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Climate Change Policy Implications of Sustainable Development Pathways in Korea at Sub-National Scale

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Abstract: Climate action is goal 13 of UN's 17 Sustainable Development Goals (SDG). Future impacts of climate change depend on climatic changes, the level of climate change policy, both mitigation and adaptation, and socio-economic status and development pathways. To investigate the climate change policy impact of socio-economic development pathways, we develop three pathways. Climate change affects socio-economic development in many ways. We interpret global storylines into South Korean contexts: Shared Socio-economic Pathway 1 (SSP1), SSP2, and SSP3 for population, economy, and land use. SSP elements and proxies were identified and elaborated through stakeholder participatory workshops, demand survey on potential users, past trends, and recent national projections of major proxies. Twenty-nine proxies were quantified using sector-specific models and downscaled where possible. Socio-economic and climate scenarios matrixes enable one to quantify the contribution of climate, population, economic development, and land-use change in future climate change impacts. Economic damage between climate scenarios is different in SSPs, and it highlights that SSPs are one of the key components for future climate change impacts. Achieving SDGs generates additional incentives for local and national governments as it can reduce mitigation and adaptation policy burden.

Keywords: shared socio-economic development pathways; sub-national; climate change policy; population; economy; land use

1. Introduction

Policy decisions are made against a long-term complex climate change problem that is inherently uncertain. Climate change policies, both mitigation and adaptation, often need to compete with each other and other development objectives. Scenarios are one of the essential components in long term policy decisions. Scenarios can provide descriptions of possible or potential acts or events in the future and differ from predictions. Robust policy decisions should be based on plausible scenarios.

Global climate change communities have developed a scenario framework to analyze future impacts and policies [1,2]. Climate scenarios have been applied widely in climate change policy analyses [3–11] and in South Korea [12–18]. Research and policymaking communities are aware of the implications of different climate scenarios.

The levels of current and future climate change impacts, vulnerabilities, and risks depend not only on climatic conditions but also on socio-economic conditions, including population, economy, technological development, and policy level [19]. Less attention has been given to socio-economic scenarios, especially in Korea. Some studies assumed the same socio-economic conditions in the future [20–22], and some studies have developed socio-economic scenarios by extrapolation of current trends [23]. This makes it difficult to compare relative vulnerability among sectors, regions and priorities of policies.

Applying consistent and systematic combinations of climate change and socio-economic scenarios would identify optimal solutions for climate change policy in the future. Studies have shown that the degree of climate change impacts heavily depend on the assumptions of socio-economic conditions [24–30]. For example, climate change vulnerability in Europe varies by up to 50% based on socio-economic assumptions [25]. Recently, studies have revealed that the sensitivity from applying different socio-economic scenarios is greater than the sensitivity from applying different climate change scenarios [26,31,32]. For example, water stress will be varied from 39% to 55% of the total population based on socio-economic scenarios [26].

The global research community has developed Shared Socio-economic Pathways (SSPs), which provide a flexible framework for local scenario development and can be used in adaptation and vulnerability studies [33–37]. SSPs have both quantitative and qualitative descriptions of various sectors. A global narrative storyline has been developed for SSPs in demography, economy, land use, human development, technology, and environment [29,33–35].

The socio-economic development pathways are even more important at the national and sub-national levels. Impacts of climate change depend on the regional climate and socio-economic conditions. Climate change policy decision-making, especially for adaptation, must consider the socio-economic context at the national and sub-national levels. While many SSP studies have developed narrative storylines globally [34,36–39], limited studies are available at the national and sub-national levels [33,36,40–44]. Often, national and sub-national SSPs are developed through stakeholder workshops in qualitative ways [33,45]. A few studies have developed SSPs at the sub-national level in quantitative ways [36,39–41].

We developed three SSPs (SSP1: low carbon adaptation-ready society; SSP2: business as usual; SSP3: high carbon adaptation-unready society) at the sub-national level in a quantitative way for the population, economy, and land use in Korea. We translated global storylines to Korean contexts. Each scenario contains narrative descriptions and quantitative information. Proxies were quantified in each sector, and proxies were downscaled from the national to the sub-national level where possible. This study analyzed the policy implication of climate and socio-economic development pathways using PAGE (policy analysis of greenhouse effect) model. Socio-economic scenarios could allow policymakers to better understand the importance of development pathways for climate change damage.

2. Materials and Methods

2.1. Socio-Economic Scenario Development

2.1.1. Scenario Outlook

We developed storylines for three SSPs considering global assumptions [2] and Korean contexts through participatory stakeholder workshops. Major elements and proxies are identified and elaborated to describe SSPs by considering Korean narrative storylines, recent projections of the population and economy, past trends of major proxies, and demand of surveys. Major proxies for SSPs are quantified using sector-specific models. An outline of this research is shown in Figure 1.

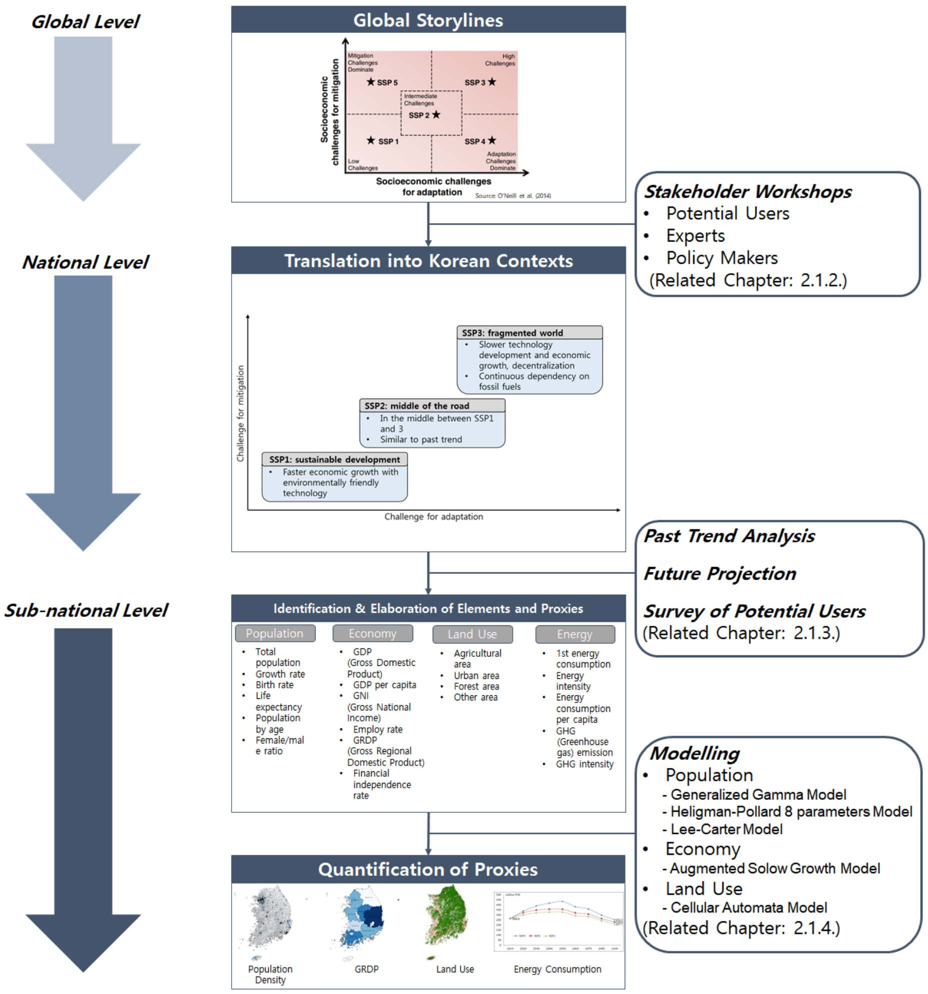

Figure 1. Scenario development procedure.

2.1.2. Translation of Global Storyline into Korean Contexts

Global storylines were translated into Korean contexts through five workshops with demography, economy, land use, and technology policymakers and researchers as participants. Most assumptions of the scenarios are in line with global assumptions [2], except for population. We assumed lower depopulation for SSP1 than SSP3, contrary to global SSPs. The population growth rate has been decreased in Korea. The birth rate in Korea has declined from 1.654 in 1993 to 1.052 in 2017 [46]. It is the lowest among Organisation for Economic Co-operation and Development(OECD) countries in 2015 [47]. The population growth rate declined from 3% in 1960 to 0.28% in 2017, and depopulation is especially prominent for younger people (ages 14 and below) [48]. We assumed that a further decrease in population growth rate will adversely affect the achievement of a sustainable development pathway.

2.1.3. Identification and Elaboration of Proxies

Major proxies for each sector were identified through a demand survey of potential users and a review of SSP studies [3,38,49,50]. Proxies were elaborated by analyses of past trends [48,51], future projections [52–54], and expert opinion in each sector. Past trends and national projection of major proxies are shown in Figure 2.

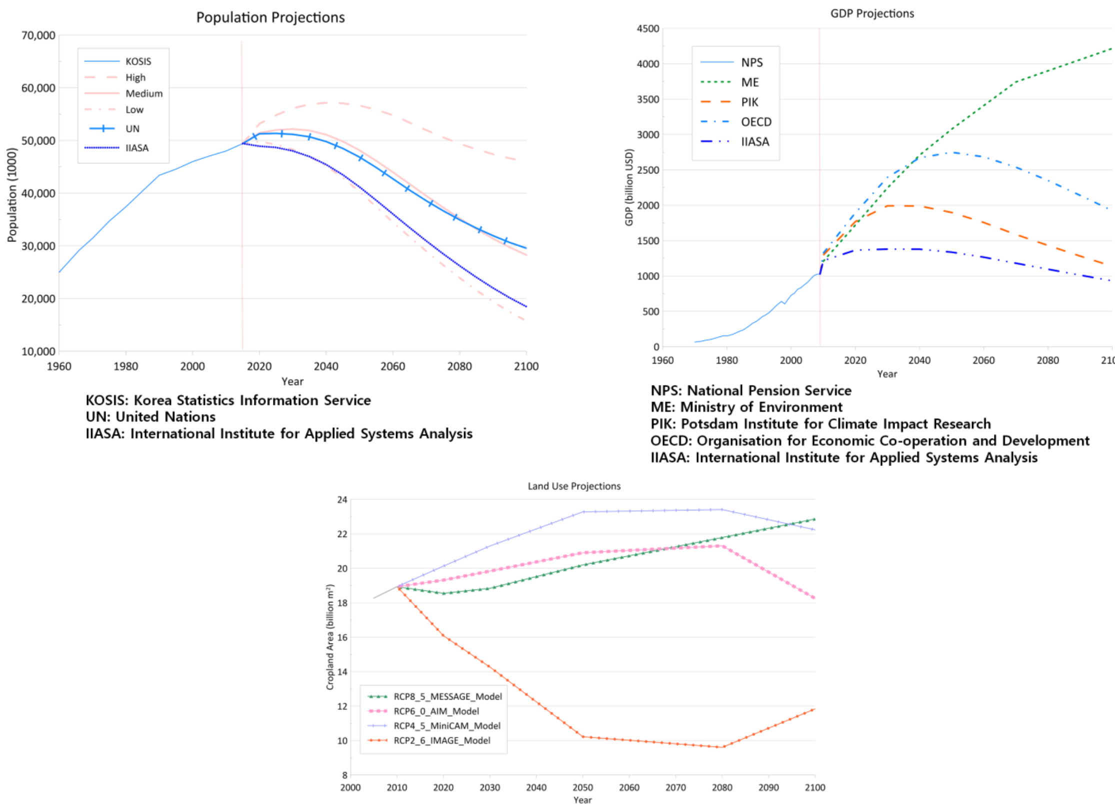

Figure 2. Past trends and projections of major proxies (top left: population, top right: GDP, bottom: land use) [48,55–57].

2.1.4. Quantification of Proxies

- Population

Population scenarios were developed using the cohort component method. Fertility, mortality, and migration rates by gender and region are quantified. Population decreased relatively less due to successful population policy in SSP1, while population decreased the most and became elderly in SSP3. The TFR (total fertility rate) for women aged 15–49 in 2013 would be 2.1 in SSP1, 1.7 in SSP2, and 1.4 in SSP3 by 2100. The number of age-specific mortality was determined by the change in the average life expectancy. The average life expectancy would increase to 105 years for SSP1 and SSP2 and 95 years for SSP3 in 2100. The interregional migration rate in 2100 is decreased to 30%, 50%, and 80% of 2013 in SSP1, SSP2, and SSP3, respectively.

- Economies

Until 2050, the economic growth for SSP2 (business as usual) was based on recent national projections [53]. Long-term projections (2050–2100) are expansions of economic growth trends that consider population size and structure (labor capital), industrial structure and productivity, and level of low-carbon technological development and transfer, as outlined in storylines. We assumed that the TFP frontier growth rate was 1.1% in SSP1 and 0.6% in SSP3 [56]. The sectoral industrial growth path was projected by a time-series model based on the demand–supply system, international division of labor, and technological development. A detailed description of the methodology is given in [57].

- Land use

The land-use projection was conducted using Cellular Automata (CA) [58]. CA derives the transition rule of subject areas for identifying patterns of land-use change. The basic units of simulation in CA are 30 m × 30 m, and the model is composed of approximately 169,000,000 grid cells. Four land-use (urban, agriculture, forest, and others) types are applied in this model. It simulates land-use change by assuming the status of a cell changes based on its neighborhood cells at a given time and space. It iterates simulations based on the transition rule of [59]. The growth coefficient, transition possibility, transition rule, and number of simulations for each zone are listed in Appendix A Table A1. SSP1 assumes that a compact city suppresses horizontal expansion for efficient urban management. In SSP2, the current land use pattern continues. The regulations of land use are eased and reckless urban sprawl occurs in SSP3.

2.2. Analysis of Policy Implication of SSPs

PAGE, an integrated assessment model that estimates the cost of mitigation and adaptation policies and the impacts of climate change [60], was used to analyze the economic impacts of climate change for the matrix of climate scenarios (RCP: Representative Concentration Pathways) and SSPs. This study uses the latest version of PAGE-ICE model [61].

PAGE-ICE has been changed from PAGE09 in the climate and damage module. PAGE-ICE includes the permafrost module in their climate model. Permafrost acts in the climate model by increasing greenhouse gas emission and decreasing earth albedo. The permafrost module increases the global mean surface temperature more than without the permafrost module. PAGE-ICE provides an option for market damage scenarios based on [62]. Many previous studies pointed out that damage functions in Integrated Assessment Models (IAM) are outdated or made without evidence [63]. PAGE-ICE provides an option to choose a market damage function with more concrete and updated studies [61].

PAGE model simulates climate change impacts of eight regions. Korea is a part of China and the Northeast Asia region. This study reweights the original data of the PAGE-ICE model to separate Korea from China and the Northeast Asia region. Detailed methodology and data are described in [64].

3. Socio-Economic Pathways in Korea

3.1. Storylines for SSPs in Korea

Narrative storylines were developed for three SSPs. In SSP1, environmentally friendly economic growth and lifestyles lead to sustainable development. Successful population policy and economic development will stimulate the birth rate. The population structure is more stable than other SSPs. Sustainable economic growth and gap shrinkage of income inequality can be expected. Internal migration between regions is decreased. Urban residency level will remain high. A tertiary industry-oriented industrial structure and rapid low-carbon technology development lead to sustainable economic development. A compact city structure lessens travel requirements and results in less energy consumption. Effective governance allows balanced economic growth and successful welfare that improves quality of life.

SSP3 assumes an aging society due to the failure of population policies. Material intensive consumption creates a manufacturing-oriented industrial structure. Internal migration increases between regions due to income inequality between classes and regions. Resource-intensive industrial structure and slow economic development results in environmental degradation and reckless urban sprawl.

3.2. Identification and Elaboration of Proxies

We identified 29 proxies in three sectors. For the population, 13 proxies were selected including total population, growth rate, birth rate, life expectancy, and internal/external migration by age (ages ≤ 4, 4–15, 15–64, ≥65, and ≥80) and by gender. The total population decreased in all three scenarios. Increase in life expectancy allows an increase in the elderly population. In the economic sector, 12 proxies were identified: national economy (i.e., GDP, GDP per capita, GDP growth rate, GNI, and employment rate), regional economy (i.e., Gross Regional Domestic Product (GRDP) and financial independence rate), industrial structure (i.e., percentages of primary, secondary, and tertiary industrial portions of GDP), international economy (export), and production and consumption (productivity). GDP increases in all SSPs, especially in SSP1. The portion of tertiary industry increases the most in SSP1. Four proxies were identified for land use: area of agricultural, urban, forest, and other. Agricultural and forest areas increase and urban areas decrease in SSP1, while urban areas increase in SSP2 and SSP3. The proxies were downscaled where possible based on data availability (Table 1).

Table 1. Spatial scales and trends of major proxies in SSPs.

Sector	Proxies	Spatial Scale			Trend		
		National	Regional	Local	SSP1	SSP2	SSP3
Population	Total population	■	■	■	↘	↘	↓
	Growth rate	■	■	■	↘	↘	↓
	Birth rate	■	■		↘	↘	↓
	Life expectancy	■	■		↑	↑	↗
	Internal migration	■	■		→	↗	↑
	External migration	■	■		↑	↗	→
	Population by age	■	■		↘	↓	↓
	Aged/child ratio	■	■		→	↗	↑
	Female/male ratio	■	■		→	→	↗
Economy	GDP	■	■		↑	↗	→
	GDP growth rate	■	■		↘	↓	↓
	GDP per capita	■	■		↑	↗	↗
	GNI	■			↑	↗	→
	Employment rate	■	■		→	↗	↗
	GRDP	■	■		↑	↗	→
	Financial independence rate	■	■		↑	↑	↗
	Primary industry	■	■		→	→	→
	Secondary industry	■	■		↓	↘	↘
	Tertiary industry	■	■		↑	↗	↗
	Export	■			→	→	→
	Productivity	■	■		↑	↗	↗
Land Use	Agricultural area	■	■	■	→	→	↘
	Urban area	■	■	■	→	→	↗
	Forest area	■	■	■	→	→	↘
	Other area	■	■	■	→	→	↘

Trend: ↗ Increase, ↑ Rapid Increase, → No change, ↘ Decrease, ↓ Rapid decrease. Spatial Scale: Colored background—data available.

3.3. Quantification of Proxies

3.3.1. Population

Depopulation is inevitable in Korea due to a rapid decrease in the fertility rate, even though life expectancy increases in all SSPs. The total population in 2100 decreased 22% (39,927,512), 45% (28,312,039), and 60% (20,527,843) compared to population in 2013 (51,141,463) in SSP1, SSP2, and SSP3, respectively. The population structures by gender and age are shown in Figure 3.

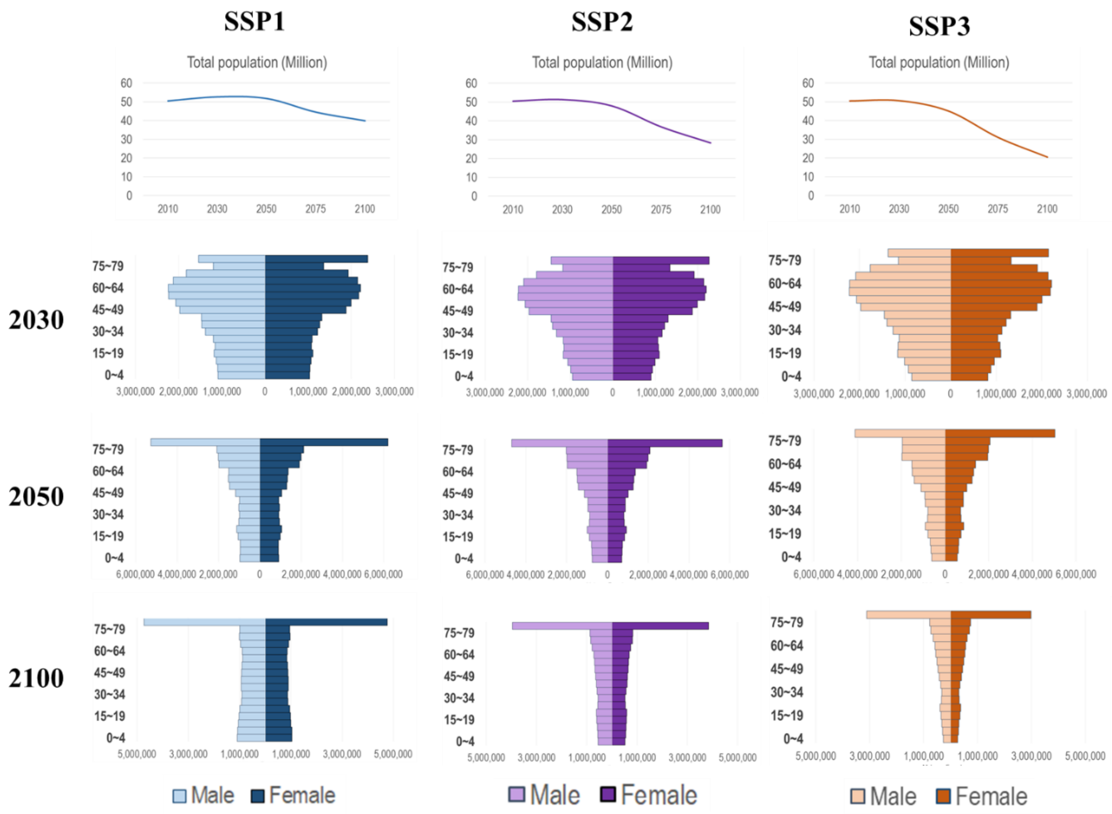

Figure 3. Population structure of Korea by gender in Shared Socio-economic Pathways (SSPs).

The portion of the working-age population (age between 15 and 64 years old) in 2100 decreased from 0.73 in 2010 to 0.46, 0.43, and 0.41 in SSP1, SSP2, and SSP3, respectively. The elderly (age over 65) population increased from 5,506,352 in 2010 to 15,318,284, 12,701,475, and 10,327,851 in SSP1, SSP2, and SSP3, respectively, in 2100. Details of other proxies are listed in Appendix A Table A2.

SSP1 assumes a compact city, which allows a relatively higher population density in cities than other SSPs. Figure 4 shows the changes in population density between 2030 and 2100 by SSPs. Populations in SSP2 and SSP3 are more distributed than in SSP1, especially in Seoul, Busan, and Jeonbuk in SSP3.

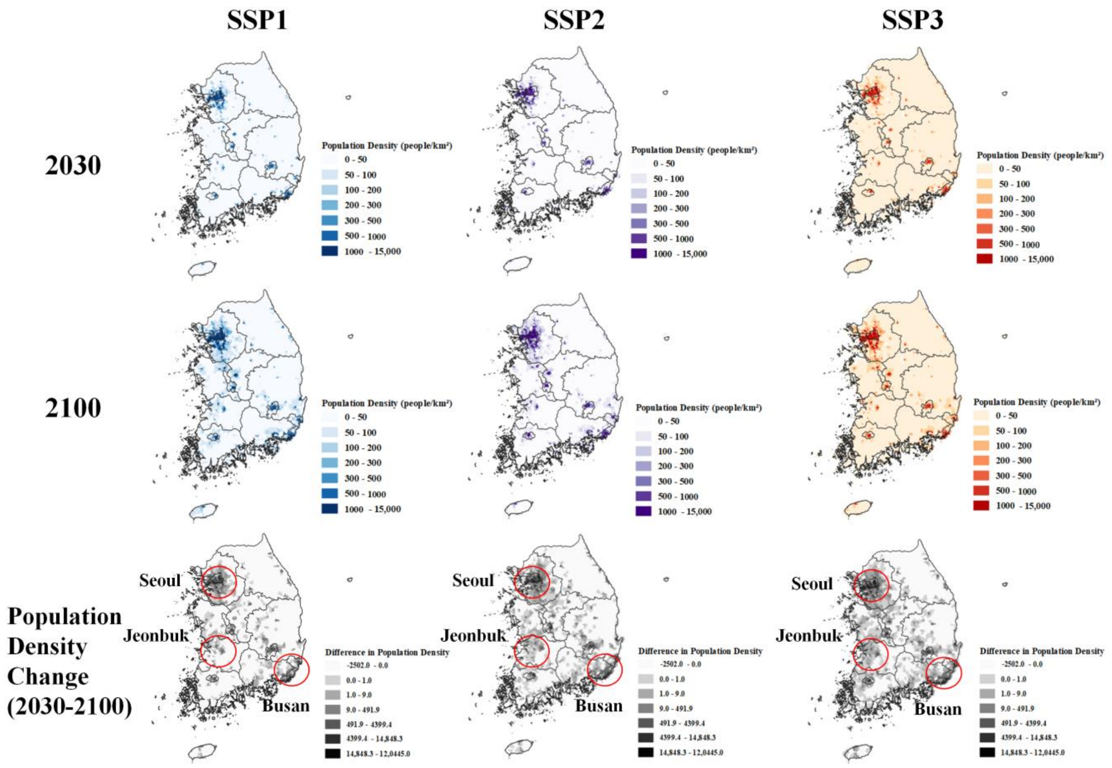

Figure 4. Population density in SSPs.

3.3.2. Economies

GDP increased 4908 trillion Korean Won (KRW) in 2100 in SSP1 and 3447 and 2348 trillion KRW in SSP2 and SSP3, respectively. The primary industry in all SSPs represents a very limited portion of the total GDP (less than 2.4%). The manufacturing industry of GDP was expected to maintain its share at mid–30% until 2050, but it was projected to continuously decline after 2050 in all SSPs. The share of the manufacturing industry would be replaced by the service industry (tertiary industry). The tertiary industry occupied 82.9% in SSP1 and 77.8% in SSP2 and SSP3, as shown in Figure 5. The difference between economic growth values in SSPs resulted from productivity. Productivity in 2100 is 1009.6 in SSP1 and 889.9 in SSP2 and SSP3 compared to 2000.

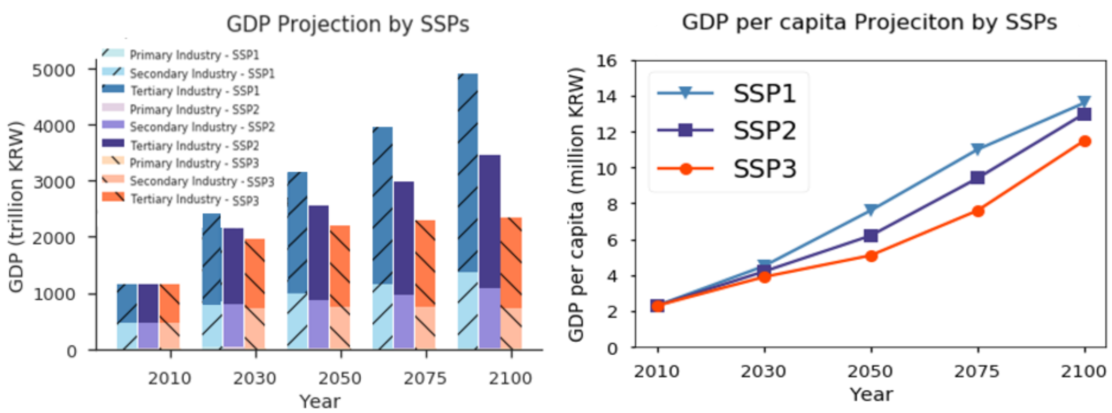

Figure 5. GDP by industry and GDP per capita by SSPs.

GDP per capita increased from 2.3 million KRW in 2010 to 13.0 million KRW in 2100 in SSP2, while it increased to 13.6 million KRW and 11.5 million KRW in SSP1 and SSP3, respectively (Figure 5).

It is mainly due to an increase in labor productivity and a decrease in population. The difference between SSPs comes from disparities in economic growth and employment.

GRDP increased continuously in SSP1 in most regions of Korea by 2050 in SSP1. GRDP in Seoul decreases, while it increased in other regions by 2100, resulting from balanced economic growth in SSP1. SSP2 had a similar pattern as that of SSP1 but with lower GRDP. GRDP in SSP3 showed more divergence due to a failure of economic and population policy. Proxies in the economic sector are summarized in Appendix A Tables A3 and A4.

3.3.3. Land Use

The land-use changes are shown in Figure 6. The transition to urban areas is more significant in SSP3 than others since SSP3 assumes reckless urban sprawl. The urban area ratio increased from 15.3% in 2030 to 18.1% in 2100. As the urban area ratio increases, the area of forest, agriculture, and other areas consistently decrease. The portion of the urban area remains the current level in SSP1 and SSP2. The results are summarized in Appendix A Table A5.

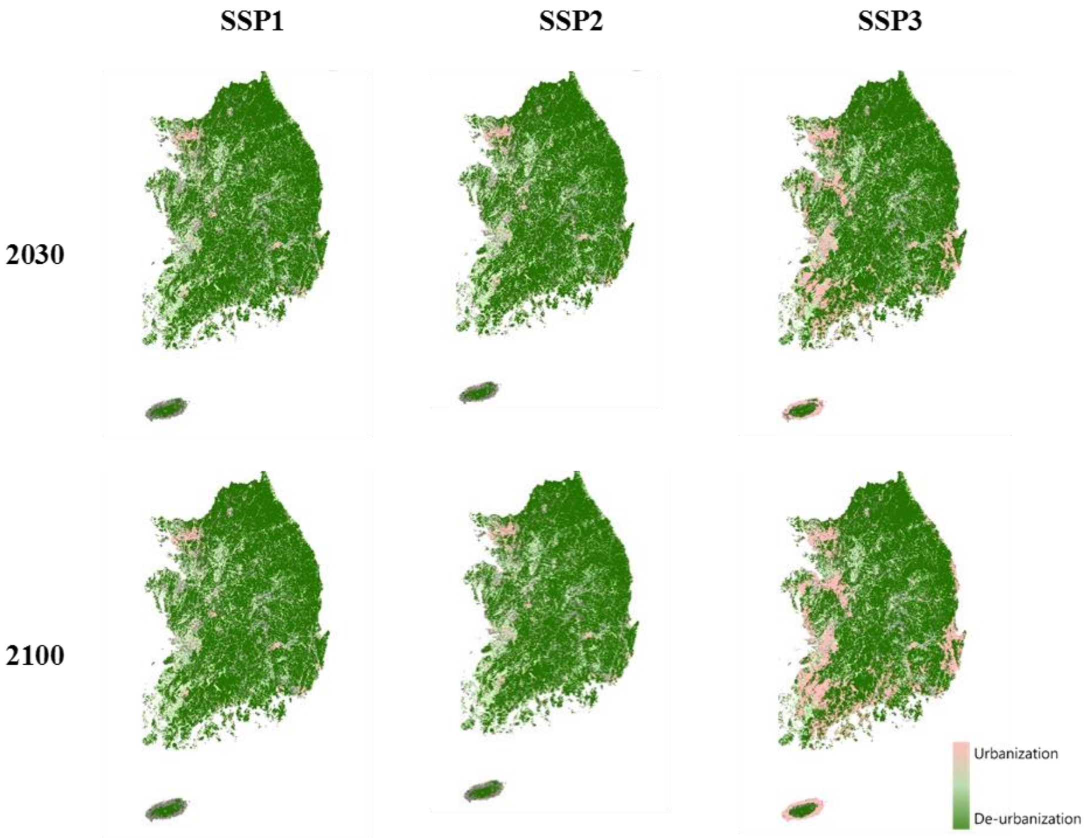

Figure 6. Urbanization level by SSPs.

4. Climate Change Policy Implications of Socio-Economic Development Pathways in Korea

The future vulnerabilities and risks of climate change are determined by the future climate and socio-economic conditions. A sensible RCP-SSP scenario combination is essential for sustainable policy decisions. Policymakers and researchers could see the influence of socio-economic development pathways by analyzing the impacts under given climate change scenario (RCPs) with different socio-economic contexts (SSPs).

The results of the PAGE simulation show that both RCP and SSP scenarios are critical as climate-change-related damage determinants. Table 2 shows the PAGE simulation results. Economic damage caused by climate change would be approximately 5.47% of GDP in Korea in 2100 under the RCP8.5-SSP3 and 0.67% under the RCP2.6 and SSP1. Under RCP4.5, the difference between socioeconomic development pathways (SSP1 and SSP3) will be 0.55% of GDP in 2100 in Korea. It will be widened by 1.52% in RCP8.5. On the other hand, for the SSP1 scenario, the results show that the difference of the economic impact between RCP2.6 and RCP8.5 will be 3.28%, while it is 4.34% in the SSP3 scenario. It highlights that socio-economic development pathways are one of the key components for future climate change impacts level. Figure 7 shows changes of economic impacts of climate change in Korea by RCP-SSP matrix.

Table 2. Major proxies for population, economy, and land use by SSPs.

Sectors	Proxies	2030		2050		2100	
		SSP1	SSP3	SSP1	SSP3	SSP1	SSP3
Population	Total population (million people)	52.66	50.66	51.82	45.09	39.93	20.53
	Ages 65+ (% of total population)	28	27	45	47	38	50
	Aged-child ratio (ACR)	2.25	2.54	4.23	5.63	2.43	5.90
	Working age population (%)	60	62	44	45	46	41
Economy	GDP (trillion KRW)	2380	1967	3137	2187	4908	2348
	GDP per capita (million KRW)	4.50	3.90	6.10	4.90	12.30	11.40
	Tertiary industry (% of GDP)	61.69	60.99	64.48	62.93	68.75	65.84
Land Use	Urban area (%)	4.60	15.30	4.60	16.70	4.60	18.10

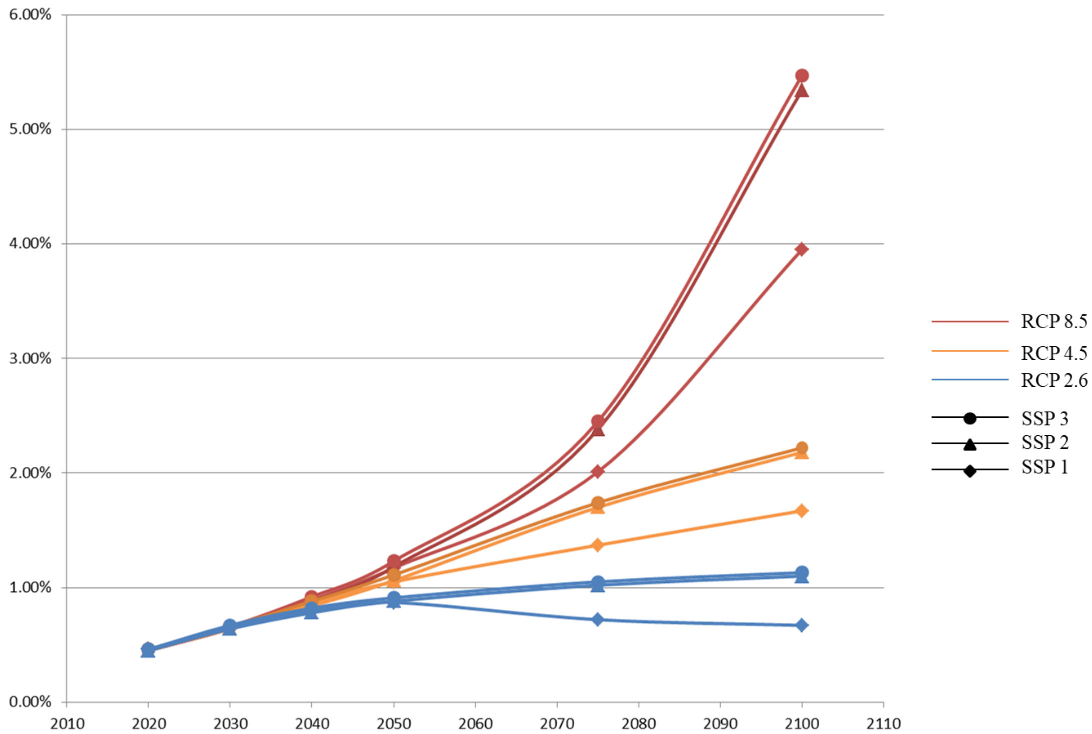

Figure 7. Economic impacts of climate change in Korea by Representative Concentration Pathways (RCP)–SSP matrix (% GDP).

The RCP–SSP scenario matrix shows the mitigation and adaptation requirements under different development pathways. In the Paris Convention, nations agreed that it was necessary to stabilize the temperature increase at less than 2 °C based on scientific research to reduce the negative effects of climate change [65]. To ensure the temperature increase remains below 2 °C, the mitigation burden varies with SSPs. SSP3 requires ambitious mitigation policies with higher costs, including rigorous international emissions trading, use of advanced low-carbon technology such as fuel cells, and higher renewable energy supply rate, as shown in Figure 8. SSP1 requires moderate mitigation with lower costs.

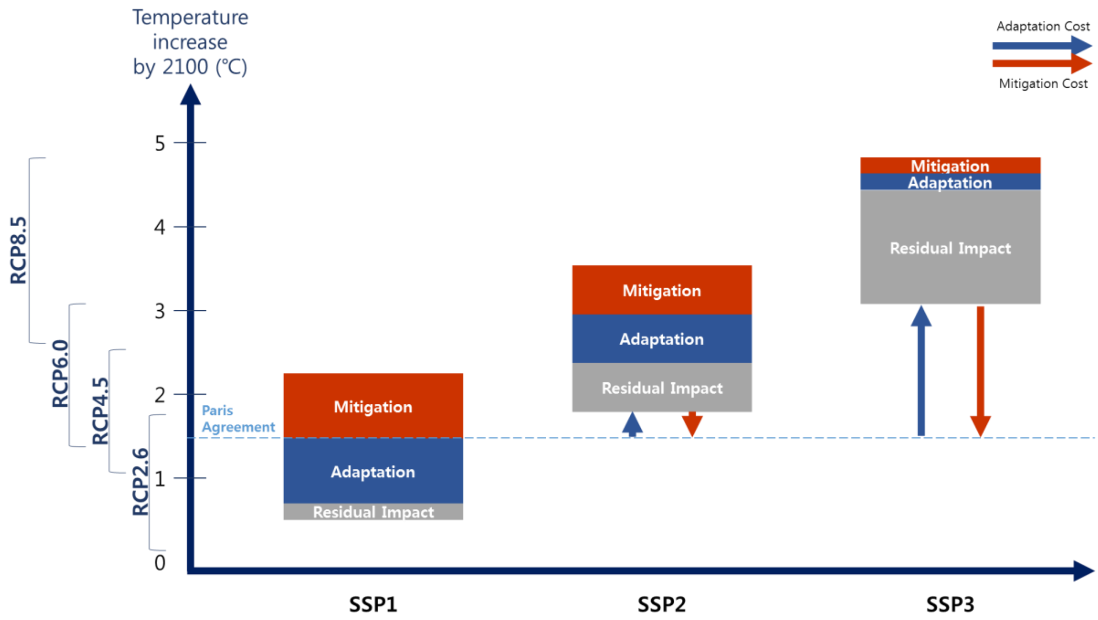

Figure 8. Mitigation and adaptation challenges by RCP-SSP matrix in Korea.

5. Conclusions

This study developed three SSPs at the sub-national level in Korea. Global assumptions were translated to reflect the Korean context. Results of main proxies are listed in Table 2. SSP1 assumes that Korea makes visible progress towards sustainable development by advancing low-carbon technology, environmentally friendly lifestyle, and low resource-intensity industrial structure. SSP3, in contrast to SSP1, is a carbon-intensive society.

This study is one of the first attempts to quantify socio-economic proxies at the sub-national level in line with global assumptions reflecting Korean circumstances. Regionally contextualized and downscaled scenarios allow policymakers to better understand the importance of potential socio-economic development pathways for climate change and sustainable development in Korea. Sustainable development pathways may generate additional incentives for local and national governments as they can reduce mitigation and adaptation policy requirements.

This study shows that the assumptions should be customized by considering regional contexts. For example, Korean population trends are different from global population trends. If we use the SSP1 global level population assumption, a drastic population decrease, Korea cannot achieve sustainable development because of depopulation. Thus, this study showed the importance of SSPs' regional contextualization.

However, further studies are required to fully apply socio-economic scenarios for regional and local sustainable development policy analysis. For adaptation, more proxies must be identified and quantified. Sectoral vulnerability assessment requires sector-specific socio-economic proxies to represent exposure (e.g., natural disaster-prone areas, infrastructure, and vulnerable population) and adaptation capacity (e.g., number of hospitals, education, and research). Quantification of extended proxies is required for SSPs. Identification and quantification of proxies for mitigation policies are also required. Mitigation policy and technology include many sectors (e.g., including transportation, buildings, energy, and industry). Policy appraisal in the long-term future requires extended proxies for capacity and activity level of each sector. Long-term endogenous relationships among variables were not sufficiently considered yet. Finally, more systematic scenario development is required for both adaptation and mitigation capacity. The current SSP framework has two axes, adaptation and mitigation policies. Often, policy analyses are conducted under a single objective, i.e., adaptation or mitigation. However, synergies and/or trade-offs do exist between adaptation and mitigation policies. To develop multifunctional policies in a specific region and time, coherent scenarios with various perspectives are essential. Climate change policies, both adaptation and mitigation, must compete with other developmental goals. Balanced socio-economic and climate pathways could help to identify optimal decision-making at global, national, and sub-national levels.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Adapted transition rules through CA simulation.

Region	Zone no.	Growth Coefficient	Transition Possibility SSP1	SSP2	SSP3	Transition Rule	Number of Simulations
Gangwon-Do	1	2	0.35	0.30	0.25	Circle 3	28
	2	2	0.40	0.35	0.30	Rectangle 7 × 7	24
	3	2	0.35	0.30	0.25	Circle 7	29
	4	2	0.40	0.35	0.30	Circle 5	27
	5	2	0.40	0.35	0.30	Circle 5	24
Gyeonggi-Do	6	3	0.40	0.35	0.30	Circle 3	17
	37	2	0.40	0.35	0.30	Circle 3	31
Gyeongsangnam-Do	7	2	0.35	0.30	0.25	Circle 5	20
	8	2	0.35	0.30	0.25	Rectangle 7 × 7	49
	9	2	0.35	0.30	0.25	Circle 5	52
	10	2	0.35	0.30	0.25	Circle 5	52
Gyeongsangbuk-Do	11	2	0.35	0.30	0.25	Circle 5	56
	12	2	0.35	0.30	0.25	Circle 2	22
	13	2	0.40	0.35	0.30	Rectangle 7 × 7	28
Gwangju	14	2	0.35	0.30	0.25	Circle 5	97
Daegu	15	2	0.40	0.35	0.30	Circle 3	36
Deajeon	16	2	0.40	0.35	0.30	Rectangle 3 × 3	19
Busan	17	2	0.35	0.30	0.25	Rectangle 3 × 3	28
Seoul	18	2	0.35	0.30	0.25	Circle 2	54
Sejong	19	2	0.35	0.30	0.25	Circle 5	64
Ulsan	20	2	0.35	0.30	0.25	Circle 5	89
Incheon	21	2	0.35	0.30	0.25	Circle 3	97
Jeollanam-Do	22	2	0.35	0.30	0.25	Rectangle 7 × 7	57
	23	2	0.40	0.35	0.30	Circle 5	32
	24	2	0.35	0.30	0.25	Circle 5	73
Jeollabuk-Do	25	2	0.40	0.35	0.30	Circle 5	46
	26	2	0.35	0.30	0.25	Rectangle 7 × 7	66
Jeju-Do	27	2	0.35	0.30	0.25	Circle 5	67
	28	2	0.35	0.30	0.25	Circle 5	63
Chungcheongnam-Do	29	2	0.40	0.35	0.30	Rectangle 7 × 7	25
	30	2	0.40	0.35	0.30	Circle 5	25
	31	2	0.35	0.30	0.25	Rectangle 7 × 7	71
	32	2	0.35	0.30	0.25	Rectangle 7 × 7	51
Chungcheongbuk-Do	33	2	0.40	0.35	0.30	Rectangle 5 × 5	23
	34	2	0.40	0.35	0.30	Rectangle 5 × 5	16
	35	3	0.35	0.30	0.25	Rectangle 7 × 7	12
	36	2	0.40	0.35	0.30	Circle 5	28

Table A2. Population size and structure for each scenario.

SSP	Population	Proxies	2010	2030	2050	2075	2100
SSP1	Size	Total zpopulation	50,515,666	52,656,373	51,821,658	44,552,924	39,927,512
		Growth rate	100%	104%	103%	88%	79%
		TFR	1.23	1.62	1.81	1.97	2.10
		Life expectancy	80.79	88.88	94.56	100.23	105.00
	Structure	Age under 4	2,299,695	2,120,127	1,874,275	1,869,520	2,140,901
		Aged 5–15	5,720,274	4,338,334	3,696,521	3,853,889	4,177,097
		Aged 15–64	36,989,345	31,695,922	22,683,520	18,889,877	18,291,230
		Age 65+	5,506,352	14,501,990	23,567,342	19,939,638	15,318,284
		Age 80+	972,733	3,920,753	11,467,147	12,959,584	9,505,630
		Proportion of working age population	73%	60%	44%	42%	46%
		Child Dependency Ratio	21.68	20.38	24.56	30.30	34.54
		Aged-Child Ratio	0.69	2.25	4.23	3.48	2.43
		Female/male ratio	100.42	100.24	100.83	103.29	103.85
SSP2	Size	Total population	50,515,666	51,341,868	47,993,192	36,855,843	28,312,039
		Growth rate	100%	102%	95%	73%	56%
		TFR	1.23	1.47	1.56	1.64	1.70
		Life expectancy	80.79	87.42	91.85	96.27	100.00
	Structure	Age under 4	2,299,695	1,849,582	1,458,404	1,175,949	1,064,903
		Aged 5–15	5,720,274	3,992,708	3,029,448	2,536,900	2,246,520
		Ages 15–64	36,989,345	31,321,863	21,231,225	15,380,443	12,299,141
		Age 65+	5,506,352	14,177,715	22,274,115	17,762,551	12,701,475
		Age 80+	972,733	3,717,509	10,306,482	10,967,647	7,795,929
		Proportion of working age population	73%	61%	44%	42%	43%
		Child Dependency Ratio	21.68	18.65	21.14	24.14	26.92
		Aged-Child Ratio	0.69	2.43	4.96	4.78	3.83
		Female/male ratio	100.42	100.12	100.30	103.34	104.60
SSP3	Size	Total population	50,515,666	50,659,561	45,088,866	31,042,558	20,527,843
		Growth rate	100%	100%	89%	61%	41%
		TFR	1.23	1.37	1.38	1.39	1.40
		Life expectancy	80.79	85.96	89.14	92.32	95.00
	Structure	Age under 4	2,299,695	1,677,352	1,173,737	763,319	532,201
		Aged 5–15	5,720,274	3,792,160	2,568,251	1,728,869	1,218,867
		Aged 15–64	36,989,345	31,284,760	20,298,597	12,922,500	8,448,924
		Age 65+	5,506,352	13,905,289	21,048,281	15,627,870	10,327,851
		Age 80+	972,733	3,526,785	9,152,246	9,034,615	6,088,629
		Proportion of working age population	73%	62%	45%	42%	41%
		Child Dependency Ratio	21.68	17.48	18.43	19.29	20.73
		Aged-Child Ratio	0.686	2.542	5.625	6.271	5.898
		Female/male ratio	100.42	99.42	99.49	102.96	105.03

Table A3. GRDP by region and SSP.

							Unit: Trillion KRW	
Region	**SSPs**	**2010**	**2020**	**2030**	**2040**	**2050**	**2075**	**2100**
Seoul	SSP1	267,701	412,720	571,541	704,315	784,662	575,900	575,212
	SSP2	267,701	368,131	467,344	541,853	580,859	441,061	432,834
	SSP3	267,701	313,830	338,041	338,264	318,969	201,797	185,230
Busan	SSP1	58,318	85,916	118,619	145,798	160,534	101,628	86,506
	SSP2	58,318	76,751	96,042	110,025	116,291	87,026	87,495
	SSP3	58,318	65,589	70,471	70,161	65,060	34,849	27,124
Daegu	SSP1	35,889	53,959	74,054	90,346	98,986	62,538	44,565
	SSP2	35,889	48,211	60,281	68,947	72,943	53,797	50,882
	SSP3	35,889	41,208	44,022	43,503	40,131	21,416	13,945
Incheon	SSP1	55,503	91,113	142,245	199,918	257,054	271,409	287,456
	SSP2	55,503	81,495	115,343	151,400	187,303	230,990	192,662
	SSP3	55,503	69,770	84,869	96,543	104,267	91,926	88,651
Gwangju	SSP1	25,303	41,718	61,309	81,574	99,135	93,685	75,399
	SSP2	25,303	37,309	49,446	60,900	70,668	74,656	51,980
	SSP3	25,303	31,934	36,556	39,368	40,193	31,769	23,296
Daejeon	SSP1	26,620	42,630	56,110	68,187	74,025	43,676	36,463
	SSP2	26,620	38,071	46,788	53,991	57,374	41,665	32,748
	SSP3	26,620	32,519	33,308	32,806	30,026	15,042	11,491
Ulsan	SSP1	50,435	77,427	124,685	187,849	265,349	411,931	520,264
	SSP2	50,435	69,621	98,739	133,046	172,567	270,451	293,779
	SSP3	50,435	60,031	76,019	93,230	110,670	139,872	159,243
Sejong	SSP1	-	14,339	34,497	46,632	57,178	59,370	70,453
	SSP2	-	12,875	28,309	35,307	40,661	40,246	43,990
	SSP3	-	11,082	20,884	22,887	23,499	19,826	21,230

Table A3. *Cont.*

							Unit: Trillion KRW	
Region	**SSPs**	**2010**	**2020**	**2030**	**2040**	**2050**	**2075**	**2100**
Gyeonggi	SSP1	230,324	389,238	556,682	703,118	792,494	508,555	489,623
	SSP2	230,324	348,374	463,441	565,619	639,343	558,587	549,307
	SSP3	230,324	298,534	332,868	340,185	321,646	171,298	149,897
Gangwon	SSP1	28,798	45,185	69,788	100,112	133,564	167,276	195,729
	SSP2	28,798	40,360	55,249	71,516	88,412	120,792	127,727
	SSP3	28,798	34,489	41,401	48,035	53,908	57,092	61,193
Chungbuk	SSP1	36,192	58,690	90,103	135,007	198,064	527,401	604,959
	SSP2	36,192	52,589	72,279	96,585	125,893	236,650	273,545
	SSP3	36,192	45,142	54,089	65,543	80,488	175,975	182,956
Chungnam	SSP1	74,817	93,996	124,331	172,125	226,826	336,978	415,673
	SSP2	74,817	84,396	102,027	130,325	161,305	228,430	259,539
	SSP3	74,817	72,640	75,270	84,479	93,220	112,527	125,256
Jeonbuk	SSP1	34,859	53,127	81,291	116,684	156,441	225,026	272,052
	SSP2	34,859	47,550	64,186	82,613	102,277	147,310	161,373
	SSP3	34,859	40,754	48,555	56,289	63,177	75,202	82,754
Jeonnam	SSP1	54,017	79,578	118,358	170,080	242,930	584,268	710,095
	SSP2	54,017	71,346	93,024	116,691	144,097	242,276	284,086
	SSP3	54,017	61,291	71,183	82,706	98,782	194,016	213,480
Gyeongbuk	SSP1	80,611	121,740	187,880	281,200	413,029	865,966	964,090
	SSP2	80,611	109,264	146,465	189,580	241,447	423,645	528,858
	SSP3	80,611	93,996	113,542	137,666	169,237	288,591	290,124
Gyeongnam	SSP1	82,637	129,880	189,427	258,481	334,350	482,422	544,727
	SSP2	82,637	116,456	151,086	185,142	217,881	280,366	343,724
	SSP3	82,637	100,051	114,022	125,913	136,319	160,829	164,312
Jeju	SSP1	10,557	16,802	27,871	42,561	59,797	91,699	111,361
	SSP2	10,557	15,009	22,300	31,377	42,042	70,448	79,185
	SSP3	10,557	12,829	16,509	20,340	23,976	31,016	34,607

Table A4. Results of proxies in the economic sector.

Elements	**Proxies**	**SSPs**	**2010s**	**2030s**	**2050s**	**2075s**	**2100**
National economy	GDP growth rate (%)	SSP1	4.60	2.91	2.20	0.87	0.42
		SSP2	3.45	2.10	1.55	0.59	0.27
		SSP3	1.86	0.77	0.44	0.11	0.03
	GDP (trillion KRW)	SSP1	1153	2380	3137	3950	4908
		SSP2	1153	2148	2550	2974	3447
		SSP3	1153	1967	2187	2285	2348
	GDP per capita (million KRW)	SSP1	2.3	4.5	6.1	8.9	12.3
		SSP2	2.3	4.2	5.3	8.1	12.2
		SSP3	2.3	3.9	4.9	7.4	11.4
	GNI (trillion KRW)	SSP1	1161	2647	4385	5448	6047
		SSP2	1161	2147	3083	3573	3820
		SSP3	1161	1583	1786	1836	1848
	Employment rate (%)	SSP1	60.9	61.6	61.8	61.8	61.8
		SSP2	60.9	61.9	62.9	63.9	65.9
		SSP3	60.9	62.1	63.4	64.0	64.6
Regional economy	GRDP (trillion KRW)	SSP1	1153	2629	4354	5410	6005
		SSP2	1153	2182	3089	3593	3866
		SSP3	1153	1572	1774	1823	1835
	Financial independence rate (%)	SSP1	54.8	65.8	78.6	87.6	97.0
		SSP2	54.8	63.9	75.6	83.4	92.4
		SSP3	54.8	62.0	72.6	79.3	87.8
Economy structure	Primary industry (% GDP)	SSP1	2.4	1.8	1.2	0.9	0.7
		SSP2	2.4	2.0	1.4	1.2	1.0
		SSP3	2.4	2.0	1.4	1.2	1.0
	Secondary industry (% GDP)	SSP1	37.8	36.5	34.3	32.2	30.6
		SSP2	37.8	37.0	35.7	34.3	33.2
		SSP3	37.8	37.0	35.7	34.3	33.2
	Tertiary industry (% GDP)	SSP1	59.9	61.7	64.5	66.9	68.8
		SSP2	59.9	61.0	62.9	64.5	65.8
		SSP3	59.9	61.0	62.9	64.5	65.8
International economy	Export (% GDP)	SSP1	55.9	57.0	57.6	57.9	58.2
		SSP2	55.9	56.9	57.4	57.6	57.9
		SSP3	55.9	56.9	57.4	57.6	57.9
Production and consumption	Productivity (%)	SSP1	100	256.1	591.0	881.0	1009.6
		SSP2	100	209.1	435.8	686.4	889.9
		SSP3	100	209.1	435.9	686.4	889.9
	Productivity trend (%)	SSP1	-	3.9	2.1	1.5	0.8
		SSP2	-	2.85	1.94	1.28	0.60
		SSP3	-	2.85	1.94	1.28	0.60

Table A5. Results of land use change in SSPs.

							(Unit: %)
Factor	**SSP**	**2020**	**2030**	**2040**	**2050**	**2075**	**2100**
Urban Area	SSP1	4.60	4.60	4.60	4.60	4.60	4.60
	SSP2	5.30	5.30	5.30	5.30	5.30	5.30
	SSP3	13.90	15.30	16.20	16.70	17.50	18.10
Forest Area	SSP1	64.70	64.70	64.70	64.70	64.70	64.70
	SSP2	64.60	64.60	64.60	64.60	64.60	64.60
	SSP3	61.60	60.90	60.40	59.70	59.50	59.10
Agricultural Area	SSP1	18.40	18.40	18.40	18.40	18.40	18.40
	SSP2	18.10	18.10	18.10	18.10	18.10	18.10
	SSP3	14.70	14.40	14.20	14.10	13.90	13.80
Other Area	SSP1	12.30	12.30	12.30	12.30	12.30	12.30
	SSP2	12.00	12.00	12.00	12.00	12.00	12.00
	SSP3	9.70	9.40	9.30	9.20	9.00	9.00

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