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Impact Analysis of Bridging on Remote Island Population

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Abstract: We analyzed the determinants of building bridges after comparing bridge islands and non-bridge islands. In addition, we examined the population change before and after the bridge building and the factors influencing the change. As a result, a remote island with high cost-effectiveness was selected and bridged. The early bridge was built in remote islands with fragile social infrastructure, and the outflow of population was suppressed owing to the improvement in standard of living by securing the medical care and education available in the bridge destination. However, around the year 2000, there are few remote islands where the changes in populations are influenced after a bridge was built.

Key words: Remote islands, bridge building, population change.

1. Introduction

Japan has a land area of 380,000 km^2, which is the 61st largest in the world, but as Japan has many remote islands, the area including the territorial seas and the Exclusive Economic Zone is 4.47 million km^2, making it the 6th largest in the world. There are 6,847 islands with a circumference of 0.1 km or more, of which 416 are inhabited.

The population ratio of Japan grew to 1.41 in 2015, as compared to 1955, but the population of remote islands continued to decline to 0.45. As a result, the outflow of population from remote island areas has been a persistent issue.

One way to eliminate the disadvantages of remote islands is through constructing bridges. A total of 181 bridges were built on 160 islands. Of these, 110 islands were connected to the mainland by bridges. They were then excluded from the areas to be developed because the disadvantages were eliminated.

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This study considers the following questions: (1) even if bridge building is possible in terms of distance, some islands are bridged while some are not; so, what are the determinants? (2) Did bridge building stop the decline in the remote island population and what factors influenced this decline?

The current policy of remote islands aims to prevent uninhabited islands. If the determinants of bridge building and influential factors of the remote island population are clarified, we can assume that it will be useful for future measures to prevent uninhabited islands, select the islands for building the bridge, and determine whether the project is to be implemented. Therefore, we used the regional attributes of the bridge destination as an analysis factor in addition to the attributes of the remote islands.

According to a previous study of bridge building by Leung et al. [1], Hong Kong has numerous outlying islands that are relatively underdeveloped and dependent on ferries. Concurrently, the Hong Kong government has expressed a desire for outlying islands to be places for urban expansion and has

proposed that more bridges, tunnels, and reclaimed land should be developed. Taking Hong Kong Island, Tsing Yi, and the pockets of island communities on Lantau Island as examples, they are connected by one or more bridges and tunnels, and these islands have experienced rapid development and population growth within a few years after the completion of the fixed infrastructure. According to Jeong et al. [2], Ganghwa Island was connected to the mainland. They showed that the traffic volume and the number of tourism facilities have increased in Ganghwa County.

Yi et al. [3] clearly indicated that the Zhoushan Islands in China experienced remarkable urban expansion and economic prosperity between 1980 and 2013. The major reason was secondary and tertiary industry growth as a result of governmental interventions and changing economic conditions on coastal industries and tourism development. Cross-sea bridges also served to accelerate island development, while population had a lesser impact. In each country, research on bridges has indicated population growth, urbanization, economic development, etc., but this is an analysis of individual islands.

In Japan, Shiotani [4] indicated that the range of living activities of islanders has expanded to the urban area of the mainland due to the bridge in the Tajima and Yokoshima islands after comparing the bridge islands by remote island type, position, bridge type, and administrative type. Yoshida [5] indicated that the industrial economy was revitalized in Okayama and Kagawa at both ends of the bridge, focusing on the straw effect after opening the Seto Ohashi Bridge, but the islands connected to the mainland were not analyzed. Maehata [6] indicated that building bridges was a process of unifying the mainland and has weakened the functioning of the communities on the bridge islands, according to the analysis of the influence of Hamahiga and Kouri island communities. Ample studies have described one bridge island, but few studies have focused on the comprehensive analysis of the bridge islands or an analysis using the regional attributes of the bridge destination.

The purpose of this study is to discuss the determinants of building bridges after comparing bridge islands and non-bridge islands. In addition, we examined the population change before and after building a bridge, and the factors influencing the change pattern.

2. Method and Materials

2.1 Target

We chose 44 bridge islands for the analysis in this paper. Fig. 1 shows a scatterplot of the year of bridge building and island population. Within 44 bridge islands, 19 bridges were built before 1985.

To discuss the determinants of building bridges after comparing bridge islands and non-bridge islands, we selected bridgeable and bridgeless islands within the longest distance to the mainland. Then 53 remote islands were chosen. These islands can be accessed from the mainland within a service time of 15 minutes.

Forty-four (44) bridge islands were chosen to study the population changes before and after bridge construction. These remote islands were used in the project of the Remote Islands Development Act, and the base year is the year when land transportation to the mainland was secured.

2.2 Method

The variables presented in Table 1 [7, 8] were analyzed using the ordered logit model for the bridge islands around 1980 and the bridge islands and bridgeable islands around 2000.

For 44 bridge islands, using 5-point census data for the 10 years before and after the bridge year on the mainland, the population transition was classified into “increase or mitigation of decline”, “small change”, and “acceleration of decline”. Next, the classification was used as a dependent variable and analyzed by an ordinal logit model.

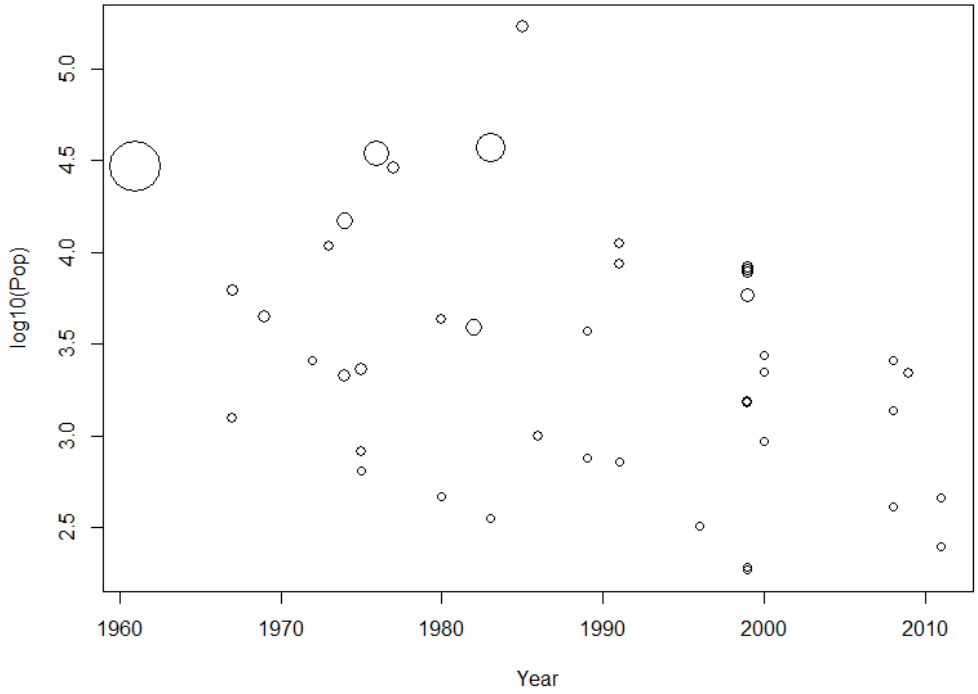


Fig. 1 Year of bridge building and the base 10 logarithm of population of the island.
A size of each point shows a ratio of island population divided by the population of the city in mainland with the largest population within 30 km from the bridge.

Table 1 Variables for the analysis of bridge building.

Population	Island and the city in mainland with the largest population within 30 km from the bridge
Traffic	Number of regular flights, annual number of passengers
Tourism	Annual number of tourists, number of guests that can be accommodated
Employment	Number of business establishments and workers in the island and the city in mainland with the largest population within 30 km from the bridge
Position etc.	Inland sea or open sea, existence of parliamentarians from the island

Table 2 Variables for the analysis of population change before and after bridge building.

Bridged island	Population, population density, existence of elementary/junior high school/high school, existence of hospital, cultivated land area, field area, cultivated land area, orchard area, number of farmers, number of fishery households, distance to the nearest station, distance to high school, distance to hospital
The city in mainland to be bridged	Population, population density, number of workers in the first, second and tertiary industries
Others	Mainland bridge year, regular passenger car toll, existence of toll

The explanatory variables deal with each element of the bridge island, the city attribute of the municipality to which it was bridged, and the traffic, as shown in Table 2 [7, 8].

3. Results

3.1 Determinants of Bridge Building

Table 3 shows the results of the ordinal logit model with the presence or absence of bridge building and

Table 3 Results of ordered logit model in Determinants of Bridge Building .

Dependent variable: bridge building time and existence of bridge (0: No, 1: Late, 2: Early bridge building)		
Explanatory variable	Coefficient	*t* value
log (island population)	1.78	5.46
log (number of tourist): log (annual number of passengers)	-0.04	-4.32
Intercepts 0|1	9.07	5.31
1|2	10.8	5.75
Number of samples = 87		
AIC 108.15 AIC(0) 168.07		

the time of bridge building at two time points as the dependent variables. No multicollinearity was observed in the model introduced in the results.

The larger the island population, the more bridged it was. A variable is log (number of tourist): log (annual number of passengers), which indicates the interaction between the mainland and the islands. It was found that the islands with less interaction before bridging were bridged early. Other variables were not selected to explain the determinants of bridge building.

3.2 Impact of the Bridge Building on the Population Transition of Remote Islands

The changes in population over the 10 years, before and after the bridge were classified into "increase or mitigation of decline", "small change", and "acceleration of decrease", as shown in Fig. 2. There were 12 remote islands where the increase or mitigation of decline in the population was eased, 19 remote islands where the population change was small, and 13 remote islands where the rate of population decline increased (Table 4).

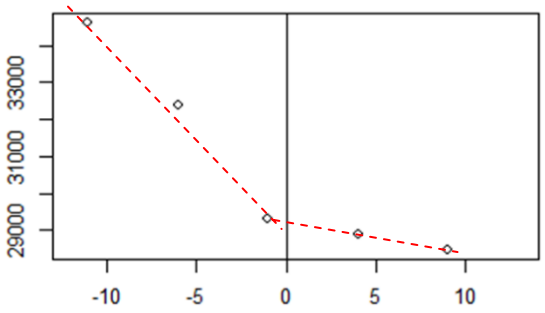
3.3 Ordered Logit Model Determinants of the Population Transition of Remote Islands

The results of the ordered logit model are shown in Table 5. The model includes all the elements of the island's regional attributes, those of municipality to which it was bridged and the traffic volume. If all of the conditions (that is, early bridge building, the average distance to stations, hospitals, and high schools in the municipality to which it was bridged is small, there is no hospital on the island, and the proportion of farmers in the island's population is large) are met, the population decline will be mitigated.

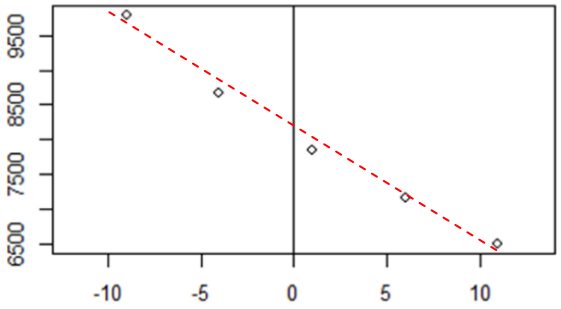
4. Discussion

4.1 Determinants of Bridge Building

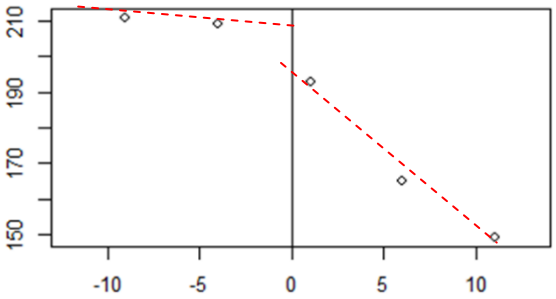
Bridges were built from an island with a relatively large population. In other words, bridges were preferentially constructed in the populous area to eliminate the disadvantages. Compared to the islands that were bridged early, the islands that were bridged later had a smaller population, but the value indicating the strength of interaction, such as the number of tourists, has increased. This is because the bridge on a remote island with a certain population size had been



Kurahashi Island (increase or mitigation of decline)



Omi Island (small change)



Sakito Island (acceleration of decline)

Fig. 2 Examples of population transition around the year of bridge building in three islands.

Table 4 Population trends of bridged islands for 10 years before and after bridge building.

Year of bridge building	Increased or mitigation of decline		Small change		Acceleration of decline	
Before 1985	8	(42%)	3	(16%)	8	(42%)
After 1985	4	(16%)	16	(64%)	5	(20%)

Table 5 Results of ordered logit model in Determinants of the Population Transition of Remote Islands.

Dependent variable: changes in the population of the bridge island (0: increased or mitigation of decline, 1: small change, 2: acceleration of decline)		
Explanatory variable	coefficient	*t* value
Bridge building year	-9.73e-2	-3.97
log (average distance to the nearest station, high school and hospital)	-1.05	-2.53
log (island population at the time of the bridge building)	0.43	2.29
log (number of business establishments of the city in mainland with the largest population within 30 km from the bridge)	0.70	1.58
Farmer/island population	0.12	2.23
Existence of hospital	-4.73	-60.69
Intercepts 0|1	-13.42	-332.71
1|2	-10.82	-20.61
Number of samples = 44		
AIC 91.64 AIC0 98.47		

completed and then the area with a large amount of traffic was selected.

4.2 Factors Associated with the Population Transition of Remote Islands by Bridge Building

Increase or mitigation of decline in population after the completion of bridge building was seen when bridges were built early. If the average distance to the nearest station, hospital, and high school becomes longer, island population tends to decline. In addition, island population and number of business establishments of the city in mainland with the largest population within 30 km from the bridge affect the transition. Interestingly, the proportion of farmers in the island's population is large, the population turned to increase or mitigation of decline after bridge building. A remote island with an early bridge building is an area where social infrastructure is vulnerable [9]. Therefore, building a bridge secured medical care and education and suppressed the outflow of the population on the island.

5. Conclusions

Bridges were constructed to help large population islands eliminate the disadvantages of being remote. After that, a remote island with high cost-effectiveness was selected and bridged. In addition, the early bridge was built in remote islands with fragile social infrastructure, and the outflow of population was suppressed owing to the improvement in standard of living by securing the medical care and education available in the bridge destination. However, around the year 2000, it was found that there are few remote islands where the changes in populations are influenced after a bridge was built.

This study focused on the island population, but since its impact on recent building of bridges is small, it is necessary to consider other variables such as changes in islander income. In addition, some bridges connect to the mainland, and some bridges connect to adjacent remote islands. Therefore, further studies that focus on the classification of bridge types and evaluate details of bridge policy are needed.

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