Cooperative-Competitive Analysis and Tourism Forecasting of Southern Offshore Islands in Taiwan by Grey Lotka-Volterra Model

Shih-Ching Lo*, Ching-Fen Lin

Abstract—**Taiwanese offshore islands have abundant ocean resources, historical culture and water activities. Generally, researchers devote their effort to tourism resources, visitor behavior, or the sustainability of natural resources of individual Taiwanese offshore islands. In this study, a cooperative-competitive model is proposed to forecast visitor volume of three southern offshore islands in Taiwan; that is, Ludao, Lanyu and Little Liuqiu. The model, which consists of three differential equations, is based on grey Lotka-Volterra (grey LV) model. Lotka-Volterra model is also a kind of evolutionary game theory. In addition, three social-economic factors are considered to describe the external effects on tourism. To make the forecast of visitor volume possible, the forecasting model of the socio-economic factors is also presented. According to the results, the model with unemployment rate presents the best explanation and forecast. The results are assessed by mean absolute percentage error (MAPE) and show good accuracy. In addition, the cooperative-competitive relationship among tourism of the three islands is analyzed by the coefficients of the grey LV model. Developing strategies for tourism of the three islands can be planned by the cooperation-competition analyses.**

Index Terms—**offshore islands tourism, dynamic competitive, grey Lotka-Volterra model, social-economic variables**

I. Introduction

NOWADAYS tourism has become one of the fastest growing industries in the world. According to the statistics of the World Travel and Tourism Council (WTTC), travel and tourism's total contribution to the global economy in 2014 was US$7.6 trillion (2014 prices), which equates to 9.8% of total economy GDP in 2014 [1].

Taiwan has great potential when it comes to tourism due to the wealth of cultural and natural resources. Visitor volumes of three Taiwanese southern offshore islands are forecasted and analyzed in this study. Small islands are attractive for visitors to visit as they create feelings of remoteness and isolation, peace, tranquility and a sense of timelessness [1]. Therefore, tourism research into island destinations has grown rapidly. This is mainly caused by two factors. First, tourism is significant for the economy of many island destinations. Second, for many researchers, islands hold a particular attraction, because they provide excellent 'laboratory' conditions for the study of international tourism growth where theories can be tested and processes can be observed in the setting of a semi-closed system [2]-[3]. The research topics of island tourism focus on islands' economy [4], islands characteristics and cultures [5], impacts of tourism [6], strategies and marketing of tourism, and development of ecotourism. As to forecast the visitor volume of islands, it is analyzed by time series models [7] or discrete choice models. Sheldon and Var [8] mentioned that time series models are the simplest and least costly techniques to forecast tourism and the gravity model is best suited to handle international tourism flows. However, time series models cannot be employed to analyze cooperative-competitive relationship among scenic spots.

In this study, a dynamic cooperative-competitive model of forecasting visitor volume is proposed firstly. This kind of model is based on the growth model, which forecast visitor volume by macroscopic data. Individual choices model is also a widely used forecasting model for visitor volume, but this kind of method involves questionnaire survey, which costs lots of time and money. Fourt and Woodlock [9], Mansfield [10], and Bass [11] started consolidated theoretical development in the univariate analysis of the life cycle of a single product. Bass et al. [12] introduced a general intervention function to include in the modeling marketing-mix variables under the control of managers, external accidents, incentives or policy measures, and so on. For two species or products, Bass model [11], [13] is also the most used model for analyzing competition between them. However, it is a parsimonious model which does not consider the competition factor in the market. Fisher and Pry [14] developed a simple substitution model based on the assumption that a new technology would displace an older established technology. The Fisher and Pry model also failed to consider the competition. Norton and Bass [15] took the Bass model as its core equation and incorporated the Fisher and Pry model to demonstrate the substitution effect. It can be used to forecast the diffusion of new technologies. Apart from these models, the mathematical Lokta-Voterra (LV) model [16]-[17] was used in many papers and it could well explore the diffusion phenomenon and reciprocal competition of two species [18]-[22]. Because the LV model describes a two-species biological model, it is also widely known as the predator-prey model, which has been used in cases of correlated populations [23]-[24]. Additionally, stochastic competitive and predator-prey models are

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considered to describe random perturbations in nature world [25]-[26].

Furthermore, equations of the system are not restricted to two. A technology system dynamics model considering three interacting technologies has been introduced by Jackson [27] and Meadows [28]. Three case sets of general application of the system dynamics model focusing on the transition from asymptotic to cyclic behavior of the technology system have been considered [29]-[30].

According to tourist destinations with identifiable stages — exploration, involvement, development, consolidation, maturity and stagnation [31] — the logistics model can be applied to tourism studies. After that, the LV model is employed to analyze cooperative and competitive relationship among scenic spots [32]. In this study, the visitor volumes in Taiwan's three southern offshore islands are analyzed. The proposed model is based on grey Lotka-Volterra (grey LV) model [33] because tourism is influenced by external environment or events such as socio-economic factors, diseases, severe weather conditions, earthquakes, terrorist incidents and so on. Time series data of the number of visitors fluctuates largely. The accumulated generation operation (AGO) of the grey theory can generate serial data smoother than the original data. Generally, forecasting smooth data is much easier than forecasting fluctuated data. According to the results, the model can forecast the visitor volume accurately with external factors such as GDP per capita, population, unemployment rate and oil prices. Actually, the Lotka-Volterra model is a kind of evolutionary theory [34]. The steady state solution of the LV model is equivalent to the Nash equilibrium with corresponding payoff functions. Therefore, analyzing the competitive relationship of tourism among the three islands by the LV model is appropriate. The paper is organized as follows. In Section 2, an introduction of southern offshore islands is presented. The social-economic factors are discussed in Section 3. Then, the dynamic competitive model is proposed and the numerical results are presented in Section 4. Finally, Section 5 concludes with a short summary and discussion of our findings.

II. Southern Offshore Island in Taiwan

Islands are special places with natural attractions for tourists. The mysterious atmosphere on the islands results from a mix of different lifestyles, colonial histories, indigenous cultures, unique land formations, flora and fauna as well as ocean and coastal resources. All islands must address the issues of economic impact, environmental consequences and those related to social, cultural and political structure of the islands. All of these are affected by the density of tourism on the islands. High tourist and resident densities on islands are the cause of many sustainability problems [35]-[37] and thus tourism carrying capacity needs to be considered. Cole [31] examined the discrete logistic equation and logistic tourism model through empirical data and then discovered that the model can benefit the future development for resort destinations.

Taiwan is located on the southeast coast of the Asian continent. The geographic location and frequent seismic activity not only create an extremely diversified topography and natural environment in Taiwan, but also result in the diverse characteristics of its offshore archipelagos. There are several offshore archipelagos in Taiwan such as Kinmen, Matsu, Penghu, Ludao, Lanyu and Little Liuqiu. Each of the archipelagos has specific culture with magnificent ocean views and many other natural wonders. Kinmen and Matsu used to be military sites of fierce fighting between Communist and Nationalist forces when the latter withdrew from the mainland in 1949. The fortress on the islands has become a memorial sightseeing spot. Penghu archipelago is located in the southwest of the Taiwan Strait. With abundant marine, land and biological resources as well as spectacular basalt landscapes and the fireworks festival, Penghu has attracted lots of visitors to boost its tourism. These three archipelagos offer different attractions for visitors. The three southern tropic islands studied in this work, namely Ludao (Green Island), Lanyu and Little Liuqiu have familiar characteristics. Therefore, we develop a cooperation-competition model based on grey LV model to analyze their visitor volume. The locations of the three islands are given in Fig. 1.

Fig. 1. The southern offshore islands of Taiwan

Ludao, also known as Green Island, is located some 33 kilometers off the coast of Taitung County. It is a volcanic island with a beautiful and diverse coast. It's also famous for coral reefs, saltwater hot springs and aboriginal culture. Water activities, such as snorkeling and diving, are also suggested for visitors to enjoy the beautiful underwater scene. It takes about 50 minutes by ferry or 15 minutes by domestic air service from Taitung to Ludao. The abandoned Ludao Lodge is also a well-known scenic site.

Lanyu, or Orchid Island, is situated off the southeastern coast of Taiwan. Like Ludao, its neighbor to the north, Lanyu was raised from the sea by the accumulation of volcanic lava. Lanyu, having a moist and rainy climate, is covered with dense rainforests and decorated by coral reefs. Lanyu also has abundant fishery resources, making it a paradise for fishermen and skin divers. The island is inhabited mainly by people of the Yami tribe, the most primitive indigenous people in Taiwan. Their traditional stone houses were built mostly underground. Also, their Flying Fish and Boat Launching Festivals can be seen nowhere else on earth. To visit Lanyu, tourists can take ferries or domestic flights.

Among Taiwan's numerous offshore islands, Little Liuqiu is the only one that is composed of coral. The island lies in the

sea about 14 kilometers to the southwest of Donggang in Pingtung County. Ferry services are the only means of transport between Donggang and Little Liuqiu. Fortunately, the travelling time is only 20 to 30 minutes, which is the shortest among that of the three studied islands. There are three special features that make this island unique: the finest location for viewing the sunset, the most species of coral, and a terrain made up of coral.

III. Social-Economic Factors of Tourism

Generally, tourism is influenced by income, prices, quality, political relations between countries, economic relations between countries, social-cultural relations between countries, changes in weather or climate, holidays, government regulations, restrictions on the use of foreign exchange and transportation technology. Some of the factors are difficult to be quantified. Hence, GDP per capita, population, unemployment rate and oil prices are chosen as the social-economic factors in this study. In addition, tourism policies, diseases, earthquakes, hurricanes or terrorist incidents will also influence tourism. However, these kinds of incidents happen occasionally and can hardly be predicted by modeling.

Therefore, only predictable and continuous socio-economic factors are considered in this study. GDP per capita is considered firstly. GDP refers to the monetary value of all finished final goods and services produced within a country in a given period. GDP is often considered an indicator of a country's standard of living. GDP per capita is GDP divided by the midyear population, which evaluates the living standard of a country. Unemployment rate, which has a negative impact on visitor volume, also measures the economic environment of tourism. When the population of a country increases, the visitor volume may also increase. Thus, population is considered as one of the factors. Moreover, oil prices will greatly influence the transport costs, which then affect the demand for tourism because transport costs are one of the major expenses when traveling. Therefore, oil prices are considered as a social-economic factor [38] due to tourism's inherent transport component. The data of four social-economic factors from 2002 to 2014 are given in Table I. During the time period, SARS outbreak occurred from 2002 to 2003 and the financial crisis took place from 2007 to 2008. Both events have greatly influenced the global economy and caused a decline in consumer wealth. Thus, tourism was also impacted during these two time periods. Among the four social-economic variables, GDP per capita and unemployment rate can be used to measure the impact of these two events.

According to our preliminary study, if external effects are considered in the model, the model can only describe the visitor volume of the studied islands under given data of external effects. To forecast the future visitor volume, the forecasting models of external effects should be proposed first. Generally, time series models are employed to forecast social-economic effects. However, the model proposed in this study is an ordinary differential equation system. It will be difficult to solve the equations if a time series model of external effects is combined with our systematic equations. Therefore, a simple linear regression model is considered to predict the external effects.

TABLE I
Data of Social-Economic Factors of Tourism

Years	GDP (NTD)	Oil price (NTD/L)	Population (people)	Unemployment (%)
2002	463,498	19	22,520,776	5.17
2003	474,069	20.21	22,604,550	4.99
2004	501,849	22.24	22,689,122	4.44
2005	516,516	24.02	22,770,383	4.13
2006	536,442	26.94	22,876,527	3.91
2007	563,349	28.61	22,958,360	3.91
2008	548,757	30.42	23,037,031	4.14
2009	540,813	27.1	23,119,772	5.85
2010	585,633	29.91	23,162,123	5.21
2011	589,576	31.94	23,224,912	4.39
2012	631,142	33.94	23,315,822	4.24
2013	652,020	34.92	23,373,517	4.18
2014	687,343	33.65	23,433,753	3.96

IV. Grey LV model for visitor volume and its results

The LV model [16]-[17] is a dynamic cooperation-competition model, which consists of two differential equations with interaction terms. The model is given by

$$\frac{dN_1(t)}{dt} = a_1 N_1(t) + b_1 N_1^2(t) + c_1 N_1(t) N_2(t), \quad (1)$$

$$\frac{dN_2(t)}{dt} = a_2 N_2(t) + b_2 N_2^2(t) + c_2 N_2(t) N_1(t), \quad (2)$$

where $N_1(t)$ and $N_2(t)$ are the two studied variables, which might be the number of visitors in two scenic spots. a_1, a_2, b_1, b_2, c_1 and c_2 are coefficients which are calibrated by empirical data . a_1 and a_2 represent the attractions of each scenic spot. b_1 and b_2 are the internal effects of each place. The internal effects include the capacity of resorts or recreation facilities, accessibility to the public transport, environmental restoration capabilities and so on. c_1 and c_2 are interactive parameters. The relationship between two variables of LV model is illustrated in Table II. Although there are five types of models, please note that there are two possible predator-prey interactions (depending on which species is the predator or prey) in the predator-prey model and two possible states (depending on which species is the stronger of the two) in the amensalism model.

TABLE II
The Relationship According to the Signs of C_1 and C_2

coefficient		Type	Explanation
c_1	c_2		
–	–	Pure competition	Both species suffer from each other's existence.
+	–	Predator-prey	One of them serves as direct food (N_2) to the other (N_1).
+	+	Mutualism	It is the case of symbiosis or a win-win situation.
–	0	Amensalism	One (N_1) suffers from the existence of the other (N_2), who is impervious to what is happening.
0	0	Neutralism	There is no interaction

In this study, a three-equation system is proposed. Also, the external effects are considered in the system. The model is given by

$$\frac{dLLQ(t)}{dt} = a_1 LLQ(t) + b_1 LLQ^2(t) + c_1 LLQ(t)LD(t) + d_1 LLQ(t)LY(t) + e_1 E_i(t), \quad (3)$$

$$\frac{dLD(t)}{dt} = a_2 LD(t) + b_2 LD^2(t) + c_2 LLQ(t)LD(t) + d_2 LD(t)LY(t) + e_2 E_i(t), \quad (4)$$

$$\frac{dLY(t)}{dt} = a_3 LY(t) + b_3 LY^2(t) + c_3 LY(t)LD(t) + d_3 LLQ(t)LY(t) + e_3 E_i(t), \quad (5)$$

where $LLQ(t)$, $LD(t)$, $LY(t)$ are the visitor volume of Little Liuqiu, Ludao and Lanyu respectively. a_i, b_i, c_i, d_i and e_i for i = 1, 2, 3 are coefficients. $E_i(t)$ for i = 1 to 4 are social-economic factors. One social-economic factor is involved in the model at a time to simplify the systematic equations.

However, the visitor volume fluctuates largely and thus is difficult to be estimated. The visitor volume of the three islands from 2002 to 2014 is shown in Figure 2. Therefore, the grey model is combined to estimate visitor volume. The GM(1,1) model proposed by Deng [39] has been widely applied in various fields. GM(1,1) is a single variable forecasting model, which cannot analyze the cooperative-competitive relationship among variables and forecast the values of variables. The grey LV model is proposed by Wu et al. [33] and has been applied to analyze the relationship between the GDP and foreign direct investment (FDI) of Ningbo city in China. The mean absolute percentage of error (MAPE) of the grey Lotka-Volterra model is 2.03%, which means that the prediction is in good agreement with the real data. In this study, grey LV model is combined with social-economic variables to predict the visitor volume of the three islands.

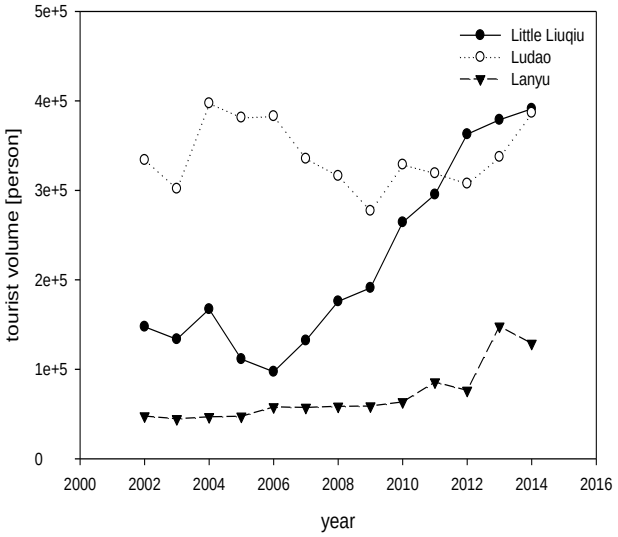

Fig. 2. The data of visitor volume of the three islands from 2002 to 2014.

The proposed model is given by

$$\frac{dLLQ^{(1)}(t)}{dt} = a_1 LLQ^{(1)}(t) + b_1 \left[LLQ^{(1)}(t)\right]^2 + c_1 LLQ^{(1)}(t)LD^{(1)}(t) + d_1 LLQ^{(1)}(t)LY^{(1)}(t) + e_1 E_i^{(1)}(t), \quad (6)$$

$$\frac{dLD^{(1)}(t)}{dt} = a_2 LD^{(1)}(t) + b_2 \left[LD^{(1)}(t)\right]^2 + c_2 LLQ^{(1)}(t)LD^{(1)}(t) + d_2 LD^{(1)}(t)LY^{(1)}(t) + e_2 E_i^{(1)}(t), \quad (7)$$

$$\frac{dLY^{(1)}(t)}{dt} = a_3 LY^{(1)}(t) + b_3 \left[LY^{(1)}(t)\right]^2 + c_3 LY^{(1)}(t)LD^{(1)}(t) + d_3 LY^{(1)}(t)LLQ^{(1)}(t) + e_3 E_i^{(1)}(t), \quad (8)$$

where $LLQ^{(1)}(t)$ is the accumulated visitor volume of Little Liuqiu, $LD^{(1)}(t)$ is the accumulated visitor volume of Ludao and $LY^{(1)}(t)$ is the accumulated visitor volume of Lanyu. a_i, b_i, c_i, d_i and e_i for i = 1, 2, 3 are coefficients. $E_i^{(1)}(t)$ for i = 1 to 4 are social-economic factors.

$$LLQ^{(1)}(t) = \sum_{j=1}^{t} LLQ(j), \quad (9)$$

$$LD^{(1)}(t) = \sum_{j=1}^{t} LD(j), \quad (10)$$

$$LY^{(1)}(t) = \sum_{j=1}^{t} LY(j), \quad (11)$$

$$E_i^{(1)}(t) = \sum_{j=1}^{t} E_i(j). \quad (12)$$

Equations (9) to (12) generate the first-order accumulated generating operation (1-AGO) of the original data. Therefore, when the systematic equations are solved, the inverse accumulated generating operation (IAGO) must be applied to the results obtained by the grey LV model to find the predicted values of the original data.

Before showing the results of the grey LV model, the forecast of the social-economic variables mentioned in Sec. 3 will be discussed. Since the accumulated series of visitor volume are employed, series data of social-economic variables are also accumulated. According to the number of variables in Eq. (6), at least six data are needed to be calibrated. Therefore, two sets of data are compared. One is from 2002 to 2014 and the other is from 2008 to 2014. The visitor volume in 2014 will be used to verify the performance of prediction. The first studied period is chosen to start from 2002 when Taiwanese government launched the Doubling Tourists Arrival Plan. The plan does stimulate growth in tourism. On the other hand, one advantage of the grey theory is that only four data are required to make the forecast. In the systematic equations (6) to (8), six variables are involved in each equation. Therefore, at least six data points are required. Thus, the second studied period starts from 2008. Mostly, regression analysis or time series models are considered to forecast visitor volume. However, these two kinds of models need a large data set to describe the long term trend. The advantage of our model is visitor volume can be forecasted by small a data set.

The coefficients, values of R-squared and significance of all regression models of socio-economic factors are shown in Table III. All regression models are in good agreement with the empirical data. The values of R-squared dare up to 0.99 and all regression models are significant. The regression models are employed to forecast the four values of socio-economic factors in 2014.

TABLE III
THE RESULTS OF REGRESSION FOR THE SOCIO-ECONOMIC FACTORS.

model: $y = ax + b$

Time period	variable (y)	a	b	R-squared	p-value
2002-2013	GDP per capita	574899.27	-1.15×10^{9}	0.99	0.00**
	Oil price	28.34	-56729.96	0.99	0.00**
	Population	2.30×10^{7}	-4.61×10^{10}	0.99	0.00**
	Unemployment rate	4.5	-9003.85	0.99	0.00**
2008-2013	GDP per capita	615778.23	-1.24×10^{9}	0.99	0.00**
	Oil price	31.67	-63561.32	0.99	0.00**
	Population	2.32×10^{7}	-4.66×10^{10}	0.99	0.00**
	Unemployment rate	4.72	-9476.21	0.99	0.00**

**significant level of 0.05

Table IV provides the comparison of forecasting results and real data. All absolute percentage errors are less than 10%.

TABLE IV
FORECASTING RESULTS AND REAL DATA OF SOCIO-ECONOMIC FACTORS IN 2014.

factor	real data (R)	forecast (F)	Absolute percentage error (%)
GDP per capita	687,343	666,420	3.04
Oil price	33.65	36.95	9.81
Population	23,433,753	23,430,277	0.01
Unemployment rate	3.96	4.34	9.60

The systematic equations are calibrated by the two-stage least squares method (2SLS). 2SLS is a method that uses simultaneous equations in forecasting procedures where right-hand variables are replaced by the result of their own equations. Firstly, 2SLS creates new independent variables to replace the originals. Then, regression is calculated as normal but uses the new variables. The variables of Eqs. (6)-(8) are chosen according to the significant level (p-value). After obtaining the value of coefficients, the model is solved by the Broyden algorithm [40], which is a numerical method for solving systematic ordinary equations. With and without social-economic factors under two time periods, ten sets of results are calibrated and validated. The adjusted R-squared value of each equation is given in Table V.

Among the forecasting results of time period 2002-2014, only the model with unemployment rate converges. In addition, only the model with population diverges during 2008-2014. The mean absolute percentage error (MAPE) and root mean square error (RMSE) are shown in Table VI. Also, MAPE and RMSE are employed to choose the best model. Because 2002 and 2008 are the initial years, the forecasting periods are 2003-2014 and 2009-2014. According to Table VI, the model without social-economic factors cannot forecast the visitor volume accurately. The result of model with unemployment rate during 2008-2014 performs the highest accuracy. Both of its MAPE and RMSE are the smallest among the five convergent models. In addition, only three MAPEs of the model with unemployment rate during 2008-2014 are smaller than 20%, which is a good forecast. The absolute percent errors (APE) of the forecasting visitor volume of Little Liuqiu, Ludao and Lanyu in 2014 are 38.01%, 41.18% and 50.35% respectively. The three APEs are larger than the MAPEs, which are averaging over the whole studied period. Figures 3 to 5 illustrate the comparison of real data and forecasts. The forecasting trend for visitor volume of Little Liuqiu and Ludao is in good agreement with the real data. The forecasting trend for visitor volume of Lanyu during 2008-2013 is also in good agreement with the real data, but there is a big difference between the forecasting and real visitor volume in 2014. The forecasting visitor volume during 2013-2014 is in a rising trend, whereas the real visitor volume is in a decreasing trend.

TABLE V
ADJUSTED R-SQUARED VALUE OF PROPOSED EQUATIONS.

Socio-economic variable	island	Time period: 2002-2013 Adjusted R-squared value	Time period: 2008-2013 Adjusted R-squared value
none	*LLQ*	0.86	0.99
	LD	0.07	0.96
	LY	0.96	0.99
GDP per capita	*LLQ*	0.94	0.99
	LD	0.46	0.96
	LY	0.95	0.99
oil price	*LLQ*	0.92	0.99
	LD	0.24	0.96
	LY	0.98	0.99
population	*LLQ*	0.94	0.99
	LD	0.47	0.84
	LY	0.95	0.99
unemployment rate	*LLQ*	0.82	0.99
	LD	0.40	0.96
	LY	0.57	0.99

TABLE VI
MAPE AND RMSE OF PROPOSED MODELS.

Socio-economic variable	island	2002-2014 MAPE (%)	2002-2014 RMSE	2008-2014 MAPE (%)	2008-2014 RMSE
none	*LLQ*	N/A	N/A	110.74	350,103.30
	LD	N/A	N/A	59.89	183,275.80
	LY	N/A	N/A	147.88	137,311.60
GDP per capita	*LLQ*	N/A	N/A	58.75	190,629.40
	LD	N/A	N/A	21.38	67,933.47
	LY	N/A	N/A	38.99	36,495.12
oil price	*LLQ*	N/A	N/A	365.10	1,158,025.00
	LD	N/A	N/A	259.70	776,055.20
	LY	N/A	N/A	311.71	341,474.50
population	*LLQ*	N/A	N/A	N/A	N/A
	LD	N/A	N/A	N/A	N/A
	LY	N/A	N/A	N/A	N/A
unemployment rate	*LLQ*	49.85	119,600.2	15.50	50,101.33
	LD	30.00	60950.53	3.98	12803.57
	LY	52.31	43870.18	19.69	18384.15

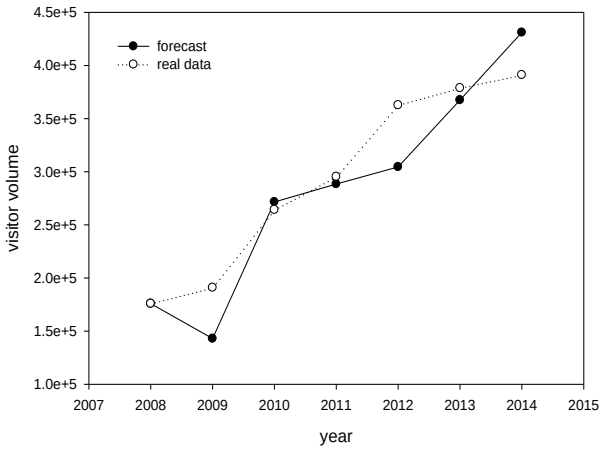

Fig. 3. Comparison of real data and forecasts for visitor volume of the model with unemployment rate of Little Liuqiu.

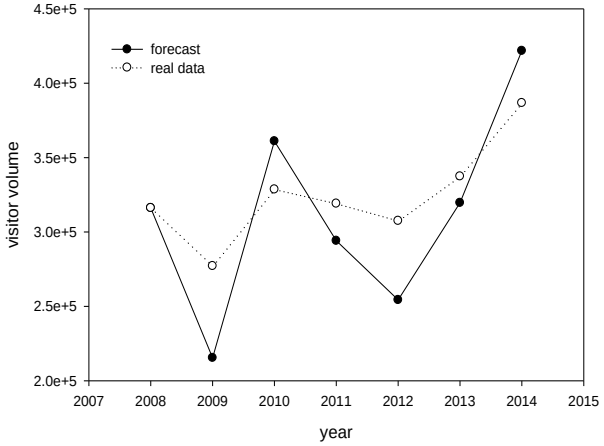

Fig. 4. Comparison of real data and forecasts for visitor volume of the model with unemployment rate of Ludao.

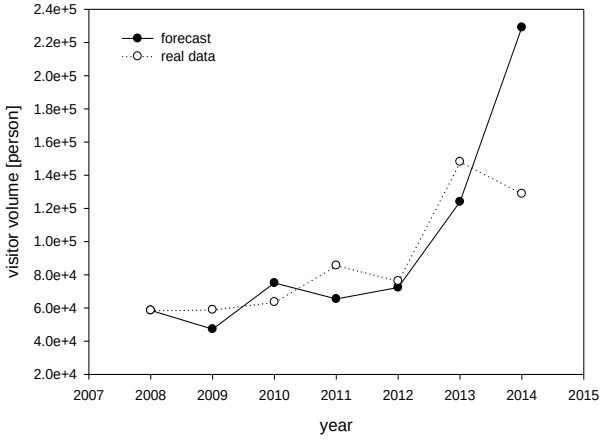

Fig. 5. Comparison of real data and forecasts for visitor volume of the model with unemployment rate of Lanyu.

The tourist season of the three studied islands is from April to October. Unfortunately, typhoons influence Taiwan during the same period, especially from July to September. Among the three islands, Lanyu has the poorest infrastructure. The main reason is that the opinions among residents of Lanyu, the aboriginal Yami (Tao in their own language) tribe, are not uniform. Some value the improved infrastructure and new lifestyle but some utterly oppose these changes. Although the development of tourism in Lanyu has started much earlier than that in the other two islands, the growth in visitor volume and tourism in Lanyu is not as strong as that in the other two islands. Typhoons often hit Taiwan from the eastern coast, close to where Ludao and Lanyu are located. In the wake of typhoons, the recovery in Lanyu is at the slowest pace among the three islands, which greatly influences the development of tourism in Lanyu. When typhoons strike, daily necessities must be transported to the three islands. If the airports and ports are shut down because of the severe weather, not only inbound visitors cannot arrive at the islands but outbound visitors cannot leave the islands. The dissatisfaction of outbound visitors would be much higher than that of inbound visitors because the outbound visitors have to endure the terrible weather, the lack of daily necessities, water outages and power failure on the islands. Little Liuqiu is rarely hit by typhoons directly among the three islands. Therefore, the growth in the visitor volume of Little Liuqiu is more significant than that of the other two islands.

The coefficients of the best model are given in Table VII. a_i for i=1, 2, 3 are positive, which means that each island still has attractions for visitors. The rate of change of visitor volume is positively proportional to visitor volume. If a_i is negative, the islands may have a bad reputation in tourism and should put efforts to rebuild it. b_i for i=1, 2, 3 are the internal effects of the three islands. Generally, b_i should be negative, which means that the growth trend is affected by the capacity. Tourism in Ludao is under this kind of situation, indicating that b_2 is negative. In recent years, Taiwanese government has been devoted to promoting tourism by investing in infrastructures, improving transportation services and planning tour packages. Little Liuqiu and Lanyu have obtained resources to upgrade tourism services. Thus, b_1 and b_3 are positive due to the tourism expansion.

TABLE VII
COEFFICIENTS OF THE MODEL WITH UNEMPLOYMENT RATE FROM 2008 TO 2014.

	coefficient				
variable	a_i	b_i	c_i	d_i	e_i
LLQ (i=1)	0.81^{**}	$6.12\times10^{-7**}$	$-8.49\times10^{-7**}$	0	0
LD (i=2)	0.74^{**}	$-8.45\times10^{-7**}$	$3.71\times10^{-7**}$	$-8.37\times10^{-7*}$	0
LY (i=3)	1.58^{**}	$1.69\times10^{-6**}$	$-8.44\times10^{-7**}$	0	-9027.66

*significant level of 0.1
**significant level of 0.05

Based on the coefficients of the interactive terms (c_i and d_i), the cooperation-competition relationship between islands are discussed. The relationship between Little Liuqiu and Lanyu is neutralism since d_1 and d_3 are 0. Ludao and Lanyu are in predator-prey relationship. So do Ludao and Little Liuqiu, which are also in predator-prey relationship. In the two pairs of relationship, Ludao plays a role of predator since c_2 and d_2 are positive. Actually, the resources, facilities and transportation services in Lanyu are indeed inferior to that of the other two islands. It's reasonable that Ludao attracts more visitors than Lanyu. However, because the two islands are so close to each other and both of them are governed by Taitung County, it's better to convert their predator-prey relationship into a cooperative relationship. Lanyu and Ludao hold

different activities. The former has the Flying Fish Festival and Yami rituals and the latter has jail tours and marine ecotourism. In addition, Ludao also attracts more visitors than Little Liuqiu. The tourist activities on the two islands are similar. Maybe cooperating with nearby scenic spots in Taiwan can generate new opportunities for both islands. Little Liuqiu is close to Kenting in Taiwan, which has tropical forests, meadows, sea cliffs, annual music festivals and National Museum of Marine Biology and Aquarium. Therefore, Kenting seems to be a good partner for Little Liuqiu to work with. As to Ludao, it can cooperate with Taitung County to boost tourism. The reason is that Taitung has some great spots like the National Museum of Prehistory and Beinan Cultural Park, where archaeological tours are provided. Taitung also has the annual Sea of Flowers Festival, which introduces some fascinating nature wonders. Above all, enhancing specific local characteristics to convert the predator-prey relationship into a win-win relationship between Little Liuqiu and Ludao would be helpful to promote offshore island tourism in Taiwan.

Unemployment rate with the coefficient (e_i) is the socio-economic factor related to the grey LV model. The unemployment statistics estimate the number of people who want to find a job but fail to do so. The unemployment data are often used as a measure of labor utilization and as an indicator of general economic activity. When a member of a family is unemployed, the family will probably face reduced income and a lower standard of living. Okun [41] examined the relationship between unemployment and national output over the past 50 years. His equation, Okun's Law, relates the percentage change in real GDP to changes in the unemployment rate. Okun's Law shows that real GDP grows at about 3% per year when unemployment is normal. For every point above normal that unemployment moves, GDP growth falls by 2%. Similarly, for every point below normal that unemployment moves, GDP growth rises by 2%. This law provides a good estimate of the effects of unemployment upon output. Economic growth may bring a better living standard, which stimulates consumption. Therefore, economic growth may lead to an increase in tourism demand. Thus, the unemployment rate shall be negatively proportional to the rate of change of visitor volume. In Table VII, e_1 and e_2 are equal to 0, showing that the visitor volume of Little Liuqiu and Ludao is independent of the unemployment rate. e_3 is negative, indicating that it is in an agreement with the deduction mentioned above. This also implies that the visitor volume of Lanyu is influenced by the economic environment.

V. Conclusions and Perspectives

In this study, a forecasting model of visitor volume for the three southern offshore islands is proposed and social-economic factors are considered. The forecasting are completed by two steps: the first step is forecasting the social-economic factor and the second step is substituting the forecasting result into the grey LV model. According to the results, the model with unemployment rate forecasts better than models with the other social-economic factors. The grey LV model is employed because the visitor volume fluctuates largely and the LV model cannot converge according to our preliminary study. Two sets of data during 2002-2014 and 2008-2014 are used in the model. The results of the data set during 2008-2014 produce a good forecast, showing that the grey LV model can forecast accurately only with a few data, which can be applied easier than regression model, time series models and individual choices models. The analysis of the coefficients presents the relationship between the tourism of the three studied islands. Highlighting the islands' uniqueness and boosting public interest may be two useful strategies for the development of the islands, but turning the predator-prey relationship to a win-win relationship will be a better way to promote tourism in Taiwan. In this study, numerical methods are employed to solve the grey LV model. Yet, derivation of analytical solutions and discrete models, which might be applied to periodic or chaotic analysis, is left for further studies.

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