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Bridging the Gaps in Infrastructure Investment for Flood Protection in Asia

Mikio Ishiwatari* and Daisuke Sasaki†

Abstract

Investment is crucial in mitigating damage caused by flooding and the Sendai Framework for Disaster Risk Reduction (DRR) emphasizes it as a priority action. Policy makers need estimates of financial impact to consider investing in DRR, but such estimates are rarely available. This paper aims to estimate the financial gaps relating to infrastructure for flood protection in Asia and proposes polices and approaches to filling these gaps. It was found that nine major flood-prone economies in the region invested USD33.6 billion in flood protection, or 0.21 percent of their GDP, in 2015. Regression analysis suggests that the annual demand for flood protection infrastructure in developing Asia will be USD94.5 billion, or USD98.4 billion with climate change effects, for the period 2016-2030. The financing gap between future needs and current investment levels is around USD61 billion, USD65 billion with climate change effects annually, or around 0.24 percent of GDP in developing Asia. Developing economies thus need to turn flood disasters into opportunities for expanding this type of investment. By reviewing the past experience of the People's Republic of China, the Philippines, and Japan, it is clear that integrating flood protection in national development planning and formulating sectoral long-term plans are effective in securing commitment to investment. Increasing finance for climate change adaptation and mobilizing the financial resources of the private sector can be used as other sources. Also, innovative approaches are needed to decrease costs and achieve sustainability.

Keywords: Disaster risk reduction, multiple regression analysis, Sendai Framework for Disaster Risk Reduction, national development plan

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1. Introduction

Investment is crucial in mitigating damage caused by flooding. Various international arenas recommend increasing investment in disaster risk reduction (DRR). The Sendai Framework for DRR, which UN Member States adopted in 2015 during the Third UN World Conference on DRR held in that city, emphasizes investment as a priority action for decreasing disaster risks and losses (UNISDR 2015). The Yangon Declaration: The Pathway Forward set the goal of doubling investment to address water-related disasters and to increase water security in the Asia-Pacific region. The declaration was adopted at the Third Asia-Pacific Water Summit in 2017 by 20 heads of state, 15 ministers responsible for water issues, and other leaders (Asia Pacific Water Forum 2017). The High-Level Panel on Water (2019), which the United Nations and the World Bank jointly established, recommends doubling investment in water-related DRR within the next 5 years.

Estimating the financial gaps in DRR is needed to consider appropriate investment policies, plans and financial arrangements. However, the estimates of the demand for DRR are rarely available, and academic literature in this area is limited. This is because budget data on DRR is rarely available and when we consider the deep uncertainties in changing climate and society is difficult to do.

This paper aims at estimating the financial gaps relating to the infrastructure of flood protection. It analyzes the trends in budgets for flood protection in the major flood-prone economies in Asia and proposes a methodology for estimating the demand for flood protection infrastructure based on actual budget data newly collected. The demand in the region until 2030 is estimated using regression analysis to apply the panel data of possible socio-economic factors, and the financial gaps are estimated. The paper also aims at proposing policies on filling these gaps by examining policies and approaches in the People's Republic of China (PRC), the Philippines and Japan, which have experienced increasing investment in flood protection. This paper has been prepared as a part of the research project "Demand estimate on social and disaster prevention infrastructure in Asia" conducted by the JICA Research Institute, Tokyo, Japan.

2. Estimate of demand for flood protection infrastructure

While various recent studies have estimated demand for economic infrastructure, these studies do not include flood protection infrastructure. But flood protection infrastructure absorbs a substantial share of infrastructure investment in some economies. For example, the accumulation of infrastructure relating to flood protection and coastal protection accounts for 12.5% of the government capital stock in Japan (Cabinet Office, Japan 2017).

The Asian Development Bank (ADB) (2017b) estimates that infrastructure demand in the transport, energy, water supply, and communication sectors in 45 Asian economies will amount to 22.6 trillion USD between 2016 and 2030. The McKinsey Global Institute (2013) estimates global infrastructure spending on transport, energy, water supply, and communication will amount to 3.3 trillion USD per year between 2016 and 2030, or 3.8 percent of total global gross domestic product (GDP).

Rozenberg and Fay (2019) estimate that low- and middle-income economies would invest between 0.046 percent and 0.52 percent of their GDP in flood and costal protection annually by 2030. They explore different scenarios for future flood protection investments based on (i) different risk tolerance, (ii) different socio-economic scenarios, (iii) different unit costs of investments, and (iv) different climate change scenarios. The results show that how much countries need to spend mainly depends on the level of risk they are aiming for and the unit costs of dike construction. The estimates for East Asia, South Asia and the Pacific are shown in Table 1.

Table 1. Necessary investment in flood protection in Asia estimated by "Beyond the Gap" (Billion USD/ Year and share-of-GDP (%))

Scenario	**East and Pacific**	**South Asia**	**Total**
High spending	77.1 (0.48)	33.0 (0.77)	110.1
Low spending	10.6 (0.07)	8.5 (0.21)	19.1
Preferred	50.1 (0.33)	25.9 (0.61)	76.0

Source: Rozenberg and Fay (2019).

Several studies have estimated the required investment in climate change adaptation (CCA) that includes flood protection. Additional needs for adaptation are estimated to be from USD30 billion to USD100 billion a year by 2030 (World Bank 2019). The UNEP report estimates that developing economies need in the range for USD140 billion to USD300 billion a year by 2030 and between USD280 billion and USD500 billion a year by 2050 for CCA (UNEP 2016).

Table 2. Estimate of necessary annual costs in flood protection

Literature	**cost (USD Billion/ Year)**	**targeted year**	**disaster**		**area**	
			flood	coastal flooding	Asia	World
Ward et al. (2010)	1.74-3.21	2050	✓		✓	
Hinkel et al. (2014)	12-31 to 27-71	2100		✓		✓
Hallegatte et al. (2013).	50	2050		✓		136 cities

Source: Author.

Some studies have calculated the theoretical necessary costs of flood protection to secure a certain level of safety. The results vary by study as shown in Table 2. These studies examine the necessary costs without considering actual investment.

A World Bank report has estimated the current annual costs of flood protection at USD14.76 billion and the costs for flood protection of CCA at USD1.74-3.21 billion over the period 2010-50 for the developing economies in East and South Asia and Pacific regions (Ward et al. 2010). These costs are however estimated based on the unrealistic assumption that no flood protection was in place in 2010 and that all protection works will be completed before 2050 to a safety level of the 50-year monthly flood in urban areas and the 10-year monthly flood in agricultural areas.

Hinkel et al. (2014) project that coastal flooding would damage 0.2–4.6 percent of global population annually in 2100 with annual losses of 0.3–9.3 percent of global GDP. Annual adaptation costs of constructing dikes would range from between USD12-31 billion to USD27-71 billion for low-and high-warming scenarios respectively. Furthermore, average flooding losses for the world's 136 largest coastal cities are estimated to be some USD6 billion per year and increase to USD52 billion per year in 2050 even without climate change. With climate change and land subsidence factored in, the losses would become USD1 trillion per year in 2050. Adaptation measures would cost some USD50 billion annually in total (Hallegatte et al. 2013).

3. Investment trends in Asia

3.1 Data collection

There are no common datasets of the investment in flood protection, and budget data is not always publicly available. Even when it is available, each economy has its own definition of flood protection infrastructure. There is thus some inconsistency in data. These problems are a limitation of this study.

Expert teams visited government offices to collect data or examine opened data in Bangladesh, PRC, India, Indonesia, Malaysia, Pakistan, Philippines, Thailand, and Vietnam for this study. These nine economies can be regarded as major flood prone economies in developing Asia. Total population and GDP of the nine economies account for over 90% of these total amounts of developing economies in Asia. In addition, the experts collected data from the high-income economies of Japan, the Republic of Korea, and Taiwan. Budget data of Myanmar were not available.

The expert teams collected data of damage and death toll caused by floods from public statistics and disaster management ministries. The economic damage data usually cover physical damage. If government data are unavailable, other datasets were used: SIGMA developed by Swiss Re Institute, NatCatSERVICE developed by Munich RE, and the EM-DAT: Emergency Events Database developed by the Centre for Research on the Epidemiology of Disasters.

All economic data were converted to 2015 prices using the flood protection deflators of Japan and the GDP deflators of the other 11 economies. Japan produces deflators by sector including flood protection. Population data were obtained from the UN World Population Prospects. Economic data on GDP, per capita GDP, and deflators were obtained from the World Economic Outlook Database.

3.2 Current investment in flood protection

Nine major developing economies in Asia invested USD33.6 billion in flood protection in 2015 (Table 3). This amount accounts for 0.21 percent of the total GDP of these economies. Investment in flood protection accounts for some 4 percent of total infrastructure investment. Twenty-five developing economies, which cover 96% of the population and 85% of the GDP of developing Asia, invested USD881 billion in infrastructure in 2015 (ADB 2017b). Total investment in Asia including the three high-income economies of Japan, Republic of Korea and Taiwan is estimated at over USD50 billion, or 0.24 percent of GDP. Investment is at almost the same level as the economic damage of USD53 billion estimated by ADB (2016).

Investment in Asia is 15-20 times the investment in flood protection in Europe and the US. Investment in Europe and the US is estimated at USD3.2 billion per year and USD2.2 billion per year, respectively (Directorate-General for Environment, European Commission 2014; Multihazard Mitigation Council 2017; USACE 2017). The PRC, the Philippines, Thailand, Japan, and Taiwan are investing over 0.1 percent of GDP in flood protection, while other economies are investing less than this. Japan's share of 0.39 percent is the highest in the region.

Table 3. Investment in flood protection in 2015

Economy	Investment (billion USD, 2015 prices)	Share of GDP (%)	Source
PRC	29.9	0.27	Min. of Water Resources
India	1.5	0.07	Min. of Finance
Philippines	1.1	0.38	Dep. of Budget Management
Indonesia	0.5	0.06	Min. of Public Works
Thailand	0.5	0.12	Royal Irrigation Department Dep. of Public Works & Country Planning, Bangkok Metropolitan Administration
Vietnam	0.1	0.05	Min. of Planning & Investment
Malaysia	0.03	0.01	Min. of Finance
Bangladesh	0.007	0.004	Min. of Water Resources
Pakistan	0.009	0.004	Federal Flood Commission
Sub-total Developing Economies	33.6	0.21	
Japan (2014)	17.5	0.39	Cabinet office, Min. of Land, Infrastructure, Transport, and Tourism
Republic of Korea	2.0	0.13	Min. of Land, Infrastructure & Transport
Taiwan	0.3	0.06	Water Resource Agency
Total	53.4	0.24	

Source: Author.

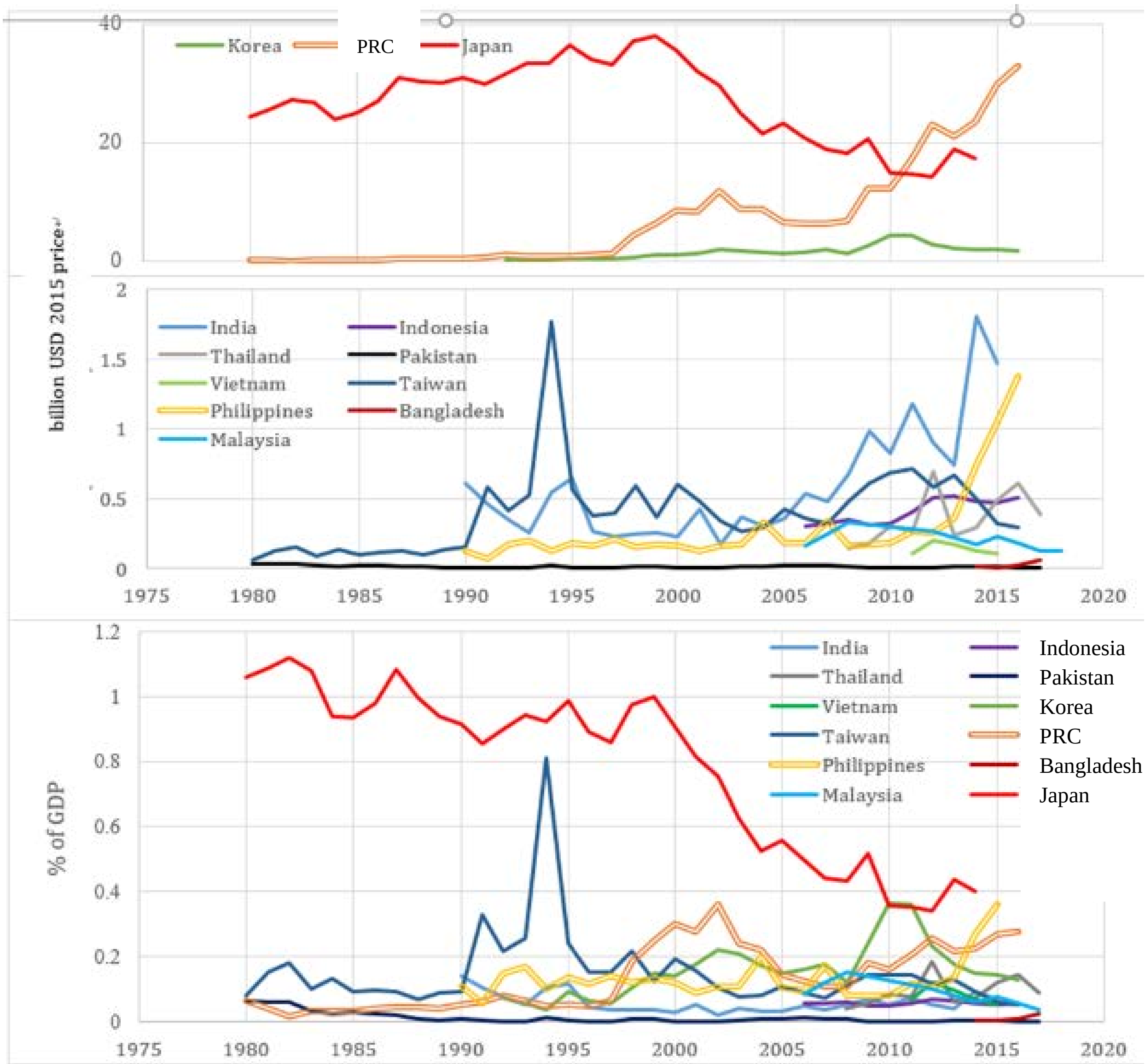

Figure 1. Trends in flood protection investment in twelve major economies in Asia

Source: Ishiwatari (2019b).

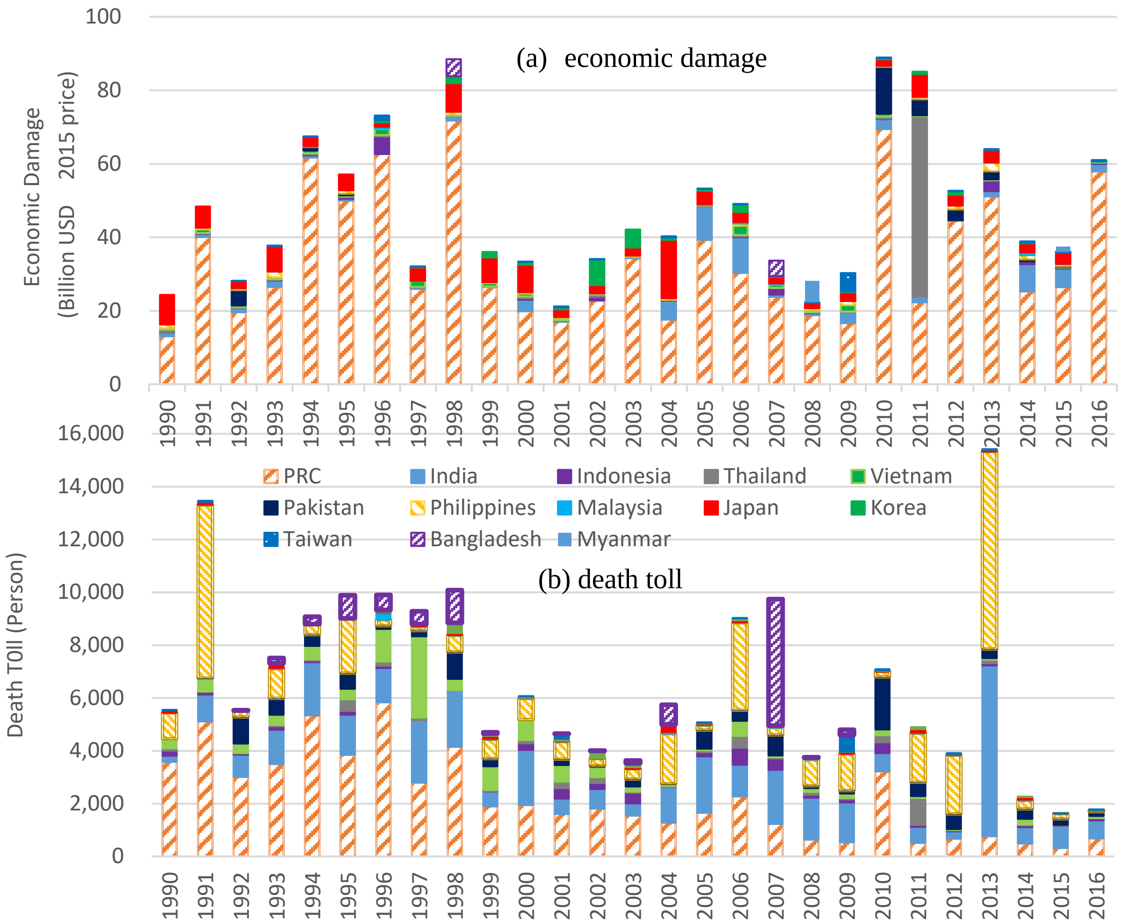

Figure 2. Trends of economic damage (a) and fatalities (b)

Note: Death toll (b) excludes two cyclone disasters, 1991 in Bangladesh and 2007 in Myanmar.

Source: Author.

3.3 Trends of investment and damage

Figure 1 shows the trends of investment in flood protection in 12 economies. The PRC, the Philippines, and India have been increasing their budgets for flood protection for the last several years, however the budgets of the high-income economies of Japan, the Republic of Korea and Taiwan are fluctuating. The developing economies increase investment in flood protection as their economies develop. These economies can only invest a limited amount in flood protection when in the stage of a low-income economy. For example, Pakistan is unable to increase investment at its current level of development. But once economies reach the level of low-middle income they have more financial leeway to start increasing investment. Economies typically invest less than 0.1 percent of GDP before reaching a GDP per capita level of USD1,300. The economies with over USD1,700 of GDP per capita invest at least 0.05 percent of GDP. India and Vietnam are reaching this level and have started increasing investment in flood protection. The average scale of investment is estimated at 0.12-0.16 percent of GDP in Asia at the middle-income economic stage with reference to the coefficient derived by using a least-squares method.

Economic damage from the 1990s ranged between 20 to 90 billion USD at 2015 prices (Figure 2a) and has not increased clearly. This could be considered as the benefits from investment in flood protection, since potential damage has increased as the economy develops in the region. The average annual damage from 1990 until 2016 was 47 billion USD. Damage in the PRC accounted for over 70% of the total, while Japan, India and Thailand accounted for 9, 5, and 4 percent respectively.

The death toll does not show a clear direction, since the two mega-disasters of 1991 Bangladesh and 2007 Myanmar accounted for some 60% of the total figure for the 13 economies during the period 1990 - 2016. The death toll from each mega-disaster reached some 140,000, while the total in the 13 economies was some 550,000. Figure 2b does not include these two cyclone disasters to allow understanding of the impacts of other disasters.

4. Estimating flood investment

4.1 Methodology

ADB (2017b), Fay and Yepes (2003), and Ruiz-Nunez and Wei (2015) conducted regression analysis to estimate the necessary infrastructure stock of power, transport, telecommunications, and water and sanitation. Infrastructure stock is derived from determinants such as income per capita, agriculture and manufacturing value-added shares to GDP, urbanization, and population density. Projected demand for infrastructure stock of new capacity was valued at the unit cost for each type of infrastructure (Ishizuka et al. 2019). Developing economies expand infrastructure demand at an accelerated pace as society changes by industrialization and urbanization and income levels increase (Hirota 2017).

These methodologies for estimating demand for economic infrastructure cannot be applied to flood protection infrastructure, since stock data on flood protection are not available. Thus, a methodology for estimating demand for flood protection infrastructure needs to be established. The authors focused on flow data on flood protection, for there exists some relevant literature regarding regression analysis, such as Asongu et al. (2018), in which the flow of foreign direct investment (FDI) was employed as the dependent variable. In this study, budget data on flood protection were adopted instead of stock data for the regression model, considering that budget data as a proxy of flow data might well reflect the size of flood investment in each economy. Demand for flood protection infrastructure was estimated by a dynamic panel model, and equation 1 was adopted:

$$\mathrm{B_{i,t}} = \alpha_1 \mathrm{B_{i,t-1}} + \alpha_2 \mathrm{y_{i,t}} + \alpha_3 \mathrm{Popden_{i,t}} + D_i + \epsilon_{\mathrm{i,t}} \qquad (1)$$

Where $B_{i,t}$ is the budget per capita of flood protection in economy i-th at time t; $y_{i,t}$ is Gross Domestic Product per capita of economy i-th at time t; $Popden_{i,t}$ is the population density of economy i-th at time t; Di is a fixed effect of economy i-th, and $\epsilon_{i,t}$ is an error term.

A dataset of the five economies of the PRC, India, Indonesia, Pakistan, and the Philippines using data that are available for 10 years from 2006 to 2015 was built to estimate the regression values. This dataset covers budget, income per capita, agriculture and manufacturing value-added shares to GDP, urbanization, and population density. The results of the estimated regression are indicated in Table 4. The model was selected based on the values of AIC (Akaike Information Criterion), and followed by performing statistical tests, namely the F-test and the Hausman test, to verify whether the fixed effects model was appropriate for the targeted data. Demand in nine developing economies was estimated based on the results obtained by multiple regression analysis with 2015 as the base year. GDP projections and population densities (2016–2030) were obtained from the datasets of ADB projection information (ADB 2017b).

4.2 Results: Estimation and financial gap

The regression analysis suggests that demand for flood protection infrastructure in nine developing economies in Asia will total USD 1,417 trillion for the period 2016-2030, and average USD 94.5billion per year (Figure 3). The share-of-GDP of investment in flood protection would increase from 0.21 percent in 2015 to 0.36 percent on average during 2016-2030.

The ADB estimates that developing Asia needs to invest USD1.5 trillion per year in infrastructure providing power, transportation, telecommunications, and water and sanitation facilities (ADB 2017b). In the ADB estimation, the demand for flood protection accounts for 6.3 percent of total infrastructure demands and is higher than the 3.1 percent (USD53 billion) for water and sanitation.

This estimation is consistent with the findings in previous sections. Middle-income economies will increase investment as their economy develops. In particular, India, Vietnam and Bangladesh, which belong to lower-middle income economies and are predicted to enjoy higher economic growth, will increase investment more than other economies.

While our methodology is different from the one in the World Bank report (Rozenberg and Fay 2019), the results fall in the range of the World Bank's prediction: USD110.1 billion for high spending scenario, USD19.1 billion for low spending scenario, and USD76.0 billion for preferred scenario. The financing gap between USD 94.5 billion of future needs and USD 33.6 billion of current investment levels is around $61 billion annually or around 0.24 percent of GDP. While the PRC and the Philippines have already secured budgets at the level of 0.3-0.4 percent of GDP, other economies have secured budgets far below what they need. These economies need to arrange financing sources to fill the gap.

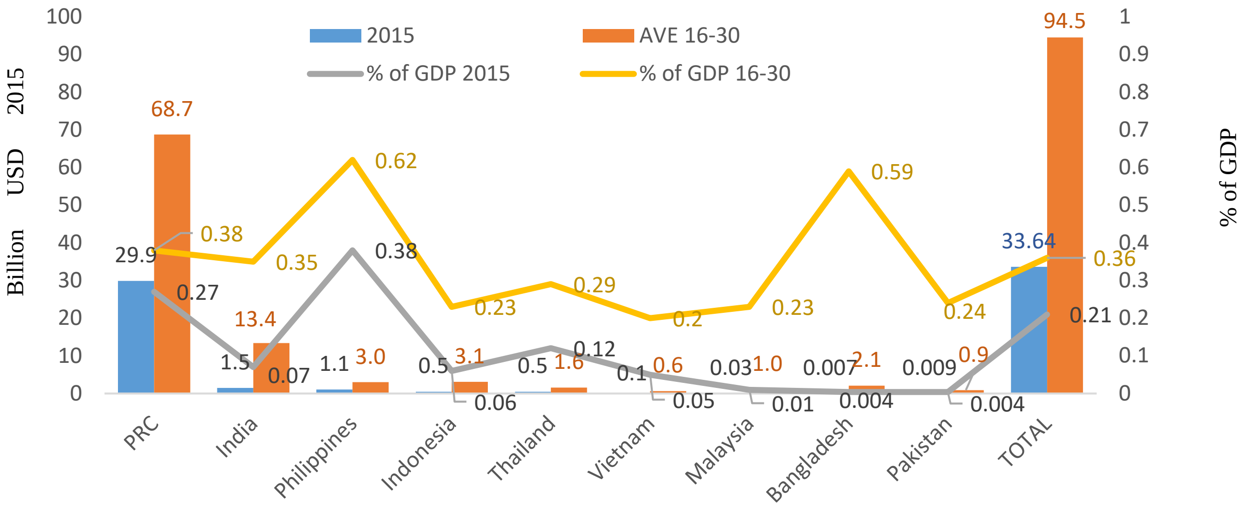

Figure 3. Estimated and current investment

Source: Author.

Table 4. Results of the estimated regression

Variables	Coefficient
Lagged value of budget	0.679203
	(4.51818)***
GDP per capita	0.0020472
	(1.82801)***
Population density	0.038973
	(1.82801)*
Observations	45
R-Squared	0.9595

*** p<0.01, **p<0.05, *p<0.1

Source: Author.

4.3 Estimate of climate change effects

Flood damage is projected to increase under a changing climate in the Asian region (Takakura et al. 2019). Accordingly, the demand for flood protection infrastructure will increase. The average annual budget increase from climate change effects during 2015-2030 was estimated by equation (2):

$$A_i = \beta \ I_i \ B_i \qquad (2)$$

Where A_i is the average annual budget increase from climate change effects during 2015-2030 in economy i-th; β is the budget increase rate per unit of damage; I_i is the increased ratio of economic damage in the economy i-th; and B_i is the average demand of flood protection infrastructure per year in economy i-th during 2015-2030 that disregards climate change effects.

The budget increase rate per unit of damage (β) was calculated as 0.5 from the correlation between budget and damage in the PRC and the Philippines, where disaster damage and budgets have been increasing in recent years. Alfieri et al. (2017) estimated the economic damage affected by river floods at global scale and included each country's increased ratio of economic damage (I_i). This estimate does not include the effect of socioeconomic changes such as projections of population, GDP, or land use. The values of A_i I_i and B_i are seen in Table 5.

Table 5. Figures of A_i, I_i and B

	A_i USD billion per year	**I_i**	**B_i** USD billion per year
PRC	2.2	0.064	68.7
India	1.1	0.17	13.4
Philippines	0.1	0.05	3.0
Indonesia	0.2	0.1	3.1
Thailand	0.1	0.08	1.6
Vietnam	0.03	0.09	0.6
Malaysia	0.02	0.03	1.0
Bangladesh	0.2	0.17	2.1
Pakistan	0.01	0.03	0.9
TOTAL	**3.9**	**NA**	**94.5**

Source: Alfieri et al. (2017) and author.

This analysis suggests that the demand for flood protection infrastructure from increased climate change effects in nine developing economies in Asia will average USD 3.9 billion per year for the period 2016-2030. The demand increases by 4 percent because of climate change.

5. Policies for filling financial gaps

This section examines the policies for filling the financial gaps and makes policy recommendations. It reviews the trends and impacts of investment in Japan, the PRC and the Philippines. These economies can turn a flood disaster from a crisis into an opportunity to expand investment in flood protection. From this, Japan and the PRC could decrease the death toll and economic damage share of GDP relatively quickly, while it would need some years to show positive impacts in the Philippines.

5.1 Japanese experience of investing in flood protection

Japan has managed investment in flood protection by establishing the approach of securing a budget over the last one and half centuries (Figure 4), and has increased flood protection budgets every time it has suffered from a major disaster. It increased investment through incorporating flood protection into national development plans, developing legislation, formulating long-term investment plans, creating special accounts, and sharing costs with local governments and communities during the modernization process from the late 19th century until the mid-20th century. This experience can be regarded as good practice for developing economies in establishing appropriate financing mechanisms.

Nakamura and Oki (2016) identify three eras of paradigm sifts in flood risk management in Japan by reviewing socio-hydrological variables: “Era 1: 1910-1935, changing society”; “Era 2: 1935-1970, responding to mega floods”; and “Era 3: 1970-2010, response to economic growth." "Era 0: 1985-1910" is added to explain the establishment of the national mechanisms of flood risk management. This section reviews the policies and investment in flood protection in Japan in line with this time framework.

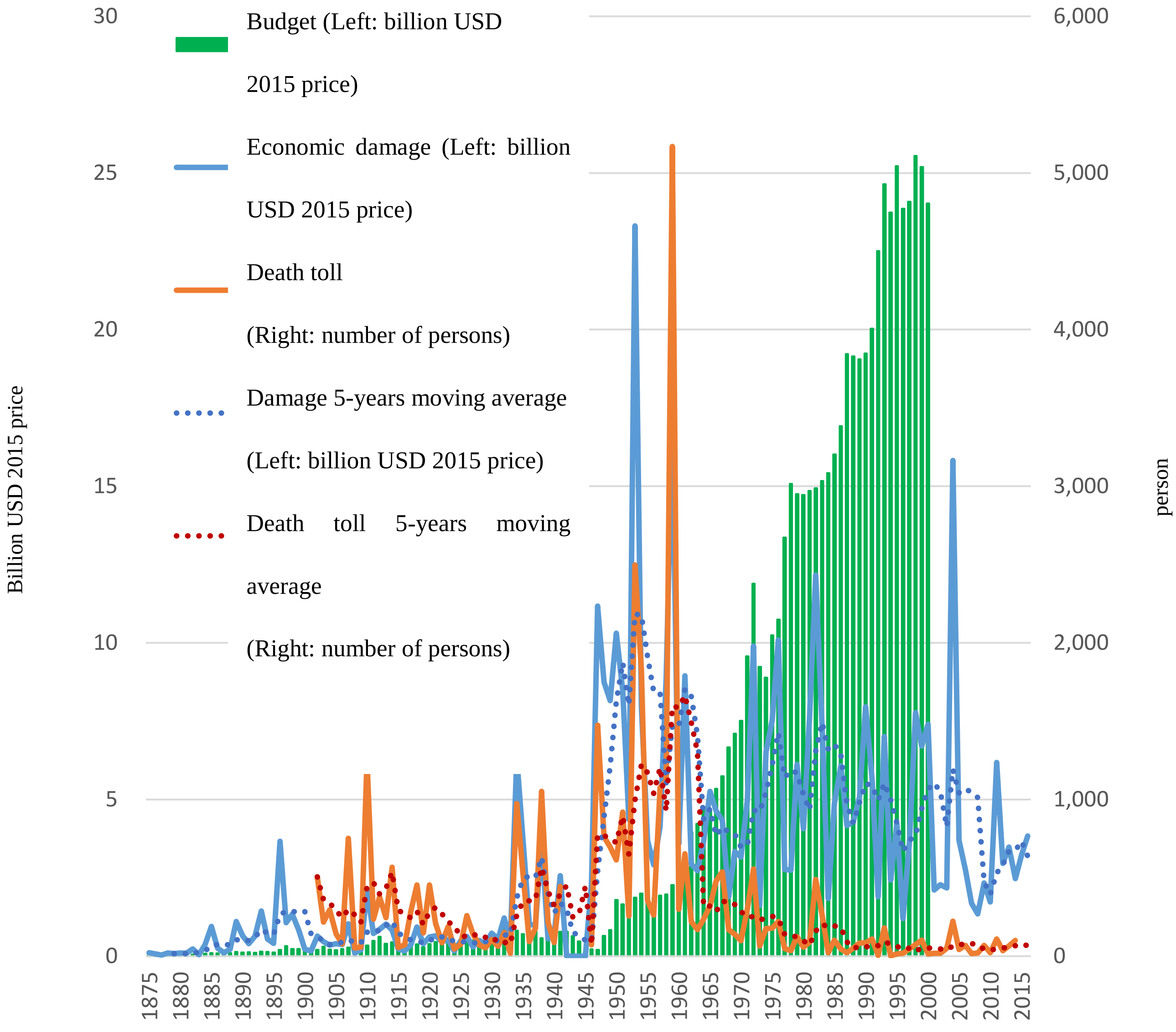

Figure 4. Trends of flood damage and investment in flood protection in Japan

Source: Adapted from Research Center of National Land Development (2006) and MLIT (yearly).

(a) Era 0: - 1910 establishing the national mechanism for flood protection

Following the beginning of modernization in the late 19th century, damage by flood disasters increased as the economy developed. Damage and human losses more than tripled in the 1890s compared to the 1880s (Takei 2017). The national government started national projects for flood protection of the Yodogawa River in Osaka and Kyoto prefectures following a flood disaster in 1885. This flood submerged most of Osaka City, and affected some 270,000 people, resulting in economic damage estimated at 4.4 percent of the then National Income. Before this disaster, prefectural governments had conducted flood protection projects, but flood protection works in major rivers required high-technology inputs and enormous budgets that prefectural governments could not meet. The national government introduced modern technology for flood protection from the Netherlands. The government hired Dutch engineers who provided advice on planning and construction of works of flood protection throughout the country.

The River Law was enacted to mitigate flood damage in 1896 when flood disasters began affecting communities throughout the country. The annual economic damage in 1896 is estimated at 11.4% of the National Income. The River Law stipulated that the national government could conduct flood protection works covering multiple prefectures. The landowners of farmlands and industrial capitalists, who contributed to economic development and suffered from flooding, promoted enactment of the law. The government then started national projects in nine major rivers (Takei 2017).

The government increased investment in flood protection by taking the opportunity to do so after major disasters. The budget for flood protection for each decade increased by eight times from the 1880s to the 1930s (Table 6). The budget for flood protection accounted for 0.5-1.3 percent of the National Income until 1910. However, these budgets were less than the economic damage from floods for most of this era (Figure 4).

Table 6. Japanese flood control budget by decades from the 1880s to the 1930s

Decade	Total budget for flood control and rehabilitation (Billion JPY, 1995 prices)	Events
1880s	179.3	1885 major flood in Osaka
1890s	374.3	1896 Major floods throughout the country 1896 Enacted River Law
1900s	518.7	
1910s	831.1	1910 largest flood in Meiji Era 1911 First long-term plan for flood control
1920s	820.4	1921 Second long-term plan for flood control 1923 Great Kanto Earthquake
1930s	1,400.7	Takahashi expansionary financing following the Great Depression 1933 third long-term plan for flood control Increasing military budget

Source: Adapted from Research Center of National Land Development (2006).

(b) Era 1: 1910-1935, changing society

The flood disasters in 1911 left some 2500 people dead or missing, and economic damage accounted for 3.6 percent of National Income. The government formulated the first long-term plan for flood protection in 1911 and continued to formulate the long-term plans for nearly one century until 2005. The government envisaged to secure long-term commitment to flood protection by including necessary costs in the plan. The first plan was formulated following another major flood. This long-term plan covered works in 50 major river basins for 18 years and mentioned the necessary cost of 1.7 percent of the national budget (Matsuura 1986). The government created a special account to manage financing flood protection separately from the general national account. This account was expected to secure budgets at a certain level without fluctuations in the national budget. The special account included shares by local governments and loan programs from postal savings.

The budgets for flood protection accounted for 0.4-1.6 percent of the National Income in the period from 1910 to 1935. The government spent 1.6 percent of the National Income in 1911 in the year of major flood disaster. This is the highest before World War II. However, Japan could not decrease flood damage before World Wat II. The government could not always secure budgets for flood protection because of inflation in the 1910s, rehabilitation efforts following the Great Kanto Earthquake in 1923, and the impact of the Great Depression in 1929. Furthermore, in the 1930s, the government allocated the major portion of the national budget for military expansion instead of public works.

(c) Era 2: 1935-1970, responding to mega floods

Japan invested limited amount in flood protection during the 1930s and World War II and suffered from a series of severe floods following World War II. Annual economic damage reached between 1 and 10% of National Income from 1946 until 1959.

The government invested about 1 percent of National Income in flood protection between the 1960s and the 1990s. Because of this intensive budget allocation, economic damage decreased to 0.1 percent of National Income (Ishiwatari 2019). The government needed to develop national resources and land to feed the increasing population.

The government formulated development plans for national lands and put the highest priority on comprehensive river basin development to increase energy and food production, covering flood protection, irrigation, and hydropower generation (Okita 1962). The government formulated the Comprehensive National Development Plan in 1962 that was aimed at developing and utilizing natural resources as well as properly distributing them throughout the country. The plan guided the comprehensive development of national lands from a long-term perspective. The plan included flood protection as the main area of infrastructure investment (Economic Planning Agency, Japan 1962).

The government formulated the 10-year plan for flood protection, which was the first long-term plan since World War II. The national Diet had decided the budgets of flood protection every year and the scales of the budgets had fluctuated. Because of the long-term plan, budgets for flood protection could be secured for multiple years. The government again created a special account for flood protection in 1960 to exclusively manage budgets for flood protection. This special account received some one-third of the cost of national projects that local governments shared.

(d) Era 3: 1970- , response to economic growth

Investment in infrastructure for flood protection provides economic impacts. Tsukahara and Kachi (2016) estimated the annual benefit from flood protection investment to have been over 6 trillion JPY, or 55 billion USD, in the mid-1990s. This was almost double the budget for flood protection. Total accumulated stock of flood protection infrastructure reached the value of JPY78 trillion, or USD710 billion, amounting to 10% of government infrastructure stock, in 2014. Areas protected from floods more than doubled from 1960, with the flood protection ratio increasing from 24% in 1960 to 56% in 2000. The Ministry of Land, Infrastructure, Transport and Tourism, Japan defines the flood protection ratio as the ratio of protected areas to risk areas of once-in-30- to 40- year floods for class-A rivers and once-in-5- to 10- year floods for non-major rivers.

The government has however halved investment since 2000 because of financial constraints. The share-of-GDP of the flood protection budget decreased from over 1 percent in 1999 to below 0.4 percent in 2010 (Figure 1). The government is currently investing some 15% of the public works budgets in flood protection and rehabilitation. To respond to needs in the stabilized stage of economic growth in the 2000s, the Japanese government has abolished sector specific plans since 2005 and integrated all sectors into the infrastructure development plan without mentioning necessary costs. While the long-term plans were useful in securing investment during the development stage of the country, there are some disadvantages, such as limited coordination among sectors, inflexibility of budget allocation, and demotivation rom decreasing budgets. Similarly, the special account for flood protection was integrated into the special account of infrastructure that includes road, port, and airport accounts in 2008.

5.2 PRC

The PRC started increasing their flood protection budgets in the late 1990s following a series of floods (Figure 5 (a)). The economy integrated flood protection into the five-year plans of national economic and social development. The ninth five-year plan (1996-2000) made water resources development including flood protection the first priority in infrastructure construction and set targets of protection from the largest floods since the nation's establishment in seven major rivers (Shen 2014, Matsuura 2003). Based on the national development plans, the five-year sector plans of comprehensive disaster prevention and reduction, and water development and reform provide guidance, are targets and list major projects (Chuncheon Global Water Forum 2017).

The flood from 1997 until 1998 was the largest flood disaster in the Yangtze River basin since 1954 (Ye and Glantz 2005). The economic damage from flooding in 1998 accounted for 3 percent of GDP. The economy has increased its flood protection budget by over 6 times from

1996 to 2006 and over 5 times from 2006 to 2016. Disaster damage decreased because of this increased investment. The annual death toll decreased from some 4,000 on average in the 1990s to less than 1,000 in the 2010s. While the absolute figures of economic damage have not decreased from the 1990s, share-of-GDP of economic damage has decreased, from 1-4 percent in the 1990s to less than 1 percent since 2000.

Once the PRC reached the lower-middle income stage of development, the economy had more financial leeway to invest in flood protection. The PRC started increasing investment in flood protection when per capita GDP reached more than USD 1,000, the level of lower-middle income economies in 1994. The economy could not invest in flood protection at the development stage of low-income economies, although flood disasters caused economic damage at 1-4 percent of share-of-GDP in the first half of the 1990s. Until 1997 the economy had invested in flood protection with less than 0.1 percent of GDP.

5.3 Philippines

The Philippines is rapidly increasing its national budget for flood protection following a series of typhoon disasters in recent years (Figure 5(b)). Typhoons Ondoy and Pepeng caused serious floods and landslides in Metro Manila and Luzon Island in September and October 2009. The total economic damage was estimated at PhP38 billion, or 0.5 percent of GDP. Following 2009, several typhoons continuously caused serious damage. In particular, Typhoon Yolanda caused a high tide disaster in the Leyte Island in 2013, resulting in economic damage of PhP95 billion, or 0.8 percent of GDP. Since the per capita GDP reached USD2,000 in the late 2000s, the economy can afford to increase budgets for flood protection.

The Philippine Development Plan 2011-2016 (NEDA, Philippines 2011) recognizes inadequate flood management measures and envisages the development of efficient and adequate infrastructure for flood protection. The budget for flood protection increased by over eight times from 2008 to 2016. The effects of this investment have not become apparent yet. The death toll or economic damage does not appear to have decreased clearly. The Philippine Development Plan 2017-2023 (NEDA 2017) understands the threats from climate change and continues the initiatives of flood protection.

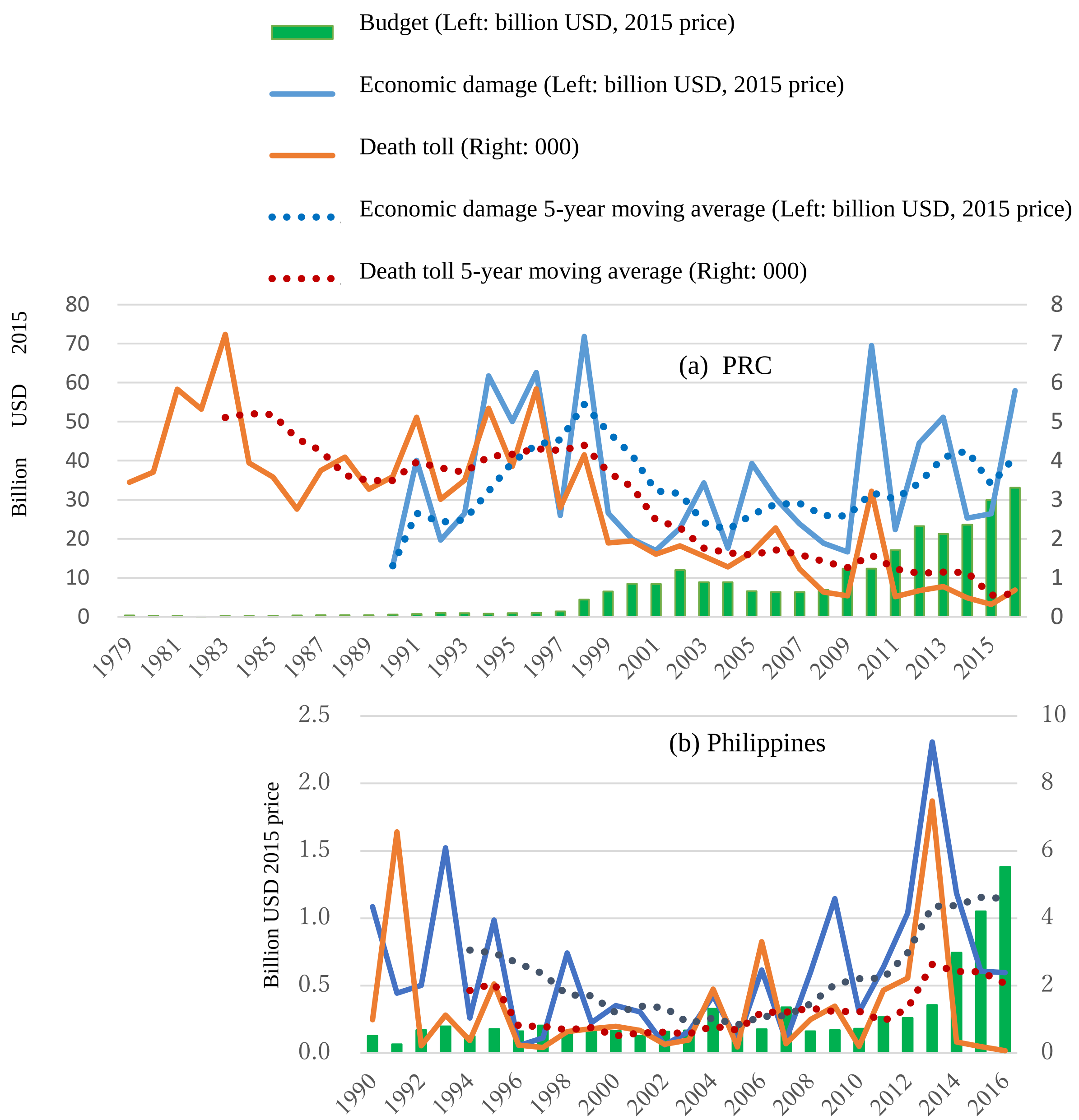

Figure 5. Investment and impact in (a) PRC and (b) the Philippines

Source: Author.

5.4 Policy options

The lessons of securing the budgets of flood protection can be obtained from practices in the PRC, the Philippines, and Japan. Ishiwatari and Surjan (2019) categorize major financing sources as (a) domestic financing, (b) official development assistance (ODA), (c) climate change adaptation financing, and (d) private financing (Figure 6).

(a) domestic financing

These three economies could secure long-term commitment of investment from national budgets by integrating flood protection in national development plans. Further, Japan and the PRC have formulated sectoral long-term plans. These two economies established mechanisms of cost sharing between national and local governments.

(b) official development assistance

A limited amount of ODA is allocated for disaster prevention and preparedness. Some 0.4 percent of the total development assistance was used for this activity from 1991 until 2010 (Kellett and Caravani 2013, Kellett et al. 2014).

(c) climate change adaptation financing

Donor countries are increasing ODA for climate change adaptation (CCA). This can be a potential financing source for DRR. The member countries of the Organization for Economic Co-operation and Development Development Assistance Committee provided USD12.4 billion for CCA from ODA in 2014, which accounts for 10% of total ODA and increased from 7 percent in 2010 (UNEP 2016).

Three major donors, the World Bank, Asian Development Bank and Japan, will provide some USD15 billion annually for CCA around 2020. The World Bank will increase CCA financing at an average of USD10 billion a year over the period 2021–25. This amount is more than doubled from the period 2015-18 (World Bank 2019). The Asian Development Bank will double annual climate financing to USD6 billion, including USD2 billion for CCA, by 2020 (ADB 2017a). The Japanese Government is providing CCA at some 2.5 billion annually.

(d) private financing

Investment by the private sector is crucial, but DRR measures do not mean profits for private companies. Governments need to establish the mechanisms for engaging the private sector in financing flood protection. For example, local governments have requested private companies to construct retardation basins when developing housing compounds in Japan. These basins compensate for flood volumes increased by development activities. Some 4,700 basins with the total capacity of over 3 million m^3 have been constructed in the Tsurumigawa river basin, where rapid urbanization as residential areas in the Tokyo Metropolitan area occurred during high economic growth. As a result, the number of houses inundated by floods decreased from several thousands in the 1970s to less than one hundred from the 1990s (Ishiwatari 2016).

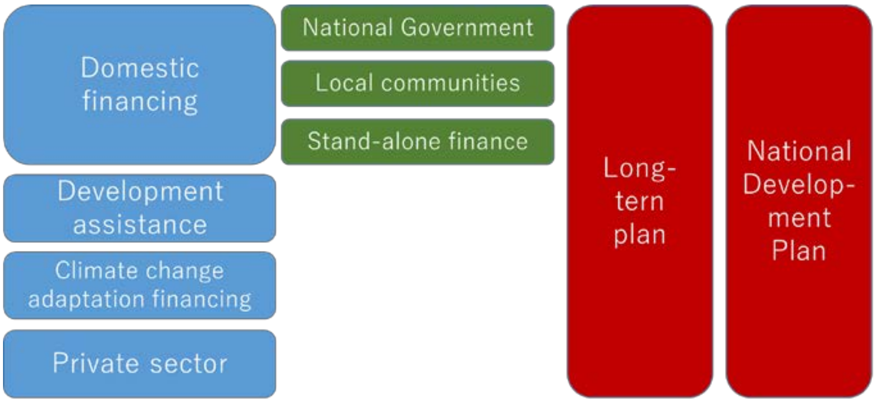

Figure 6. Concept of DRR investment

Source: Ishiwatari and Surjan (2019).

5.5 Innovative approaches to reducing cost and achieving sustainability

The costs of flood protection can be reduced by applying innovative solutions. Nature-based solutions can be more cost-effective than conventional engineered approaches in some cases. For example, a combined nature-based and engineered approach in New York City could reduce the cost of flood protection by USD 1.5 billion, or 22percent, compared to the engineered approach alone (Browder et al. 2019). Also, this approach brings social and environmental benefits associated with fisheries, forestry, eco-system protection, and recreation (Global Commission on Adaptation 2019).

Japan initiated an environment-friendly approach for flood protection projects in the 1990s and started some 600 projects to enhance eco-systems in river basins and coastal areas. This approach uses the natural functions of flood protection instead of the conventional "grey structure" made from concrete and steel and can reduce the cost of projects. The River Law was revised in 1997 to include environmental preservation as the objective of flood protection projects and requires that a balance between environment and flood protection be achieved (Alexander et al. 2019; Takahasi and Uitto 2004).

For example, the Ministry of Land, Infrastructure, Transport and Tourism, Japan, created wetlands as a recovery program from a flood disaster in the Maruyamagawa River to create a habitat for storks. Local communities also support the effort to create a better environment for storks by producing pesticide-free rice in their paddy fields. This became a brand rice, leading to the stimulation of the local economy. The country has been expanding this approach. Recovery works following the Great East Japan Earthquake and Tsunami in 2011 include the combined approach of green belts and dyke structure to prepare for tsunamis (Ranghieri and Ishiwatari 2014).

Each country should secure the operation and maintenance (O&M) costs of infrastructure as well as reducing overall costs by introducing innovative solutions. In Japan, the O&M costs of the national government increased by 30 percent from 2010 and reached some 30 percent of the flood protection budget in 2017. This is because the country has continuously developed structures. The national government is managing over 10,000 facilities assisting flood protection throughout the country. The country has initiated measures for reducing the costs of O&M. River management agencies have introduced information and communication technologies to monitor facilities and river conditions, developed databases of three-dimensional data for facilities, and involved local communities and civil society organizations in the O&M of facilities (Council of Infrastructure Development 2013).

6. Conclusion

This study found that twelve major flood-prone economies in Asia invested in flood protection at over USD50 billion, or 0.24 percent of GDP, in 2015. These economies are considered to have made the majority of investments in flood protection in the region. Major flood-prone economies in terms of economic damage by floods were included except for Myanmar where data are not available. Nine developing economies in Asia invested USD33.6 billion, which accounted for 0.21 percent of their total GDP, in flood protection in 2015. This amount accounted for some 4 percent of total infrastructure investment.

The financing gap between future needs and current investment levels is around USD61 billion or USD65 billion when accounting for climate change effects annually or around 0.24 percent of GDP in developing Asia. The methodology of multiple regression analysis using time series data was used in the study. The regression analysis suggests that demand for flood protection infrastructure in nine developing economies in Asia will average USD 94.5billion per year for the period 2016-2030. With climate change effects, this amount increases to USD 98.4 billion (by 4 percent). The share-of-GDP of investment would increase from 0.21 percent in 2015 to 0.36 percent on average during 2016-2030.

To fill the financial gap, economies need to turn flood disasters from crises into opportunities for expanding this type of investment. The PRC, the Philippines, and Japan have secured commitment of investment by integrating flood protection in national development planning and sectoral long-term plans. The PRC and Japan have succeeded in decreasing human losses and economic damage in share-of-GDP by increasing investment. Increasing finance in climate change adaptation can be expected to be a financial source for flood protection. Innovative approaches are needed to decrease costs and achieve sustainability. Mobilizing finance from the private sector should be another.

In this study, the regression model did not take non-economic factors such as geographical background and political climate into account in an explicit manner, as well as the existing literature such as ADB (2017b). Further research regarding elaboration and sophistication of the model will be required in the future.

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Abstruct (in Japanese)

要約

治水への投資は、仙台防災枠組が優先行動として強調しているように、洪水被害を軽減するために不可欠である。政策立案者が防災への投資を検討するにあたり、どれほど資金需要のギャップがあるのかの推定を必要とするが、現在、そのような推定値はほとんど利用できない。このペーパーはアジア地域における治水インフラ投資の財政ギャップを推定し、そのギャップを埋める政策とアプローチを提案することを目的としている。 2015 年にはアジア地域の 9 つの主要な洪水頻発国と地域において 336 億米ドル、GDP の 0.21%、を治水に投資したことが明らかになった。重回帰分析により、発展途上国における 2016 年から 2030 年までの治水インフラの年間需要は 945 億米ドル、気候変動の影響を加味すると 984 億米ドル、と推計される。将来需要と現在の投資レベルとの資金ギャップは約 610 億米ドル、気候変動の影響を入れると 650 億米ドルとなる。これはアジアの発展途上国の GDP の約 0.24%にあたる。こうした国々は水害を危機から治水投資を拡大させる機会に変える必要がある。中華人民共和国、フィリピン、および日本の過去の経験を検討することにより、国家開発計画に治水を組み込み、セクター別の長期計画を策定することが投資を確保するのに効果的であることが明らかになった。気候変動適応における資金は増加しており、また、民間部門の資金を動員することで、さらなる財源を確保できる。また、コストを削減し、持続可能性を達成するには、革新的なアプローチも求められている。

キーワード: 災害リスク軽減、重回帰分析、仙台防災枠組、国家開発計画

Working Papers from the same research project

"Research on Demand Estimate on Infrastructure in Asia"

JICA-RI Working Paper No. 191

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