option. Within these zones, a comprehensive negative regulatory approach should be introduced to prevent fourth-sector business models, such as fishing village space regeneration and marine waste resource recovery, from being unnecessarily constrained by existing regulations. This approach can contribute to a transition from subsidy-dependent welfare policies toward self-sustaining local economic models based on endogenous innovation capacity.

Governments also need to develop coastal-specific evaluation indicators and establish intelligent policy monitoring and feedback systems. Rather than relying on one-off support programs, a data-driven decision-making platform is required to connect regional shrinking-society risk indices with the performance data of fourth-sector firms. Such a platform can be used to detect early warning signals in vulnerable coastal regions, set priorities for supporting social innovation organizations, and quantitatively track policy outcomes. If this feedback system is established, governments can improve the timeliness and effectiveness of policy interventions through evidence-based public administration as shown in Fig. 3.

5.4 Limitations and future research

This study has several limitations. First, it is limited by sample representativeness and data availability. Because the sample was constructed primarily around firms subject to external

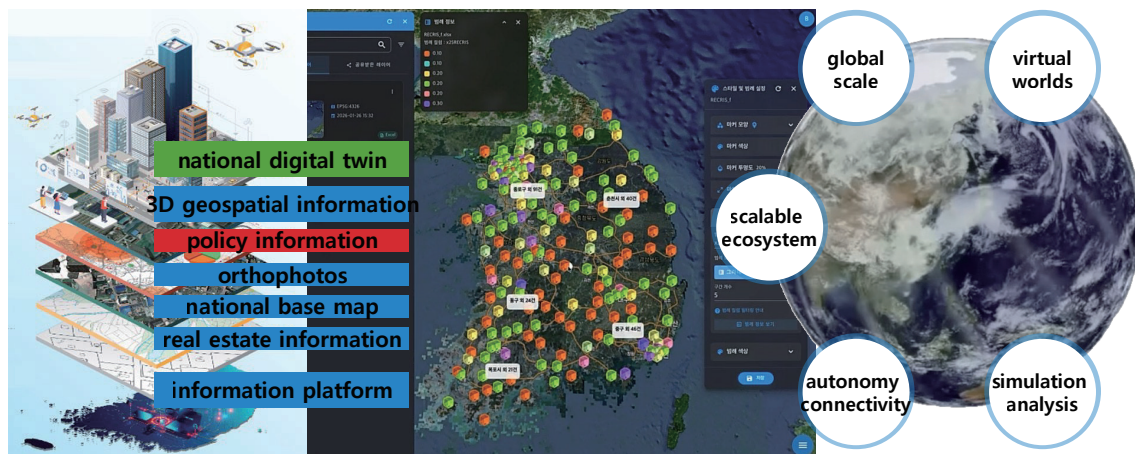


Fig. 3. (Color online) Conceptual framework of a national digital twin and spatial information system.

audit disclosure requirements, small unlisted cooperatives, village enterprises, and other social economy organizations that play important roles in coastal economies were not sufficiently included. Therefore, the possibility of selection bias cannot be ruled out. In future research, a more comprehensive database that includes non-disclosing organizations by combining public data with field-based surveys should be constructed.

Second, we did not fully account for heterogeneity across coastal industries. Coastal economies consist of industries with distinct value chains, such as seafood processing, port logistics, and marine tourism; however, we examined them within an integrated analytical framework. In future studies, industry-level subgroup analyses to specify social innovation models and risk response approaches that are better aligned with the characteristics of each coastal industry should be conducted.

Finally, there is a possibility of qualitative information loss in the process of constructing the social innovation index through text mining. Although converting corporate disclosure materials and news texts into quantitative indicators enables systematic measurement, this approach has limitations in fully capturing the authenticity, motivation, and embedded value of social innovation activities. Future research should adopt mixed methods by combining quantitative analysis with qualitative approaches, such as in-depth interviews and case studies. This would allow for a more comprehensive examination of the causal mechanisms linking the motivations, implementation processes, and outcomes of social innovation activities.

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