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Contents

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The Macroeconomic Effectiveness of Resilience Investment in the Context of Earthquake Risk

Takeru Mori[*], Yusuke Kanda[**]

Abstract

Many people fear that Japan will continue to experience massive earthquakes, and many believe that the Japanese economy is experiencing deflation. Public investment is important for both reducing and preventing damage from natural disasters. Some view such investment as a countermeasure that will not only increase the resilience with which Japan deals with disasters but also facilitates the nation's recovery from deflation. Others have voiced concern that public investment will detract from the economic efficiency of Japan. Taking into account the probability of earthquake occurrence and extent of damage, this study analyzed the macroeconomic effects of public investment and examined whether public investment could increase the resiliency and economic efficiency of Japan.

Keywords: Public investment, Great earthquake, Economic efficiency, Resilience

JEL Classification: H20, H61, H68

1. Introduction

Japan faces the constant risk of major earthquakes, and predictions of these events, such as the Capital earthquake and Nankai Trough earthquake, have been made. The Central Disaster Prevention Council estimated as many as 320,000 fatalities from the Nankai Trough earthquake and as many as 11,000 deaths from the Capital earthquake (Japanese Cabinet Office, 2009). Another model predicted much more damage from the Capital earthquake, estimating the number of deaths at 150,000 (Nankai Trough Earthquake Study Measures Working Group, 2012). In a 1988 report, the Central Disaster Prevention Council estimated the probability of the occurrence of a 7-magnitude great earthquake within the next 30 years at 70% for a Capital earthquake and at 88% for a Tokai earthquake (Central Disaster Management Council Japan, 1988). Given the increased probability of a major earthquake, public investment in the country's infrastructure (e.g., maintenance of the transportation system and reinforcement of the seismic design of buildings) has recently emerged as a very important factor in disaster prevention and mitigation. Thus, a system for developing resilience to minimize the damage from a natural disaster through accurate risk prediction and the construction of public works is needed. Issues related to economic growth can also be considered within this framework.

"Resilience" is an important concept when considering the future economic growth of Japan. Indeed, without a system to enable resilient responses to local and global risk factors,

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neither governments nor private companies can grow in the context of the current highly competitive environment. Resilience has emerged repeatedly as an important topic related to the domestic and global economy.

However, others believe that the notion of resilience is antithetical to economic rationality and effectiveness. According to this line of thinking, if limited funding is allocated to the development of resilience in the context of the risk of earthquakes, the resulting uncertainty would decrease the competitiveness of nations and businesses. In reality, risk is present in all economic situations. Therefore it is possible to manage risk, and risk is necessary for economic growth.

Although some investment is needed to develop resilience, overinvestment leads to a decrease in competitiveness. Therefore, the level of investment should correspond to the risk of disaster. Great risk will require heavy investment, whereas less serious risk might permit less investment. Owing to Japan's high risk for a major earthquake, public investment is necessary to maintain resilience in the face of this kind of future disaster. Public investment in resilience may be regarded as "resilience investment."

In this study, we investigated the appropriate level of resilience investment in the context of economic growth targets and the occurrence probability of damage from a major earthquake. Additionally, we developed models based on the macro-economic simulation model used for analysis by the Japanese government. Finally, we examined the level of resilience that would reduce the risk to Japan's macroeconomy and ascertained the level of resilience appropriate for the sustainable development of the Japanese economy.

2. Methodology

2.1 Scenario Analysis

To demonstrate the macroeconomic effect of public investment, we employed scenario analysis to compare the occurrence with the absence of an earthquake. This analysis also considered macroeconomic simulation models in which an investment in resilience was or was not made to measure resilience effects.

We estimated the potential effect of two disasters, a Capital earthquake and a Nankai Trough earthquake. As shown in Table 1, the damage from each disaster was measured in terms of a variety of categories and classified under two divisions. "Direct damage" was measured in terms of numbers of dead and injured, disruption of the infrastructure (including homes, roads, railways, the water supply, and sewage systems), and damage to private facilities. "Indirect damage" included such factors as decreases in exports and rapid increases in imports due to the demand for materials and alternative energy. Some of the predicted values of damage presented in Table 1 were based on the extant literature (marked with asterisks), whereas other values were estimated in this study. Estimation of indirect damage requires an appropriate period of observation following a disaster; this period consists of the time until the affected area returns to a normal level of economic activity. "Duration of damage" was also considered indirect damage and is presented in Table 2.

The projected magnitude of the major earthquake in these scenarios is presented as "an average value obtained from the trend of past earthquakes," and the probability of

Table 1 Estimated Damage from Major Earthquakes

Index		Capital Earthquake	Nankai Trough Earthquake	Great East Japan Earthquake
Direct Damage	Number of deaths (people)	11,000	266,000	19,553
	Number of injuries (people)	210,000	334,000	5,943
	Destroyed, burned buildings	850,000	1,214,000	128,927
	Unemployment (people)	1,070,000 *	593,000 *	179,254
	Social capital stock (trillion yen)	8.99 *	14.2 *	7.24
	Housing stock (trillion yen)	35.1*	48.3*	5.20
	Private sector stock (trillion yen)	88.2*	35.1*	3.62
	Accessibility (Disruptions of transport network)	Metropolitan Expressway-Aqua line	Tomei Expressway	Sendai Airport Access line
Indirect Damage	Total private consumption	12.6 trillion yen decrease*	62.3 trillion yen decrease*	3.6 trillion yen decrease
	Exports of goods and services	12.9% decrease *	12.1% decrease *	2.7% decrease
	Imports of goods and services	(Material) 1.3 trillion yen increase *	(Material) 1.9 trillion yen increase *	(Material) 0.2 trillion yen increase *
		(Energy) No increase **	(Energy) 5.2 trillion yen increase	(Energy) 5.2 trillion yen increase
	Utilization rate	17.9% decline *	9.9% decline *	3.0% decline

* As estimates have not been published, estimates in this study were based on previous studies (see Expert Committee for Capital Earthquake, 2005; Nankai Trough Earthquake Study Measures Working Group, 2012, 2013; Kansai Institute for Social and Economic Research, 2011; Foundation for Real Estate Information Network for East Japan, 2012; Japanese Cabinet Office 2005, 2012, and 2013; The Bank of Tokyo-Mitsubishi UFJ, 2011; Japanese Ministry of Internal Affairs and Communications, Japanese Ministry of Land, Infrastructure and Transport, 2010; Mizuho Research Institute, 2011).

** We assumed that a nuclear power plant would not be located in areas affected by the Great East Japan Earthquake and hypothesized that alternative energy demands would not occur.

*** Based on data from the Japanese government, private sector capital investment was taken to be proportional to the rate of operation (Japanese Cabinet Office, 2011).

occurrence is also described as "about 88% within 30 years" (Japanese Cabinet Office, 2012). Therefore, although the actual size of an earthquake cannot be determined, our estimates are probably highly accurate. Our simulations valued damages based primarily on mean values from Table 1, and we used the probability distribution of occurrence to measure stochastic changes in earthquake size. Because the scenarios must also consider maximal damages, the use of only mean values is not sufficient (i.e., reports estimate 150,000 deaths in the event of a Capital earthquake; mean values lead to estimates of 110,000 deaths). Additionally, the initial occurrence of the two earthquakes (Capital earthquake and Nankai Trough earthquake) were set to vary according to a probability density function (see Figure 1) obtained from published occurrence probability figures. The probability figures were derived from a Poisson process (The Headquarters for Earthquake Research Promotion, 2010). We identified two scenarios: one based on "A Resilience plan for Japan," published by the Japanese government, and the other on a government plan to invest 200 billion yen over 10 years for a resilience system. We examined the following two scenarios: (1) an investment of 20 trillion yen per year over a 10-year period and (2) an investment of half that amount.

In this study, we assumed that damages, both direct and indirect, would be reduced by resilience investment. Improvements in the earthquake-proof infrastructure (e.g., roads, railways, and buildings) could decrease loss of life, disruptions to the traffic network, and

Table 2 Duration of Indirect Damage

Index	Duration	Basis
Exports of goods and services	5 years	· Data on the period of recovery from the shocks before business activities returned to baseline show a decrease in corporate profits of about 30% during the 3 years after a supply-chain disruption compared with the general situation. It is assumed that the disruption will continue for 5 years.
Total private consumption	5 years	· It is assumed that consumer consumption awareness depends on income. Therefore, total private consumption can be assumed to equal the recovery from a disruption in the supply chain for exported goods and services.
Imports of goods and services	Material: 10 years Energy: 3 years	· Imports of goods and services goals for 10 years until the completion of reconstruction. However, these are initially dependent on external demand and gradually become dependent on domestic procurement. · In the case of energy dependence, a 3-year period will be needed before resuming operations; this is based on the case of the Great East Japan earthquake.
Utilization rate	3 years	· The decline in utilization capacity caused by the Great East Japan Earthquake has not yet been resolved. However, the utilization rate has been increasing since November 2012, and it will reach a level similar to that before the earthquake at the end of 2013. This decline in utilization is expected to continue for 3 years.

****: As estimates have not been published, our estimates were based on previous studies (see Hendricks and Singhal, 2005; Japanese Cabinet Office, 2009; Japanese Ministry of Health, Labour and Welfare, 2012).

Figure 1 Probability Density Function for the Initial Occurrence of an Earthquake

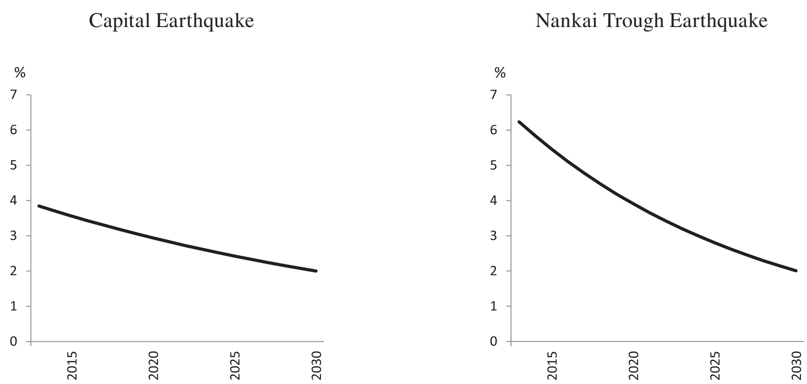

Figure 2 Overview of the Macroeconometric Simulation Model

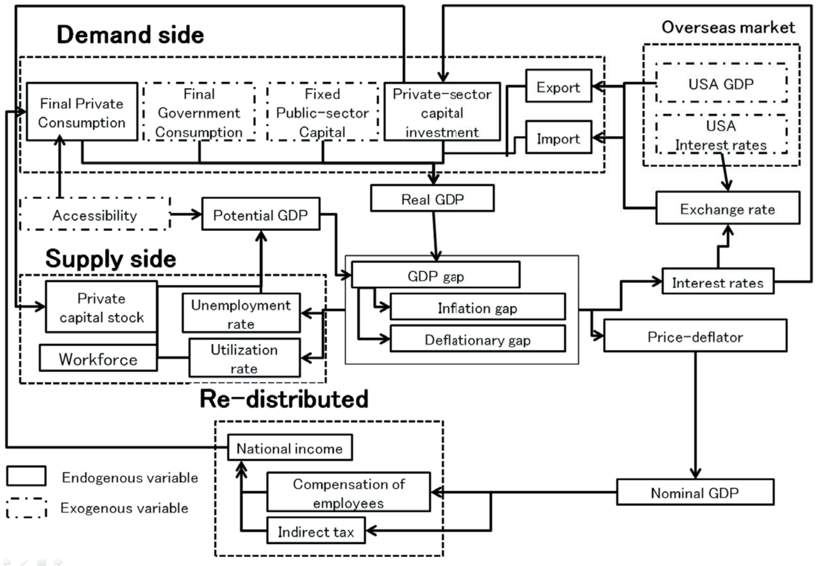

Table 3 Assumed Damages from Great Earthquakes after Resilience Investment

Index		Capital Earthquake	Nankai Trough Earthquake
Direct Damage	Number of deaths (people)	4,000 *	52,000
	Number of injuries (people)	77000*	81,300*
	Destroyed, burned buildings	325,000	288,900
	Unemployment (people)	390,000*	121,000*
	Social capital stock (trillion yen)	3.45*	12.5*
	Housing stock (trillion yen)	13.4*	25.7*
	Private sector stock (trillion yen)	6.32*	18.6*
	Accessibility (Disruptions of transport network)	Metropolitan Expressway - Aqua line	Tomei Expressway
Indirect Damage	Total private consumption	4.5 trillion yen decrease	13.0 trillion yen decrease
	Exports of goods and services	3.7% decrease	4.6% decrease
	Imports of goods and services	(Material) 0.5 trillion yen increase (Energy) No increase	(Material) 0.4 trillion yen increase (Energy) No increase
	Utilization rate	6.5%	2.0%

losses of social capital, housing, and the private sector from fires and tsunamis. If direct damage can be minimized, it may also be possible to decrease indirect damage. We referenced some predicted values, such as anticipated deaths from a Nankai Trough earthquake under a resilience system, and estimated other values, including direct and indirect damages, by anticipating the conditions that would obtain under a resilience-oriented system. Additionally, we created a hypothetical scenario involving a nuclear power plant that was severely damaged by a Great East earthquake but that operated continually (Table 3).

2.2 Modeling

We simulated a macroeconomic model to measure resilience and effectiveness under the aforementioned assumptions. The macroeconomic model used in this study was based on a model adopted, and later revised, by the Japanese government (Hino et al., 2012) to compute the effects of improved infrastructure on the nation's macroeconomy. The model demonstrates that domestic demand is expanded by resilience investment and that accessibility is increased by the development of transportation networks. As a consequence, private consumption is improved and GDP ultimately increases. Conversely, it is demonstrable that an increased unemployment rate, decreased supply due a reduced capacity utilization rate, and decreased demand due to reduced temporary private consumption, results in a reduction in the GDP.

Investment in public works increases inflation by a factor of 1.65 and deflation by a factor of 5.26 (Fujii, 2012). The aforementioned macroeconometric model estimated a similar effect on inflation and deflation. However, our advanced model accounts for the inflation/deflation effect from the GDP gap between supply and demand and the difference in the multiplier effect. We measured the effect of resilience investment by focusing on changes in the GDP, tax revenue, and labor population using the advanced macroeconomic simulation model. We also considered the impact of resilience investment on Japan's current deflationary and inflationary trends; in a hypothetical situation, there is no distinction between inflation and deflation.

2.3 Estimation Results of Macroeconomic Model

The macroeconomic model proposed in this research is composed of many sub-models. In this paper, the authors present some of the estimation results for important economic variables related to macroeconomic simulation. These results are shown in Tables 4, 5, 6, 7, and 8. First, Table 4 shows potential GDP as a production function. As adjusted R^2 is high, the estimated results represent a sufficiently good fit. Second, Table 5 shows private final consumption expenditures, represented of the consumption function, and this model is also a sufficiently good fit. Table 6 presents the estimated results related to the labor force. The estimated results of models of indirect and current taxes are show in Tables 7 and 8. Tax revenue was defined as the sum of these taxes. In this study, current taxes included tax income and wealth, and indirect taxes were based on the SNA data provided by the Japanese Cabinet Office; however, social insurance premiums were not included in this model.

Table 4 Estimated Parameters of the Potential GDP Model

ln(Y) = c(1)+(1.0−c(2)))*ln(KFP*ROU)+c(2)*ln(WT*LF*(1−UR))+c(3)*ln(ACC)

Term	Constant term	KEP*ROU	ACC	Adjusted R^2	D.W.
Parameter	−9.388	0.686	1.068	0.991	0.205
t-value	−2.90	11.3	2.97		

Y: Potential GDP, KFP: Private sector capital stock, ROU: Capacity utilization, WT: Working time, LF: Labor force, UR: Unemployment rate, ACC: Accessibility.

Table 5 Estimated Parameters of the Private Final Consumption Expenditure Model

ln(R_1)=c(1)+c(2)*ln(YDV)+c(3)*ln(GAP1)+c(4)*ln(GAP2)
+c(5)*ln(ACC)+c(6)*DR20012007

Term	Constant term	YDV	GAP1	GAP2	ACC	DR20012007	Adjusted R^2	D.W.
Parameter	−16.771	0.456	0.954	0.288	2.532	0.015	0.988	1.47
t-value	(−24.1)	23.6	2.45	4.26	26.6	3.32		

R_1: Private final consumption expenditure, YDV: Disposable income, GAP1: Inflation gap, GAP2: Deflation gap, ACC: Accessibility, DR20012007: Dummy variable.

Table 6 Estimated Parameters of the Labor Force Model

Ln(LF)=c(1)+c(2)*ln(POP)+c(3)*ln(YWV/POP)+c(4)*DC2004

Term	Constant term	POP	YDW/POP	DC2004	Adjusted R^2	D.W.
Parameter	2.250	0.626	0.213	−0.006	0.994	0.496
t-value	2.05	5.20	0.213	−2.20		

LF: Labor force, POP: Population, YDW: Compensation of employees, DC2004: Dummy variables.

Table 7 Estimated Parameters of the Indirect Tax Model

Dln(ITAXV)=c(1) +c(2)*Dln(N_0)+c(3)*DC2000

Term	Constant term	N_0	DC2000	Adjusted R^2	D.W.
Parameter	0.018	0.772	−0.026	0.764	1.463
t-value	2.64	5.46	−2.64		

ITAXV: Indirect tax, N_0: Nominal GDP, DC1999: Dummy variables.

Table 8 Estimated Parameters of Current Taxes Model

Dln(TYPV)=c(1)+c(2)*Dln(N_0)+c(3)*DC1999

Term	Constant term	N_0	DC1999	Adjusted R^2	D.W.
Parameter	−0.060	2.288	0.069	0.488	2.101
t-value	−2.62	5.15	2.25		

TYPV: Current taxes, N_0: Nominal GDP, DC1999: Dummy variables.

3. Analysis

3.1 Investment of 200 trillion yen

As shown in Figure 3, when 200 trillion yen is invested for resilience, there is no GDP fluctuation over the subsequent 10 years [Case A: no earthquake and no investment]. However, there is a risk of earthquake in a real situation. If an earthquake occurs, the GDP decreases. As seen in the third case [Case C: average earthquake and no investment], the GDP is reduced greatly after 2014, to 470 trillion yen, because of the possibility that a Nankai Trough earthquake will occur in 2013 or 2014. The difference between cases A and C is the expected value of the economic damage caused by the earthquake. This difference is approximately 60 trillion yen per year, with a cumulative cost of approximately 510 trillion yen after 10 years as shown in Table 9. When calculated per capita, individual income will have been reduced by approximately 4 million yen over a period of 10 years. Our analysis also found that approximately 550 trillion yen would be lost per capita, with GDP increasing to 710 trillion yen. It is estimated that it may require ~23 years for the line separating cases A and C to be crossed. This would mean a return of the GDP to its original level following a cumulative decline of 720 trillion yen and a loss of tax revenue amounting to approximately 50 trillion yen. Additionally, it is possible that the labor force and the available fixed capital would be damaged by the disaster, which may decrease the GDP, leading to inflation, and thereby partially suppress the multiplier effect. However, in this study, the effects of the disaster on both the demand and the supply sides were calculated based on data on the economic damage related to the Great East Japan Earthquake, and so on. Thus, the demand and supply GDPs estimated in this paper may not be realistic.

This analysis considered only an average earthquake; the possibility of more serious damage by a major earthquake should also be considered. Therefore, a simulation with an occurrence probability of approximately 10% damage, a "worst-case" scenario, was also computed.

In the fifth case [Case E: massive earthquake and no investment], the GDP will decline, finally reaching 450 trillion yen. The total reduction in the GDP over 10 years will equal 740 trillion yen, a 6 million yen loss in income per capita. Tax revenue losses over 10

Figure 3 Estimated GDP (with a resilience investment of 200 trillion yen)

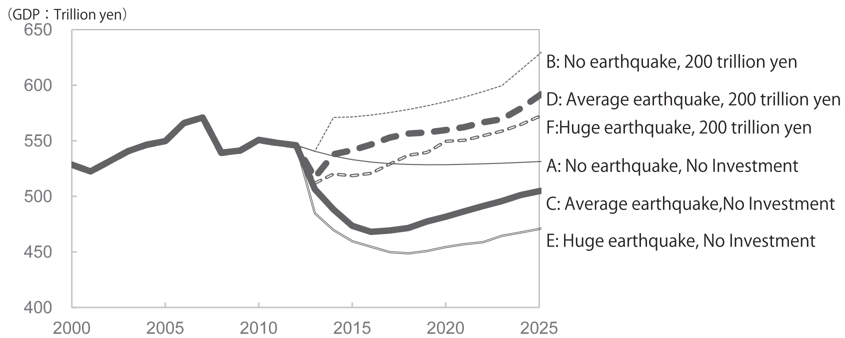

Table 9 Macroeconomic Effects of Resilience Investment (with a resilience investment of 200 trillion yen)

Case	Disaster	Resilience investment	Cumulative GDP for 10 Years (trillion yen)	Cumulative tax revenue for 10 Years (trillion yen)	Workforce after 10 years (ten thousand)
Case A	No	No	5,313.8	677.0	6,404.1
Case B	No	200 trillion yen	5,794.4	798.5	6,569.0
Case C	Average Scale	No	4,799.4	611.2	6,341.0
Case D	Average Scale	200 trillion yen	5,506.2	729.1	6,510.0
Case E	Huge Scale	No	4,572.6	554.7	6,279.2
Case F	Huge Scale	200 trillion yen	5,374.5	679.8	6,557.6

years will equal 85 trillion yen. Computed values are cumulative over one decade, but when one considers that the damage will continue for 11 more years, the seriousness of such a disaster for the Japanese economy becomes more apparent.

Predictions indicate that the probability of a major earthquake is very high, lending credence to predictions of significant Japanese economic losses in the future (i.e., losses of approximately 4-6 million yen per person over 10 years).

This study also modeled the extent to which damage could be mitigated through the promotion of resilience investment. The investment scenario considered involved 20 trillion yen over a 10-year period. As mentioned above, the GDP loss caused by a major earthquake would be approximately 60 trillion yen per year in the first case. However, as presented in in Figure 3, the fourth case [Case D: average earthquake and investment of 200 trillion yen], which involved a 200 trillion yen investment in a resilience system, indicated that economic growth would continue, that the economy would overcome the damage, and that the GDP would increase by 600 trillion yen over the subsequent 10 years. This suggests that resilience investment not only minimizes economic damage and fills the gaps associated with deflation but also leads to economic growth. Thus, these data show that a resilience investment of 200 trillion yen would result in economic growth in Japan as well as minimize the damage caused by a major earthquake. The positive impact was calculated as 710 trillion yen over one decade and as approximately 1,870 trillion yen over 20 years when we compared cases C and D. Table 11 presents a comparison of the ratio of tax revenues to nominal GDP with and without a resilience investment 10 years earlier. The data reveal a 3.3% improvement in the absence of a resilience investment. Additionally, Table 10 summarizes the multiplier effect of the resilience investment per year. These data indicate that the maximum value of the multiplier given the risk of an earthquake is 4.25.

Our estimates also indicated that resilience investment would result in an increase in tax revenues. Simulation results indicated that increased tax revenues would total 200 trillion yen after 13 years. The positive effects demonstrated by simulation analysis would require an enormous investment on the part of the Japanese government. However, as this tax analysis shows, a 200 trillion yen financial expenditure could be recouped within 13 years.

The maximum estimated damage resulting from a major earthquake would include 150,000 deaths in the case of a *Capital earthquake* and 320,000 deaths in the case of a

Table 10 Multiplier Effect of Investment per Year (with a resilience investment of 200 trillion yen)

	No Earthquake			Average earthquake			Huge earthquake		
	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP
1st year	1.74	1.63	0.26	2.49	2.06	0.98	2.52	2.12	1.77
2nd year	1.92	1.89	0.38	3.40	2.93	1.58	2.95	2.52	1.95
3rd year	2.11	2.19	0.54	3.93	3.46	1.72	3.30	2.87	2.17
4th year	2.30	2.49	0.74	4.18	3.77	1.84	3.96	3.49	2.55
5th year	2.47	2.79	0.94	4.25	3.97	2.03	4.41	3.92	2.94
6th year	2.65	3.09	1.17	4.01	3.87	2.13	4.43	3.95	3.18
7th year	2.83	3.38	1.41	3.90	3.88	2.28	4.76	4.22	3.42
8th year	3.03	3.67	1.67	3.79	3.84	2.43	4.67	4.13	3.67
9th year	3.25	3.97	1.95	3.77	3.85	2.62	4.79	4.20	3.96
10th year	3.49	4.29	2.26	3.69	3.78	2.70	4.71	4.12	4.13

Table 11 Tax Revenue-to-nominal GDP Ratio 10 Years after Resilience Investment (with a resilience investment of 200 trillion yen)

	No investment	Investment
No earthquake	14.0%	16.0%
Average earthquake	13.9%	17.2%
Huge earthquake	13.3%	15.6%

Nankai Trough earthquake. Direct and indirect damages would also increase significantly as the scale of the earthquake increased.

Without resilience investment, we estimate that the GDP would decline by 70 trillion yen over the 10 years following a maximum-scale earthquake. Additionally, a decline in tax revenue of approximately 11 trillion yen, along with negative effects on national life and economic activity in Japan, would also be expected.

With a resilience investment of 200 trillion yen, the GDP would continue to gradually increase at a level similar to that estimated for the economic activities following the occurrence of an average-scale earthquake, even in the case of a maximum earthquake event. The cumulative 10-year GDP would increase to nearly 800 trillion yen as compared with the case where no resilience investment occurred. Additionally, the tax revenue-to-nominal GDP ratio would improve, reaching 2.3%, and the multiplier effect of the resilience investment would increase to 4.79. Additionally, the difference in tax revenues would equal nearly 120 trillion yen over 10 years, and the 200 trillion yen of resilience investment could be recovered from the resulting increase in tax revenues after 15 years.

To summarize, a resilience investment of 200 trillion yen over 10 years would minimize the damage caused by an earthquake, fill the deflationary gap by expanding domestic demand, and grow the Japanese economy, even in the event of a *Capital earthquake* or *Nankai Trough earthquake*. Thus, an investment of 200 trillion yen can result in both resilience and efficiency in a deflationary economy.

3.2 Investment of 100 trillion yen

We next considered the case in which the government invests 100 trillion yen in resilience over a period of 10 years. The scale of the hypothetical earthquake was the same as in the 200-trillion investment scenario. The simulation results are presented in Figures 4 and 5. When 100 trillion yen is invested for resilience, the trend in the GDP differs significantly from that in the 200-trillion investment model. The difference in the 10-year cumulative GDP between the 100-trillion investment cases (Case B and D) and the no-investment cases (Case A and C) equaled 280 trillion yen. A comparison of the differences between cases F and B and between cases E and A revealed that the difference in the cumulative 10-year GDP was ~420 trillion yen as shown in Table 12. The positive impact of a 100-trillion investment is 420 trillion yen in cases of an average earthquake (Case C and D). However, when 200 trillion yen is spent for resilience, the positive impact on the GDP was calculated to be 710 trillion yen over a decade. This indicates that an additional investment of 100 trillion yen makes a significant difference in the scale of the economic impact.

Figure 4 Estimated GDP (with a resilience investment of 100 trillion yen)

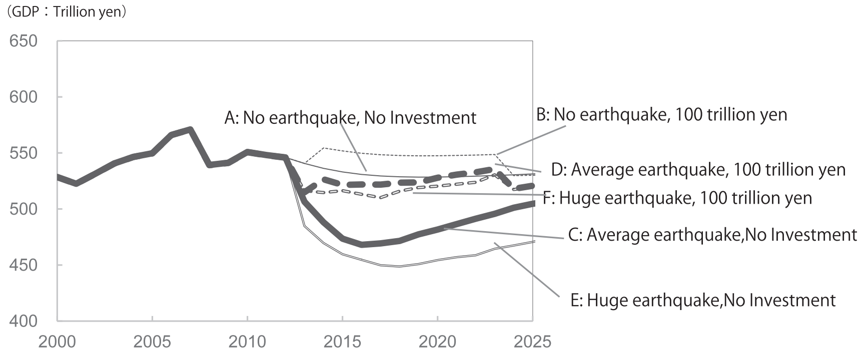

Figure 5 Estimated GDP (with a resilience investment of 200 trillion yen, no deflation)

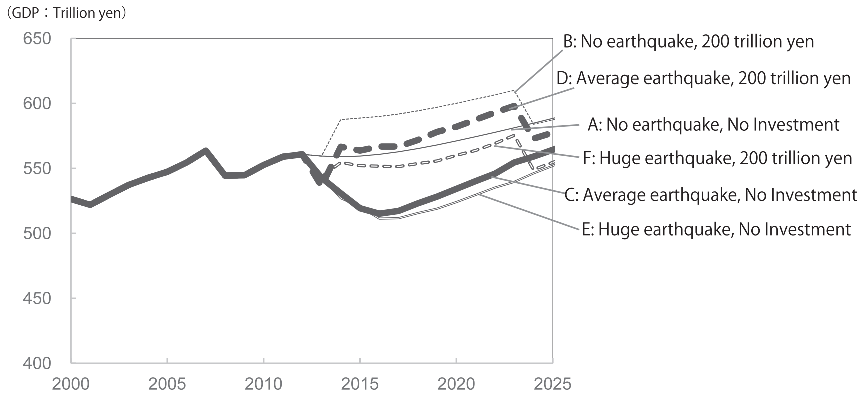

Table 12 Macroeconomic Effects of Resilience Investment (with a resilience investment of 100 trillion yen)

Case	Disaster	Resilience Investment	Cumulative GDP for 10 Years (trillion yen)	Cumulative tax revenue for 10 Years (trillion yen)	Workforce after 10 years (ten thousand)
Case A	No	No	5,313.8	677.0	6,404.1
Case B	No	100 trillion yen	5,483.5	717.1	6,449.7
Case C	Average Scale	No	4,799.4	611.2	6,341.0
Case D	Average Scale	100 trillion yen	5,247.1	655.6	6,404.0
Case E	Huge Scale	No	4,572.1	554.7	6,279.2
Case F	Huge Scale	100 trillion yen	5,164.5	624.5	6,380.1

In each of the three cases (Case B, D and F) that assumed an investment of 100 trillion yen, there was either no change or a small decline in the GDP trends, according to the scale of earthquake. This result was notably different from that of the of 200-trillion investment scenarios, which produced an increasing trend. Under conditions of a massive earthquake, the GDP might decline by 450 trillion yen, which would influence the Japanese macroeconomy. Additionally, Table 14 summarizes the tax revenue-to-nominal GDP ratio, which would increase to 0.1%, and Table 13 summarizes the multiplier effect of resilience investment per year. This result indicates that the maximum value of the multiplier under conditions of the risk of an earthquake would be 5.28.

Table 13 Multiplier Effect of Investment per Year (with a resilience investment of 100 trillion yen)

	No earthquake			Average earthquake			Huge earthquake		
	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP
1st year	1.82	1.70	0.25	3.83	3.13	1.58	4.50	3.66	4.16
2nd year	1.88	1.85	0.35	4.80	3.96	2.31	5.67	4.60	4.22
3rd year	1.89	1.97	0.45	5.38	4.37	2.70	5.85	4.71	4.37
4th year	1.89	2.09	0.55	5.25	4.15	2.94	6.03	4.84	4.63
5th year	1.90	2.19	0.63	5.20	4.21	3.15	6.72	5.39	4.99
6th year	1.90	2.28	0.70	4.63	3.80	3.11	6.83	5.43	5.18
7th year	1.90	2.35	0.76	4.62	3.86	3.25	6.60	5.15	5.44
8th year	1.89	2.41	0.81	4.41	3.72	3.33	6.51	4.99	5.69
9th year	1.88	2.46	0.85	4.14	3.51	3.32	6.51	4.91	5.99
10th year	1.88	2.50	0.88	4.00	3.37	3.27	6.60	4.89	6.15

Table 14 Tax Revenue-to-nominal GDP Ratio 10 Years after Resilience Investment (with a resilience investment of 100 trillion yen)

	No investment	Investment
No earthquake	14.0%	14.3%
Average earthquake	13.9%	14.0%
Huge earthquake	13.3%	13.7%

These results indicate that a resilience investment of 100 trillion yen would not be sufficient to prevent deflation in the event of a major earthquake. There was no change in the GDP even in case B; over time, the GDP would decline due to decreases in investment, especially in 2023, when the resilience investment ended. It would be impossible to cover the deflationary gap with an investment of 100 trillion yen, but such an investment would not lead to economic growth. We projected that tax revenues would increase by approximately 40 trillion yen over 10 years; this is lower than the tax revenues in the case of a 200-trillion investment, but is higher than it would be if no investment were made.

If a major earthquake were to hit the country when it was not emerging from deflationary economic conditions, economic activities would be decreased by direct and indirect disaster damage and result in decreased demand and an increase in the deflationary gap. Ultimately, such a quake would probably lead to a decrease in the GDP.

To summarize, it would be difficult to achieve resilience and efficiency following a major earthquake with an investment of 100 trillion yen. Simulation results indicated that this level of investment could negatively influence Japanese financial conditions.

3.3 Investment without Deflation

In the previous section, we considered resilience investment in circumstances of deflation and concluded that large-scale public investment could cover the deflationary gap, resulting in both resilience and efficiency. We also simulated the macroeconomic effect of resilience investment assuming that Japan was in a situation of inflation without a deflationary gap.

Again, we considered the case of a resilience investment of 200 trillion yen over 10 years (See Figure 5 and Table 15). Were a major earthquake to occur in a situation where the government has promoted a base scenario corresponding to the third case [Case C: average earthquake and no investment], the GDP would decline by 40 trillion yen with a cumulative cost of 420 trillion yen after 10 years and of 520 trillion yen after 20 years. This is a serious result, but it is an acceptable risk when compared with the deflationary model (510 trillion yen after 10 years and 710 trillion yen after 20 years). When compared with case D (i.e., average earthquake and investment of 100 trillion yen), the positive impact was calculated as 710 trillion yen over 10 years, and the maximum value of the multiplier of the investment would increase to 2.58. However, these effects are smaller than they would be with deflation (see Table 16).

Conversely, it is possible to reduce risk with resilience investment. Comparisons between the fourth and second scenarios [Case D: average earthquake and investment of 200 trillion yen and case B: no earthquake and investment of 200 trillion yen] and between the third and first scenarios [Case C: average earthquake and no investment and case A: no earthquake and no investment] showed approximately 220 trillion yen cumulative over 10 years, and GDP of 21 trillion yen in 2023. This comparison demonstrates the remediation of damages to the macroeconomy when compared with the case in which no resilience investment is made. Moreover, after 10 years, the GDP would be at a higher level than the current GDP. Even when we considered a maximum damage situation, the GDP would remain at the current level after 10 years.

However, when the case involving inflation is compared with that involving deflation, we can see that the effect of resilience investment is significantly smaller in the former, and the trend in the GDP also differs greatly between the scenarios. If we promote resilience investment when there is no deflationary gap, the GDP will increase due to the expansion of domestic demand caused by 10 years of investing, but the GDP will decrease when investment ends. Additionally, as seen in Figure 5, the growth of the GDP would decrease due to “crowding out.” Private investment is also strong in the inflationary case, where no deflationary gap exists. In a deflationary environment, large-scale government funding places financing pressure on the private sector. This negates any economic stimulus effect,

Table 15 Macroeconomic Effects of Resilience Investment (with a resilience investment of 200 trillion yen, no deflation)

Case	Disaster	Resilience Investment	Cumulative GDP for 10 Years (trillion yen)	Cumulative tax revenue for 10 Years (trillion yen)	Workforce after 10 years (ten thousand)
Case A	No	No	5,658.0	774.3	6,517.6
Case B	No	200 trillion yen	5,918.8	834.3	6,569.1
Case C	Average Scale	No	5,238.0	696.9	6,470.9
Case D	Average Scale	200 trillion yen	5,721.8	779.2	6,530.6
Case E	Huge Scale	No	5,130.2	675.4	6,427.4
Case F	Huge Scale	200 trillion yen	5,550.6	746.1	6,496.0

Table 16 Multiplier Effect of Investment per Year (with a resilience investment of 200 trillion yen, no deflation)

	No Earthquake			Average Earthquake			Huge Earthquake		
	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP
1st year	1.43	1.36	1.43	1.79	1.51	1.79	1.37	1.09	1.37
2nd year	1.46	1.41	1.46	2.22	1.81	2.22	1.59	1.21	1.59
3rd year	1.46	1.43	1.46	2.58	2.07	2.58	2.02	1.55	2.02
4th year	1.45	1.45	1.45	2.48	1.91	2.48	1.99	1.48	1.99
5th year	1.45	1.47	1.45	2.44	1.86	2.44	1.91	1.40	1.91
6th year	1.45	1.49	1.45	2.49	1.90	2.49	1.84	1.35	1.84
7th year	1.45	1.51	1.45	2.39	1.81	2.39	1.80	1.34	1.80
8th year	1.45	1.53	1.45	2.37	1.80	2.37	1.71	1.29	1.71
9th year	1.44	1.55	1.44	2.35	1.79	2.35	1.70	1.32	1.70
10th year	1.44	1.57	1.44	2.18	1.65	2.18	1.79	1.45	1.79

Table 17 Tax Revenue-to-nominal GDP Ratio 10 Years after Resilience Investment (with a resilience investment of 200 trillion yen, no deflation)

	No Investment	Investment
No earthquake	14.9%	15.4%
Average earthquake	14.5%	15.1%
Huge earthquake	14.0%	14.8%

even when the government makes a huge investment. This was observed only in the deflationary case; in such a scenario, the earthquake damage is minimized and, at the same time, grows the Japanese economy. These effects do not exist under inflationary conditions.

The simulation also indicated that tax revenues would also increase due to GDP growth of 60 trillion yen over 10 years; there is a decline in the GDP after the investment period ends, with an attendant decrease in tax revenues. Such decreased tax revenues would make it difficult to recover an investment of 200 trillion yen. The basic trends when an investment of 100 trillion yen is made under deflationary conditions are similar to those when an investment of 200 trillion yen is made, as shown in Figure 6 and Table 18, 19, 20.

However, as noted at the beginning of this section, economic conditions characterized by the presence of inflation and the absence of a deflationary gap do not exist in reality. This virtual case was presented to compare the macroeconomic effects of resilience investment with those of deflation.

Figure 6 Estimated GDP (with a resilience investment of 100 trillion yen, no deflation)

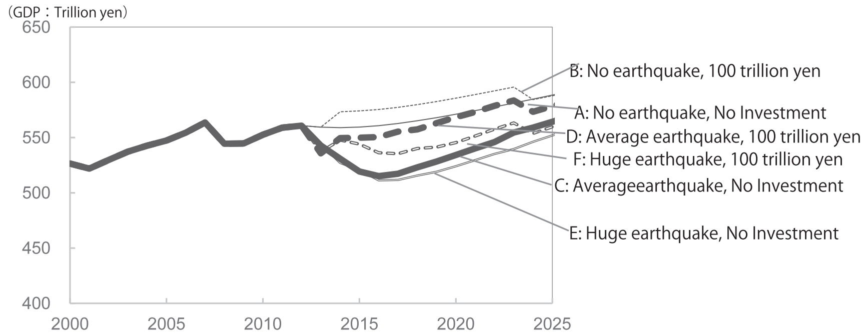

Table 18 Macroeconomic Effects of Resilience Investment (with a resilience investment of 100 trillion yen, no deflation)

Case	Disaster	Resilience Investment	Cumulative GDP for 10 Years (trillion yen)	Cumulative tax revenue for 10 Years (trillion yen)	Workforce after 10 years (ten thousand)
Case A	No	No	5,658.0	774.3	6,517.6
Case B	No	100 trillion yen	5,789.0	834.3	6,569.1
Case C	Average Scale	No	5,238.0	696.9	6,470.9
Case D	Average Scale	100 trillion yen	5,721.8	742.7	6,505.2
Case E	Huge Scale	No	5,130.2	675.4	6,427.4
Case F	Huge Scale	100 trillion yen	5,419.5	702.0	6,468.7

Table 19 Multiplier Effect of Investment per Year (with a resilience investment of 100 trillion yen, no deflation)

	No earthquake			Average earthquake			Huge earthquake		
	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP	Real GDP	Nominal GDP	Potential GDP
1st year	1.43	1.37	1.43	1.87	1.38	1.87	2.06	1.56	2.06
2nd year	1.47	1.42	1.47	3.05	2.29	3.05	2.37	1.66	2.37
3rd year	1.46	1.44	1.46	3.53	2.56	3.53	2.49	1.61	2.49
4th year	1.46	1.46	1.46	3.81	2.67	3.81	2.37	1.39	2.37
5th year	1.46	1.48	1.46	3.44	2.25	3.44	2.46	1.43	2.46
6th year	1.46	1.50	1.46	3.48	2.23	3.48	2.24	1.24	2.24
7th year	1.46	1.53	1.46	3.42	2.16	3.42	2.14	1.17	2.14
8th year	1.45	1.55	1.45	3.29	2.05	3.29	2.18	1.25	2.18
9th year	1.45	1.57	1.45	3.28	2.07	3.28	2.24	1.36	2.24
10th year	1.45	1.59	1.45	2.91	1.76	2.91	2.36	1.53	2.36

Table 20 Tax Revenue-to-nominal GDP Ratio 10 Years after resilience investment (with a resilience investment of 100 trillion yen, no deflation)

	No Investment	Investment
No Earthquake	14.9%	12.8%
Average Earthquake	14.5%	14.7%
Huge Earthquake	12.4%	12.2%

4. Conclusion

In this study, we theoretically and quantitatively examined the conditions that would lead to economic resilience, efficiency, and economic growth in the event of a future disaster. Using an advanced macroeconomic simulation model, we analyzed the effects of resilience investments of 200 trillion and 100 trillion yen, simulating the conditions of a Capital earthquake and a Nankai Trough earthquake. Four main findings were obtained from this study.

First, using predictions published in a Japanese government report, we calculated that the GDP would probably decrease to 60 trillion yen as a result of either a *Capital earthquake* or *Nankai Trough earthquake* event. The 10-year cumulative value would decrease sharply to 510 trillion yen. Notably, this estimated loss is a stochastic average value expected from a variety of situations including both the occurrence and the absence of an earthquake. These results strongly indicate the need for preparation that views a future earthquake event as the default condition.

Appropriate resilience investment related to the occurrence of an earthquake can minimize damage and also facilitate an escape from deflationary conditions. Economic growth can also be maintained in spite of a major earthquake event. An investment of 200 trillion yen for 10 years, will reduce damage to the macroeconomy and also act as an effective economic stimulus. Our study estimated that this level of investment would contribute 600 trillion yen to the GDP by 2025. However, the third finding of this study was that an investment of 100 trillion yen would be insufficient to fill the deflationary gap caused by a disaster and would have only a minor economic stimulus effect.

We also considered a hypothetical situation where no deflationary gap exists. Simulations demonstrated that resilience in the context of disaster could be achieved through investment, but that the economic stimulus effect would be limited by "crowding out." However, an investment of 100 trillion yen over a 10-year period could substantially mitigate damage to the GDP. It is important to note that although the model parameters were estimated based on real data, the numerical results described above were calculated based on specific assumptions. Therefore, further study is needed to verify whether the required level of investment depends on the extent of damage to the GDP.

By modifying the scale of investment to fill the deflationary gap, it is possible not only to build a resilience system but also to maximize efficiency in the service of economic growth.

Based on the scenarios described above, we conclude that assertions that "economic efficiency (rationality) and resilience conflict with each other and that there is a trade-off is between these two" are not valid under conditions of deflation and in situations involving a high risk of an earthquake. In these situations, sufficient resilience investment can lead to efficient economic growth and the development of a system that protects the economy against the impact of earthquakes. As a result of Japan's deflationary economic environment and the probability of a major disaster, the nation faces significant economic risk. Therefore, a policy of public investment for economic growth and resilience is strongly indicated.

Future work is needed to test and elaborate on the presuppositions of this study. Additional work is also needed to determine the most effective levels of investment in various regions. This study demonstrates that resilience investment can contribute to building a robust national economy capable of withstanding risk and emerging from deflation.

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