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Investments in flood protection: Trends in flood damage and protection in growing Asian economies

Mikio Ishiwatari* and Daisuke Sasaki†

Abstract

Investing in flood protection is crucial in mitigating flood damage. However, most recent studies have not included an examination of actual investment data nor studied the relationships between investment in flood protection measures and damage or benefits. This paper aims at assessing policies toward flood protection by empirically analyzing flood damage and investment in flood protection measures in Asian economies. The trends of investment and damage in terms of the share of gross domestic product (GDP) vary by country. The People's Republic of China (PRC) and Japan in the Post-WWII era were able to steadily decrease economic damage, while the Philippines, Taiwan, Republic of Korea (ROK), India, and Pakistan fluctuated in their budget outlays and damage. In cases of either a rising or decreasing trend, it was demonstrated that the Bayesian structural time series model can simulate investment to some degrees. It was also found that investment in flood protection is cost-effective at the regional and national levels. The annual benefits for the past two decades are estimated at 159 billion USD in PRC and 120 million USD in the Philippines. The net benefit (benefit minus cost) accumulation from 2016 in Asian developing economies is predicted to reach 263 billion USD against an investment of 157 billion USD by 2030.

Keywords: Bayesian Structural Time Series model, climate change, cost-benefit analysis, economic internal rate of return, flood damage

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1. Introduction

Economic damage caused by disasters is increasing globally because of economic and population growth (Botzen, Deschenes, and Sanders 2019; Kousky 2014). Climate change is increasing the frequency and intensity of extreme weather events, while flood damage is beginning to escalate (IPCC 2014; Sillmann et al. 2013). Investing in flood protection is crucial in mitigating damage, as the Sendai Framework for Disaster Risk Reduction stresses (UNDRR 2015).

While estimating the needs and benefits of investing in flood protection is crucial in strengthening investment policies, most recent studies have not examined actual investment data nor studied the relationship of investment to damage and benefits. One reason for this is because the budget data of flood protection is rarely publicly available. Even when data is available, such data cannot be compared directly due to differential definitions of flood protection infrastructure. For example, Japan tracks investments in landslide protection and coastal protection separately from flood protection, while other countries do not. Most of the investment in flood protection comes from the construction of infrastructure such as dams and dikes.

Ishiwatari (2019) collected investment data in major flood-prone economies in Asia, including all high-ranked economies in economic damage by floods. These nine countries, which are Bangladesh, PRC, India, Indonesia, Malaysia, Pakistan, The Philippines, Thailand, and Vietnam, are responsible for the majority of disaster-related spending in the region. The total population and gross domestic products (GDP) of the nine economies account for over 90% of the total for developing economies in Asia. It was found that these economies increase flood protection investment according to development stages. The economies with less than USD1,300 of GDP per capita can invest limited amounts, less than USD1 per person or 0.1% of GDP. Once they reach the low-middle income stage, they start increasing investment in flood protection, at least USD1 per person or 0.05% of GDP, with an average investment of 0.12-0.16% of GDP.

While benefit analysis methodologies have been established for individual flood protection projects, the benefits of investment in flood protection have not been analyzed at the regional and country levels because of the lack of national budget data. Understanding the benefits at the country level is necessary to establish policies for financing investment in flood protection.

This paper aims at assessing policies related to flood protection investment. The analysis may help to clarify its relationship with economic growth and provide justification for such investments. By using datasets created by Ishiwatari (2019), it examines (i) the relationship between investment and economic growth and flood damage and (ii) the benefits of mitigating damage by investment.

First, past trends of flood protection investment in Japan and major flood-prone economies in Asia are examined. Second, the time series of the investment amounts in the People's Republic of China (PRC) and Taiwan are analyzed to simulate investment trends by adopting a Bayesian structural time series (BSTS) model. Finally, the benefits of investment are estimated at the national and regional levels in Asia.

2. Analysis of past investment trends

This section examines (1) the relationship between flood damage and investment; (2); the relationship between flood damage, budget for flood protection, and national income, (3) the time series of investment in Japan and major flood-prone economies in Asia. Both Japan following World War II, and from the 1990s, PRC, have succeeded in steadily decreasing flood damage. Japan before World War II and other economies were unable to decrease damage consistently and experienced increasing flood damage at times. There is a positive correlation between flood damage and the budget of flood protection in Japan before World War II and the Philippines in the 2000s and 2010s. The BSTS model succeeds in simulating investment, to some degree, in both cases of a rising trend in PRC and a decreasing trend in Taiwan.

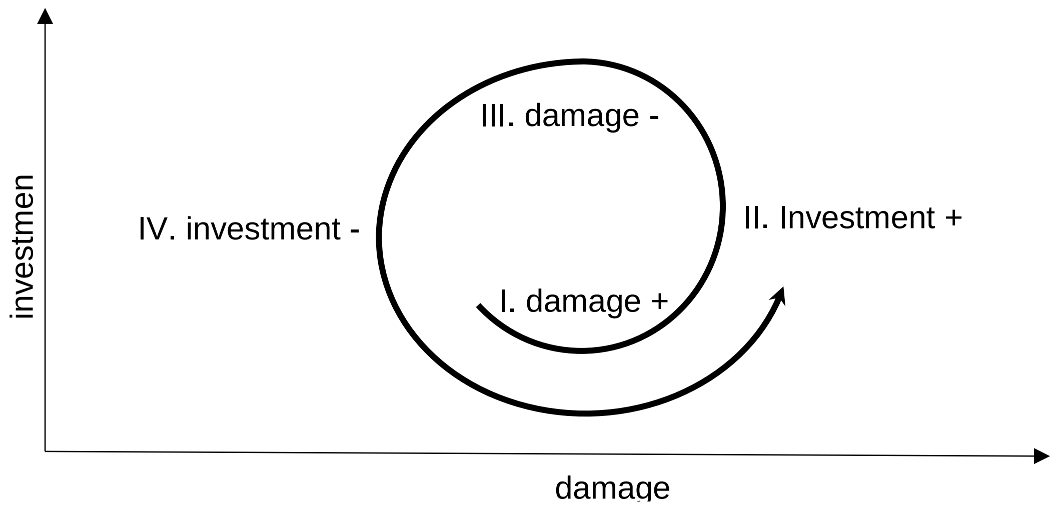
2.1 Trend of damage and investment in Japan

Japan has reduced flood damage by investing in flood protection over the century. However, while increasing overall, the trend was less than consistent during this period. When flood damage increased as the national economy grew, the government started increasing investment in flood protection. Once the investment began to reduce the damage, the government reduced its investment and shifted spending to other areas. As a result of reducing investments in protection, the damage started to increase again when severe flooding occurred. This cycle is shown as a counterclockwise trajectory in Figure 1.

The decadal trends in flood damage and flood protection budgets are analyzed as a share of the national income since the 1880s (Figure 2). Since GDP data from the 19th century is not available, national income is used instead. In the 1880s, flood damage increased to some 2% of the national income as Japan modernized and the government increased the budget for flood protection in the 1890s. From the 1900s until the 1920s, flood damage decreased. In the 1930s and 1940s, flood damage again increased, but the government reduced investment in flood protection because of the Great Depression, the Great Tokyo Earthquake, military expansion, and war. In the latter half of the 1940s, Japan suffered from a series of severe floods, and damage costs reached more than 5% of national income in the 1940s. This prompted the government to expand its budget in the 1950s, and damage has constantly decreased until now.

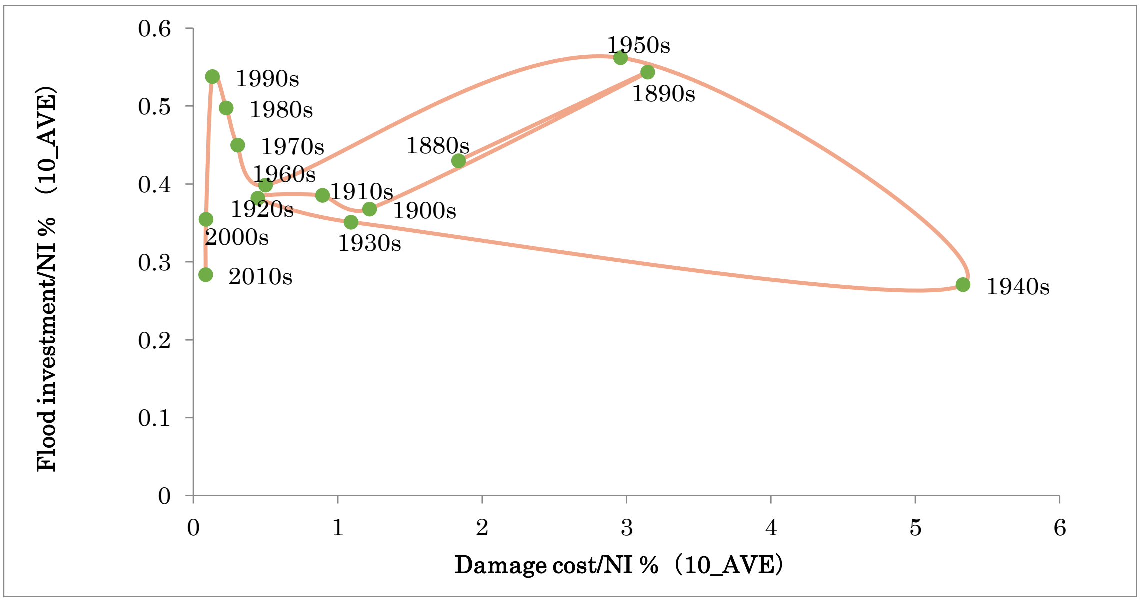
From the 1960s to the 1990s, Japan did not follow this cycle as figure 2 shows. Since disaster losses were decreasing, the government could have cut the budget but continuously increased it in reality. During the high growth period from the 1960s to the 1990s, flood protection accounted for 0.4-0.6% of the national income. From the 2000s onwards, the budget has decreased because of financial constraints on the national budget.

Figure 1: The cycle of flood damage and investment



Source: Authors

Figure 2: Flood damage and investment in Japan



Source: Authors

The budget for flood protection has increased with the development of the country (Table 1). There is a positive correlation between per capita national income and per capita budget for flood protection in Japan except for the periods of 1910-1920 and the 2000s and 2010s. There is a negative correlation between per capita national income and damage throughout the post-World War II period. As the economy developed, the budget for flood protection increased, and the flood damage decreased.

There is a positive correlation until 1920 between flood damage and the budget for flood protection for the year and the following years. Since the budget does not necessarily reflect the year of the disaster, budgets with time lag were examined. It was found that the budget tends to increase one or two years after disasters. These are negatively correlated during the post-WWII period, when the government could secure budgets for flood protection without any preceding flood disasters.

Table 1: Correlation coefficients of damage, budget and national income (per capita) in Japan

Japan	NI and budget (per capita)	NI and damage (per capita)	Budget and damage (per capita)	Damage and budget 1yr later	Damage and budget 2yr later	Damage & budget 3yr later
Pre-WWII	++					
1875-1900	++		+	++	+	+
1901-1920				+	+	
1921-1941	+					
Post-WWII	++	-	-	-	-	-
1945-1960	++					
1961-1980	++					
1981-2000	++					-
2001-2015						

++: 0.6-1.0, +: 0.4-0.6, -: -0.4- -0.6, --; -0.6- -1.0

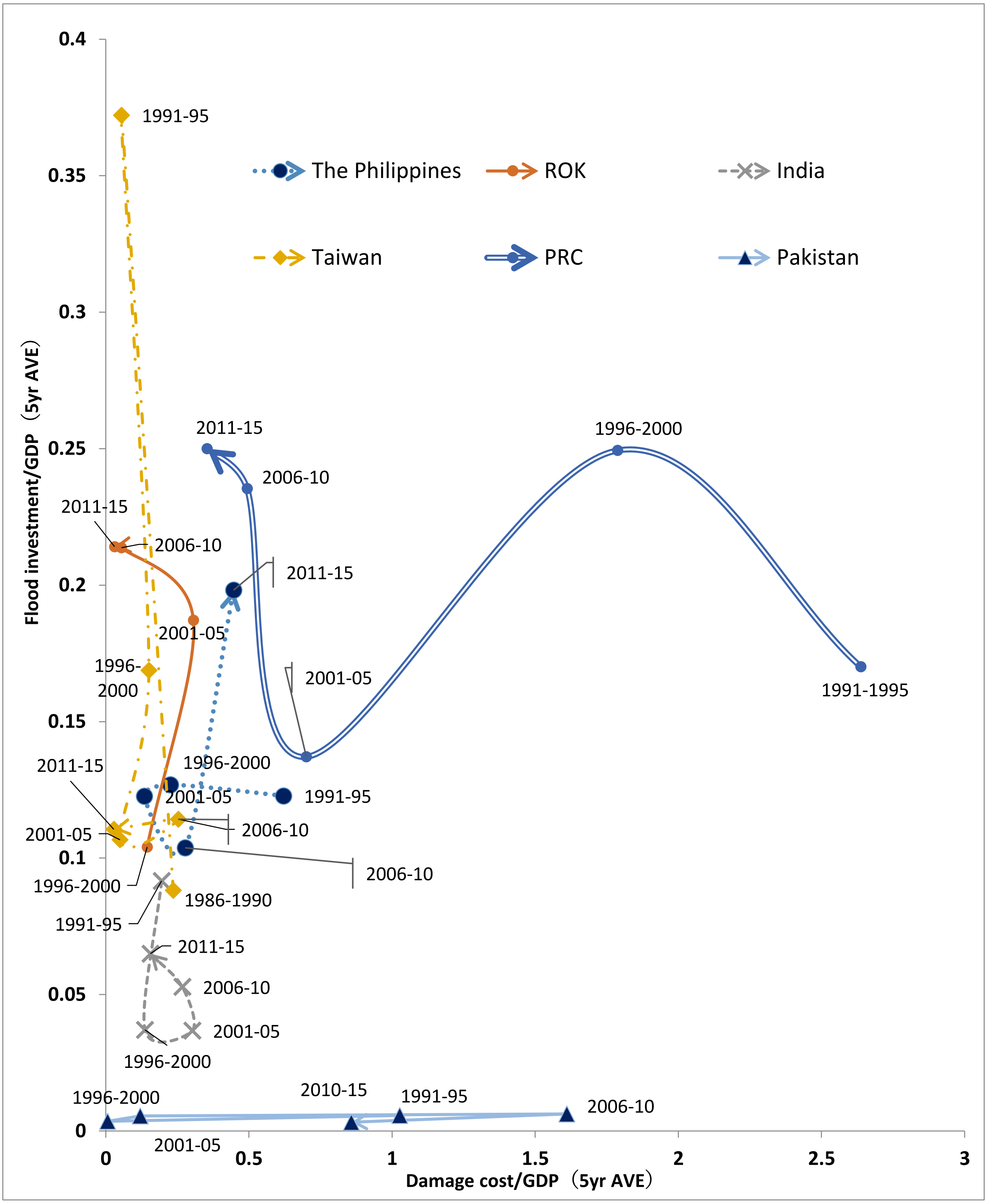
Source: Authors

2.2 Trends of damage and investment in Asia

The budget trends of six flood-prone economies in Asia, for which more than 25 years of data is available, are analyzed. A simple five-year average of damage and budget as a percentage of GDP is shown in Figure 3. PRC increased the budget in the late 1990s, the late 2000s, and the 2010s, while economic damage has consistently declined, even during the period of budget decreases in the early 2000s. The Republic of Korea has increased its budget from the 1990s, and even though damage increased in the 1990s, it then decreased. The Philippines has kept the budget at about 0.1% of GDP. Damage has increased since the late 2000s, and the government has started increasing the budget in the 2010s. However, the damage has not yet shown signs of decreasing. Taiwan increased the budget in the 1990s and kept it at about 0.1% of GDP since the 2000s. India has increased its budget since the 2000s, with damage decreasing. Pakistan experienced damage at over 1% of GDP in the first half of the 1990s and the latter half of the 2000s. The Pakistani government has not increased the budget regardless of the increase or decrease in damage and maintains smaller budget outlays than other flood-prone economies.

Counterclockwise trajectories explained in Figure 1 can be observed in the Republic of Korea, Taiwan, India, and the Philippines. PRC has not taken a reverse trajectory of damage increase and has consistently mitigated the damage.

Figure 3: Flood damage and investment of flood-prone economies in Asia



Source: Authors

Table 2: Correlation coefficients of damage, budget and national income (per capita) in Asian economies

	GDP and budget (per capita)	GDP and damage (per capita)	Budget and damage (per capita)	Damage and budget 1yr later	Damage and budget 2yr later	Damage & budget 3yr later
PRC 1990－2015	++					
1990-2000	++					
2001-15	++					
Philippines 1990－2015	++				+	
1990-2000		-		-	+	
2001-15	++	+		++	++	+
India 1990－2015	++					
1990-2000	--			+		
2001-15	++					
Pakistan 1990－2015						
1990-2000					++	
2001-15						

++: 0.6-1.0, +: 0.4-0.6, -: -0.4- -0.6, --; -0.6- -1.0

Source: Authors

Per capita damage, per capita budget, and per capita GDP are compared in four economies for which data are available since 1990 (Table 2). There is a positive correlation between GDP per capita and per capita budget in some periods in the three economies except Pakistan. Economic growth is likely to enable the economies to increase their budgets.

There is a negative correlation between GDP per capita and damage per capita in the Philippines up to 2000, in which damage decreased as the economy developed. After 2001, this changed to the opposite—a positive correlation—and damage increased. There is no correlation in the other economies.

There is no clear relationship between the amount of damage per capita in a given year and the per capita budget for flood protection. For the Philippines after 2000, there is a positive correlation between the amount of damage in a given year and the budget one and two years later. There is a gap of one to three years between disasters and budget increase. The Philippines government varied its budget for flood protection depending on the magnitude of flood disasters.

2.3 Predicting the amount of flood protection investment based on a Bayesian Structural Time Series (BSTS) model

As discussed above, the authors observed a certain relationship between flood investment and damage costs. Followed by this, the time series of the amount of flood protection investment itself is to be analyzed in this subsection. The very question to be asked is how we can predict a future amount with the actual values that are observed in the past.

For the methods, the authors adopt a BSTS model, which can be implemented with the 'bsts' package for R (Scott 2020). This model was explained in a detailed manner in Scott and Varian (2014), while the main points are as follows: First, the model can be represented in state space form that comprises two equations.

$$y_t = Z_t^T \alpha_t + \epsilon_t \qquad \epsilon_t \sim \mathcal{N}(0, H_t) \tag{1}$$

$$\alpha_{t+1} = T_t \alpha_t + R_t \eta_t \qquad \eta_t \sim \mathcal{N}(0, Q_t) \tag{2}$$

where $y_t, \alpha_t, \epsilon_t, \eta_t, Z_t, H_t, T_t, R_t, Q_t$ are the vector of observations, the state vector, observation noise, system noise, respectively, and hereafter, deterministic matrices. Equation (1) is called the observation equation, which interlinks the vector of observations y_t with the state vector α_t. Meanwhile, equation (2) is called the transition equation, which describes how the state vector α_t evolves. Second, the model adopts a Markov chain Monte Carlo (MCMC) sampling algorithm to conduct a simulation using Bayesian model averaging (Hoeting et al. 1999; Madigan and Raftery 1994).

In this study, the authors implemented a BSTS model in R using the 'bsts' package and introduced an autoregressive model (AR(p)):

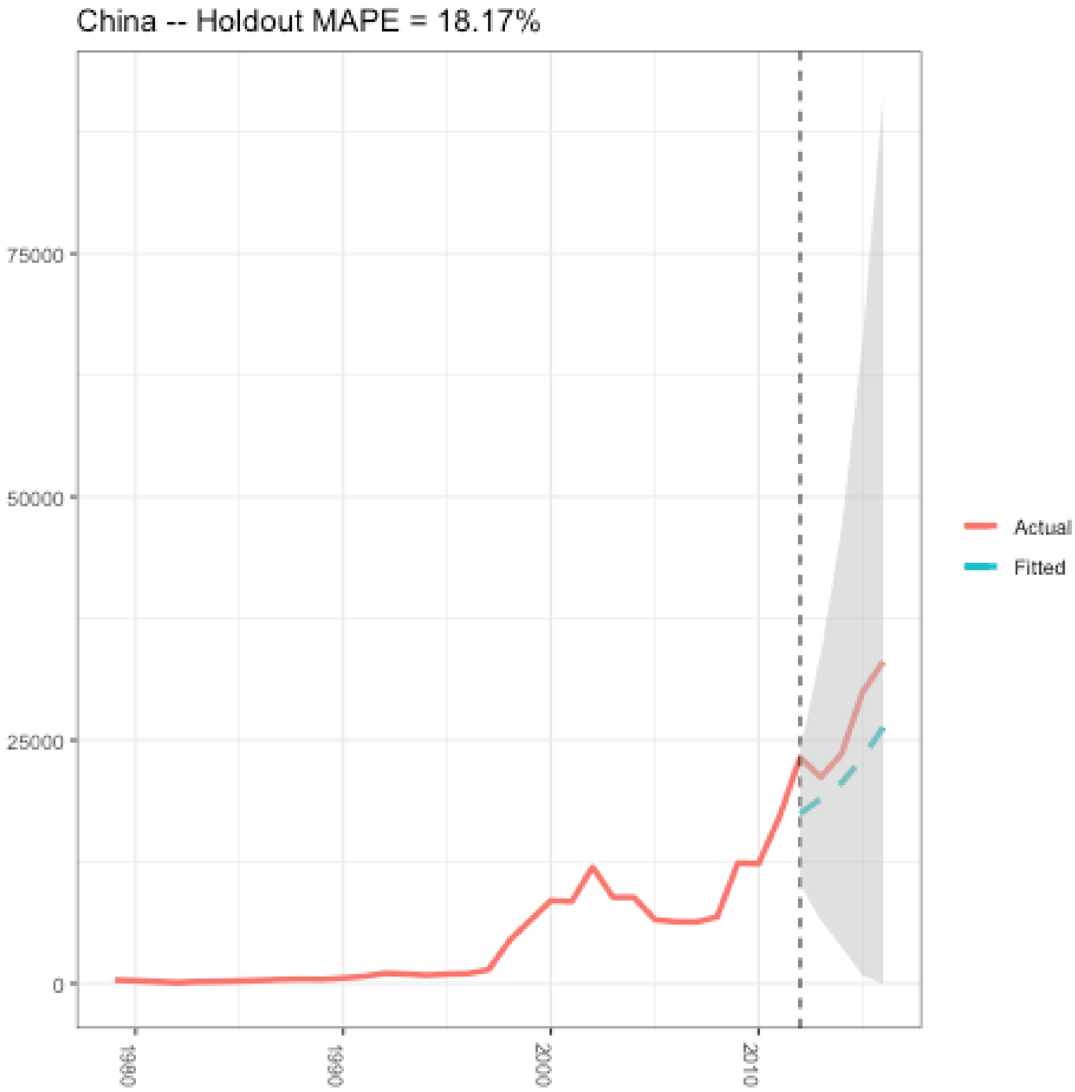
$$\alpha_t = \phi_1 \alpha_{t-1} + \cdots + \phi_p \alpha_{t-p} + \epsilon_t \qquad \epsilon_t \sim \mathcal{N}(0, \sigma^2) \tag{3}$$

to simulate the amount of flood protection investment. Two cases, namely PRC and Taiwan, that contrasted in the recent trends after the year 2011 are examined; that is to say, the amount of flood protection investment in PRC has generally been increasing since 2011, while Taiwan is the opposite. The number of MCMC draws is set to 1000 (see Appendix A for the R source code).

The output result of PRC is as shown in Figure 4. The red line represents the actual values of the amount of flood protection investment in PRC, while the blue line represents the fitted values. The gray shaded area indicates the 95 percent credible interval for the prediction. As we can see, the forecasting result seems to show a moderate degree of accuracy, i.e., the fitted values reflect a rising trend as well as the actual values. The mean absolute percentage error (MAPE) of the case of PRC is 18.17%, which indicates, roughly speaking, that the fitted values have deviated from the actual values by about 20% on average. The output result of Taiwan is shown in Figure 5. The legends are the same as in Figure 4. According to Figure 5, the forecasting result appears to reflect the same trend of the actual values, namely a decreasing trend, as that of the case of PRC. The MAPE of the case of Taiwan is 24.13%, which can be interpreted as almost fitting the same level as the case of PRC. From the standpoint of a future forecast of the amount of flood protection investment, both results of the MAPE could be considered to be acceptable, provided that the simulation results are used as a reference for mid-to-long term policymaking.

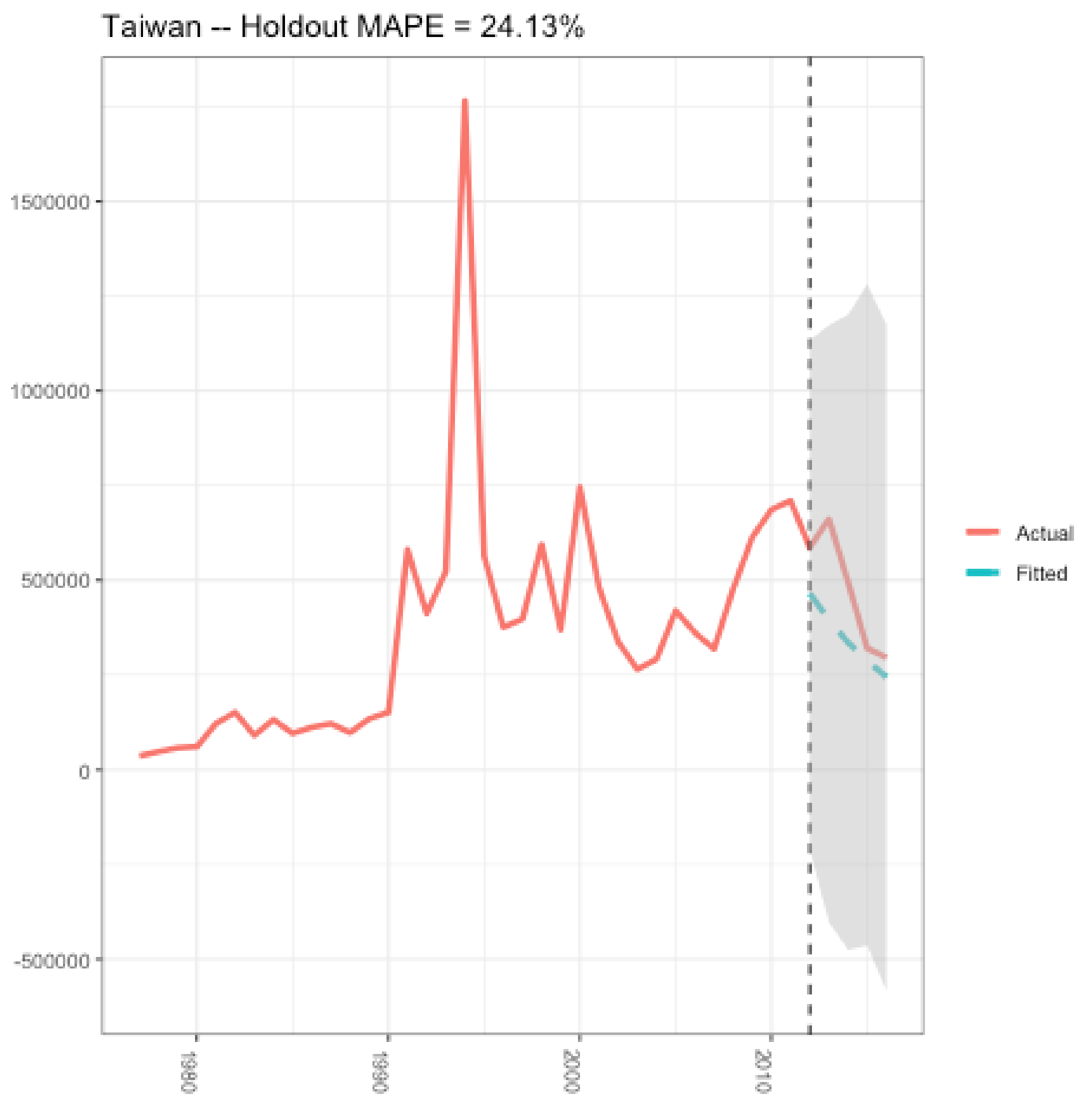
Based on the above results, the BSTS model has succeeded in simulating to some degrees both the case of a rising trend and that of a decreasing trend. Therefore, the authors consider that the approach using the BSTS model may be effective to a certain extent in forecasting the amount of flood protection investment in the future, and that stakeholders could ascertain the scale of future flood protection investment in each economy.

Figure 4: Output result of the BSTS model of PRC



Source: Authors

Figure 5: Output result of the BSTS model of Taiwan



Source: Authors

3. Benefit of investment

This section analyzes the benefits of (1) the past investment in PRC and the Philippines by estimating assets accumulated in at-risk areas and (2) future investment projected in Asian developing economies. Both cases show positive benefits, indicating the efficiency of investment in flood protection.

3.1 Benefits by past investment in PRC and the Philippines

This subsection estimates the benefits of investment in PRC and the Philippines. The two economies, which have increased flood protection budgets and provided budget and damage data for over two decades, are selected to understand the benefits. Other economies examined in Section 2.2 are not estimated because of limited data and lower levels of investment. Tsukahara & Kachi (2016) propose a method of analyzing cost-effectiveness for flood protection investment at the national level in Japan in the post-World War II era. They estimate the annual benefit of flood protection investment as the difference between the asset costs accumulated in original at-risk areas of floods and actual damage costs caused by floods in a given year. The difference is regarded as the number of assets in the area protected by infrastructure constructed for flood protection. All assets accumulated in the original at-risk areas would be damaged by floods without infrastructure for flood protection. This method does not consider expanding the risk areas, and its estimates of benefits are on the lower side.

This method is applied to estimate the benefits of flood protection investment in the PRC and the Philippines. It is assumed that the assets in the at-risk area of floods are accumulated in proportion to the increase in GDP per capita. This can be justified, because in Japan, flood damage density, which is defined as the amount of flood damage divided by the area affected, increased in proportion to GDP per capita until the mid-1990s during economic growth (Figure 6).

The estimation of benefits can be described as follows:

$$BE_t = A_t - Dam_t \quad (6)$$

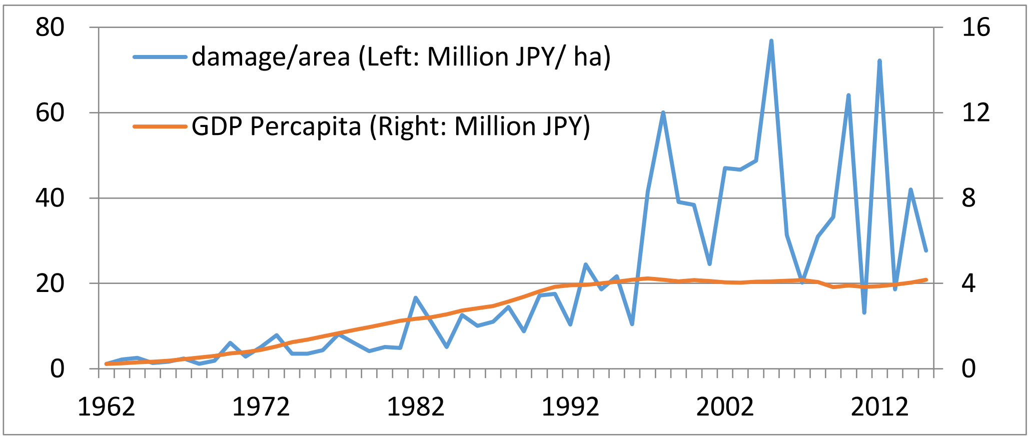
$$A_t = Dam_0 \ (1 + yr_t) \quad (7)$$

where BE_t is the benefit at time t, A_t is the assets accumulated in the original at-risk area at time t, Dam_t is the damage reported at time t, Dam_0 is damage reported at the base year, and yr_t is the growth rate of GDP per capita from the base year until time t. Damage data are used as the five-year moving average.

The results are shown in Figures 7 and 8. The annual benefit in PRC is estimated at 159 billion USD in 2016, and in the Philippines, at 120 million USD in 2015.

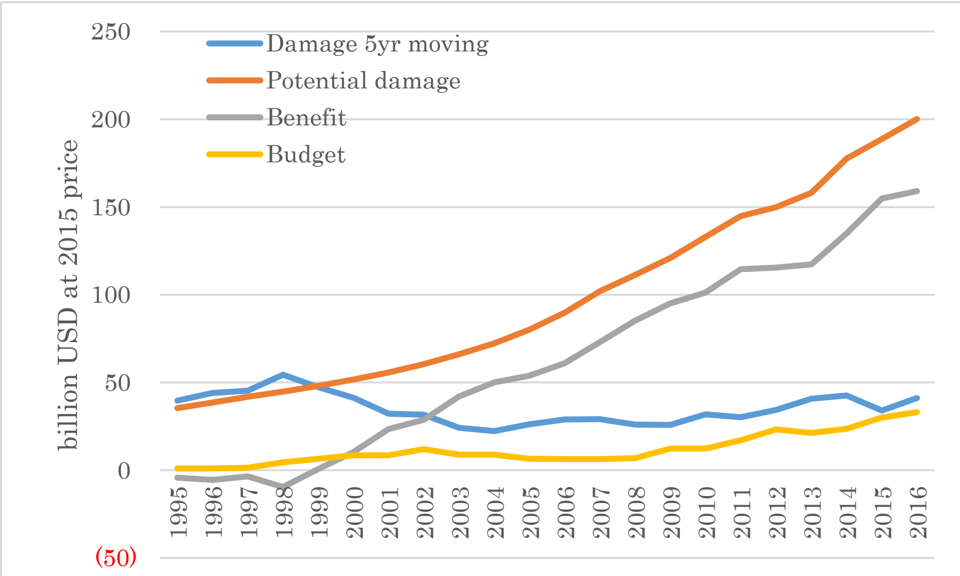
Annual benefit in PRC reached some five times the investment in 2016. GDP per capita increased six times over the last two decades in PRC, and accumulated assets increased accordingly. Reported per capita damage has increased by a few percent from 1995. In the Philippines, annual benefit has decreased in the 2010s. This is because a series of severe disasters has occurred since 2009.

Figure 6: Flood damage density and per capita GDP in Japan



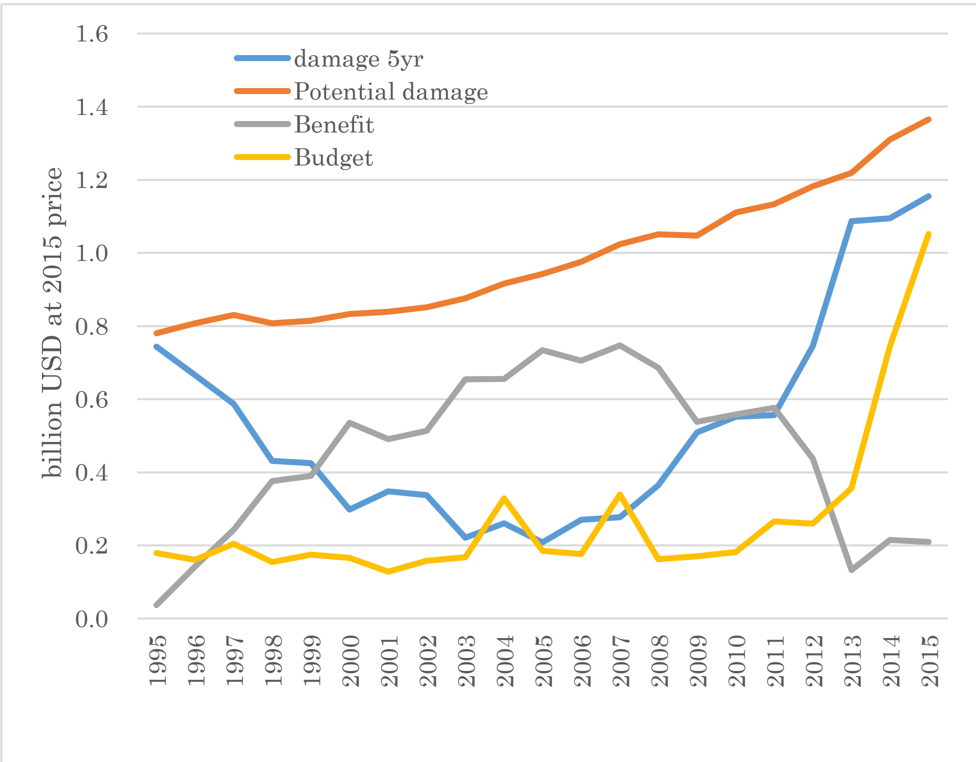
Source: Data from Statistics Bureau of Japan

Figure 7: Benefits in PRC



Source: Authors

Figure 8: Benefits in the Philippines



Source: Authors

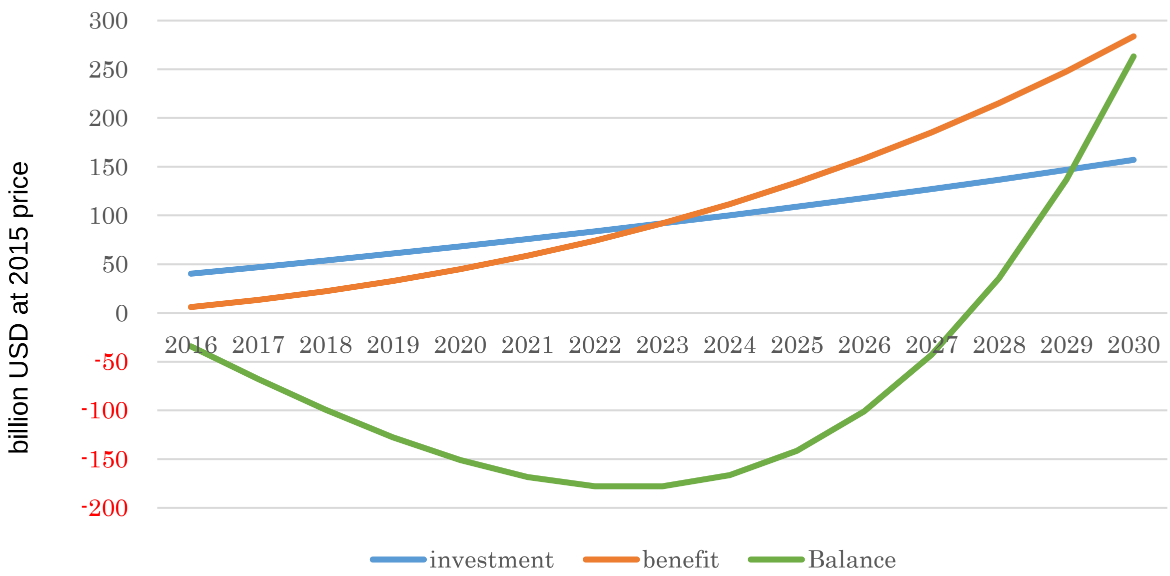
3.2 Benefits of future investment

This sub-section examines the benefits of future investment in flood protection in Asia by using the actual economic rate of return of flood protection projects supported by the Japan International Cooperation Agency (JICA). The agency is implementing programs of Japanese Official Development Assistance. Ishiwatari and Sasaki (2020) estimate the annual demand for flood protection in Asian developing economies at USD94.5 billion for the period 2016-2030 by using regression analysis.

JICA has conducted post-project evaluations and calculated an economic internal rate of return for 30 flood protection projects supported by Japanese yen loans. The average economic internal rate of return for these projects is estimated at 15.0% (Ishiwatari 2016). The economic rate of return is the discount rate at which the stream of net economic returns (economic benefits minus costs) is equal to a present value of zero. The expected annual average damage reduction is calculated by cumulating the annual average damage reduction based on the flood flow scale. This average annual damage reduction by flood discharge is calculated by multiplying the damage reduction at a certain flood discharge by the probability of occurrence of that flood. The benefits include the reduction of direct damage to assets such as houses and factories and indirect damage such as business interruption.

At the early stage of investment, the cost exceeds the benefit (Figure 9). However, as per capita GDP grows, the benefit exceeds the cost. The net benefit (benefit minus cost) accumulation becomes positive in 2028 and reaches 263 billion USD in 2030.

Figure 9: Benefit and investment in flood protection in Asia



Source: Authors

4. Conclusion

This study analyzed investment in flood protection and flood damage in terms of the share of GDP in major flood-prone economies in Asia. A growing economy adds value to properties in at-risk areas, leading to increased flood damage.

Some economies could reduce damage by investing in flood protection, but declining trends of damage vary by country. PRC from the 1990s and Japan in the post-WWII era were able to decrease economic damage steadily by securing the budgetary allocations for flood protection. Other economies unnecessarily show the simple direction of consistent decline of damage. Japan from the 1890s until the 1960s, India, Taiwan, the Republic of Korea, and the Philippines proceeded with a cycle consisting of damage and changes to budget allocations: (1) damage increases, (2) to decrease the damage, investment increases, (3) as a result of investment, damage decreases, (4) as damage decreases, investment decreases, and (1) because of decreasing investment, damage increases again (Figure 1). Major floods triggered increasing budgets for flood protection shown in the Philippines in the late 2010s and Japan in the 1940s and 50s. Pakistan retains the budget at a lower level than other economies regardless of repeated major floods.

It is not easy for governments to maintain the scale of the budget for flood protection and to continuously reduce the damage from flooding. There are one to three-year gaps between disasters and increasing budgets, even in cases where the relationship can be confirmed. This is because governments cannot increase the flood budget immediately after flood disasters. Also, flood damage does not decrease immediately, because flood protection works require construction periods. Damage in the Philippines has not yet declined, but this is expected following budget expansion in the 2010s. If disasters do not happen within certain periods, governments are likely to reallocate budgets away from flood protection to other priority areas,

Formulating policies is crucial in securing the budgets of flood protection in the long-term to steadily decrease damage. Ishiwatari and Surjan (2019) argue that PRC, the Philippines, and Japan in the post-WWII era were able to secure investment by integrating disaster risk reduction in national development plans and formulating multiyear sectoral plans. Once the governments have confirmed these plans, budgets for flood protection can be allocated steadily every year, even though the financial situations of countries fluctuate (Ishiwatari 2021). Establishing a budget line specifically for disaster risk reduction is also useful. The Philippines has established a unique mechanism of disaster risk reduction funds that the national and local governments can use for both preparedness and recovery programs (Government of the Philippines 2010). This mechanism allows national and local governments to invest in disaster risk reduction continuously at a certain level.

It was found that the Bayesian structural time series (BSTS) model can simulate near-future investment in flood protection to some degree, in the case of a rising trend in the PRC or a decreasing trend from Taiwan. Further studies might adopt a BSTS model to forecast the amount of flood protection investment in the near future.

Based on these results, the authors conclude that investment in flood protection is cost-effective at the regional and national levels. The annual benefits of investment for the past two decades are estimated at 159 billion USD in PRC and 120 million USD in the Philippines. The annual benefit in PRC is estimated at five times of investment in 2016. The net benefit (benefit minus cost) accumulation in developing Asia is predicted to reach 263 billion USD against an investment of 157 billion USD in 2030.

These findings can provide governments in Asia with evidence to strengthen their investment policies toward flood protection. The results show that investment in flood protection has contributed and will contribute to the country's growth in the region. To further support evidence-based policymaking on investment in flood protection, the methods of analyzing costs and benefits need to be improved. There are limitations to the current methods, which unnecessarily cover all benefits of flood protection programs. Evaluating the saving of human lives and mitigation of long-term indirect impacts is a challenge.

Additional studies should revisit the analysis on the benefits of investment in flood protection, taking into account the financial and socioeconomic impacts caused by the COVID-19 pandemic. Each economy needs to develop investment policies in making societies more resilient during the recovery from the pandemic.

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Appendix A

R source code for Bayesian Structural Time Series (BSTS) modeling

```
library(lubridate)
library(bsts)
library(dplyr)
library(ggplot2)

data_CHI <- read.csv("data_CHI.csv", header = F)
data_TWN <- read.csv("data_TWN.csv", header = F)

data_CHI <- ts(data_CHI, start = c(1979), frequency = 1)
data_TWN <- ts(data_TWN, start = c(1977), frequency = 1)

f <- function(data, start_y, end_y, h, AR_lags, f_title) {
  data_train <- window(data, start = c(start_y), end = c(end_y))

  ss <- AddAutoAr(list(), data_train, lags = AR_lags)
  bsts.model <- bsts(data_train, state.specification = ss, niter = 1000, ping=0)

  burn <- SuggestBurn(0.1, bsts.model)
  p <- predict.bsts(bsts.model, horizon = h, burn = burn, quantiles = c(.025, .975))

  d2 <- data.frame(
    c(as.numeric(-colMeans(bsts.model$one.step.prediction.errors[-(1:burn),])+data_train),
    as.numeric(p$mean)),
    as.numeric(data), as.Date(time(data)))
  names(d2) <- c("Fitted", "Actual", "Date")

  MAPE <- filter(d2, year(Date)>end_y) %>%
summarise(MAPE=mean(abs(Actual-Fitted)/Actual))

  posterior.interval <- cbind.data.frame(
    as.numeric(p$interval[1,]),as.numeric(p$interval[2,]),
    subset(d2, year(Date)>end_y)$Date)
```

```
  names(posterior.interval) <- c("LL", "UL", "Date")

  d3 <- left_join(d2, posterior.interval, by="Date")

  vline_d <- paste(as.character(end_y+1),"01","01",sep="-")

  png(filename = paste0(f_title,".png"))
  plot <- ggplot(data=d3, aes(x=Date)) +
    geom_line(aes(y=Actual, colour = "Actual"), size=1.2) +
    geom_line(data = subset(d3, year(d3$Date)>end_y), aes(y=Fitted, colour = "Fitted"),
size=1.2, linetype=2) +
    theme_bw() + theme(legend.title = element_blank()) + ylab("") + xlab("") +
    geom_vline(xintercept=as.numeric(as.Date(vline_d)), linetype=2) +
    geom_ribbon(aes(ymin=LL, ymax=UL), fill="grey", alpha=0.5) +
    ggtitle(paste0(f_title, " -- Holdout MAPE = ", round(100*MAPE,2), "%")) +
    theme(axis.text.x=element_text(angle = -90, hjust = 0))
  print(plot)
  dev.off()
}

f(data_CHI, 1979, 2011, 5, 4, "China")
f(data_TWN, 1977, 2011, 5, 4, "Taiwan")
```

Abstract (in Japanese)

要約

治水投資：成長するアジアでの投資と被害の推移

洪水被害を軽減するには、治水投資が不可欠である。しかし、実際の投資データや、治水投資と被害や便益との関係を扱う研究は限られている。本稿では、アジアにおける洪水被害と治水投資を実証的に分析することで、治水政策を分析することを目的としている。国内総生産(GDP)に占める投資と被害の割合の傾向は、国によって異なる。第二次世界大戦後の中華人民共和国と日本は、経済被害を着実に減少させることができた。一方、フィリピン、台湾、大韓民国、インド、パキスタンは、治水予算と被害額が変動した。上昇傾向、下降傾向のいずれの場合でも、ベイジアン構造時系列モデルにより投資をある程度予測できることを明らかにした。また、治水投資は、地域および国レベルで費用対効果が高いことがわかった。過去 20 年間の年間利益は、中国では 1,590 億米ドル、フィリピンでは 1 億 2,000 万米ドルと推定される。アジアの発展途上国における 2016年からの純利益(利益から費用を引いたもの)の累計は、2030年までに 1,570 億米ドルの投資に対して 2,630 億米ドルに達すると予測される。

キーワード: ベイズ構造時系列モデル、気候変動、費用便益分析、内部収益率、洪水被害

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