Karia *Economic Structures* (2021) 10:5
https://doi.org/10.1186/s40008-021-00236-6

Journal of Economic Structures

RESEARCH Open Access

Are there any turning points for external debt in Malaysia? Case of adaptive neuro-fuzzy inference systems model

Abdul Aziz Bin Karia*

*Correspondence:
abdulaziz@sabah.uitm.edu.my
Faculty of Business and Management, Universiti Teknologi MARA (UiTM) Sabah, Kota Kinabalu, Malaysia

Abstract

This paper intends to investigate whether the turning points exist between tax revenue, gross domestic product, government expenditure, and gross domestic saving towards Malaysia's total external debt. The researcher implements the adaptive neuro-fuzzy inference system model to forecast the total external debt in Malaysia. The total external debt prediction then projects the three-dimensional surface diagrams to depict whether the turning points exist among the variables. This study's empirical finding reveals that the turning points are noticeable between the tax revenue, gross domestic product, and gross domestic saving toward external debt in Malaysia. However, government expenditure depicts a direct relationship with external debt. This finding demonstrates that the anomaly between the theories and scholarly activities. This study also recommends that the tax revenue be collected at maximum holding the government expenditure and gross domestic product are maximum statistics to reduce Malaysia's external debt.

Keywords: External debt, Tax revenue, Gross domestic product, Government expenditure, Gross domestic saving, Adaptive neuro-fuzzy inference system

1 Introduction

External debt is borrowing monetary aids from the different monetary centers. This external monetary aid does not purely refer to the governments, and it also includes external borrowing from commercial banks, household and international financial institutions. One of the contributors towards the external debt is tax revenues when it is insufficient to finance excessive government expenditure. Malaysia is classified as one of the 15 most indebted low- and middle-income countries (Dupuis and Vachon 2017). External debt in Malaysia, which includes short-term, medium, and long-term debt, stood at RM873.8 billion which is equivalent to 71.08% of its gross domestic product (GDP) as of December 2016.[1] Moreover, based on data provided by World Bank (2018), the total external debt to gross national income ratio in Malaysia is recorded as the highest among all emerging economies which is equivalent to 69.58%. Furthermore,

[1] Refer to the Bank Negara Malaysia (2016) report, http://www.bnm.gov.my/index.php?ch=statistic_nsdp&pg=statistic_nsdp_extdebt&lang=en#.

Malaysia's external debt to export goods and services on primary income ratio was 38.81% in 2007. Ten years later, this ratio soared to 94.50% in 2016. As this ratio is equivalent to 100%, it gives us the impression that the export revenues from goods and services are no longer covering the external debt. Raising the ratio of external debt to export revenues leads to a risk of insolvency over a long period (Dupuis and Vachon 2017; Zhu et al. 2018). Data gathered on the ratio between international asset reserves to total external debt will shed more light on this area. In 2016, Malaysia's total reserves-to-total external debt ratio were 47.15%, which implies that Malaysia's international assets reserves to cover the external debt is less than 60%. Although Malaysia's external debt has increased dramatically, it is vital to finance the domestic sources to offset the development and other needs of a country (Siddique et al. 2016). Another concern is that the past literature has revealed that a rise in external debt can cause economic turmoil (Gupta et al. 2007; Catão and Milesi-Ferretti 2014).

The neoclassical growth theory reveals that there is a strong positive correlation between economic growth and debt. Borrowing from abroad is healthy to finance investment, which significantly stimulates economic growth and vice-versa. However, most of these studies focused on the impact of external debt to economic growth and found that there is an inverse relationship between debt and economic growth (Adegbite et al. 2008; Panizza and Presbitero 2014; Zouhaier and Fatma 2014). In this sense, a higher (lower) level of external debt will burden (stimulate) economic growth. The noteworthy hypothesis from the study of Reinhart et al. (2012) reveals that as the debt to economic growth ratio increases above 90%, it will slow down the economic activity. Apart from slowing down the economic activity, it will also lead to the stagnation of growth. In a similar vein, Westphal and Rother (2012) also argued that economic growth and debt would have nonlinear relationship with a turning point. As the debt to economic growth ratio hits 90% to 100%, it will show signs of a turning point. Surprisingly, both of these studies are opposed to the public debt overhang theory. The hypotheses highlighted by the study of Reinhart et al. (2012) and Westphal and Rother (2012) should not be disregarded. Based on the previous empirical evidence in the literature, most of the areas of discussion that are highlighted focused primarily on the impact of external debt on economic growth. The determinants of external debt also should not be put aside. This is supported by the study of Mensah (2016), whereby the external debt is not granger caused to economic growth. However, economic growth is an influence on external debt. Therefore, the researcher is concerned with (1) how the economic growth will have a direct, inverse relationship with turning point towards Malaysia's external debt?

Relying on the theory built on tax smoothing approach to the fiscal policy proposed by Barro (1979), the government will use expansionary and contractionary fiscal policy to mitigate the tax rates from changing too steep. The government will run expansionary (contractionary) fiscal policy when high (low) government spending needs. Concerning this theory, varying the government expenditure is necessary to buffer the tax rate to perpendicular (Battaglini and Coate 2008). Therefore, to improvise the theory of tax smoothing approach Battaglini and Coate (2008) presented a dynamic political economy theory of public spending, taxation, and debt. Therefore, the tax revenue can be raised by two approaches; income tax and borrowing for the capital market. It is considered an excellent tool to finance government expenditure and essential in maintaining

economic stability. As mentioned previously, raising external debt could harm economic activity. According to Feldstein (2015) and Zhu et al. (2018) increase in debt would slow down the economic activity, including social expenditure such as pensions and health programs. However, collecting more tax revenue could contribute to that process. In this perspective, the researcher believes that the policymakers are in a dilemma. If they consider increasing the social expenditure, it will accumulate more to the government expenditure, whereby this expenditure needs to be financed by external borrowing. Like two sides of the same coin, this will indirectly contribute more to the external debt. Furthermore, the so-called external debt is one of the components of public debt. As the public debt to economic growth ratio reaches 90 to 100% it will be stagnant and negative economic growth. Therefore, the researcher addressed the questions (2) Whether the increase in government expenditure should be finance by the external debt? (3) Is the turning point noticeable between tax revenue and government expenditure towards the external debt?

Since the government expenditure is logically complementary to the national saving, it is important to shed more light on this aspect. The government is responsible for using its power in stabilizing the economy during inflation and economic downturn. The study of Holtfrerich et al. (2016) found that the government is said to stimulate economic growth by increasing its expenditure during the recession period. This is due to government expenditure being the stabilizing function. Since the gross domestic saving is the gross domestic product minus final consumption expenditure, an increase in government expenditure will reduce the national saving. The hypothesis highlighted by Fry (1989) reveals the effect of national saving and domestic investment ratios on external debt. It is said that the saving and domestic investment ratios show a downward slope as the external debt increases. Reflecting on this point, reduction (increase) in national saving will show the sign of increase (decrease) in government expenditure. The stabilizing function of government expenditure and national saving is opposite to one another. The finding of Mensah (2016) revealed that as the government expenditure increases, there would be a need to finance this expenditure from external borrowing. Therefore, the hypothesis highlighted by Fry (1989) should not be rejected. As a result, it is vital to induce a drop in external debt when the economy shows overheating signs. The government should show the quality to run up additional debt to overcome the recession (Holtfrerich et al. 2016). The previous literature is quite revealing on several points. However, in the eyes of the researcher, the question on (4) what will be the optimum point for government revenue, expenditure, and national saving in reducing the external debt is also important to be discussed in scholarly activities.

Reflecting on the arguments raised in the literature, to the researcher's knowledge, this is among the newest pieces of evidence to predict external debt using adaptive neuro-fuzzy inference system (ANFIS) model. The ANFIS characteristics that are a hybrid between the artificial neural network (ANN) and fuzzy inference system (FIS) will answer the four research questions in the current work. The most important is that the ANFIS model's superiority explains the external debt's turning points that are still lacking in the scholarly activity. Regarding the ANFIS prediction, the three-dimensional surface diagram will determine the optimum points of economic growth, government revenue, expenditure, national savings, and external debt in Malaysia.

Remainder of this paper is structured as follows: Sect. 2 provides theoretical background on adaptive neuro-fuzzy inference system approach (ANFIS), Sect. 3 presents data and the empirical results of external debt in Malaysia, and finally, Sect. 4 presents the conclusion and recommendations.

2 Methods

2.1 Adaptive neuro-fuzzy inference system approach (ANFIS)

The current work refers to the ANFIS model proposed by Jang (1993). The use of the ANFIS model to predict a wide range of discipline is snowballing as this model has revealed its capability in learning ability (Atsalakis et al. 2018). Keles et al. (2008) successfully used the ANFIS model to predict domestic debt in Turkey. Another study by Wei et al. (2014) also successfully predicted the Taiwan stock exchange weighted index (TAIEX) using the ANFIS model. Apart from that, a recent study by Mohaddes and Fahimifard (2018) discovered that the ANFIS model is outperformed compared to other econometrics models in predicting agricultural product export revenues in Iran. Although ANFIS has been employed in various types of studies, there is a minimal study on the employment of predicting macroeconomics indicators. The ANFIS, which is considered as a hybrid model between the artificial neural network (ANN) and fuzzy inference system (FIS), is superior in predicting many fields with minimal errors (Abdulshahed et al. 2015). The study of Wang et al. (2015) reveals that the ANN is useful in predicting long-term time-series data. However, it needs a large data sample to avoid the problem of overfitting behavior (Chan et al. 2006; Karia et al. 2013). On the one hand, Atsalakis et al. (2018) highlighted that the FIS is good imprecision the information and framework of approximate reasoning. However, FIS has been accused of lacking self-learning capability. Therefore, the ANFIS model that is combined with ANN and FIS does not require large number of sample data and parameters (Talpur et al. 2017; Atsalakis et al. 2018). Additionally, the hybrid of ANN and FIS reduces its dependency on experience and is very systematic (Haznedar and Kalinli 2018). Hence, this makes it a suitable model to predict external debt in Malaysia. Additionally, the FIS that comes with a precision ability of "*If-then*" rules will be very beneficial in determining the optimum amount of tax revenue, gross domestic product growth, government spending and gross domestic saving by which significantly influence the level of external debt in Malaysia.

Based on previous empirical evidence, this study utilized the rules of FIS that was introduced by Takagi and Sugeno (1985), which can be derived as follows:

Rule 1: If x is A_1 and y is B_1, then $f_1 = p_1x + q_1y + r_1$.
Rule 2: If x is A_2 and y is B_2, then $f_2 = p_2x + q_2y + r_2$.

Each of the input variables will be assigned with three rules that include minimum, average, and maximum for tax revenue, growth of domestic product growth, government expenditure, and gross domestic saving. Since four of the inputs are normally distributed, Fig. 1 reveals that the Gaussian shape of membership function would be best in utilized with the *if-then* rules. Therefore, there are four inputs that come with

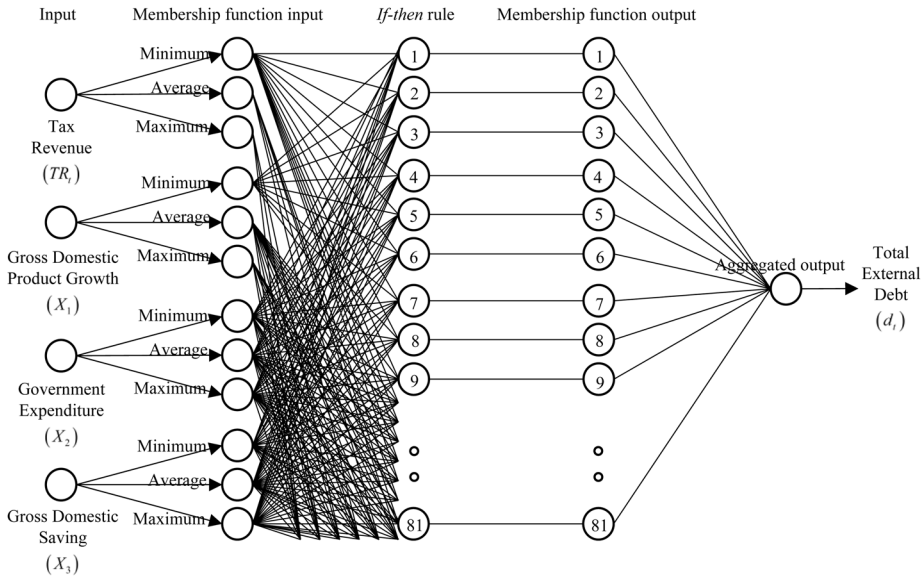

Fig. 1 The basic architecture of the ANFIS model to predict the external debt in Malaysia

three membership function inputs each and 81 rules of if-then and membership function output.

Since this study utilized the Takagi–Sugeno–Kang inference system, there will be five layers that include layer 1 as fuzzy layer; layer 2 as product layer; layer 3 as a normalized layer; layer 4 as defuzzify layer and layer 5 as output layer (XiangJun and Hashimi 2012).

Layer 1 The first layer is considered as an input node. This input layer will be converted into a set of fuzzy rules based on the number of membership functions assigned by the researchers. Each of the node i is an adaptive to the function as follows:

$$O_i^1 = \mu_{A_i}(x), \text{which } i = 1, 2, \tag{1}$$

$$O_i^1 = \mu_{B_i-2}(y), \text{which } i = 3, 4. \tag{2}$$

The input node i is denoted by the x and y. In this case, the researcher considers x as tax revenue, gross domestic product growth, government expenditure and gross domestic saving. Meanwhile, the $\mu_{A_i}(x)$ and $\mu_{B_{i-2}}(y)$ are denoted as linguistic variables. There are a variety of membership functions such as Gaussian, two-Gaussian, triangular, trapezoidal, generalized bell, and pi-shaped that can be considered by the researcher (Karia et al. 2013).

Layer 2 The second layer will multiply the incoming signal from the O_i^1. The O_i^1 will demonstrate the characteristic of the inputs in the first layer. Meanwhile, the second layer represents the if-then rule that will be multiplied with O_i^1 which can be derived as follows:

$$O_i^2 = \mu_{A_i}(x) \times \mu_{B_i}(y), \quad i = 1, \ldots, 4. \tag{3}$$

Layer 3 The third layer is also known as the static node. It estimates the ratio of the ith sum of all rules' of firing strengths against the rule's firing strength. This ratio of normalized firing strength can be computed as follows:

$$O_i^3 = \frac{w_i}{w_1 + w_2}, \quad i = 1, \ldots, 4, \tag{4}$$

$$w_i = \mu_{A_i}(x) \times \mu_{B_i}(y). \tag{5}$$

Layer 4 This layer will be an adaptive node that mimics the i-th function. The $\overline{w}_i$ is the output from the Q_i^3. The consequent parameter set is represented by p_i, q_i and r_i:

$$O_i^4 = \overline{w}_i f_i = \overline{w}(p_i x + q_i y + r_i). \tag{6}$$

Layer 5: Also known as the overall of summation incoming signals $(\sum)$:

$$O_i^5 = \sum_i \overline{w}_i f_i = \frac{\sum\limits_i w_i f_i}{\sum\limits_i w_i}. \tag{7}$$

Considering all of the layers included in the model, it is apparent that the ANFIS model can produce an excellent universal adaptive node that can be further applied in this study. The Matlab statistical software that comes with the rules viewer for inputs and output for the ANFIS model will help researchers and policymakers to change the value of inputs, in this case, $TR_t, X_{1,}X_2$ and X_3 to predict the output, d_t (Guneri et al. 2011; Atsalakis et al. 2018).

2.2 Statistical analysis

The current work employed three statistical evaluation criterions to evaluate the forecasting performance. The three criterions are coefficient of determination (R^2), root mean square error (RMSE), and mean absolute percentage error (MAPE).

$$R^2 = \frac{\left[\sum_{i=1}^{n}\left(d_{f_i} - \overline{d}_{f_i}\right)\left(d_{t_i} - \overline{d}_{t_i}\right)\right]^2}{\left[\sum_{i=0}^{n}\left(d_{f_i} - \overline{d}_{f_i}\right)^2\right]\left[\sum_{i=0}^{n}\left(d_{t_i} - \overline{d}_{t_i}\right)^2\right]}, \tag{8}$$

$$\text{RMSE} = \sqrt{\left[{}^{1}\!/_{n}\sum_{i=0}^{n}\left(d_{f_i} - d_{t_i}\right)^2\right]}, \tag{9}$$

$$\text{MAPE} = {}^{1}\!/_{n}\sum_{i=0}^{n}\left|\frac{\left(d_{f_i} - d_{t_i}\right)}{d_{t_i}}\right| \times 100, \tag{10}$$

where n is denoted as observation, d_{f_i} and d_{t_i} are the forecasted and original series of external debt, respectively. The $\overline{d}_{f_i}$ and $\overline{d}_{t_i}$ represent the average of forecasted and original series of external debt, respectively.

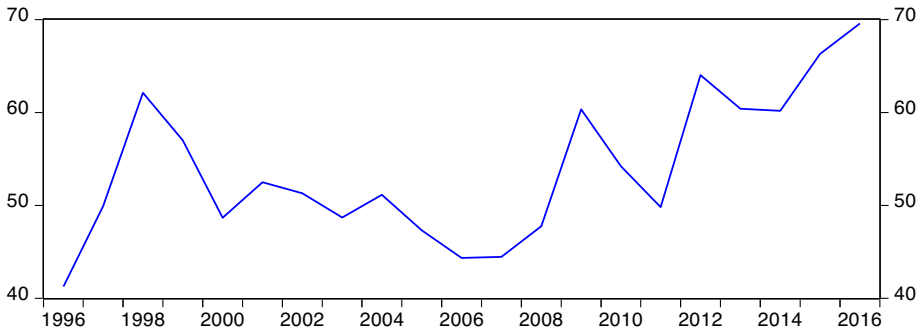

Fig. 2 The total external debt as a percentage of gross national income in Malaysia starting from 1996 to 2016

3 Results and discussion

3.1 Data

In this study, there are four inputs and one output variables to be utilized on the ANFIS model. The input and output samples are obtained from the World Bank (2018) from the period of 1996 to 2016 which include 21 years of observation. With regard to the objectives of this study, the following model is derived:

$$d_t = \beta_0 + \beta_1 \mathrm{TR}_t + \beta_n \mathrm{X}_{nt} + \varepsilon_t, \tag{11}$$

where d_t represents the total external debt as percentage of GNI in period of t; β_0 is constant; TR_t is tax revenue as percentage of GDP at time t, X_{nt} is a vector of other relevant factors that are included under this study such as gross domestic product growth in annual percentage, government expenditure and gross domestic saving both in percentage of GDP in period of t and ε_t is the other factor that is not included in this model.

3.2 Inputs and output definitions

Figure 2 depicts the performance of Malaysian total external debt as a percentage of gross national income from 1996 to 2016. This figure is quite revealing in several points as it demonstrates a rising trend from 1996 to 2016. As can be seen, the debt to gross national income shows its peak at 69.58% in 2016. Hence, there is a need to determine the factor that contributes to this movement.

3.3 Data pre-processing

Table 1 reveals the descriptive statistics for all of the input and output which are standardized in percentage values. This percentage is very useful to this study, where it can help the researcher to interpret the input and output so that the element of purposiveness can be fulfilled.

Besides that, the input and output for the ANFIS model which are denoted as TR_t, X_{nt} and d_t consist of 21 observations in total. This information is very important as it is one of the criteria for the researcher to set the membership function inputs. For example, the TR_t show the minimum, average and maximum value for about 13.33%, 15.47% and 19.75%, respectively. Therefore, these statistics will be included as minimum, average and maximum for TR_t in O_1^2. This statistics also continue for vector for other relevant

Table 1 Descriptive statistics that include input and output variables to be considered in ANFIS model

	Indicator	Minimum	$\overline{X}$	Maximum	S	n
Input variable						
1. Tax revenue (TR_t)	% of GDP	13.332	15.465	19.753	1.776	21
2. Gross domestic product growth (X_1)	Annual %	− 7.359	4.863	10.003	3.712	21
3. Government expenditure (X_2)	% of GDP	9.769	12.122	13.842	1.178	21
4. Gross domestic saving (X_3)	% of GDP	32.564	41.016	48.670	4.730	21
Output variable						
1. Total external debt (d_t)	% of GNI	41.256	53.867	69.575	7.836	21

factors such as gross domestic product growth (X_1), government expenditure (X_2) and gross domestic saving (X_3). As a result, the statistics that includes minimum, average and maximum for X_1, X_2 and X_3 will be in second layer of O_2^2, O_3^2 and O_4^2.

Figure 1 demonstrates the architecture of the ANFIS model, there are four inputs, three membership functions each input and 81 *if-then* rules in total. Since there is no predetermined set of membership function is best with a given TR_t, X_1, X_2 and X_3, researcher consider the perspective from Luh (2012) that the Gaussian is frequently use in virtue of its good error bound and numerical tractability. The Gaussian-shaped membership function obtained from this study can be derived from $\mu_A(x) = e^{\frac{-(x-c)^2}{2\sigma^2}}$ as portrayed in the normally distributed data (Palit and Popovic 2005). In this study, the input X_1 indicates that there was a negative economic growth in the years 1998 and 2009 with − 7.36% and − 1.51%, respectively. However, in the year 1996, Malaysian economic growth hit 10.00%, which is considered as maximum growth in this sample. Therefore, the range of input X_1 should be between − 7.36 to 10.00. For the inputs of TR_t, X_2 and X_3, the ranges are between 13.33 to 19.75, 9.77 to 13.84, and 32.56 to 48.67, respectively. Since this study aims to identify the direct and inverse with a turning point, the in-sample forecast is the most suitable approach to meet this objective (Karia et al. 2013). The sample inputs of TR_t and X_{nt} will be training inputs to predict outside the estimation period which denoted as d_f. Therefore, to measure the ability of the ANFIS model in predicting the d_f, the researcher compared it with the actual d_t. This is referred to as forecasting evaluation performance and can be achieved with Eqs. (8), (9), and (10).

3.4 In-sample forecasting

This section discusses the in-sample forecasting for the external debt in Malaysia using the proposed four inputs. For the ANFIS training algorithm, the researcher employed a hybrid optimizing technique of the FIS that came with 0.05 error tolerance. With regard to the training and testing dataset, the best performance of the ANFIS model was set at 120 epochs as it depicted a 0.003 error tolerance. Upon completing the training and testing performance, the ANFIS model demonstrated an average testing error of 0.002.

Figure 3 plots the ANFIS model prediction against the original series of external debt in Malaysia at the last 120 epochs. This figure is quite revealing as its shows that the ANFIS model is fit to predict the external debt. Moreover, the ANFIS model

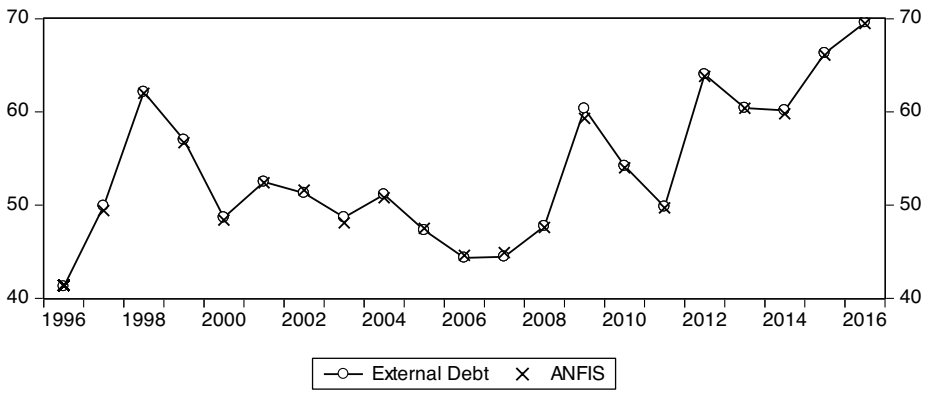

Fig. 3 Plot of the ANFIS prediction against the original series of external debt in Malaysia starting from 1996 to 2016

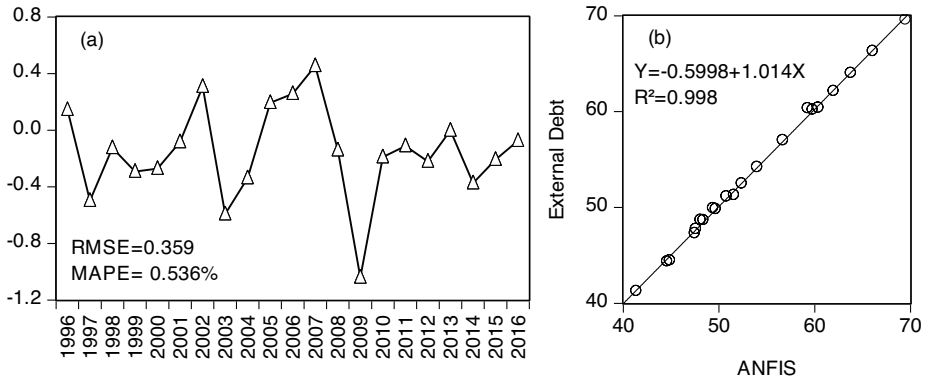

Fig. 4 **a** Plot of the ANFIS forecasting errors with the original external debt in Malaysia; **b** scatter plot of the ANFIS forecasting against external debt in Malaysia

demonstrates its adaptability to the hybrid ANN and FIS models. The Gaussian-shaped MF, with three MF inputs among them, was the best fit with the given historical data that trained by ANN model. To evaluate the forecasting performance, the researcher employed the existing forecasting evaluation criteria as indicated in Eqs. (8), (9), and (10) which are demonstrated in Fig. 4. The ANFIS model demonstrated the errors ranging from $-1.041 \leq e \leq 0.454$. The reported RMSE is 0.359 which is statistically significant according to the Diebold and Mariano (1995) perspective. Besides that, the reported MAPE was also statistically significant as it indicated 0.536% that was still within the ranging range that was highlighted by Lewis (1982).

3.5 Three-dimensional surface diagrams

This section describes a functional relationship that is direct, inverse with a turning point between the inputs and output and aims to address the questions set out in this study. Figure 5a–c depicts three-dimensional surface diagrams that explain the relationship between two inputs and one output after the ANFIS forecasting. The y-axis is presented by the output, while the x-axis and z-axis are the two inputs.

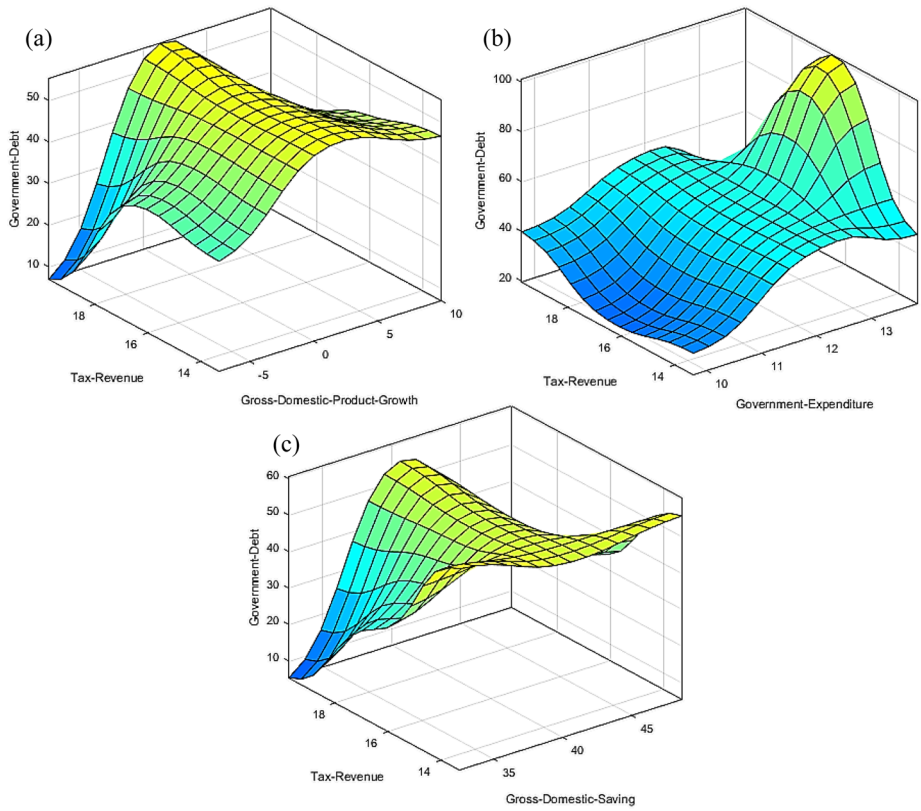

Fig. 5 Three-dimensional surface diagram of inputs and output parameters after ANFIS analysis. **a** The relationship between tax revenue and gross domestic product to the external debt; **b** the relationship between tax revenue and government expenditure to the external debt; **c** the relationship between tax revenue and gross domestic saving to the external debt

As presented in the descriptive statistics, it is said that the external debt as the output is at the minimum when it is below 41.256, average ranging at 53.867 and above 69.575 is considered maximum. Furthermore, the tax revenues are minimum, average, and maximum at 13.332, 15.465, and 19.753, respectively. The gross domestic product growths are − 7.359, 4.863, and 10.003, respectively. The government expenditures are 9.769, 12.122, and 13.842, respectively. The gross domestic savings are 32.564, 41.016 and 48.670, respectively.

The results in this study reflect those Mensah (2016) which found that the economic growth influenced the external debt. Consider Fig. 5a, the two inputs and one output are the tax revenue and gross domestic product growth to the external debt after the ANFIS forecasting. This empirical result reveals that the Malaysian external debt forecasted by the ANFIS model depicts at its peak point (average statistics) when the tax revenue is maximum statistics and gross domestic product growth at average statistics. However, when the tax revenue at maximum statistics and gross domestic product growth at minimum statistics (negative growth), then external debt at minimum statistics (lowest point). These conditions are in line with the neoclassical growth theory proposed by Forslund et al. (2011), whereby it was stated that there are strong positive correlations between gross domestic product growth and debt. However, for

the case of external debt in Malaysia, the anomaly of this theory revealed the turning point when the tax revenue ranging from minimum to maximum statistics and the gross domestic product is average statistics. As highlighted previously, it is consistent with the hypothesis highlighted by the study of Westphal and Rother (2012). The external debt will show a negative relationship as the tax revenue ranging from minimum to maximum statistics and gross domestic product growth increases from average to maximum statistics. These conditions are supported by previous empirical evidence which argued that the gross domestic product would have negative relationship with the external debt (Adegbite et al. 2008; Panizza and Presbitero 2014; Zouhaier and Fatma 2014; Bittencourt 2015; Waheed 2017). The ANFIS model proved that as the gross domestic product increases, the external debt would increase. However, at one point, the external debt depicts the evidence of a turning point as the gross domestic product increases further.

Figure 5b depicts the three-dimensional surface diagram that includes tax revenue and government expenditure towards the external debt in Malaysia projected by the ANFIS model. If tax revenue hits 19.753 (maximum statistics) and government expenditure is 13.842 (maximum statistics) then the external debt is below minimum statistics. On the one hand, if the tax revenue is collected at minimum statistics and government expenditure at minimum statistics, the external debt is below minimum statistics. Furthermore, if the tax revenue is average statistics and government expenditure at maximum statistics, then the external debt above maximum statistics. This evidence proved that the tax revenue and government expenditure are positive and have a direct relationship with the external debt. This condition is supported by the dynamic political economy theory of public spending, taxation, and debt that was proposed by Battaglini and Coate (2008). In addition, recent study by Holtfrerich et al. (2016) highlighted that the reason for direct relationship as government revenue is considered as a good mechanism to finance the government expenditure. Therefore, an increase in government expenditure will also increase the tax revenue. Financing the government expenditure with the condition of insufficient tax revenue will lead to an increase the external borrowing. The most important part of this study is the ANFIS model forecast that as the government of Malaysia induces a drop in their expenditure, then the external debt will also reduce. However, the most striking result as the tax revenue is at average statistics, and given that government expenditure at maximum statistics then the external debt hit nearly to 100 which above than maximum statistics. Moreover, the turning point of external debt is visible when the government expenditure is maximum statistics, and tax revenue is minimum (average) [maximum] statistics then the external debt is minimum (maximum) [minimum] statistics. With reference to the first case, if government induces a rise in tax revenue from minimum to average statistics given with government expenditure is maximum statistics then the external debt has appeared increase to maximum statistics. This can be explained by the hypothesis of Wamser (2014) that revealed that a firm tends to substitute the internal debt to external debt as the government induced rise in corporate tax. For the second case, induce drop in tax revenue from maximum to average statistics given with government expenditure is maximum statistics will influence the external debt to increase up to the maximum statistics. This is consistent with the hypothesis that argues a rise in government revenue will induce higher government

expenditure (AbuAl-Foul and Baghesani 2004; Gounder et al. 2007; Aslan and Tasdemir 2009; Al-Zeaud 2014). Therefore, a reduction in government revenue holding government expenditure remains unchanged (maximum statistics), would lead to the external borrowing to finance such expenditure (Holtfrerich et al. 2016).

Figure 5c depicts the three-dimensional surface of forecasted tax revenue and gross domestic savings to the external debt. According to Al-Zeaud (2014), the expansionary fiscal policy that stimulates economic growth tends to reduce the gross domestic savings. This due to the government policy that increases its expenditure will reduce the national saving. In one hand, Saeed and Somaye (2012) point out that stabilizing the fiscal deficit can be done through inducing a drop in government expenditure and/or inducing an increase in government revenue would be effective. If the tax revenue is maximum statistics and gross domestic savings is minimum statistics then the external debt is below minimum statistics. This is supported with the data in Fig. 5b, whereby an increase in government expenditure that is sufficiently financed by tax revenue that both up to the maximum statistics will reduce the external debt. The external debt started to show an increasing trend as the tax revenue started to reduce from maximum to average statistics and gross domestic savings increase from the minimum to average statistics. Meanwhile, the external debt started to drop (increase) consider the changes in tax revenue are ranging from average to maximum statistics but gross domestic saving change average to maximum (maximum to average) statistics. This is supported by the hypothesis of Fry (1989), whereby gross domestic savings showed a downward slope as the external debt increases. This three-dimensional surface diagram also reveals that the turning point of the external debt is noticeable as the tax revenue is at maximum statistics and gross domestic saving is at average statistics. Surprisingly the external debt remains higher (maximum statistics) as the tax revenue is minimum statistics and gross domestic saving are minimum, average, and maximum statistics. The three-dimensional surface diagram of 3.3(b) and (c) gives the researcher an impression that if the tax revenue is collected insufficiently such at minimum and average statistics, the external debt tends to increase.

To present a visual explanation of the turning point of the inputs and output, the researcher also considers the two-dimensional diagram. The four inputs are the tax revenue, gross domestic product growth, government expenditure, and gross domestic savings and the external debt as the output as depicted in Fig. 6a–d. The visual explanation on this figure is quite revealing as the tax revenue, gross domestic product growth, and gross domestic saving demonstrates the turning point with the external debt. However, the government expenditure shows a direct relationship with external debt.

4 Conclusions

Previous studies argue that a rise in external debt will slow down economic activities and social expenditure such as pensions and health programs (Feldstein 2015; Holtfrerich et al. 2016). Moreover, empirical evidence from the literature also predicts that the relationship among the variables using panel data analysis which based from the averaging analysis. Some studies found positive and negative relationships that supporting or contradicting the theory. Therefore, the researcher considers that the adaptive behavior of the ANFIS model is useful to capture the problem addressed.

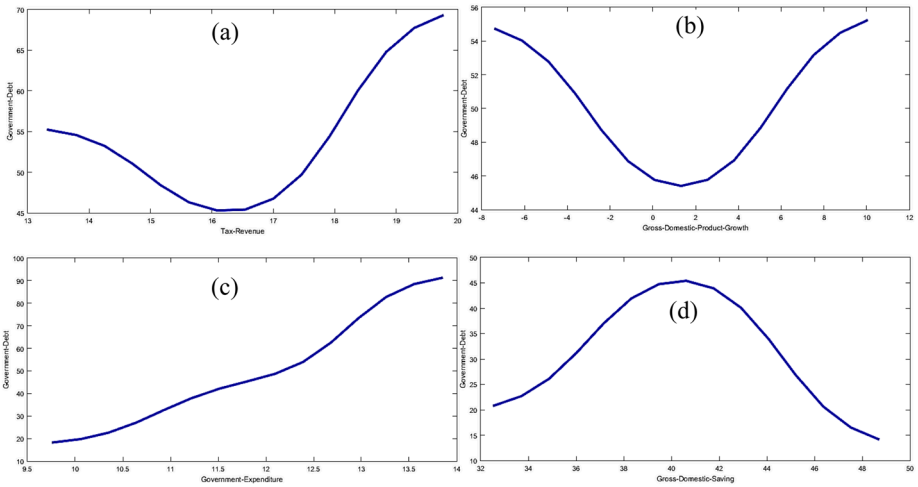

Fig. 6 Two-dimensional surface diagram of input and output parameters after ANFIS analysis. **a** Individual analysis of tax revenue and external debt; **b** individual analysis of the gross domestic product and external debt; **c** individual analysis of government expenditure and external debt; **d** individual analysis of gross domestic saving and external debt

Therefore applying the ANFIS model that comes with FIS eliminates the need for experts or knowledge acquisition methods by applying the "*if-then*" rules and membership functions. This would be very advantageous for the researcher to identify at what point of the proposed inputs, which are tax revenue, gross domestic product growth, government expenditure, and gross domestic saving will have direct, inverse with a turning point with the external debt in Malaysia.

The predicted results from the ANFIS model proved that the turning point exists between the tax revenue, gross domestic product growth, and gross domestic saving towards the external debt. Supported with Azam and Feng (2015) and Farhani (2016) studies, the government expenditure showed a direct relationship with external debt. The turning point is noticeable if the tax revenue is at maximum statistics and gross domestic product growth is at average statistics then the external debt is at average (peak) statistics. This explains why some studies reveal supporting and contradicting to the neoclassical growth theory. Based on evidence taken from the ANFIS forecasting, the external debt will drop below the minimum statistics on the tax revenue is set at maximum statistics and gross domestic product growth either at maximum or minimum (negative) statistics.

This study also supports the dynamic political economy theory of public spending, taxation, and debt as proposed by Battaglini and Coate (2008) with the evidence of tax revenue and government expenditure towards the external debt in Malaysia. It is found that there is a direct relationship between government expenditure and external debt. From the three-dimensional surface diagram, the turning point is noticeable if the tax revenue is average statistics and government expenditure is at maximum statistics then the external debt is above than maximum statistics. Therefore additional (reduction) of tax revenue will reduce (increase) the external debt holding government expenditure remains maximum statistics. The best option to reduce the external debt (below

minimum statistics) is by reducing the government expenditure given that the tax revenue can be changed to either minimum, average or maximum statistics.

Previous empirical evidence such as that of Holtfrerich et al. (2016) addressed that tax revenue is a good tool in financing government expenditure. A rise in government expenditure would also increase social expenditure such as pension and health program (Feldstein 2015). However, the forecasted results from the ANFIS model give the researcher an impression that if the tax revenue is collected insufficiently, the external debt tends to increase significantly. For example, the ANFIS model proved that an increase in government expenditure to maximum statistics followed by average statistics increase in tax revenue which holds the condition that insufficient revenue to finance such expenditure will lead to the increase the external debt. Moreover, an increase in government expenditure will reduce the gross domestic saving. The complementary between government expenditure and gross domestic savings sounds logical as this study also supports Fry's (1989) hypothesis. The ANFIS model that forecasts the three-dimensional surface diagram depicts the gross domestic saving reduce from maximum to average statistics, and the external debt will increase to average (peak) statistics. Similar to the study of Waheed (2017), and it was found that an increase in gross domestic savings leads to decreasing in external debt. This is also consistent with the study whereby as the gross domestic savings increase from the minimum to average statistics, the external debt will rise (peak) statistics. However, as the gross domestic savings reduce from average to minimum statistics, the external debt tends to show a direct relationship as it also reduces from average to below minimum statistics. This proves that the turning point exists between the gross domestic saving and external debt in Malaysia. Specificity the projected three-dimensional surface diagram from ANFIS forecast proved that the turning point is noticeable when gross domestic saving is at average statistics, given with any statistics of tax revenue, then the external debt is at average (peak) statistics.

With this study as a foundation, future recommendations of the research can be pursued. The current work has several limitations. Firstly, the evidence is based on Malaysia, and therefore the scope can be enlarged to the developing, emerging economies and advanced countries. This evidence will contribute to the body of knowledge in terms of the relationship of tax revenue, gross domestic product growth, government expenditure, and gross domestic saving towards the external debt that is based on the average data analysis. Moreover, instead of using tax revenue as one of the indicators to explain the external debt, the use of tax rate is also crucial as it can help readers to gain more knowledge on the optimum tax rate and at what amount of tax rate will burden the country's external debt.

Acknowledgements
The author would like to thank the anonymous referees, journal, and English editors for their insightful comments and suggestions that significantly improved this manuscript.

Authors' contributions
Every section of the study was researched and written by the author. The author read and approved the final manuscript.

Authors' information
The author is a lecturer at Universiti Teknologi Mara (UiTM) Kota Kinabalu, Sabah, Malaysia, specializing in microeconomics, macroeconomics, econometrics, and artificial intelligence.

Funding
Not applicable.

Availability of data and materials
The four of the variables used in this study can be found at the World Bank (2018), World Development Indicator (WDI).

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication

Competing interests
The author declares that he has no competing interests.

Received: 4 February 2019 Revised: 19 May 2021 Accepted: 20 May 2021
Published online: 25 May 2021

References

Abdulshahed AM, Longstaff AP, Fletcher S (2015) The application of ANFIS prediction models for thermal error compensation on CNC machine tools. Appl Soft Comput 27:158–168. https://doi.org/10.1016/j.asoc.2014.11.012
AbuAl-Foul B, Baghesani H (2004) The casual relation between government revenue and spending: Evidence from Egypt and Jordan. J Econ Finan 28(2):260–269. https://doi.org/10.1007/BF02761616
Adegbite EO, Ayadi FS, Ayadi OF (2008) The impact of Nigeria's external debt on economic development. Int J Emerg Mark 3(3):285–301. https://doi.org/10.1108/17468800810883693
Al-Zeaud HA (2014) The causal relationship between government revenue and expenditure in Jordan. Glob J Manag Bus Res 5(2):117–127
Aslan M, Tasdemir M (2009) Is fiscal synchronization hypothesis relevant for Turkey? Evidence from cointegration and causality test endogenous structural breaks. J Money Invest Bank 12:14–25
Atsalakis GS, Atsalaki IG, Zopounidis C (2018) Forecasting the success of a new tourism service by a neuro-fuzzy technique. Eur J Oper Res 268(2):716–727. https://doi.org/10.1016/j.ejor.2018.01.044
Azam M, Feng Y (2015) Does military expenditure increase external debt? Evidence from Asia. Defense Peace Econ 28(5):1–18. https://doi.org/10.1080/10242694.2015.1072371
Barro RJ (1979) On the determination of the public debt. J Polit Econ 87(5):940–971. https://doi.org/10.1086/260807
Battaglini M, Coate S (2008) A dynamic theory of public spending, taxation and debt. Am Econ Rev 98(1):201–236. https://doi.org/10.1257/aer.98.1.201
Bittencourt M (2015) Determinants of government and external debt: evidence from the young democracies of South America. Emerg Mark Financ Trade 51(3):463–472. https://doi.org/10.1080/1540496X.2015.1025667
BNM (Bank Negara Malaysia) (2016) from Central Bank of Malaysia. http://www.bnm.gov.my/index.php?ch=statistic_nsdp&pg=statistic_nsdp_extdebt&lang=en#
Catão IAV, Milesi-Ferretti GM (2014) External liabilities and crises. J Int Econ 94(1):18–32. https://doi.org/10.1016/j.jinteco.2014.05.003
Chan ZSH, Ngan HW, Rad AB, David AK, Kasabov N (2006) Short-term ANN load forecasting from limited data using generalization learning strategies. Neurocomputing 70(1–3):409–419. https://doi.org/10.1016/j.neucom.2005.12.131
Diebold FX, Mariano RS (1995) Comparing predictive accuracy. J Bus Econ Stat 13(3):253–263
Dupuis F, Vachon H, (2017) Snapshot of external debt in emerging and developing countries. Desjardins, Economic Studies.
Farhani S (2016) Usage of military spending, debt servicing and growth for dealing with emergency plan of Indian external debt. Int J Econ Manag Eng 10(3):802–813. https://doi.org/10.5281/zenodo.1112191
Feldstein M (2015) Raising revenue by limiting tax expenditure. National Bureau of Economic Research, pp 1–11
Forslund K, Lima L, Panizza U (2011) The determinants of the composition of public debt in developing and emerging market countries. Rev Dev Financ 1(3–4):207–222. https://doi.org/10.1016/j.rdf.2011.09.004
Fry MJ (1989) Foreign debt instability: an analysis of national saving and domestic investment responses to foreign debt accumulation in 28 developing countries. J Int Money Financ 8:315–344. https://doi.org/10.1016/0261-5606(89)90001-6
Gounder N, Narayan P, Prasad A (2007) An empirical investigation of the relationship between government revenue and expenditure: the case of the Fiji islands. Int J Soc Econ 34(3):147–158. https://doi.org/10.1108/03068290710726711
Guneri AF, Ertay T, Yucel A (2011) An approach based on ANFIS input selection and modeling for supplier selection problem. Expert Syst Appl 38(12):14907–14917. https://doi.org/10.1016/j.eswa.2011.05.056
Gupta P, Mishra D, Sahay R (2007) Behavior of output during currency crises. J Int Econ 72(2):428–450. https://doi.org/10.1016/j.jinteco.2006.10.003
Haznedar B, Kalinli A (2018) Training ANFIS structure using stimulated annealing algorithm for dynamic systems identification. Neurocomputing 302:66–74. https://doi.org/10.1016/j.neucom.2018.04.006
Holtfrerich CL, Feld LP, Heun W, Illing G, Kirchgässner G, Kocka J, Schularick M, Streeck W, Wagschal U, Walter S, Weizsäcker CCV (2016) Government debt: causes, effects and limits. German National Academy of Sciences Leopoldina, Berlin

Jang JSR (1993) AFIS: aadaptive-network-based fuzzy inference system. IEEE Trans Syst Man Cybern 23(3):665–685. https://doi.org/10.1109/21.256541
Karia AA, Bujang I, Ahmad I (2013) Forecasting on crude palm oil prices using artificial intelligence approaches. Am J Oper Res 3:259–267. https://doi.org/10.4236/ajor.2013.32023
Keles A, Kolcak M, Keles A (2008) The adaptive neuro-fuzzy model for forecasting the domestic debt. Knowl-Based Syst 21(8):951–957. https://doi.org/10.1016/j.knosys.2008.04.007
Lewis CD (1982) Industrial and business forecasting methods: a practical guide to exponential smoothing and curve fitting. Butterworth Scientific, London
Luh LT (2012) The shape parameter in the gaussian function. Comput Math Appl 63(3):687–694. https://doi.org/10.1016/j.camwa.2011.11.032
Mensah D (2016) External debt among HIPCs in Africa: accounting and panel VAR analysis of some determinants. J Econ Stud 44(3):431–455. https://doi.org/10.1108/JES-05-2015-0080
Mohaddes SA, Fahimifard SM (2018) Application of Adaptive neuro-fuzzy inference system (ANFIS) in forecasting agricultural products export revenues (case of Iran's agriculture sector). J Agric Sci Technol 17(1):1–10
Palit AK, Popovic D (2005) Computational intelligence in time series forecasting: theory and engineering applications. Springer, Berlin
Panizza U, Presbitero AF (2014) Public debt and economic growth: Is there a causal effect? J Macroecon 41(1):21–41. https://doi.org/10.1016/j.jmacro.2014.03.009
Reinhart CM, Reinhart VR, Rogoff KS (2012) Public debt overhangs: advance-economy episodes since 1800. J Econ Perspect 26(3):69–89. https://doi.org/10.1257/jep.26.3.69
Saeed, Somaye (2012) Relationship between government spending and revenue: evidence from oil exporting countries. Int J Econ Manag Eng 2(2):95–97
Siddique A, Selvanathan EA, Selvanathan S (2016) The impact of external debt on growth: evidence from highly indebted poor countries. J Policy Model 38(5):874–894. https://doi.org/10.1016/j.jpolmod.2016.03.011
Takagi T, Sugeno M (1985) Fuzzy identification of systems and its applications to modeling and control. IEEE Tans Syst Man Cybern 15(1):116–132. https://doi.org/10.1109/TSMC.1985.6313399
Talpur N, Salleh MNM, Hussain K (2017) An investigation of membership functions on performance of ANFIS for solving classification problems. In: Paper presented at the 5th international research and innovation summit (IRIS 2017), Universiti Tun Hussein Onn Malaysia, Langkawi, 7–8 December 2017. https://doi.org/10.1088/1757-899X/226/1/012103
Waheed A (2017) Determinants of external debt: a panel data analysis for oil and gas exploring and importing countries. Int J Econ Financ Issues 7(1):234–240
Wamser G (2014) The impact of thin-capitalization rules on external debt usage- a propensity score matching approach. Oxford Bull Econ Stat 76(5):764–781. https://doi.org/10.1111/obes.12040
Wang WC, Chau KW, Qiu L, Chen YB (2015) Improving forecasting accuracy of medium and long-term runoff using artificial neural network based on EEMD decomposition. Environ Res 139:46–54. https://doi.org/10.1016/j.envres.2015.02.002
Wei LY, Cheng CH, We HH (2014) A hybrid ANFIS based on n-period moving average model to forecast TAIEX stock. Appl Soft Comput 19:86–92. https://doi.org/10.1016/j.asoc.2014.01.022
Westphal CC, Rother P (2012) The impact of high government debt on economic growth and its channels: an empirical investigation for the euro area. Eur Econ Rev 56(7):1392–1405. https://doi.org/10.1016/j.euroecorev.2012.06.007
World Bank Group (2018) International debt statistics. International Bank for Reconstruction and Development/World Bank, Washington DC
Xiangjun W, Hashimi MMYA (2012) The comparison of adaptive neuro-fuzzy inference system (ANFIS) with nonlinear regression for estimation and prediction. In: Paper presented at the 2012 international conference on information technology and e-services, Sousse, Tunisia, 24–26 March 2012. https://doi.org/10.1109/ICITeS.2012.6216601
Zhu X, Lin S, Wang L, Wu W, Qin Q (2018) A study of the turning point of China's Debt. Springer, Singapore. https://doi.org/10.1007/978-981-13-1325-7
Zouhaier H, Fatma M (2014) Debt and economic growth. Int J Econ Financ Issues 4(2):440–448

Publisher's Note