PREDICTION OF MALAYSIAN GROSS DOMESTIC PRODUCT AND FOREIGN DIRECT INVESTMENT USING NUMERICAL METHOD WITH OPTIMIZATION APPROACH

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Abstract

The interaction between economic growth and foreign direct investment (FDI) is an ongoing fascination among researchers. The Lotka-Volterra model was utilized to describe the interaction of gross domestic product (GDP) and FDI respectively in Malaysia. In this study, the optimization method was used to evaluate the GDP and FDI relationship between 2009 to 2018 in Malaysia. The result demonstrates the existence of predator-prey relationship between the GDP and the FDI in Malaysia.

Keywords: *Foreign Direct Investment, Gross Domestic Product, predator-prey model, Lotka-Volterra model, optimization*

1. Introduction

The vast literature of FDI-GDP recognizes the major contribution of foreign direct investment (FDI) to economic growth [1-7]. Economy wise, FDI plays a crucial role in stimulating economic growth by promoting the development of domestic capital and facilitating the transfer of new technologies.

Regardless of the rise or decrease of FDI inflows, Malaysia's gross domestic product (GDP) is seen as more stable and steadily increasing over time. Among other things, this indicates the difficulty to predict the contribution of FDI to economic growth. That said, this trend is just a preliminary forecast. Until today, the FDI-GDP relationship is a subject that is still under discussion. In addition to that, empirical results on the FDI-GDP relationship are still questionable and lacked conviction.

However, numerous studies uncovered that FDI accorded positive effects on GDP growth, as an after-effect of the knowledge spills and technology transfer [1][2]. On the flip side, studies have also found conflicting results in which FDI conferred negative impacts on GDP [3][4]. There are other studies that uncovered a mixed outcome which showed how FDI can contribute to both positive and negative effects, such as the study findings reported by [5]. Lastly, studies such as [6] and [7] reported no significant relationship between FDI and GDP in Malaysia.

While previous discourses have touched on the relationship between the Malaysian FDI and the GDP, there exists no clear evidence of a concrete interaction between the variables. Among FDI locations, Malaysia is the one of the most preferred. Between 2005 to 2019, FDI in Malaysia averaged RM7686.97 million. FDI in Malaysia rose to RM21725.64 million in the first quarter of 2019, the highest in the quarterly series [8]. Amidst the huge collection of literature, no researchers have yet to recognize the relationship between FDI and GDP in Malaysia using mathematical modelling methods.

Generally, the predator-prey model is used to effectively describe the dynamics of two competing species, one as a predator and the other as prey. Lotka-Volterra model and Rosenzweig-MacArthur model are examples of the most widely used predator-prey models. Various approaches have been employed to solve the interactions between predator and prey, among others being the methods of Variational Iteration

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[9], Homotopy analysis method [10], Adams-Moultan and Fourth Order Runge-Kutta methods [11], non-standard weighted average approach [12] and lastly non-standard trimean approach [13][14], to cite a few.

The goal of this study is to examine the relationship between Malaysia's FDI and GDP using the Lotka-Volterra model, since this model can robustly determine the relationship between GDP and FDI in Malaysia. The reminder of this paper will be outlined like so, where Section 2 provides the methodology and methods used and proceed to the presentation of empirical result in Section 3. Section 4 concludes the paper.

2. Methodology

2.1. The Lotka-Volterra model

The Lotka-Volterra model is a differential equation system that goes by another name, the predator-prey model that describes the competitive interactions between two species. The equation of the model is based on the logistic curve, with the objective of expanding the analysis of technology diffusion in a competitive or cooperative market. In the Lotka-Volterra model, two species which was denoted as X and Y, are described by Eq. (1) [15]:

$$\begin{cases} \frac{dX}{dt} = aX - bX^2 - cXY \\ \frac{dY}{dt} = pY - qY^2 - rYX \end{cases} \quad (1)$$

The expressions X^2 and Y^2 denotes the interactions within species, while XY and YX illustrated interactions between different species. Parameters a and p are the capacity of population X and Y to grow, respectively. Meanwhile, the limiting parameters of population size decrease are represented by the parameters b and q, with parameters c and r representing competition rates between the two species. Lastly, the signs of parameters c and r disclosed the type of relationships between species as indicated in Table 1, presented as suggested by Wu and Liu [16].

Table 1. Type of interactions between species according to the sign of parameters c and r

Sign of c	Sign of r	Type of interaction	Explanation
+	+	Pure competition	Occurs when each other's existence harms both species
+	-	Predator-prey	Occurs when one of them serves as direct food to the other
-	-	Mutualism	Occurs in the case of symbiosis or a win-win situation

2.2. Dataset

Based on the 2019 version of World Development Indicators, GDP per capita growth (US$ 2010 constant prices) data was procured. In the meantime, FDI inflow (percentage of GDP) are collected from the database of the United Nations Conference on Trade and Development (UNCTAD). This research uses the Malaysian panel data that covers a 10-year period from 2009 to 2018, which was after the 2007-2008 global financial crisis.

2.3. Fitting Lotka-Volterra model to data of GDP and FDI of Malaysia using Python

Python is one of data scientists' most widely used programming languages [17]. Scipy is a Python library comprising numerous scientific computation and data analysis features [18]. The function *ode.int* is a well-known ODE integrator for numerical solving system of coupled ordinary differential equations (ODEs). The system solves via lsoda from the FORTRAN library odepack that was provided by scipy. In-depth details can be found in [19].

The optimizer *fmin* was imported from scipy in order to find the parameters that will aid the Lotka-Volterra model data fit for GDP and FDI of Malaysia. To identify the minimum of objective function originating from a guessing point, the optimizer *fmin* uses the downhill simplex algorithm. The algorithm for the optimization methods that apply Lotka-Volterra model to fit GDP and FDI data using scipy is shown below.

Algorithm for the optimization method

Set the model equation
Set the ODE integrator

Generating the data to fit the system of ODEs
X = GDP per capita (constant 2010 US$)
Y = FDI inflow (% of GDP)

Set up info for the system of ODEs
define the model initial parameter a, b, c, p, q, r,
define the model initial conditions of X and Y
define the model steps start time and end time

Set score fit the system of ODEs
define the solution to the system
define the pick of model points to compare
define the score difference between model and data point

Find the best fit of parameter of the system of ODEs
define the optimization function

Generate solution to system
define the new model parameter

Output
Display the new parameter
Display the predicted value of X and Y

2.4. Model adequacy check

In order to ascertain the accuracy of the model, the mean absolute percentage error (MAPE) was used in this study. This is done by assuming that Y_i and $\hat{Y}_i$ are the actuals and the predicted values respectively with $i = 1, 2, \ldots, n$.

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right| \times 100.$$

Table 2. Predictor capability levels of MAPE

MAPE	Prediction capability
Less than 10	High accuracy
10 and less than 20	Good accuracy
20 and less than 50	Reasonable accuracy
Above 50	Lack of accuracy

3. Results and Discussions

We apply the Eq. (1) to the dataset of GDP and FDI in Malaysia using optimization method from scipy Python. GDP per capita (constant 2010 US$) is referred to as X, and FDI inflow (% of GDP) is referred to as Y. By using the optimization method, we set up the model system using data from 2009 to 2018, as shown in Eq. (2):

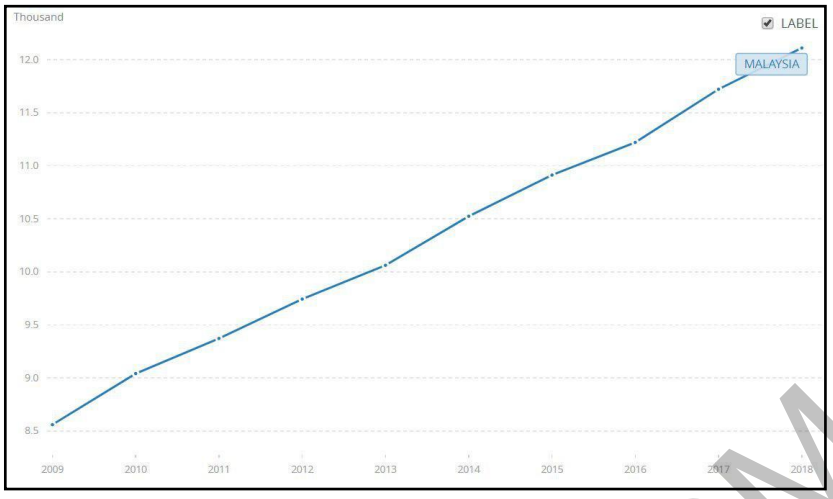
$$\begin{cases} \frac{dX}{dt} = -12.08X + 3.31X^2 - 2.53XY \\ \frac{dY}{dt} = -44.49Y - 7.59Y^2 + 11.30YX \end{cases} \quad (2)$$

From our simulation result, we found that $c = 2.53$ and $r = -11.30$ for GDP and FDI, respectively. Since the value of parameter $c > 0, r < 0$, it follows that the GDP and FDI in Malaysia are in predator-prey relationship, in accordance to Table 1. We concluded that GDP, as the one that assumed the role of predator, inhibited the FDI (as the one that assumed the role of prey in economic growth) inflow in Malaysia. This finding is similar to the one reported by [16], that revealed how the GDP and FDI in Ningbo city was also in a predator-prey relationship, with the FDI according a negative effect on the GDP. However, in contradiction to [20], the relationship of GDP and FDI of Shanxi province is mutualism, where the value of parameters $c < 0$ and $r < 0$.

There may exist a predator-prey relationship between GDP, which may be the outcome of an economic growth that was left unscathed by FDI. In circumstances such as this, the presence of FDI benefited GDP, thus producing the FDI positive influence on GDP growth rate scenario. As the threat posed by GDP went unrecognized by FDI, the GDP in return did not trigger any significant growth spurt in FDI. However, simultaneously, market shares from FDI are slowly being taken away by the GDP. Under this situation, the GDP had a negative impact on FDI's growth rate, hence the said predator-prey relationship.

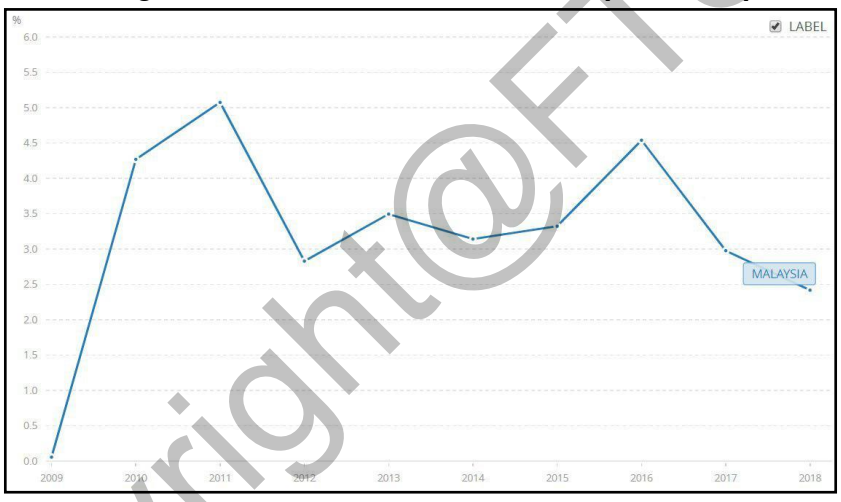
With that said, as the result shows, Malaysia's GDP per capita in Malaysia will rise sharply, while Malaysia's FDI inflow is expected to slow down gradually. We can see this clearly depicted in Figure 1 and Figure 2. From Figure 1, Malaysia had a consistent GDP per capita (constant US$) growth record over the period 2009 to 2018 at an average annual rate of 3.78%. In the meantime, the pattern of FDI has slightly changed over time, as shown in Figure 2. There has been substantial fluctuation observed in recent years, where it tended increase and decrease throughout the 2009 to 2018 period. This disappointing development pattern has become a major concern of researchers and policy makers.

Figure 1. GDP per capita (constant 2010 US$) – Malaysia



Source: The World Bank Data

Figure 2. Foreign direct investment, net inflows (% of GDP) – Malaysia



Source: The World Bank Data

The actual values and the predicted values of the optimization method are presented in Table 3 for the annual GDP per capita. Since the MAPE of optimization method is 0.0002%, this means that the scipy Python optimization method yields very high accuracy prediction performance.

Table 3. Predicting values of GDP per capita and MAPE

Year	Actual value	Predicting value
2009	8559.23	8559.26
2010	9040.57	9040.60
2011	9372.01	9372.04
2012	9743.10	9743.11
2013	10061.72	10061.73
2014	10524.07	10524.09
2015	10912.15	10912.17
2016	11219.63	11219.63
2017	11720.74	11720.76
2018	12109.49	12109.49
MAPE		0.0002

For FDI, the actual values and the predictive values of optimization method were presented in Table 4. The MAPE of optimization method is 10.4801% which showed that the optimization method has very good predictive accuracy.

Table 4. Predicting values of FDI inflow and MAPE

Year	Actual value	Predicting value
2009	0.72	0.71
2010	3.55	4.21
2011	4.09	4.00
2012	2.94	2.80
2013	3.75	3.53
2014	3.22	3.15
2015	3.40	3.28
2016	3.82	3.22
2017	2.99	3.24
2018	2.28	3.23
MAPE		10.4801

4. Conclusion

In this paper, we analyze Malaysia's gross domestic product (GDP) and foreign direct investment (FDI). By using the concept of optimization *fmin* search algorithm in Python, we obtain the optimum value of parameters a, b, c, p, q and r. The sign of estimated parameters c and r determines the type of relationships as depicted in Table 1. From our simulation result, we find that $c = 2.53$ and $r = -11.30$ for the GDP and FDI values respectively. Hence, we conclude that the GDP and the FDI for Malaysia exhibited the predator-prey relationship. The positive c and negative r reflects the GDP preying on FDI, and both competes for economic growth in Malaysia.

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