PENERBIT UMT
Menjana Khazanah Ilmuwan

Journal of Mathematical Sciences and Informatics
Journal Homepage: https://journal.umt.edu.my/index.php/jmsi
eISSN: 2948-3697
DOI: http://doi.org/10.46754/jmsi.2023.06.001

IMPACT OF COVID-19 PANDEMIC ON MALAYSIAN SOCIO-ECONOMICS: A STATISTICAL-DYNAMICAL APPROACH

SYERRINA ZAKARIA[1*], NOR FATIMAH CHE SULAIMAN[2], UMMU ATIQAH MOHD ROSLAN[1,3], AZWANI ALIAS[1,3] AND SITI MADHIHAH ABDUL MALIK[1]

[1]Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia; syerrina@umt.edu.my, ummuatiqah@umt.edu.my, azwani.alias@umt.edu.my, madhihah@umt.edu.my. [2]Faculty of Business, Economics and Social Development, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia; n.fatimah@umt.edu.my. [3]Special Interest Group on Modelling and Data Analytics (SIGMDA), Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia; ummuatiqah@umt.edu.my, azwani.alias@umt.edu.my

**Corresponding author: syerrina@umt.edu.my*

ARTICLE INFO

Article History:
Received 22 February 2023
Accepted 8 June 2023
Available online 30 June 2023

Section Editor:
Ruwaidiah Idris

Keywords:
COVID-19;
Gross Domestic Product;
unemployment rate;
poverty rate;
income group;
statistical analysis;
mathematical model.

ABSTRACT

The COVID-19 pandemic is a global crisis affecting virtually every country in the world, with profound consequences on various aspects of life, including the economy, society, environment, demographics, and health sector. Despite frequent reporting of its repercussions in newspapers and on social media, few technical analyses have been published. Hence, this study aims to analyse the impact of the pandemic on three income groups with several socio-economic factors in Malaysia namely, economic development (GDP), unemployment rates and poverty rates. Correlation and regression analyses were used to measure the existence of a relationship among the rate of COVID-19 cases, economic development, unemployment rates and poverty rates. The findings revealed that the COVID-19 pandemic has had a significant impact on economic development, unemployment rates and poverty rates. The results of this study will give insight to the government into the distribution of the appropriate aid and the development of a recovery plan to reduce the impact of COVID-19 on Malaysians.

2020 Mathematics Subject Classification:

INTRODUCTION

Unemployment has been a persistent global issue, presenting a significant social and economic challenge arising from an imbalance between labour market demand and supply, and is sometimes worsened by population growth. Unfortunately, this problem has been exacerbated dramatically during the COVID-19 pandemic, resulting in a massive global unemployment crisis that is distinct from previous unemployment periods [1]. As such, there is a need for a Malaysia-specific model that considers unemployment as an effect of the pandemic. Several studies have indicated that lockdown measures are one of the main factors driving business closures, subsequently leading to increased unemployment. A study by [2] demonstrated a rise in unemployment rates across five selected European countries due to the pandemic. These economies faced two main problems simultaneously: Lockdown measures and the closure of many industrial sectors, which led to a surge in unemployment among their populations.

In 2020, the Malaysian economy experienced a downturn as reflected by the performance of its Gross Domestic Product (GDP) which recorded a 5.6% decline. This contraction was a stark contrast to the preceding year's growth of 4.4% and it can be attributed to restrictions imposed on economic activities that are part of the COVID-19 containment measures (Figure 1). The Malaysian economy last saw a decline in 2009 (-1.5%), and the 2020 economic downturn was the worst after the one in 1998 (-7.4%).

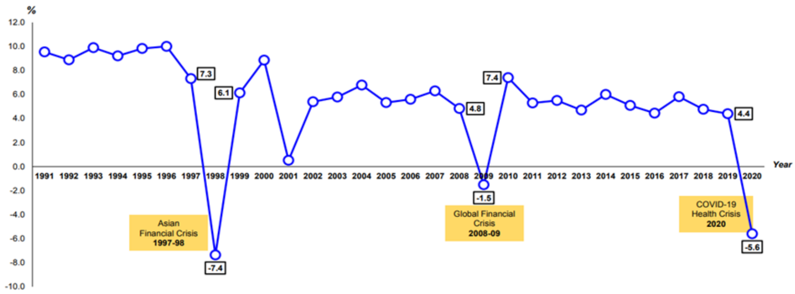

Figure 1: Malaysia's GDP before and after the COVID-19 pandemic [3]

The implementation of the first Movement Control Order (MCO) in Malaysia, which commenced on 18 March 2020, followed by subsequent MCOs, led to the closure of many economic sectors, particularly non-essential ones. As a result, the unemployment rate surged to 4.5% in 2020—affecting 711,000 individuals—the highest rate since 1993 (4.1%). According to the Salaries and Wages Survey Report (2020), average salaries and wages decreased by 9.0% compared with 2019. The COVID-19 pandemic has not only affected the bottom 40% of households (B40), but also those in the middle 40% (M40) and top 20% (T20) groups, as well as their disposable incomes.

Unemployment rates have been one of the benchmarks of labour market impact during economic downturns. Based on quarterly figures from the Department of Statistics Malaysia (DoSM), job losses were a direct consequence of the economic shutdown imposed to contain the COVID-19 epidemic. Malaysia's widespread restrictions—the first Movement Control Order lasted from March to June 2020—resulted in a staggering 17.1% GDP contraction in Q2 2020. Correspondingly, the overall unemployment rose from 3.2% in 2019-Q4 to 5.1% in 2020-Q2. Based on this data, unemployment declined towards the end of 2020 and even moderated in 2021 for the youth segment.

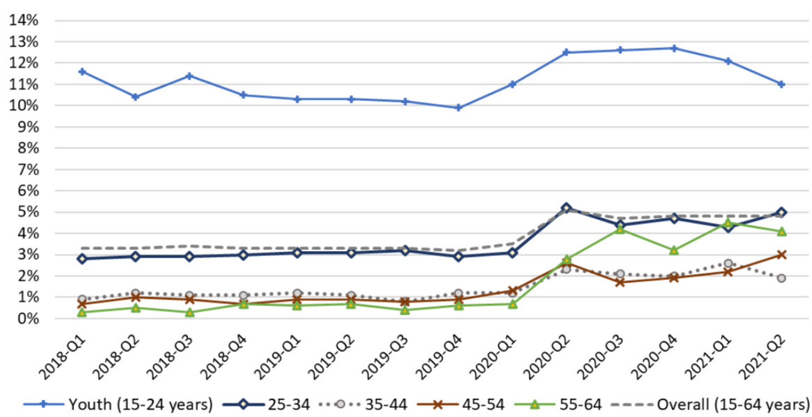

Figure 2: Malaysia's quarterly unemployment rate (2018-2021) [4]

The battle against the pandemic lasted until 2021, and its effects have somewhat impeded economic and labour market recovery processes. As a result, the Malaysian labour market remains in a challenging situation due to uncertainties. Overall, the spread of COVID-19 has had a major impact on household income and further affected the structure of household groups in the country.

In general, poverty can be measured using numerous methods, including absolute poverty and relative poverty. A household falls under absolute poverty when its income is below than Poverty Line Income (PLI) and insufficient to meet basic needs, such as food, clothing and housing. Hardcore poverty occurs when a household's income is lower than the food PLI. Relative poverty, on the other hand, is defined as a situation where household income is less than half the median of household income. Different countries use their own benchmarks to measure poverty, but most upper-middle income countries, including Malaysia, commonly utilise the absolute poverty measurement. This method serves as the key indicator in monitoring poverty eradication efforts [3].

Based on a 2021 DoSM study, it is estimated that the number of poor households in Malaysia increased to 639,800 thousand households in 2020, compared with 405.4 thousand households in 2019 (Figure 4). The incidence of absolute poverty also rose from 5.6% in 2019 to 8.4% in 2020. Additionally, the incidence of hardcore poverty is estimated to have increased from 0.4% in 2019 to 1.0% in 2020, affecting 78 thousand households (compared with 27.2 thousand households in 2019). This indicates a rise in the number of households whose income falls below the food PLI between the two years. In contrast, relative poverty recorded a decrease from 16.9% to 16.2%, involving 1.2 million households. This decrease is attributed to a significant reduction in household income, resulting in the median value for 2020 being lower than that of 2019.

The pandemic has had far-reaching effects on various sectors, including health [5], economic [6], [7], social [8], industrial and environmental sectors. However, this study specifically focuses on examining the impact of the COVID-19 pandemic on socioeconomic factors, such as economic development, unemployment and poverty rates.

The impact of the COVID-19 pandemic can be analysed using various methods, one of which is statistical analysis. Based on [9], two statistical models were used to analyse the cumulative incidences of COVID-19 in Italy and Spain during the early stages of the outbreak, namely the Susceptible-Infected-Recovered model and the log-linear regression model. Additionally, another study in [5] also employed multiple logistics regression to examine the pandemic's association with health conditions.

A significant body of research has been dedicated to mathematical modelling of the unemployment problem [10]-[16]. For instance, ref [17] proposed a nonlinear mathematical model for the unemployment issue. Similarly, ref [18] investigated the impacts of self-employment on unemployment rates. Ref [19], meanwhile, introduced a new variable to the equation, the number of immigrants. And, ref [20] took a novel approach to studying unemployment by incorporating four variables into their nonlinear dynamic model.

In existing literature, there are limited sources that integrate both statistical and mathematical approaches to analyse and solve real-world problems. Statistical methods, such as correlation and regression analysis, have been utilised to identify significant factors. Building on these identified factors, this study will model poverty and unemployment among Malaysian citizens during the COVID-19 pandemic using ordinary differential equations. Motivated by the previous works of [21], [22] and [10], this study combines these models to cater to the unemployment situation in Malaysia. In line with these facts and statistical insights, this study aims to investigate the impact of the COVID-19 pandemic on socioeconomic factors, employing both statistical analysis and mathematical modelling.

This paper is organised as follows. The discussion is divided into two parts, statistical and dynamical model approaches. The next section presents a discussion of the findings, and the paper ends with a summary of key conclusions.

METHODOLOGY

In this section, two approaches were used to analyse COVID-19 cases with several selected factors, namely statistical and dynamical approaches.

Statistical Approach

For the statistical part, this paper used correlation analysis, regression analysis, and paired T-test. The primary data used in this study consists of the COVID-19 case rate, divided into two study periods, namely before the pandemic (2018 to 2019) and during the pandemic (2020 to August 2021). The socioeconomic factors considered in this study are the unemployment rate, GDP, poverty rate and the median monthly income for three income groups, namely the B40, M40, and T20.

Correlation Analysis

It is believed that there is a significant relationship between the indicators of economic development, i.e. GDP, unemployment rate and poverty rate, and the COVID-19 rate. To measure this relationship, the Pearson Correlation coefficient was employed. The formula for the sample correlation coefficient, r, is [23]:

$$r = \frac{\mathrm{n}(\sum \mathrm{xy}) - (\sum \mathrm{x})(\sum \mathrm{y})}{\sqrt{\mathrm{n}(\sum \mathrm{x}^2) - (\sum \mathrm{x})^2)\,[\mathrm{n}(\sum \mathrm{y}^2) - (\sum \mathrm{y})^2}}, \tag{1}$$

where n is the number of pair data, x is the COVID-19 incidence rate and y is the socioeconomic factors. The COVID-19 incidence rate was obtained as follows:

$$\mathrm{y} = \frac{\text{Number of COVID-19 cases}}{\text{Number of population}}$$

The significant relationship between variables x and y was tested using the hypotheses below. The hypothesis statements are:

H_0: $\rho = 0$ (There is no significant correlation between x and y)

H_a: $\rho \neq 0$ (There is a significant correlation between x and y)

Based on a significance level of $\alpha = 0.05$, the null hypothesis will be rejected if the p-value is less than the significance level. This means that there is a significant correlation between these variables.

Regression Analysis

The ordinary least square (OLS) method is a linear regression technique used to measure the relationship between dependent and independent variables. In this study, the OLS model was used to examine the relationship between the COVID-19 case rate as an independent variable and each socio-economic factor as the dependent variable. The simple OLS model equation is as follows [24]:

$$Y = \alpha + \beta X + \varepsilon, \quad (3)$$

where Y is the dependent variable, α is the constant value, β is the regression coefficient and ε is the random error.

Paired T-test

The test statistic for the Paired Samples t-Test, denoted as t, can be written as:

$$t = \frac{\bar{x}_{diff} - 0}{s_{\bar{x}}}$$

where:

$$s_{\bar{x}} = \frac{s_{diff}}{\sqrt{n}}$$

and x_{diff} represents the sample mean of the differences, n is the sample size (number of observations), s_{diff} is the sample standard deviation of the differences and $s_{\underline{x}}$ is the estimated standard error of the mean.

The calculated t value is then compared to the critical t value with df = n - 1 from the t-distribution table for a chosen confidence level. If the calculated t-value is greater than the critical t-value, then the null hypothesis is rejected (and it can be concluded that the means are significantly different). Alternatively, a decision can be made based on p-value, where if the p-value is less than the significance level (0.05), then the null hypothesis is rejected.

Dynamical Model Approach

In this section, a dynamical model approach, also known as a mathematical model, is proposed to investigate the dynamics of income groups in Malaysia, which include the factors discussed previously: Poverty and unemployment rates.

Formulation of Mathematical Model, Finding Equilibrium Points and Stability Analysis

Let T(t) represent the population size of the T20 income group at time t, M(t) represent the population size of the M40 income group at time t, and B(t) represent the population size of the B40 income group at time t in Malaysia. In order to describe the dynamics of this model mathematically, the following assumptions are considered:

i. The populations of T20, M40 and B40 are increased by birth rate, δ and decreased by death rate, μ.
ii. The conversion rate from T20 to M40 is influenced by the unemployment rate, c_1, and poverty rate, k, while the conversion rate from M40 to B40 is influenced by unemployment rate, c_2, and poverty rate, k.

The relationship between the income groups and the above assumptions can be visualised in Figure 3.

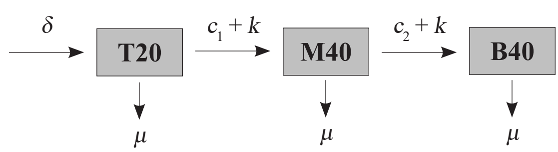

Figure 3: The relationship between income groups (variables) and the factors involved (parameters)

From Figure 3, the dynamics of this model can be represented mathematically with the following set of differential equations:

$$\dot{T} = \delta - (c_1 + k)\, TM - \mu T,$$
$$\dot{M} = (c_1 + k)\, TM - \mu M - (c_2 + k)MB,$$
$$\dot{B} = (c_2 + k)MB - \mu B,$$

With the initial populations, $T(0) > 0$, $M(0) > 0$, and $B(0) > 0$. It is observed that model (4) has at most three equilibrium points, namely E_1, E_2 and E_3. The possible equilibrium points are:

i. Only population of T20 exists, $E_1 = (\frac{\delta}{\mu}, 0, 0)$

ii. All populations exist, $E_2 = (T^*, M^*, B^*)$, where

$$T^* = \frac{\delta(c_2 + k)}{\mu(c_1 + c_2 + 2k)}$$

$$M^* = \frac{\mu}{c_2 + k}$$

$$B^* = \frac{c_1 c_2 \delta + (c_1 + c_2 + k)\delta k - (c_1 + c_2 + 2k)\mu^2}{\mu(c_1 + c_2 + 2k)(c_2 + k)}$$

iii. No B40 income group population $E_2 = (T^*, M^*, 0)$ where

$$T^* = \frac{\mu}{c_1 + k}$$

$$M^* = \frac{c_1\delta + \delta k - \mu^2}{\mu(c_1 + k)}$$

Next, we will determine which equilibrium point exists or is sustained in the future. To achieve this, an approach called stability analysis will be used to find the stability of these equilibrium points. This approach has been widely used to analyse many real-world applications, such as in biology, ecology, economy etc. (e.g. [21],[22]). The stability types for each equilibrium point can be characterized based on their eigenvalues. Below are the characteristics:

i. If all eigenvalues obtained are negative, then, the equilibrium points are said to be stable.

ii. If at least one of the eigenvalues is positive, then, the equilibrium points are said to be unstable.

The Jacobian matrix for model (4) is determined as:

$$J(T^*, M^*, B^*) = \begin{pmatrix} -(c_1 + k)M - \mu & -(c_1 + k)T & 0 \\ (c_1 + k)M & (c_1 + k)T - (c_2 + k)B - \mu & -(c_2 + k)M \\ 0 & (c_2 + k)B & (c_2 + k)M - \mu \end{pmatrix}$$

First, model (4) has the following Jacobian matrix near E_1:

$$J(E_1) = \begin{pmatrix} -\mu & \frac{-(c_1+k)\delta}{\mu} & 0 \\ 0 & \frac{(c_1+k)\delta}{\mu} & 0 \\ 0 & 0 & -\mu \end{pmatrix}$$

From the above Jacobian matrix, we solve the det $(J(E_2) - \lambda I) = 0$ to obtain the following eigenvalues:

$$\begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{pmatrix} = \begin{pmatrix} -\mu \\ \frac{-C+\sqrt{D}}{2E} \\ \frac{-C-\sqrt{D}}{2E} \end{pmatrix},$$

From above, both λ_2 and λ_3 are negative. This equilibrium will be stable at $\lambda_1 < 0$. E_1 if $c_1\delta + \delta k < \mu^2$ holds. Otherwise, E_1 will be unstable if $c_1\delta + \delta k > \mu^2$.

Secondly, the Jacobian matrix of model (4) around equilibrium point is reduced to:

$$J(E_2) = \begin{pmatrix} \frac{-(c_1+k)\mu}{c_2+k} - \mu & \frac{-(c_1+k)(c_2+k)\delta}{A} & 0 \\ \frac{(c_1+k)\mu}{c_2+k} & \frac{(c_1+k)(c_2+k)\delta}{A} - \frac{B}{A} - \mu & -\mu \\ 0 & \frac{B}{A} & 0 \end{pmatrix}$$

where $A = \mu(c_1+c_2+2k)$, $B = c_1 c_2\delta + c_1\delta k - c_1\mu^2 + c_2\delta k - c_2\mu^2 + \delta k^2 - 2k\mu^2$.

From the above Jacobian matrix, we solve the det$(J(E_2) - \lambda I) = 0$ to obtain the following eigenvalues:

$$\begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{pmatrix} = \begin{pmatrix} -\mu \\ \frac{-C+\sqrt{D}}{2E} \\ \frac{-C-\sqrt{D}}{2E} \end{pmatrix},$$

where:

$$C = c_1\mu + \mu k,$$

$$D = c_1^2\mu^2 - 4\delta c_1 c_2^2 - 8c_1c_2\delta k + 4c_1c_2\mu^2 - 4c_1\delta k^2 + 6c_1k\mu^2$$
$$- 4c_2\delta k^2 + 4c_2\mu^2 - 8c_2\delta k^2 + 12c_2k\mu^2 - 4\delta k^3 + 9k^2\mu^2$$

Finally, the Jacobian matrix of model (4) around equilibrium point reduced to:

$$J(E_3) = \begin{pmatrix} -\left(\frac{F}{\mu} - \mu\right) & -\mu & 0 \\ \frac{F}{\mu} & 0 & \frac{-(c_2+k)F}{\mu(c_1+k)} \\ 0 & 0 & \frac{(c_2+k)F}{\mu(c_1+k)} - \mu \end{pmatrix}$$

where $F = c_1\delta + \delta k - \mu^2$.

From the above, the eigenvalues obtained are as follows:

$$\begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{pmatrix} = \begin{pmatrix} -\mu \\ -\dfrac{F}{\mu} \\ \dfrac{B}{\mu(c_1 + k)} \end{pmatrix}.$$

From the above, $\lambda_1<0$. For the second eigenvalue, $\lambda_2<0$ if and only if $F/\mu>0$. Meanwhile, $\lambda_3<0$ if and only if $B<0$.

RESULTS AND DISCUSSION

This section discusses the results of this study.

Statistical Results

Correlation

Several factors in this study showed a significant correlation with the rate of COVID-19 cases. Based on Table 1, there is a strong positive correlation ($r = 0.832$) between the rate of COVID-19 cases and the poverty rate. Conversely, there is a strong negative correlation ($r = -0.832$) between the rate of COVID-19 cases and the median monthly incomes of the B40, M40 and T20 groups. However, no significant correlation was found between the rate of COVID-19 cases and the unemployment rate (r = 0.341) and GDP (r = -0.318). Therefore, it can be concluded that the pandemic has an impact on economic factors, especially on household income, contributing to an increase in the poverty rate among the Malaysian population.

Table 1: Correlation coefficient

Socio-economic Factor	COVID-19 Rate	P-value
Unemployment rate	0.341	0.141
GDP	-0.318	0.172
Poverty rate	0.832	0.000
B40 median income	-0.832	0.000
M40 median income	-0.832	0.000
T20 median income	-0.832	0.000

Regression Analysis

A simple regression model was constructed based on factors that have a significant relationship with the rate of COVID-19 cases, as identified through correlation analysis. These factors include the poverty rate and median monthly income for B40, M40 and T20 income groups.

Based on Table 2, an increase of 1 unit for the COVID-19 rate will cause an increase of 0.5 unit for the poverty rate. Meanwhile, an increase of 1 unit in the COVID-19 rate causes a decrease of 183,728 units in the median monthly income for the B40 income group. For the M40 income group, every 1 unit change of the COVID-19 rate will cause a decrease in the median income by 416,099 units. The next factor is the median monthly income for the T20 income group, which will experience a decrease of 897,607 units when there is a change in the COVID-19 rate by 1 unit.

Table 2: The OLS regression coefficients and models

Socio-economic Dependent Factor, y	COVID-19 Case Rate, x	Coefficient	OLS Model
Poverty rate	$\hat{a}$	8.572	$Y = 8.572 + 0.500X$
	β	0.500	
B40 median income	$\hat{a}$	2744.210	$Y = 2744.210 - 185.728X$
	β	-185.728	
M40 median income	$\hat{a}$	6148.036	$Y = 6148.036 - 416.099X$
	β	-416.099	
T20 median income	$\hat{a}$	13262.526	$Y =13262.526 - 897.607X$
	β	-897.607	

Paired Samples T-test

The COVID-19 pandemic is believed to have had a considerable impact on the economy. As per the results presented in Table 3, several factors displayed significant mean differences before (2018 to 2019) and during (2020 to August 2021) the COVID-19 pandemic. These significant factors include the unemployment rate, poverty rate and median monthly income for the B40, M40 and T20 income groups. However, there is no significant mean difference for the GDP factor before and during the COVID-19 pandemic, as indicated by the p-value of 0.110.

Table 3: The OLS regression coefficient

Pair	Differences in Mean	T-statistic	P-value
Unemployment rate	-1.2600	-10.523	0.000
GDP	7432.5000	1.678	0.110
Poverty rate	-1.9024	-6.142	0.000
B40	417.5919	10.088	0.000
M40	660.8949	4.584	0.000
T20	1186.5345	3.334	0.003

Dynamical Model Results

In this section, numerical analysis is performed for model (4) using the set of parameter values shown in Table 4.

Table 4: Values of parameters from model (4)

Parameter	Description	Value	Reference
δ	Birth rate for Malaysian population	0.035	[25]
μ	Death rate for Malaysian population	0.033	[25]
c_1	Unemployment rate which moves from T20 to M40	0.006	Estimated from data
c_2	Unemployment rate which moves from M40 to B40	0.023	Estimated from data
k	Poverty rate	0.59	Estimated from data

Based on the values in Table 4, the values of equilibrium points for model (4) and their corresponding eigenvalues and types of stability are shown in Table 5. Recall that model (4) has three possible equilibrium points: First is the case where only the T20 income group will exist in the future E_1; second is where all income groups exist in the future E_2; and, finally, only T20 and M40 will exist in the future E_3. However, only one of these equilibrium points will occur in the future. The existence of the equilibrium point is based on the results of the stability analysis via eigenvalues, as shown in Table 5. From the table, the only stable equilibrium point is E_2, while the others are unstable. This means that E_2 is predicted to happen in the future with the following proportions: T20 = 0.538, M40 = 0.054 and B40 = 0.469. Based on these values, it is projected that the population distribution of Malaysia's income groups will be in the following order: T20 > B40 > M40. Thus, with the current poverty and unemployment rates, there will be a significant gap between the T20 group and the B40 and M40 groups. The number of people in the M40 group is expected to decrease as more individuals move to the B40 group. The time series when the poverty rate $k = 0.59$ is illustrated in Figure 4.

Table 5: The stability of the equilibrium points for model (4)

Equilibrium Point	Eigenvalues	Type of Stability
$E_1 = (1.06, 0, 0)$	$\lambda_1 = 0.599, \lambda_2 = -0.033, \lambda_3 = -0.033$	Unstable
$E_2 = (0.538, 0.054, 0.469)$	$\lambda_1 = -0.033, \lambda_{2,3} = -0.016 \pm 0.136i$	Stable
$E_3 = (0.055, 1.005, 0)$	$\lambda_1 = 0.583, \lambda_2 = -0.033, \lambda_3 = -0.599$	Unstable

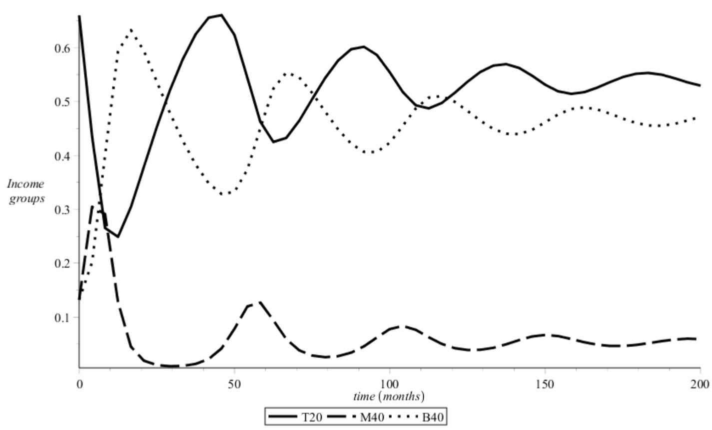

Figure 4: The prediction for the income groups with the initial populations (0.66,0.132,0.132) for poverty rate $k = 0.59$

However, if the poverty rate is lowered to $k = 0.1$, the following proportions are obtained: T20 = 0.57, M40 = 0.268, and B40 = 0.222 (Table 6). These results indicate that if the poverty rate decreases, then the following situation might occur as shown in Figure 5:

i. The number of people in the T20 group will increase from 0.538 to 0.57,

ii. The number of people in the M40 group will increase from 0.054 to 0.268,

iii. The number of people in the B40 group will decrease from 0.469 to 0.222, as more and more people have transitioned to the M40 group.

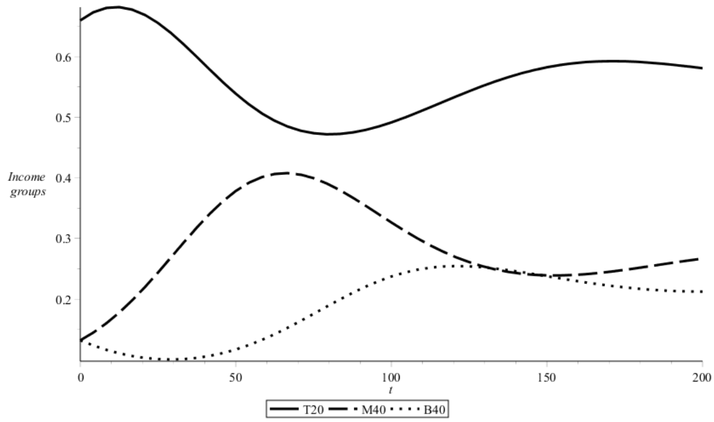

Figure 5: The prediction with the initial populations (0.66,0.132,0.132) for a lower poverty rate of $k = 0.1$

Table 6: The changes in income groups for two different values of poverty rates

Predicted Proportions of the Population	**Poverty Rate**	
	Current Rate $\boldsymbol{k = 0.59}$	**Proposed Rate** $\boldsymbol{k = 0.1}$
T20	0.538	0.57
M40	0.469	0.222
B40	0.054	0.268

Moreover, reducing the unemployment rate does not result in significant changes in the income groups. Therefore, the Malaysian government needs take the appropriate action to reduce the poverty rate in Malaysia.

CONCLUSIONS

As anticipated in [1] and [2], the COVID-19 pandemic has indeed had a significant impact on both the unemployment and poverty rates. The pandemic has also affected household income, where the median monthly household income showed a decline. As highlighted in the Department of Statistics report, this decline caused a downward movement of those in the T20 group to the M40 group, and those in the M40 group to the B40 group. Those in the B40 group also faced worsening conditions, pushing them into extreme poverty.

Based on results of the regression analysis, several factors were affected by the COVID-19, pandemic such as poverty rate and income groups. Therefore, these factors were integrated in the proposed mathematical model, which also considered the unemployment rate. Through this model, we successfully analysed the poverty and unemployment rates for the three income groups in Malaysia during the COVID-19 pandemic using differential equations. The investigation of the model's equilibrium points, using stability analysis and time series plots, provided valuables insights. At the current rates, the populations of the T20 and B40 groups are much higher compared with the M40 group, indicating a significant gap between the T20 and B40 groups. It appears that the pandemic has exacerbated existing disparities, making the rich even richer and pushing the poor further into hardship. However, this problem can be solved by reducing the poverty rate, for example from the current poverty rate of 0.59 to 0.1. This improvement would have a positive impact on the Malaysian economy. As a result, more people are expected to belong to the T20 and M40 income groups, while the B40 group would see a decline in its population. Given these insights, it is crucial for the authorities to take action to alleviate the issue of poverty in the country.

While this study focused on analysing the impact of the COVID-19 pandemic on socioeconomic factors such as unemployment and poverty rates, it should be acknowledged that the pandemic's effects extend to many other factors. Sectors such as health, education, environment, politics, tourism and manufacturing are some of the domains that have also experienced significant disruptions. The findings of this study are expected to benefit stakeholders involved in distributing aid and support in the preparation of the pandemic recovery plan. If the relevant data can be acquired in the future, it is expected that the results of the analysis will be offer a clearer picture of the challenges faced in Malaysia. This, in turn, will enable pertinent stakeholders, including government and private agencies, to develop a more holistic recovery plan and distribute appropriate aid to all segments of society. Consequently, the results of this study align with Sustainable Development Goal 1, SDG1 (No Poverty).

CONFLICTS OF INTEREST

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Malaysia Terengganu for its support and assistance throughout this research.

REFERENCES

[1] Almalki, A., Gokaraju, B., Acquaah, Y., & Turlapaty, A. (2022). Regression analysis for COVID-19 infections and deaths based on food access and health issues. *Healthcare*, *10*(324).

[2] Al-Maalwi, R., Al-Sheikh, S., Ashi, H.A. & Asiri, S. (2021). Mathematical modeling and parameter estimation of unemployment with the impact of training programs. *Mathematics and Computers in Simulation* (MATCOM), *182*(C), 705-720. https://doi.org/10.1016/j.matcom.2020.11.018

[3] Al-Sheikh, S., Al-Maalwi, R., &. Ashi, H. A. (2021). A mathematical model of unemployment with the effect of limited jobs. *Comptes Rendus. Mathématique*, *359*(3), 283-290.

[4] Ashi, H. A., Al-Maalwi, R. M., & Al-Sheikh, S. (2022). Study of the unemployment problem by mathematical modeling: Predictions and controls. *The Journal of Mathematical Sociology*, *46*(3), 301-313.

[5] Blustein, D. L., Duffy, R., Ferreira, J. A., Cohen-Scali, V., Cinamon, R. G., & Allan, B. A. (2020). Unemployment in the time of COVID-19: A research agenda. *Journal of Vocational Behavior*, *119*, 103436.

[6] Bluman, A. (2014). *Elementary statistics: A step by step approach* (9th ed.). Mc Graw Hill Education.

[7] Chu, J. (2021). A statistical analysis of the novel coronavirus (COVID-19) in Italy and Spain. *PLOS One, 16*(3), e0249037.

[8] Daud, A. A. M., & Ghozali, A. W. (2015). Stability analysis of a simple mathematical model for unemployment. *Caspian Journal of Applied Sciences Research*, *4*(2), 15-18.

[9] Department of Statistics Malaysia. (2021, November 12). *Department of statistics Malaysia press release Malaysia economic performance third quarter 2021*. DoSM.

[10] Department of Statistics Malaysia. (2022, February 8). *Principal statistics of labour force, Malaysia, Fourth Quarter (Q4) 2021*. DoSM.

[11] Department of Statistics Malaysia. (2022). *Press Release Household Income Estimates and Incidence of Poverty Report* (pp. 2019–2021). DoSM.

[12] Hyman, M., Mark, C., Imteaj, A., Ghiaie, H., Rezapour, S., Sadri, A. M., & Amini, M. H. (2021). Data analytics to evaluate the impact of infectious disease on economy: Case study of COVID-19 pandemic. *Patterns*, *2*(18).

[13] Misra, A. K., & Singh, A. K. (2011). A mathematical model for unemployment. *Nonlinear Analysis*: *Real World Applications*, *12*(1), 128-136.

[14] Misra, A. K., & Singh, A. K. (2013). A delay mathematical model for the control of unemployment. *Differential Equations and Dynamical Models*, *21*(3), 291–307.

[15] Munoli, S. B., & Gani, S. (2016). Optimal control analysis of a mathematical model for unemployment. *Optimal Control Application and Methods*, *37*, 798–806.

[16] Pathan, G., & Bhathawala, P. H. (2015). A mathematical model for unemployment with effect of selfemployment. *IOSR Journal of Mathematics*, *11*(1), 37-43.

[17] Pathan, G., & Bhathawala, P. H. (2016). Unemployment-discussion with a mathematical model. *International Journal of Business Management and Economic Research*, *3*(1), 19-27.

[18] Pathan, G., & Bhathawala, P. H. (2017). A mathematical model for unemployment-taking an action without delay. *Advance in Dynamical Models and Application*, *12*(1), 41–48.

[19] Pathan, G., & Bhathawala, P. H. (2018). Mathematical model for unemployment control-a numerical study. *Journal of Emerging Technologies and Innovative Research*, *5*(8), 253-259.

[20] Roslan, U. A. M., Zakaria, S., Alias A., & Malik, S. (2018). A mathematical model on the dynamics of poverty, poor and crime in West Malaysia. *Far East Journal of Mathematical Sciences*, *107*, 309–319.

[21] Roslan, U. A. M., Alias A., Zakaria, S., Malik, S., & Sulaiman, N.F.C. (2021). Mathematical model on relationship between expenditure in education and household income group in Malaysia. *AIP Conference Proceedings*, *2355*, 040009. https://doi.org/10.1063/5.0053371

[22] Singh, K., Kondal, D., Mohan, S., *et al.* (2021). Health, psychosocial, and economic impacts of the COVID-19 pandemic on people with chronic conditions in India: A mixed methods study. *BMC Public Health*, *21*(685). https://doi.org/10.1186/s12889-021-10708-w

[23] Su, C. W., Dai, K., Sana Ullah & Zubaria Andlib. (2022). COVID-19 pandemic and unemployment dynamics in European economies. *Economic Research-Ekonomska Istraživanja*, *35*(1), 1752-1764.

[24] Verma, P., Dumka, A., & Bhardwaj, A. (2021). A statistical analysis of impact of COVID19 on the global economy and stock index returns. *SN Computer Science*, *2*(27).

[25] Yang X. D., Su X.Y., Li H. L., Ma R. F., Qi F. J., & Cao Y.E. (2021). Impacts of socio-economic determinants, spatial distance and climate factors on the confirmed cases and deaths of COVID-19 in China. *PLOS ONE*, *16*(7), e0255229. https://doi.org/10.1371/journal.pone.0255229