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Sustainability Science and Implementing the Sustainable Development Goals

Inclusive wealth of regions: the case of Japan

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Abstract The Inclusive Wealth Index (IWI) is a stock-based comprehensive indicator used to evaluate sustainability based on the wealth of nations, including a finer scale that considers the wealth of regions, in which these indicators are required for governance in the administrative regional hierarchies to achieve Sustainable Development Goals. However, few studies have applied the measure to finer-scale wealth relative to the national level. In this paper, we fill the gap by examining the IWI in all prefectures in Japan, where sustainability is increasingly being lost as a result of depopulation, an aging population, and the excessive burden of environmental regulations. We determined that all regions in Japan maintained sustainability from 1991 to 2000. Then, regional sustainability was lost in 8 prefectures from 2001 to 2005 and in 28 prefectures from 2006 to 2010. This trend is consistent with those found in previous studies, though more severe. The decreasing wealth growth is caused by the increasing damage to health capital, mainly in rural areas, whereas produced capital has had positive effects but has not mitigated the damage. Finally, we illustrate how this index can be applied to evaluate projects in response to the intense debate in regional public policy for rural sustainability through a case study of seawalls as a recovery project in the wake of the Great East Japan earthquake.

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Introduction

Sustainable Development Goals (SDGs) aim to achieve various social, economic, and environmental issues summarized by 17 goals in the Agenda 2030 for both developing countries and developed countries as a result of the cross-border obstacles (e.g., pollution and trade). Sustainable growth in developed countries has been hampered by the burden of environmental regulation, aging populations and regional disparities in wealth within a country (Wright and Lund 2000; Tachibanaki and Urakawa 2012). The regional disparities in wealth as a result of aging and future depopulation, which are leading to an unsustainable society, have become increasingly common, particularly in Japan (Abe and Alden 1988; Han et al. 2012; Tachibanaki and Urakawa 2012; Hayashi 2015).

As a key solution for the regional problems of SDGs in developed countries, good governance should be developed at all levels, from the national to the regional (Sacks 2012; UN General Assembly 2015). The promotion of good governance is beset by two key challenges: (1) improving a comprehensive indicator to judge sustainability and (2) ensuring the consistent application of the indicator to various regional levels, from the local to the national level.

With regard to the first point, Dasgupta et al. (2015) suggest that SDGs should be evaluated with an objective and simple indicator that determines whether the regions are sustainable; however, the socio-ecological aspects of widespread SDGs make it difficult to evaluate the performance of governance in each region (Zurlini and Girardin 2008). Indicators for the comprehensive evaluations of sustainability, which indicate non-decreasing regional wealth, have been controversial because several factors have not been fully reflected because the GDP, which is recognized as a proxy for wealth, does not include the depletion of natural resources and non-market services (e.g., the depletion of forests, household jobs, and ecosystem services; for further detail, see Coyle 2014). Therefore, as sustainability criteria, flow-based indicators are inadequate for representing wealth, which has resulted in the need for stock-based indicators to evaluate wealth, such as the Inclusive Wealth Index (IWI) applied in this study (Mumford 2016; Walker et al. 2010). The IWI measures the productive base for the wealth of future generations as the accumulation of various capital values. Moreover, the IWI is a superior indicator of sustainability as a result of both a theoretical foundation from welfare economics and the rich policy implications regarding what capital should be invested into realize a sustainable economy (e.g., Arrow et al. 2012; Dasgupta 2009; Dasgupta et al. 2015; Heal and Kriström 2005).

However, with regard to the second challenge, indicators of sustainable development are not well integrated from the local level to the national level. This issue has caused heightened tensions regarding the policy priorities of the central authorities vs. the regional authorities for the promotion of sustainable development (Mascarenhas et al. 2010; Zurlini and Girardin 2008). A limited number of studies estimate the IWI at the regional level: Mumford (2012) estimates the IWI at the provincial level in the USA, and Yamaguchi et al. (2016) estimate the IWI in Miyagi Prefecture, Japan. However, inclusive wealth accounting has previously been applied on a national scale (e.g., Arrow et al. 2012; UNU-IHDP and UNEP 2012, 2014). Thus, the IWI should be estimated for all regions within a country to comprehensively understand regional sustainability and to ensure consistent estimations at different levels. Furthermore, the estimation of regional wealth may indicate the heterogeneity of wealth in Japan, even if we simply investigate the disparity in sustainability between urban and rural areas.

Therefore, in this paper, we investigate the regional IWI in all 47 prefectures in Japan from 1990 to 2010 and perform a simple comparison between urban and rural areas. Furthermore, linking a policy evaluation of public infrastructure to the regional sustainability is meaningful for policymakers, even though few researchers have used the inclusive wealth concept to evaluate regional policy (e.g., Fenichel et al. (2016) focused on the effects on natural capital; Uehara et al. (2016) proposed an ecosystem evaluation method).

Our main contribution is the identification of regional sustainability trends within all 47 prefectures in Japan. We indicate that regional sustainability in Japan has been continually damaged, and most prefectures ultimately cannot secure wealth for future generations, which implies that society will become unsustainable as a result of the depletion of health capital caused by the aging population. We also clarify how the disparity in total wealth between rural and urban areas is expanding because of the decreasing quality of health capital and the declining growth rate of produced capital in rural areas; however, the growth in produced capital, including public investments, represents a vehicle of previous economic growth in rural Japan.

The remainder of this paper is structured as follows. First, we explain the analytical frame work of inclusive wealth with an overview of holistic regional sustainability in Japan. We then briefly explain the data, present the calculated IWI results and discuss how the IWI is distinct from other sustainability indices. We subsequently illustrate the application of the inclusive wealth approach to policy evaluation. The final section provides summaries and implications of this study with regard to achieving SDGs.

Framework of regional sustainability measurement

Basic inclusive wealth approach

GDP or adjusted GDP indicators are not sufficiently accurate in reflecting social well-being, even though we use subjective well-being data because part of well-being is constructed by unobserved flow-based data (Mumford 2016). The inclusive wealth approach evaluates well-being using observable stock-based data from flow-based data; moreover, the approach provides a sustainability condition based on the stock of wealth derived from the current value for future consumption (Arrow et al. 2012; Walker et al. 2010). The sustainability condition requires the non-decline of inclusive wealth per capita, which is analogous to the definition presented in the Brundtland Report (Pearson et al. 2013; WCED 1987).

We formulate an inclusive wealth approach (see Arrow et al. 2012), where the inclusive wealth at time t is intergenerational well-being, which is denoted by $V(t)$. $V(t)$ depends on a set of capital stocks, $K(t)$, through the consumption of goods and services; time-invariant exogenous events directly affect $V(t)$, which is expressed as follows:

$$V(K(t), t). \tag{1}$$

We now consider that $K(t)$ is composed of produced, natural, and human capital at time t. The capital assets are indexed by i. Non-decreasing inclusive wealth represents a suitable definition of sustainability in wealth accounting under the assumptions that $V(t)$ converges with an economic forecast at t and is a differentiable function at $K(t)$ (Mumford 2012; Arrow et al. 2012). The sustainability condition, differentiating Eq. 1 with respect to time, is indicated as follows:

$$\frac{\mathrm{d}V(t)}{\mathrm{d}t} = \sum_i \frac{\partial V(t)}{\partial K_i(t)} \frac{\mathrm{dK_i(t)}}{\mathrm{d}t} + \frac{\partial V}{\partial t} \geq 0. \qquad (2)$$

Arrow et al. (2012) defined the (spot) shadow price of capital i at time t, $p_i(t)$, as follows:

$$p_i(t) \equiv \frac{\partial V(t)}{\partial K_i(t)}. \qquad (3)$$

The definition helps us understand the first term on the right-hand side of (2) as the amount of investments in the three types of capitals at t. Thus, the perturbation of inclusive wealth in (2) is also referred to as an inclusive investment or a comprehensive investment (e.g., Mumford 2012; Arrow et al. 2012). If an inclusive regional investment is positive, then the region is sustainable because the productive capacity in the region is higher than that during the previous period.

In a practical setting, we follow Arrow et al. (2012) and assume that the shadow price is constant over time for each type of capital; then, we use an index of inclusive wealth at t, measured by the shadow value of the entire capital stock, $\sum_i P_i K_i(t)$. This practical application of IWI explicitly incorporates the exogenous factors represented by $\partial V(t)/\partial t$ in (2). These adjustment factors reflect the effects of resource trading, oil capital gains, and CO_2 emissions. Further, we include the effects of population change as an other exogeneous factor to reflect depopulation in Japan (see, e.g., Yamaguchi et al. 2016). Therefore, a positive change in inclusive wealth per capita is the most important way of assessing regional sustainability.

Regional sustainability

While assessing a sustainable economy requires regional wealth indicators, the proposed indicators are usually estimated at the national level (Graymore et al. 2008; Gradimi et al. 2015). We note two main difficulties associated with applying the IWI or other sustainability indicators at the regional level: (1) the selection of types of capital and (2) the spatial unit problem, which includes theoretical consistency between the national level and the regional level. We should thus reshape the framework of IWI measurement according to these points, as indicated below. With regard to the first point, the selection of capital stocks and data availability are essential. In the case of Japan, which is currently experiencing social structural changes because of depopulation and aging, we should include detailed human capital, such as the health capital that is estimated by Arrow et al. (2012) and UNU-IHDP and UNEP (2012). Furthermore, we include fishery capital to reflect a plentiful natural resource in the seas surrounding Japan.

With regard to the second point, the IWI can be basically applied to a finer scale (prefectures or municipalities) rather than to the national level (Mumford 2016). However, the spatial units of the indicator may cause problems. Yamaguchi et al. (2016) discuss how the spatial unit of a region is selected as appropriate for judging the regional sustainability; the desired regional unit should satisfy a limited distribution of capital assets, the institutional anatomy, data availability, the mobility of capital assets assumed as ownership, and other exogenous factors caused by exports to other regions. While several of the previously described requirements may not be satisfied, we observe prefectures rather than municipalities for the regional level because the data required to estimate the IWI, which has conditions that are essential to ensure a valid indicator of sustainability, can be obtained only at the prefecture level (e.g., Graymore et al. 2008).[1]

Regional wealth and disparity in Japan

A sustainable regional economy is realized by shrinking the regional gaps related to the living environment based on the finding that regional disparities in income or social capital negatively affect the average status of human health and happiness in Japan (Tachibanaki and Urakawa 2012, p. 164). While most studies regarding regional inequality use income data as the welfare index, the economic flow will be accumulated in the region as a part of capital stocks. Thus, a regional disparity of the flow leads to the unequal growth of capital, which may lead to unsustainability in a rural economy. Therefore, studies regarding welfare inequalities and its causes would be beneficial for understanding sustainability in Japan.

From this perspective of sustainability, we provide an overview of the regional disparity of income from 1955 to 2010. Tachibanaki (2006) indicates that income disparity, measured by Gini coefficients, did not expand at the age of the rapid economic growth that started in approximately 1955; moreover, the trend was diminished in 1973 when the 1973 oil shock placed a heavy burden on the Japanese economy. At that time, rural workers, who were mostly farmers, began benefitting from new and increasing opportunities through seasonal jobs with industrial

[1] The prefecture level may not satisfy the limited distribution of capital assets and the mobility of capital assets, and optimal solutions for spatial units in Japan are not the main object of this study. Thus, we leave this question for future research.

companies in urban areas, where they could receive relatively high wages because of economic growth; however, the higher wages that could be earned in urban areas increased the income disparity.

In turn, the regional disparity started to expand after the oil shock. The disparity continually expands during the bubble economy referred to as the period of asset price increases, which provides wealth for real and monetary asset owners. The depression after bursting the bubble economy in 1991 did not stop the expanding trend. Tachibanaki and Urakawa (2012) suggests that this trend will still be present in the future; whereas some researchers provide a different view of the disparity trend, including the gap converging after 1990.

In addition to the use of inequality indicators, a time series analysis, including a panel unit root test, or spatial econometric methods have been applied to confirm the convergence of income after 1990 (e.g., Seya et al. 2012; Otuka and Goto 2016 for the inequality of the total factor productivity). Taking a more long-term perspective—from 1955 to around 2000—Barro and Sala-i-martin (1992) and Shibamoto et al. (2016) support this convergence in prefectural level data, even though the debate continues.[2]

Behind the previously described welfare inequality in Japan, several factors drive the expansion or narrowing of this gap, including capital stocks in the IWI. For example, public investments, particularly investments in infrastructure, may reduce income disparities (e.g., Merriman 1990; Shioji 2001). The capital value of infrastructure investments is included as produced capital in the IWI; Hayashi (2015) indicates that the cost of CO_2 in rural areas, which the IWI considers a depletion factor with regard to natural capital, increases the welfare disparity. In addition, the IWI comprehensively evaluates the wealth of human capital stock, including health status and happiness, an important proxy for welfare, which cannot be proxied by income.[3] Therefore, the inclusive wealth framework services a comprehensive indicator of wealth, which is well suited for the complex economy in recent Japan. Even if a simple comparison of sustainability is calculated as the IWI between rural–urban areas, it would provide meaningful implications for regional sustainability.

Data

We briefly explain our method of regional IWI estimation: we utilize and modify an IWI database at the prefecture level in Japan during 1990–2010, as proposed in Ikeda et al. (2016). Ikeda et al. (2016) mainly rely on the methodologies used by the UNU-IHDP and UNEP (2012, 2014), but they apply them to a finer scale in Japan. In this study, the main elements of the IWI in Japan are values for produced capital, human capital (education and health), and natural capital (agricultural land, timber and non-timber forest, fisheries, minerals), and adjustment factors (resource trade, oil capital gains, CO_2 emissions) are also considered. We retrieve most of the data on human capital, natural capital, and CO_2 emission from the database in Ikeda et al. (2016). We then modify the produced capital in Ikeda et al. (2016) and estimate the other two adjustment factors.

We first explain the method for calculating the data retrieved from Ikeda et al. (2016).[4] Regarding education capital, the stock amount was calculated as $P \times \exp(rT)$, where P was the population of the workforce; r was the interest rate, which was assumed to be 8.5%; and T was the average number of years of educational attainment. In other words, the population of the workforce and educational attainment are vehicles of education capital growth. The other type of human capital, health capital, was the discounted life expectancy (5% discount rate was assumed), weighted by the population in each cohort. Thus, in regions with aging populations, the stock of health capital decreases unless the positive effect of increasing longevity compensates for the negative effect of a decreasing birth rate, which further weights the older cohort in the calculation.[5] By contrast, Ikeda et al. (2016) relied on a relatively common method to evaluate natural capital (e.g., Hamilton et al. 2005; Lange et al. 2010; Sato et al. 2015; UNU-IHDP and UNEP 2012, 2014). Ikeda et al. (2016) calculated natural capital by multiplying the amount of the asset and the net present value of the future rental flow as a proxy for the shadow price, assuming a

[2] Kawagoe (1999) reexamined the results of Barro and Sala-i-martin (1992) by applying a panel unit root technique to nearly the same datasets and obtained evidence of no convergence. However, Shibamoto et al. (2016) reconcile the debate by classifying it as results for deviation from short-run and long-run growth equilibrium; short-run deviations from regional growth equilibrium (e.g., the bursting bubble economy) reduce the inequality of income, whereas the long-run growth equilibrium from 1955 to 1999 makes inequalities among prefectures converge. The results seem to be valid if the dataset extends to 2012, which is covering our dataset period.

[3] Wilkinson and Pickett (2006) review the relationship between health and income disparity. Refer to Oshio and Kobayashi (2009, 2010) for the case of Japan.

[4] We focus on the methods for estimating the stock amount of human capital and natural capital because of several complexities arising from the estimation framework for the shadow price of human capital and CO_2 emissions, as well as the limited space for explaining these complexities here. See appendix 2 in Ikeda et al. (2016) for detailed assumptions and data.

[5] The data required for human capital are mainly obtained from the national census in Japan (1990, 1995, 2000, 2005, 2010) and life tables around the census years from the Japanese Mortality Database of the National Institute of Population and Social Security Research.

future rental flow equal to the current flow at a 5% discount rate. The future rental flow was proxied by multiplying the market price and the rental rate; the shadow price was thus calculated as the average net present value of the future rental flow. Then, the stock is the physical amount of the assets available for our consumption.[6] Ikeda et al. (2016) used the following proxies for the different stocks of capital; the volume of natural forest as the timber capital stock; the accessible area of natural forest, assumed to be 10% of the total, as the non-timber capital stock; the total crop-land area as the agricultural capital stock; the fish catch as the fishery capital stock; and the volume of mineral reserves (gold, silver and zinc) as the mineral capital stock.[7]

Then, we modify produced capital to be the accumulation of gross investments in a steady state economy. We follow a method applied by King and Levine (1994), which is referred to as the perpetual inventory method (PIM). Although Ikeda et al. (2016) only consider the effect of private investments in produced capital, we add the effect of public investments. This approach puts greater weight on produced capital in the composition of the IWI and potentially indicates how local governments efficiently plan their budgets.

Next, we estimate the effects of the resource trade and oil capital gains as adjustment factors of the IWI. From the perspective of which region is responsible for natural resource use, as indicated by Atkinson et al. (2012), we should not exclude the actual value of an imported product from the value of inclusive wealth; we should instead use a counterfactual value when the resources are obtained within the region. Therefore, the unit value of the imported product is calculated based on the resource rental rate of Japan. Although the adjustment factor of the resource trade in Japan is same as that in Ikeda et al. (2016), the value is proportionately distributed according to the value of produced capital modified in this study. Finally, the oil capital gains are calculated, and the adjustment is included in the previous data. We calculate the regional consumption share of oil using a method applied in Yamaguchi et al. (2016) and regional consumption data from a prefecture-level survey of energy consumption.[8] We subsequently distribute the capital loss of oil consumption in Japan to each region according to this rate.[9]

Unless otherwise specified, all data are computed in 2000 Japanese Yen, which have been converted using a GDP deflator obtained from International Monetary Fund (IMF) database.[10]

Results and discussion

Sustainability of each prefecture in Japan

First, we provide an overview of regional sustainability in Japan based on economic growth. As indicated in Fig. 1, sustainable growth is exhibited by the positive values for the adjusted IWI and GDP growth between 1990 and 2000 in nearly all 47 prefectures. However, many prefectures have become less sustainable since 2000. In fact, 43 prefectures exhibited negative growth rates from 2006 to 2010. We further investigate the sustainability indicator per capita as a result of the depopulation in Japan, which violates the previously described simple analysis. The growth in the adjusted IWI per capita presented in Fig. 2 indicates that the extent of sustainability is slightly reduced from 1991 to 1995 and that unsustainability is moderated from 2006 to 2010: the growth rate was negative in only 1 prefecture from 1996 to 2000, 8 prefectures from 2001 to 2005, and more than half of the prefectures (28) from 2006 to 2010. In addition, prefectures exhibiting positive economic growth (positive GDP growth per capita) should amend their policies if their sustainability has been lost. We indicate that the sustainability problem arose in 18 prefectures from 2006 to 2010.

Figure 3 investigates why the overall IWI has decreased by comparing the annual growth rates of each capital change to the non-adjusted IWI in the first year of the 5-year period. To compare the effects of population changes to those of the three main types of capital on the growth rate of IWI, we follow Arrow et al. (2012) and Yamaguchi et al. (2016) and use the intuitive definition of the per capita growth of IWI by subtracting the rate of change in the population from that in the non-adjusted IWI. We also use the same method to calculate the effects of the other adjustment factors. Figure 3 indicates that human capital had a negative effect on IWI growth, particularly since 2001, although the negative effects of adjustment factors remained high. As indicated in Fig. 4, the effect of human capital mainly pertained to health capital. Health capital had decreased even more since 2001 to approximately the same degree as human capital. Moreover,

[6] The data were mainly available from statistical surveys of the Ministry of Agriculture, Forestry and Fisheries (MAFF).

[7] Ikeda et al. (2016) relied on the value of mineral capital in Japan, as estimated by Sato et al. (2015).

[8] Agency for Natural Resource and Energy, http://www.enecho.meti.go.jp/statistics/energy_consumption/ec002/results.html#headline5. Accessed Sep 2016.

[9] The global data on capital gains and consumption, in this case for Japan, are available from the BP Statistical Review of World Energy June 2015.

[10] IMF, http://www.imf.org/external/pubs/ft/weo/2015/01/weodata/weorept.aspx?sy=1980&ey=2020&scsm=1&ssd=1&sort=country&ds=.&br=1&pr1.x=28&pr1.y=18&c=158&s=NGDP_D&grp=0&a=. Accessed Dec 2015.

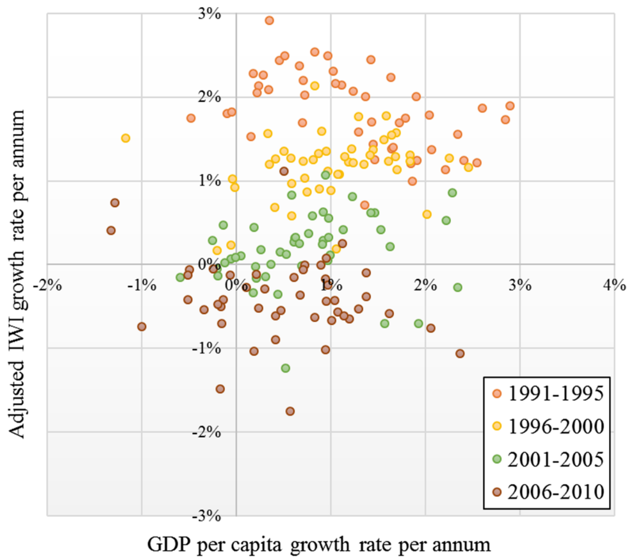


Fig. 1 Adjusted IWI growth rate and GDP per capita growth rate. The adjusted IWI growth rate is calculated as the average annual growth over 5 years

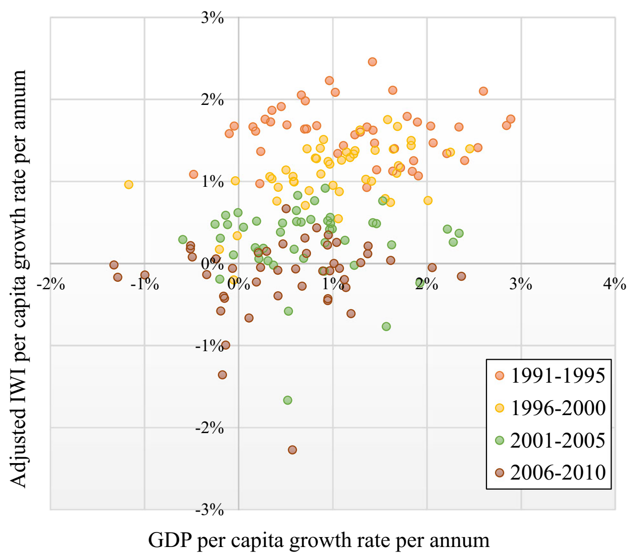


Fig. 2 Adjusted IWI per capita growth rate and GDP per capita growth rate. This estimation is calculated in the same way explained in Fig. 1

produced capital and natural capital had a positive effect on IWI growth, although produced capital could not ultimately compensate for the damage to human capital. Recent depopulation, which automatically increased the calculation if other factors were maintained, had a positive effect on the adjusted IWI growth per capita, explaining the recent moderated loss of the IWI, as previously indicated.

Furthermore, we confirm the consistency of our results and an aggregated IWI in Japan with the findings of previous research. From the database of UNU-IHDP and UNEP (2014), the IWI per capita in Japan continually decreases but exhibits positive values from 1990 to 2010 (see Muñoz et al. 2014). This tendency of the IWI per capita is approximately the same when we account for the IWI per capita growth without adjustments, as indicated in the appendix. The comparison also supports the robustness of our results. In contrast to our results, human capital indicates a positive contribution to the IWI growth in appendix 1 of Muñoz et al. (2014), even though the signs of the contributions of produced capital and natural capital are the same. This difference may arise because Muñoz et al. (2014) only considered education capital for human capital, which also had a positive impact on the IWI growth in our results.[11] These findings indicate that health capital should be empirically included in human capital, as suggested in Arrow et al. (2012).

Urban–rural disparity in sustainability

We categorize 47 prefectures into rural, urban, and hybrid areas based on GDP, as in Hayashi (2015) and, subsequently, investigate the disparity in sustainability between urban and rural areas.[12] In general, the growth rates of the adjusted IWI in both rural and urban areas have decreased as a result of the decreased growth of produced capital over 20 years, as shown in Table 1. Furthermore, the growth rate of the adjusted IWI decreased more in rural areas than in urban areas from 1990 to 2010 (5th column in Table 1). The urban–rural disparity in the adjusted IWI is amplified by the disparity in human capital that seems to be caused by rapid decreasing of it in rural areas. However, the per capita statistics for rural areas are contradictorily higher than those in urban areas (7th column in Table 1) due to depopulation, which we discuss below. In other words, sustainability in urban areas was relatively worse than that in rural areas; in addition, it has not been maintained in urban areas recently.

The rural–urban disparity in the growth of the adjusted IWI had increased since 1996. As shown in Tables 1 and 2, the disparity in human capital, particularly health capital, has been a major factor in this widening gap. Produced capital was a factor reducing the disparity from 1996 to

[11] Muñoz et al. (2014) reported that produced capital, human capital (only education capital), and natural capital accounted for 63 percent, 36 percent, and approximately 0 percent of the average annual growth rate of the IWI in Japan over a 20-year period.

[12] Nine prefectures are identified as rural areas (Aomori, Akita, Iwate, Yamagata, Kochi, Saga, Kumamoto, Miyazaki, and Kagoshima); ten as urban areas (Saitama, Tokyo, Kanagawa, Gifu, Aichi, Kyoto, Osaka, Hyogo, Hiroshima, and Fukuoka). We omit the other prefectures for simplicity. The calculation of the annual growth ratios for each component in IWI are based on aggregated values in above prefectures in each area (rural and urban). Thus, the aggregated values per capita are almost same as weighted average values among prefectures in an area by the population though we use the approximation for it.

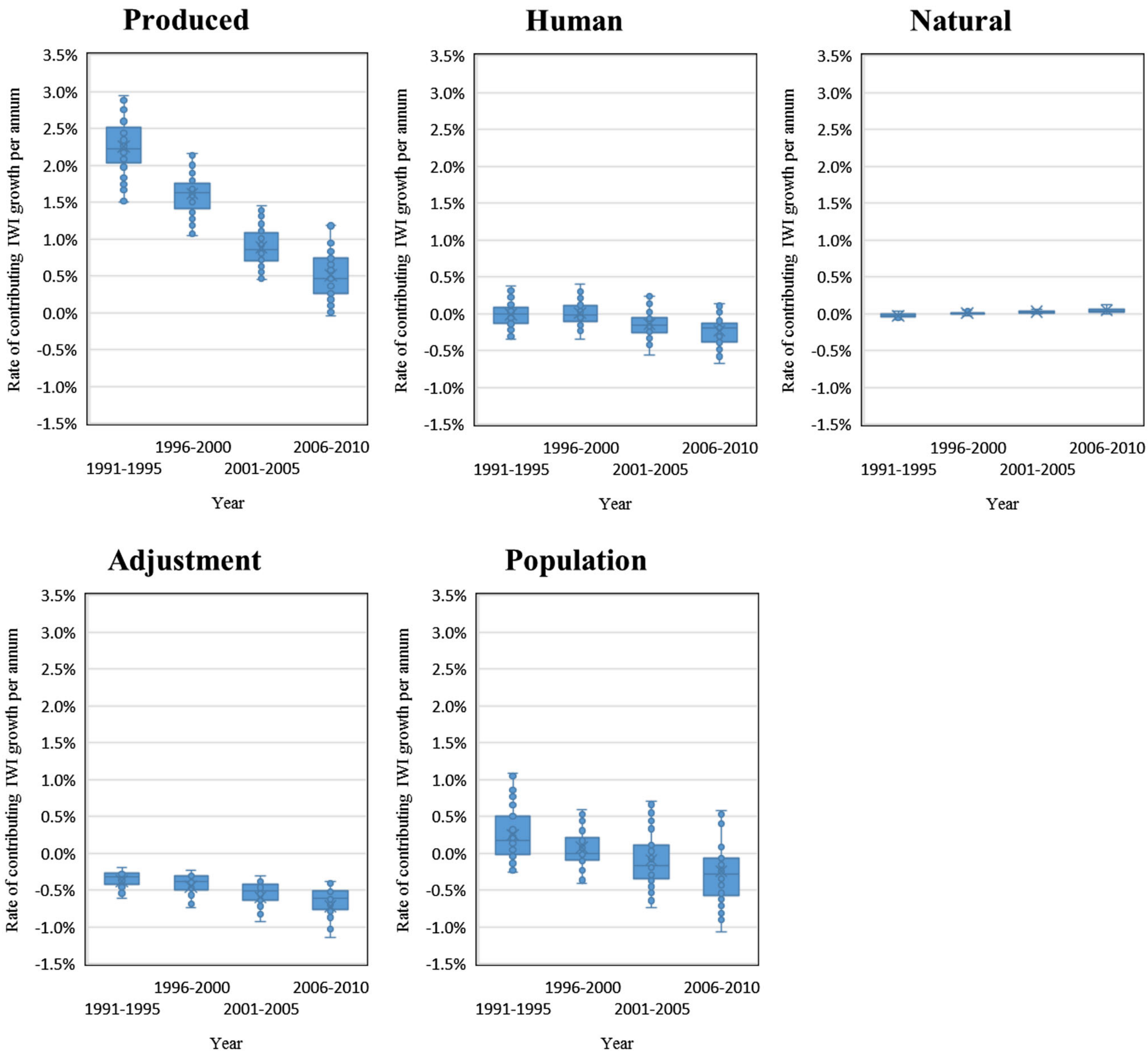
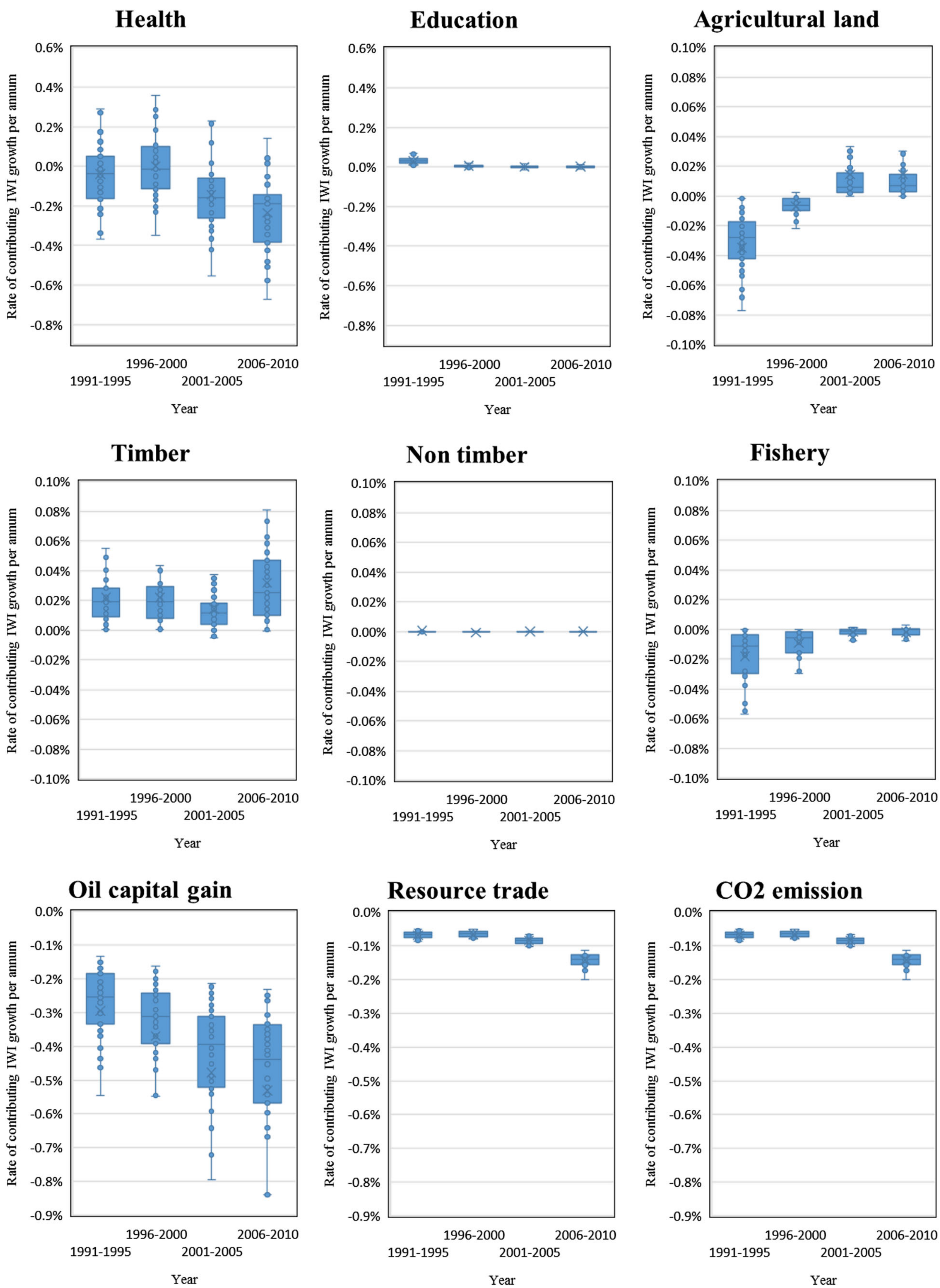


Fig. 3 Five-year compound annual growth rate of capital in the IWI growth from 1991 to 2010. The contributing rate was calculated based on changes in the capital value to the non-adjusted IWI in the previous year. This type of capital is listed above each figure. *Box* 25th and 75th percentiles; *bars* min and max values. The *scatter plot* also shows individual data for each prefecture inside the *box*

2000; however, this factor has contributed to the increased disparity since 2001. Natural capital has had a small yet decreasing effect on the disparity since 1996. We should note that the expanding effect of produced capital on the regional disparity, except from 1996 to 2000, may conflict with the results regarding the positive effect of TFP in Otuka and Goto (2016), which was an adjusted factor for produced capital in the database of UNU-IHDP and UNEP (2014).[13] If we include the TFP adjustment in the estimated IWI data, our results regarding produced capital may be similar to those of Muñoz et al. (2014). However, we leave this avenue open for future research because of the inadequacy of TFP data at the prefectural level, as suggested by Yamaguchi et al. (2016).

As indicated in Table 1, the adjustment factors in this research appear to have a decreasing effect on the rural–urban disparity similar to the effect of natural capital. As indicated in Table 2, the depletion of natural capital because of CO2 emissions seems to help reduce the gap, which may also conflict with the results of Hayashi (2015). With regard to other adjustment factors, oil capital gains have also helped

13 Higashikata (2013) suggests not only the same effect of public investment as that in Otuka and Goto (2016) but also the opposite effect of private investment on the disparity.


Health
0.6%
0.4%
0.2%
0.0%
-0.2%
-0.4%
-0.6%
-0.8%
Rate of contributing IWI growth per annum
1991-1995
1996-2000
2001-2005
2006-2010
Year
Education
Agricultural land
0.10%
0.08%
0.06%
0.04%
0.02%
0.00%
-0.02%
-0.04%
-0.06%
-0.08%
-0.10%
Timber
Non timber
Fishery
Oil capital gain
0.0%
-0.1%
-0.2%
-0.3%
-0.4%
-0.5%
-0.6%
-0.7%
-0.8%
-0.9%
Resource trade
CO2 emission

◀**Fig. 4** Detailed factors contributing to the IWI in terms of human capital, natural capital, and adjustment factors. This note is the same as that described in Fig. 3

reduce the gap because the total absolute value is large and the negative effect is focused on an industrialized rural area with a distribution weight for each prefecture in this study.

As an exogenous factor, population change has had the most pronounced effect on the disparity in the IWI per capita, and made the sign of the disparity change. The disparity in the adjusted IWI per capita was positive, 0.02%, in the first 5 years. However, the increased disparity in the population sufficiently complemented the increased gap in produced and human capital in Table 1, resulting in a negative sign and a reduction in the urban–rural disparity, which conflicts with the

Table 1 Changes in urban–rural disparity in the IWI per annum (%)

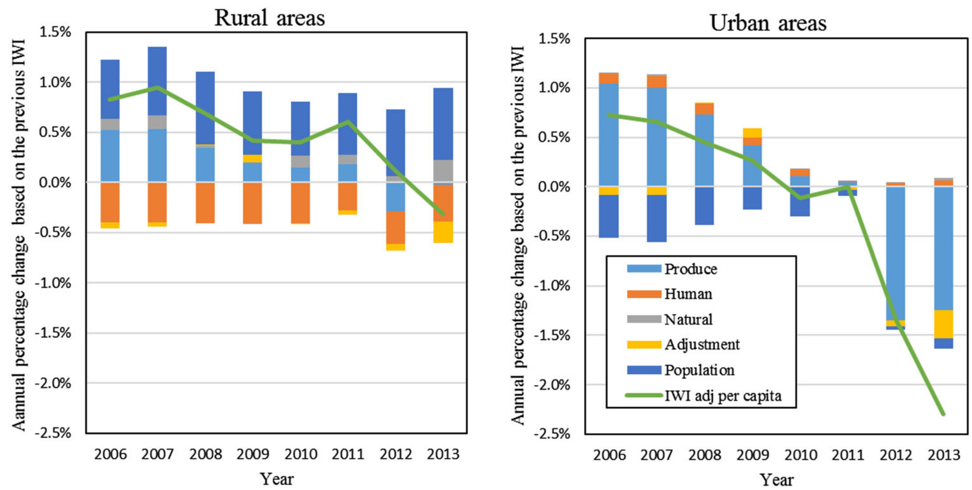
	Produced capital	Human capital	Natural capital	Adjustment factors	Adj IWI[a]	Population growth	Adj IWI per capita
Urban area							
1991–1995	2.34	−0.05	0.00	−0.41	1.91	0.33	1.58
1996–2000	1.46	0.22	0.00	−0.46	1.22	0.38	0.85
2001–2005	0.91	0.07	0.00	−0.59	0.41	0.40	0.02
2006–2010	0.66	0.10	0.01	−0.72	0.06	0.36	−0.30
Rural area							
1991–1995	2.09	−0.12	−0.03	−0.32	1.65	0.02	1.63
1996–2000	1.63	−0.14	0.02	−0.38	1.16	−0.12	1.28
2001–2005	0.79	−0.29	0.05	−0.50	0.06	−0.40	0.47
2006–2010	0.35	−0.41	0.08	−0.58	−0.56	−0.64	0.08
Urban–rural disparity							
1991–1995	0.25	0.07	0.03	−0.09	0.26	0.32	0.02
1996–2000	−0.17	0.35	−0.02	−0.08	0.06	0.50	−0.36
2001–2005	0.12	0.37	−0.04	−0.09	0.35	0.80	−0.37
2006–2010	0.31	0.51	−0.07	−0.14	0.62	1.00	−0.26

[a] Total growth rate for produced capital, human capital, natural capital, and adjustment factors, except population growth

Table 2 Changes in urban–rural disparity in the IWI per annual in detailed types of capital (%)

	Human capital		Natural capital					Adjustment factors		
	Health	Education	Agricultural land	Non-timber	Timber	Fishery	Mineral	Oil capital gains	Resource trade	CO_2 emissionss
Urban area										
1991–1995	−0.09	0.04	−0.01	0.00	0.00	0.00	0.00	−0.29	−0.07	−0.04
1996–2000	0.21	0.00	0.00	0.00	0.00	0.00	0.00	−0.35	−0.07	−0.04
2001–2005	0.07	0.00	0.00	0.00	0.00	0.00	0.00	−0.45	−0.09	−0.04
2006–2010	0.08	0.01	0.00	0.00	0.01	0.00	0.00	−0.53	−0.14	−0.04
Rural area										
1991–1995	−0.14	0.01	−0.05	0.00	0.04	−0.03	0.00	−0.22	−0.07	−0.03
1996–2000	−0.14	0.00	−0.01	0.00	0.04	−0.01	0.00	−0.29	−0.06	−0.03
2001–2005	−0.29	0.00	0.02	0.00	0.03	0.00	0.00	−0.39	−0.08	−0.02
2006–2010	−0.41	0.00	0.02	0.00	0.06	0.00	0.00	−0.41	−0.14	−0.02
Urban–rural disparity										
1991–1995	0.05	0.02	0.04	0.00	−0.04	0.02	0.00	−0.06	−0.01	−0.02
1996–2000	0.36	0.00	0.01	0.00	−0.04	0.01	0.00	−0.06	0.00	−0.01
2001–2005	0.36	0.00	−0.02	0.00	−0.03	0.00	0.00	−0.07	0.00	−0.01
2006–2010	0.49	0.01	−0.02	0.00	−0.05	0.00	0.00	−0.12	−0.01	−0.01

Fig. 5 Comparing recent changes in the IWI and related factors in rural and urban areas. The annual percentage change for each main type of capital is calculated based on the IWI in the previous year. The adjusted IWI per capita reflects the overall changes for each type of capital with the adjustments



figures suggested by the Genuine Progress Indicator in Japan (see Hayashi 2015).

The magnitude of the health capital effect on the urban–rural disparity could not be overlooked. The magnitude may be proportional to the population changes in both areas if the health stock per capita in both areas was at the same level and changed to the same extent.[14] We further investigate the changes in the health stock per capita in both areas and the related gaps, as indicated in Table 3. The health stock per capita became positive, thus widening the gap, though not from 1991 to 1995. Moreover, urban areas exhibited a limited recovery period from 1996 to 2000 and in recent years, whereas rural areas continued to deteriorate. The decreasing trend in both areas may be caused by the negative effect of the decreasing birth rate exceeding the positive effect of increasing longevity in Japan, according to the method used to calculate discounted life expectancy. Thus, the aging population in rural areas may explain the decreasing health capital from 1996 to 2010.

Implications for regional policies

Previous research has indicated the negative effects of regional disparities in wealth on health status, happiness and life satisfaction (e.g., Oshio and Kobayashi 2009, 2010 for Japan; Alesina et al. 2004 for Europe and the USA). In this study, the social status of sustainability may affect individual wealth. This type of discussion focuses on the problem of regional disparity and provides policy implications regarding social security (e.g., Tachibanaki and Urakawa 2012). If the disparity in sustainability faces this problem, this study may support the need to invest in nursing care insurance and the childcare system to recover health capital in rural areas.

When we estimate the IWI from 2011 to 2013 through simple exploration, as indicated in Fig. 5, the growth rates of the adjusted IWI per capita in both areas are negative or close to zero.[15] Moreover, the gap in the IWI has also increased as a result of the losses in produced capital in urban areas and gains in rural areas. This trend reflects the significant impacts of the Great East Japan earthquake that occurred in the Tohoku region, in which some prefectures categorized as rural areas are located. In the recovery phase, the state invested heavily in rural areas, which may have resulted in an increase in produced capital. This IWI analysis could not effectively evaluate the effects of investments in produced capital after the disaster; however, wealth-based evaluations of specific investment projects would be of interest to policymakers. Thus, we subsequently discuss how we could evaluate the project with regard to inclusive wealth.

Application of inclusive wealth to the project evaluation

In this section, we focus on the evaluation of projects. A cost benefit analysis (CBA) has conventionally been used to evaluate projects. Such analysis may indicate whether projects should be completed; however, it is not sufficient for measuring the sustainability of regions. Thus, we introduce the concept of a cost benefit analysis including

[14] We assume the shadow price of health capital in each area is a constant value during the evaluation period; thus, we avoid considering the effects of the gap of shadow prices in both areas.

[15] We update the IWI database by assuming constant shadow prices for each type of capital because shadow prices do not fluctuate under a stable economy with inclusive wealth accounting. We extrapolate only 3 years to compare with the 20-year database. Nonetheless, we update the data on capital stocks that have a major impact on the composition of IWI. Thus, health capital in 2013 is estimated using updated life tables and then interpolating missing data in 2011 and 2012 through linear interpolation. Produced capital, almost all natural capital and the adjustment factors are estimated from 2011 to 2013. However, we only extrapolate the stock of education capital, mineral capital and CO_2 emissions due to limited data availability and the small impacts on the IWI.

Table 3 Changes in health stock per capita per annum (%)

	Urban	Rural	Disparity
1991–1995	−0.46	−0.24	−0.21
1996–2000	0.09	−0.17	0.26
2001–2005	−0.28	−0.28	0.01
2006–2010	−0.26	−0.39	0.14

inclusive wealth (CBIW), based on the social cost benefit analysis stated in Dasgupta (2009). In comparing two cost benefit analyses, we characterize CBIW.

Seawall in Tohoku as an evaluative case study

In 2011, the unprecedented Great East Japan earthquake and tsunami devastated the Tohoku region in Japan. The tsunami caused catastrophic damage. After this terrible experience, the Ministry of Land, Infrastructure and Transport (MLIT) provided guidelines for building seawalls to mitigate the impact of such disasters. The MLIT divided tsunamis into 2 levels: level-1 tsunamis (L1) occur relatively frequently (once per decade or century), and level-2 tsunamis (L2) are the largest tsunamis (occurring less than once in a millennium). Seawalls are designed to completely prevent an L1 based on the guidelines of the MLIT. By contrast, L2 should be mitigated via both intangible and tangible measures. In accordance with the guidelines, regional governments affected by the disaster have established plans to construct the seawalls that may reach 15 m high and completely defend districts from an L1. However, regional governments should resolve disputes related to the high construction costs of large seawalls and the subsequent decrease in tourists because of the destruction of the beautiful scenery.

Here, we focus on the city Rikuzentakata. Rikuzentakata is located in the south of the Iwate prefecture and was severely damaged by the Great East Japan earthquake and tsunami (Fig. 6). The tsunami killed 1757 people in the city (7% of the population). Furthermore, as of June 30, 2014, 4069 households—more than half in the city—were affected by this disaster. The maximum height of the seawall at Rikuzentakata will be 12.8 m, but the height was only 8.5 m as of 2011. The construction costs in a part of Rikuzentakata, the Takata area, will reach approximately 25 billion yen.

Two cost benefit analysis approaches

First, we confirm this situation. The observed project is the construction of sixteen seawalls in Rikuzentakata. In both approaches, we make the following standard assumptions:

(a) Gains obtained from the seawalls in containing the tsunami or preventing consequent damages are the only source of annual benefits in the CBA and annual changes in the IWI.
(b) In accordance with the manual by the MLIT, the social discount rate is 4% to obtain the present discounted values.
(c) The planned seawalls completely protect against a 13-m tsunami.
(d) In this calculation, we did not include the damages caused by the tsunami pouring in from adjacent districts.

Assumption (a) means that both expected values can be calculated based on the value of assumed damages by a tsunami and event probability, i.e., the tsunami hazard curve. These assumptions reduce the accuracy of these calculations; however, we can still discuss the features of the two methods. The section aims to clarify the differences and to examine the utility of the CBIW.

The manual provided by the MLIT is used to calculate the costs and benefits in the CBA (MLIT 2009; MAFF and MLIT 2004). The considered assets include houses, household products, establishments, field products, farmland, public facilities, and human life. In the CBA, the project costs for the 16 seawalls are assumed to include the construction costs, maintenance costs and salvage values. Furthermore, the annual maintenance cost is assumed to be 0.5% of the construction costs. By contrast, the CBIW is evaluated using the values for natural capital, produced capital, and human capital without any adjustment factors. The MLIT manual in the CBA is also applied to estimate the damage to the capital stocks. Unlike the CBA, the CBIW includes the value for the forest capital in natural capital or the education capital in human capital. In addition, the shadow prices for each type of capital in Iwate Prefecture are also used in the CBIW to evaluate the damage to wealth caused by the tsunami.

We use the tsunami hazard curves, as shown in Fig. 7, estimated by Fukutani et al. (2014), which are based on the website of the National Research Institute for Earth Science and Disaster Resilience (2013).[16] The baseline data for the IWI in Rikuzentakata in 2010 are obtained from the appendix of Managi (2017).[17] Due to data limitations, both the benefits in the CBA and the changes in the IWI are assumed to be constant at every year. We also utilize data from the National Land Numerical Information, which are publicly available, to evaluate the seawall projects using GIS data with 500-m mesh.[18]

[16] We have omitted some cases in which it is difficult to identify the fault of the hypocenter and the maximum Mw is less than 7.4.

[17] The data can be obtained from the authors upon request.

[18] We use the following two assumptions to make the spatial data tractable: The height of each mesh is the average height of the mesh; the run-up height is the same as the tsunami height.

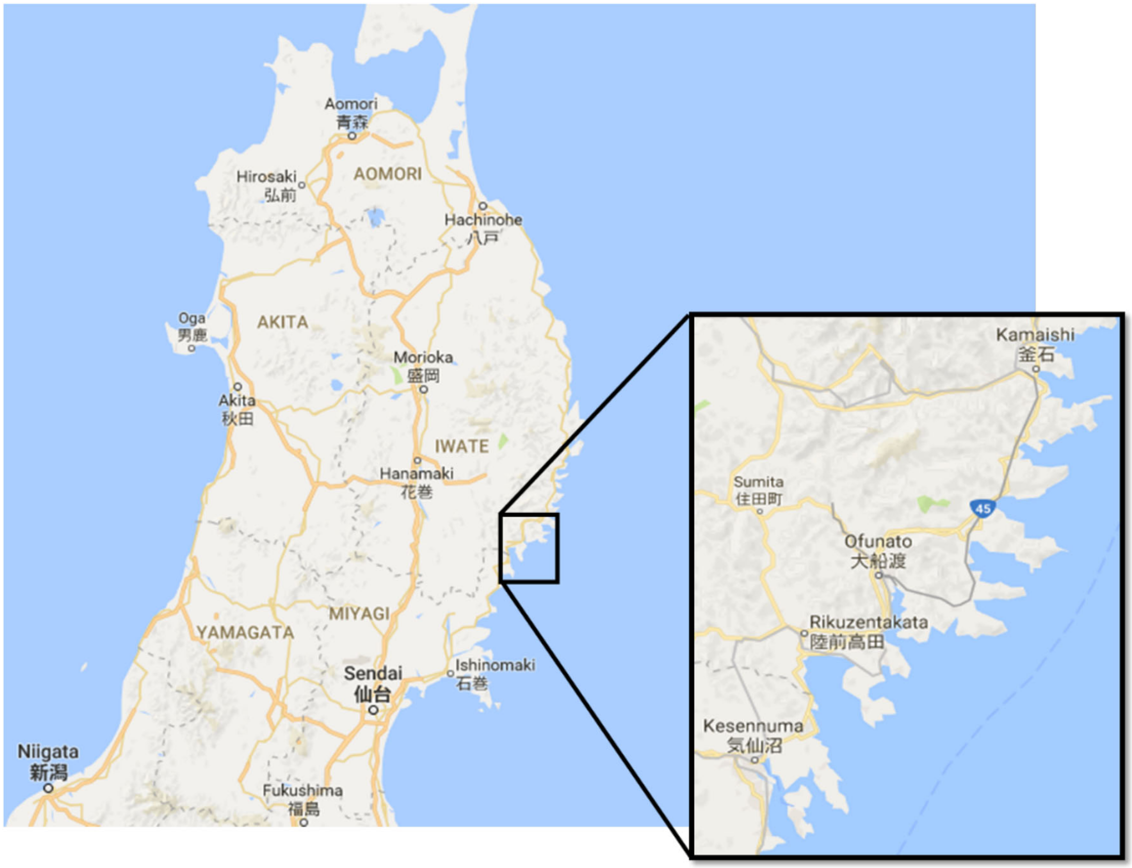


Fig. 6 Location of Rikuzentakata city Source: Google Map

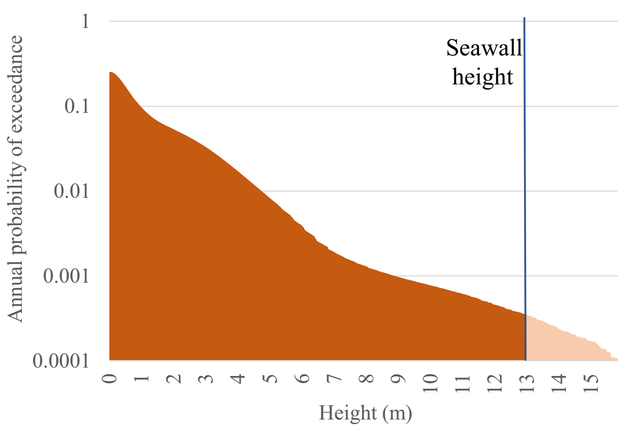


Fig. 7 Tsunami hazard curve in Rikuzentakata

Should we implement the seawall project?

Table 4 compares the CBA and the present discounted values of changes in wealth obtained from preventing a tsunami by the seawalls in CBIW. According to the CBA, this project should not continue, except with regard to human damage (case 1); however, this claim changed when the effect of human damage on benefit is included (case 2). The comparison indicates that building the seawalls is worth the cost to protect human life. In case 3 of the CBIW, regional wealth seems to be improved by the seawalls.[19]

We further investigate the project evaluation method of the CBIW in Fig. 8. Without the seawalls, the IWI will decrease approximately 4.6% in 20 years compared with 2010 as the base year. In contrast, with the seawalls, the IWI decreases approximately 0.81%. Since the probability of L1 and L2 is extremely low, the reduction of the IWI in just 20 years may be larger than expected; however, the seawalls can sufficiently reduce the risks of tsunamis lower than 13 m high (of course, all L1 are included in this height), as demonstrated by largeness of the brown area in Fig. 7. Thus, we consider the results to be reasonable, and Rikuzentakata is likely to improve its

[19] We should notice that the cost of the CBIW is not the construction cost (108.6 billion yen) used in the CBA but rather the depletion of natural capital as a result of the construction (0.2 billion yen). Although the construction costs indicate the increase in produced capital in terms of inclusive wealth, in this case, the national government of Japan invests in the seawalls. Thus, the cost should not be added to the produced capital in the CBIW, and it is convenient for analyzing the effect of the seawalls.

Table 4 Results by cost benefit analysis (CBA) and cost benefit analysis including inclusive wealth (CBIW) in billions of constant 2000 Yen

	Case 1	Case 2	Case 3
Method	CBA (without human damage)	CBA (with human damage)	CBIW
Total cost	108.6	108.6	0.2
Total benefit	78.4	130.0	40.1
NPV[a]	−30.2	21.4	–
CBR[b]	0.72	1.19	–
IRR[c] (%)	2.71	4. 8 2	–

[a] Net present value

[b] Cost benefit ratio

[c] Internal rate of return

sustainability through the seawall project. In particular, by constructing the seawalls, the reduction rates for produced, human, and natural capitals are improved by 4.9, 3.8, and 10.8%, respectively, over 20 years. The vehicle that increases natural capital is the substantial protection of the fishery capital because fishing ports have been necessarily constructed along the coast and suffer the serious damage when tsunamis strike. Furthermore, human capital is also well protected by the seawalls, which may be consistent with the result of the CBA.

These findings indicate that the CBIW is suitable not only for the evaluation of the projects themselves but also for the sustainability of the region. Even if the cost benefit ratio is relatively high, the project might not be implemented if the regional sustainability is low. Although we cannot deny that the evaluation is rough, this type of study should be promoted for the rational choice of a regional project that improves regional sustainability (see, e.g., Fenichel et al. 2016; Collins et al. 2017).

Concluding remarks

Responding to an intense debate regarding regional sustainability in Japan, the application of the IWI to regional problems would be helpful in governing among different administrative hierarchies of regions to realize SDGs (Dasgupta et al. 2015; Mumford 2016; Tachibanaki and Urakawa 2012). The IWI is a more comprehensive indicator for evaluating sustainability, based on the stock of wealth rather than other proposed indicators; however, thus far, there have been few regional applications, but even these applications lack consistency in the construction of their datasets for regions and nations. Thus, we investigate the regional IWI in all prefectures in Japan and propose an approach to evaluate the effects of public projects on regional sustainability.

We initially investigate the heterogeneity of regional sustainability in Japan and confirm the consistency of the indicator between the national and regional levels as follows. The estimation results of the IWI, which are consistent with the results at the national level, indicate not only the increasing wealth of Japan but also the decreasing growth rate in all prefectures. Produced capital has a positive effect on the growth, whereas the depreciation of health capital—part of human capital—severely damages such growth. These results are partially consistent with national-level data provided by Muñoz et al. (2014), except for the effect of health capital. We subsequently consider the problem of regional sustainability, which is caused by depopulation and migration in rural areas in Japan. We find that sustainability in rural areas is at a higher level than that in urban areas because of depopulation, which has a pronounced effect, making the IWI divided by population positive. However, the disparity in total wealth between rural and urban areas is expanding because of the decreasing quality of health capital and the decreased growth rate of produced capital in rural areas.

In addition, we demonstrate an application of the inclusive wealth approach to evaluate a controversial seawall project in Japan. This approach provides the scope of regional sustainability influenced by targeted projects rather than the profitability of such projects, which is typically considered in a basic CBA. This illustration would be beneficial to policymakers who are encountering regional problems in Japan.

With regard to achieving SDGs, these insights also provide fruitful images by creating a readable measurement of sustainability from the regional level to the national level as a governance tool because the SDGs cannot be achieved unless the quality of governance at all levels is improved (UN General Assembly 2015; Sacks 2012). Clearly, several hurdles remain that should be overcome by elaborating the shadow price and confirming the

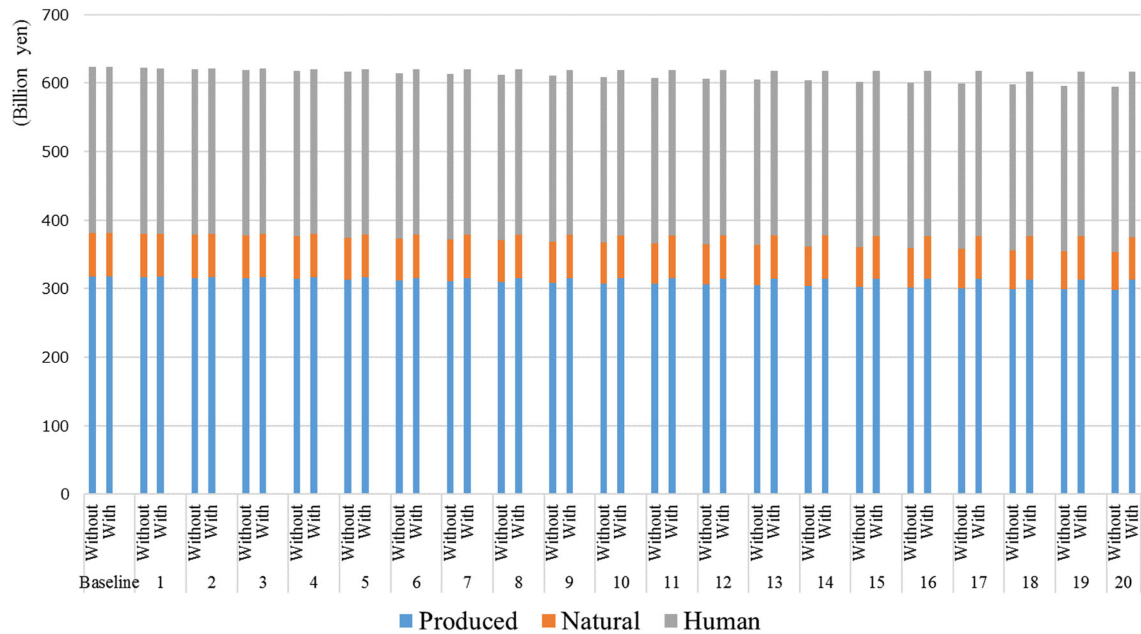


Fig. 8 Inclusive wealth changes with and without the construction of seawalls in Rikuzentakata

consistency of our tool with other sustainability indicators, as suggested by Engelbrecht (2016). However, some local governments have approached their sustainability problems using our application of the IWI, although examining such interventions may be beyond the scope of this research (refer to examples in Managi 2016). The IWI has been shown to have the potential to overcome governance problems to realize regional sustainability in Japan, and the case examined may represent an effective model for governments in other nations.

Furthermore, with aging populations in developed countries, effective health care interventions are necessary, and the estimation of health status becomes an important issue to improve global health, as proposed in Goal 3 of the 2030 Agenda (UN General Assembly 2015; Farlow 2016). We do not consider the damages resulting from non-communicable diseases, which Farlow (2016) highlights as a recent shift in the global burden of disease; however, our research indicates the significant effect of health capital in reducing sustainability and the need to invest in the health sector as an urgent priority in Japan, which was calculated as the wealth of life expectancy. In addition, the localized estimation for health capital may also complement the lack of this information worldwide, as suggested by Farlow (2016).

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Appendix

See Fig. 9.

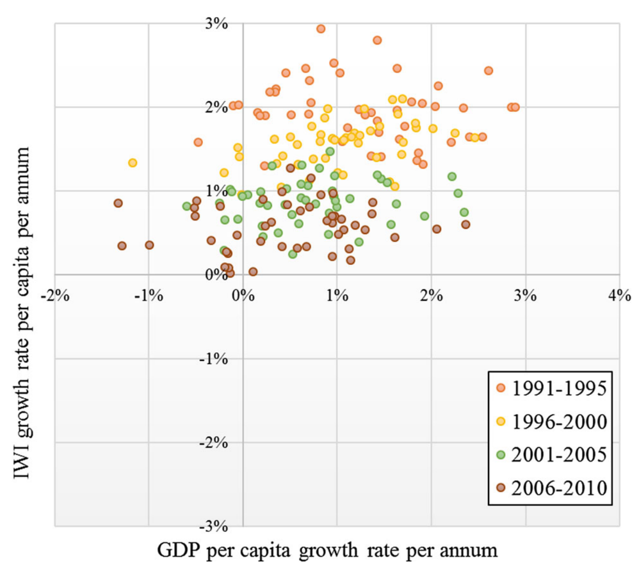

Fig. 9 IWI per capita growth rate and GDP per capita growth. The IWI is composed of produced, human, and natural capital without any adjustment

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