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# Numerical modelling of the impact of coronavirus disease 2019 on fertility and population growth rate in Malaysia

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**ABSTRACT**

Over the past four years, the world has grappled with an unprecedented global pandemic caused by COVID-19, resulting in a significant surge in reported cases and fatalities across numerous countries. This health crisis has had far-reaching demographic repercussions, with a notable decline in global birth rates, plummeting by 1.12% in 2020 compared to the preceding year. This trend is exemplified in Malaysia, where the number of births dwindled from 123,751 in September 2019 to 116,434 during the corresponding period in 2020. The reluctance to have children stems from the heightened vulnerability to the virus, compounded by financial constraints due to widespread unemployment, further dampening population growth. This study is dedicated to comprehending the impact of COVID-19 on Malaysia's population growth rates and forecasting its trajectory for the subsequent five years following the outbreak. Researchers scrutinized the data using numerical methods and population modeling and employed the Euler method, aided by MATLAB software, to compare their findings against authentic population figures. Their analysis disclosed that the COVID-19 pandemic affected Malaysia's population growth rates, although it did not directly impact mortality rates, as recovery rates exceeded mortality rates. In essence, the pandemic has primarily influenced birth rates, contributing to a noteworthy demographic shift in the country.



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## 1. INTRODUCTION

Coronavirus disease 2019 (globally known as COVID-19), which is an acute respiratory syndrome coronavirus 2 (SARS-CoV-2), represents a different variant of coronavirus, causing pneumonia cluster cases in Wuhan, Hubei Province, China [1]. Since the outbreak of the first cases toward the end of 2019, the number of pneumonia cases has skyrocketed, and the virus has been rapidly spreading, causing the quick spread of an epidemic throughout China [2], [3]. In Thailand, on 13 January 2020, the first COVID-19 case was confirmed by officials, signaling the commencement of the virus outbreak all around the globe [4]. On 24 January 2020, the first COVID-19 case was confirmed in Malaysia, and the infection wave continued until 15 February 2020, recording 22 points [5]. After that, no cases were reported for 11 days (from 16 to 26 February 2020), but the never-ending second wave began on 27 February 2020. As the second week of March 2020 arrived, there were many reported cases, and approximately a hundred cases were confirmed as there was clear evidence of human-to-human virus transmission. On 16 March 2020, however, Malaysian

PM Tan Sri Muhyiddin Yassin aired the enforcement of the movement control order (MCO), i.e., the movement control order, and stated that this order would be initially effective from 18 to 31 March 2020 [6]. He clarified that most premises and facilities, including educational institutions, must be closed except for several essential services in the country. Interstate and international travel were prohibited; people were advised to stay home to interrupt the virus infection chain. However, the order was extended several times. From April 1 to 14, 2020, Malaysia enforced phase 2 of movement control order, followed by phase 3 from 15 to 28 April, whereas phase 4 was implemented on 29 April throughout 12 May 2020, further extended until 9 June. During phase 4, however, some MCO restrictions were relaxed with a ban on inter-state travel without excusable reasons.

Four main factors influence population size and growth: birth rates, mortality rates, emigration, and immigration. The population size and growth were also influenced by economic development, education, social and cultural factors, and female labor market participation. The country witnessed a rapid increase in cases because of the rising number of COVID-19 cases reported by the Malaysian Ministry of Health (MoH) [7]. An average of 1965 cases were reported daily and mounted to 2525 on 31st December 2020 [8]. The number of deaths caused by COVID-19 recorded a slight percentage of 0.42% of the overall cases reported since January 2020 [9]. However, Malaysia has experienced an abrupt reduction in births from July to September 2020, with 116,434 births [10]. Compared to the number of births during the same period in 2019, with 123,751 deliveries, there is a difference of 5.9%, according to the Department of Statistics Malaysia [11]. This cutback affected the population growth rate in Malaysia. With the outbreak of COVID-19, there were speculations regarding its impact on demographics. Based on the data available, this crisis might have led to a baby boom or bust. The main question was, ‘Would this situation of existential and financial uncertainty trigger a baby bust?’ or ‘Would the opportunity of slowing down grant couples the impetus to have a family?’ There was a significant variation in the results depending on the individual’s country where they live. Malaysia has witnessed noticeable declining fertility rates, whereby births declined by 4% compared with 2019, recording lower rates.

Recent research on short-term fecundity effects of natural disasters like hurricanes, floods, and earthquakes, which cause significant damage or loss of life, has shown that rising birth rates typically follow the peak mortality rates within one year. Research on more extended periods, from one to five years after the disaster, has revealed a pattern of increasing fertility [12]. The main drivers of such medium-term recoveries are the parent’s desire to have babies as a replacement for the lost ones and structural changes in people’s expectations regarding the kids’ survival likelihood. Fertility might also have a symbolic value, especially after unanticipated mortality shocks, with new births serving as a constructive reframing process and denoting a normal situation. In ground-breaking investigations on the effects of the flu pandemic in 1889 on the rates of population in France, Jacques Bertillon observed a connection between excessive influenza fatalities and a delay of 9 months of birth depression [13]. The most enormous pandemic situation of the 20th century, the 1918-1919 H1N1 flu, was used to investigate this association further. The “Spanish flu” pandemic between 1918 and 1919 resulted in a 13% decline in the birth rates in America [14]. The increasing number of mortalities and morbidity of individuals of reproductive age, as well as the increased incidences in maternal mortality, alongside stillbirths, accompanied by slower conception rates, were caused by social isolation and infection fear. These are some of the channels for harmful fertility impacts. Regarding future increases in fertility, researchers differed over whether the baby boom, which occurred in 1920, might be directly linked to the pandemic, the ending of World War I, or a combination of two reasons. After couples re-joined, a peaceful situation allowed for restoring many postponed marriages and pregnancies; in addition to remarrying war widows [15], [16], many studies were conducted about the harmful effects of COVID-19 on males’ and females’ reproductive systems [17]. Angiotensin-converting enzyme 2 (ACE2) can act as a cellular attachment site to SARS-CoV-2 spike protein, anchoring this virus to target cells [18]. SARS-CoV-2 invasion, as well as the cellular internalization, triggers down-regulation of the membrane-bound ACE2, thereby increasing serum ACE2, causing Ang1-7 depletion and unrestricted AngII activity [19], and affecting vasoconstriction, angiogenesis, inflammation, apoptosis, and oxidative stress, as shown in Figure 1.

Figure 1 SARS-CoV-2 interaction with the ACE2 receptor and RAS impairment lead to harmful impacts in multiple biological systems. ACE2 is found on the surface of numerous types of cells, e.g., cardiac fibroblasts, respiratory epithelial cells, cardiomyocytes, vascular smooth muscle cells (VSMCs), endothelial cells, kidneys, the central nervous system (CNS), gut, as well as human reproductive system [20]. This universal ACE2 can make different organs vulnerable to SARS-CoV-2 contagion, explaining the damage to multiple organs with Coronavirus. The expression of the RAS components in males’ and females’ reproductive systems signals that these are vulnerable to SARS-CoV-2 contagion, as shown in Figure 2.

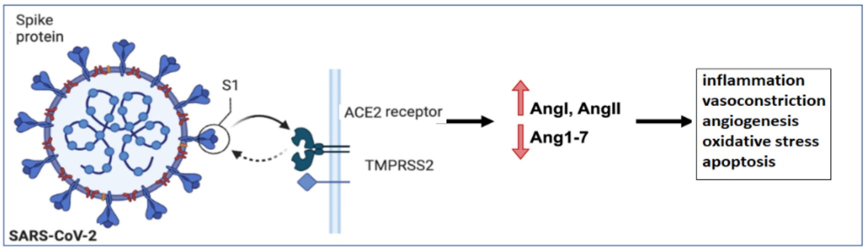


Figure 1. SARS-CoV-2 interaction with the ACE2 in multiple biological systems

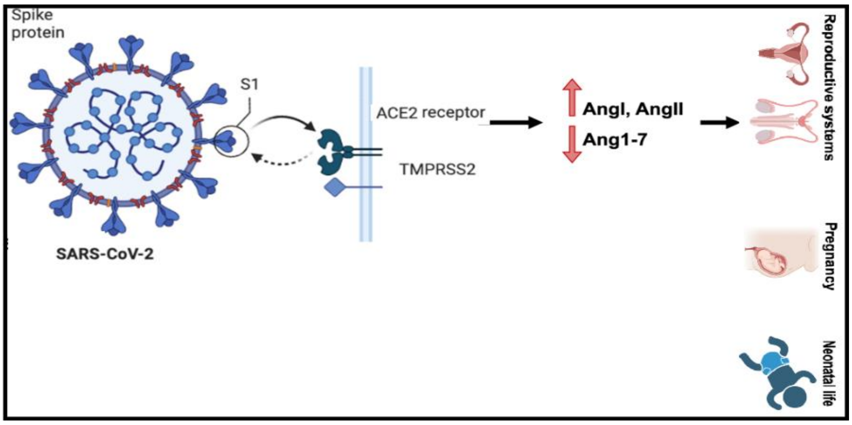


Figure 2. SARS-CoV-2 interaction with the ACE2 and potential procreation

Figure 2 SARS-CoV-2 interaction with the ACE2 receptor and RAS impairment lead to harmful impacts and potential procreation. COVID-19, in contrast to the flu outbreaks of 1918–1919, disproportionately affected older persons. COVID-19 can affect the reproductive choices of individuals who choose to consider and those who do not. Worrying thoughts and doubts about the pandemic might also impact sexual activity, with people losing their jobs, and economic unpredictability might cause noticeable pregnancy delays. Therefore, a plausible cause for today's negative short-term changes in fertility is not the death and morbidity of prospective parents. Additionally, child mortality was extremely low during the COVID-19 pandemic, eliminating another cause of many fertility reflections during fertility-mortality disasters during the current Malthusian era. The COVID-19 pandemic's effect on fertility rates might vary depending on how cultures have evolved in their demographic evolution from higher rates of birth and non-utilization of contraception to lower and controlled fertility rates. High-income nations, a few transitional economies, and most metropolitan places within lower-income countries, as well as middle-income nations, recorded a rate of 2.1 kids/female as a replacement fertility level. However, higher birth rates continued to be the custom in many poor rural zones. In some nations, fertility rates fell to an absurdly low 1.3 children per woman. Although this pattern may not always be actual for some developed countries where the relationship was reversed, the decline in the fertility levels in the world generally matched the long-established adverse association of fertility development [21]. One might conclude that development setbacks brought on by reduced life expectancy and income shocks triggered by COVID-19 would increase fertility in countries with a human development index between 0.85 and 0.9 or lower but decrease fertility in advanced nations. However, in developing nations, higher population growth has been sustained by higher fertility rates, exacerbating issues with food supply, poverty, unemployment, and public health. An additional fertility drop in high-income countries has accelerated the weakening and aging of their population, which surfaced as a policy concern.

In high-income nations, recent developments in female education are a crucial driver for the constant decline in fertility rates. Thus, fertility can be preserved via extensive childcare outsourcing [22]. However, during the COVID-19 pandemic, extended school closings and compulsory physical distancing led to home education and home childcare to the extent that this has imposed a heavy burden on parents' time and effort, and the closure has reduced desired fertility and delayed childbearing. The fertility rates were significantly affected by how couples and parents could share their time to carry out house responsibilities and childcare during the imposed lockdown [23].

On the other hand, gender equality in sharing domestic chores would diminish a significant burden on women with positive fertility implications [24], [25], and the forced lockdown had multiple immediate impacts on fertility. The maternal age is high in higher-income nations, which helps reproductive technology for couples who want to have children. Most reproductive technology cycles during the lockdown were canceled or suspended [26]. However, the reopening of fertility clinics has not counterbalanced lost bikes, leading to significant economic losses. In 2020, higher-income nations experienced the steepest decrease (−6.1%) reported by the International Monetary Fund as opposed to a fall of (−1%) in developing countries; the lockdown has adversely affected millions of families. Childbearing is irreversible; therefore, the enormous costs of child education, job loss, and low income have significantly reduced fertility [27]. A similar situation occurred during the Great Recession of 2008 when fertility rates declined, specifically in economic solid downturn nations [28]. Besides, persistent insecurity and uncertainty made parents reschedule their plans, significantly reducing fertility rates. Families considered luck coping mechanisms. Evidence substantiated that fertility rates declined during challenging economic uncertainty in countries with outstanding social capital and vital trust [29] and Malaysia [30].

Therefore, Policy responses are crucial in deciding the pandemic’s impact and economic and social effects. Austerity, for example, could not provide solutions during the economic recession of 2008 [31]. Given the coronavirus pandemic's scope, a fertility drop was expected in particularly high-income countries. There are many models to make the forecasting [32]–[42]. The main objective of this research involves investigating the impact of the Coronavirus pandemic on the population growth rate in Malaysia and predicting the population rate for the next five years after the spread of this virus. The numerical method was used to find the population growth rate and identify the effect of COVID-19 on the population growth rate in Malaysia. A population model was also used to estimate Malaysia’s population for the next five years. Figure 3 shows potential post-pandemic productiveness trajectories based on the regional revenue level, which refers to increased and decreased population rates. Based on the plotted data of this study's estimated population, it has been confirmed that if the COVID-19 pandemic did not occur, there would be a higher population rate than the obtained results. Regarding the projected population over the next five years, a long-term effect of this pandemic is expected to be present on the population growth rate in Malaysia. Although economic development and the eradication of poverty have directed much attention during COVID-19, several potential effects of the pandemic on future generations mirror a significant cause of concern.

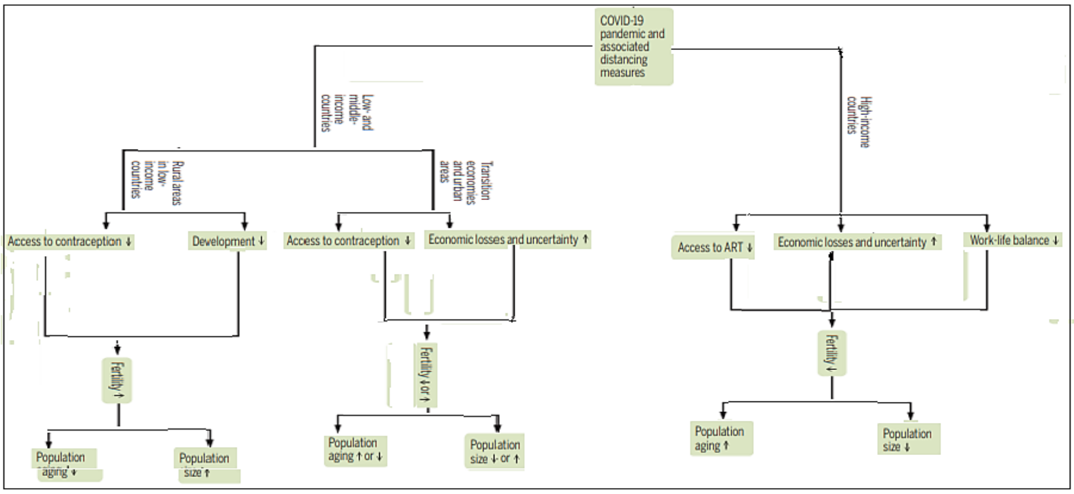


Figure 3. Potential post-pandemic productiveness trajectories based on the regional income level

## 2. COVID-19 PANDEMIC AND ITS EFFECT ON FERTILITY

The COVID-19 pandemic has influenced the fertility trajectories of human populations. There have been fewer births during high mortality caused by wars, scarcities, and pandemics. The impact of the COVID-19 pandemic on society and the economy is projected to influence women’s fertility plans. Moreover, the pandemic’s effect on fertility has influenced how quickly people age, how future health issues can be resolved, and the potential for global economic growth. It was believed that the coronavirus outbreak would cause a “baby boom” as couples were more likely to have children because they spend more time together; however, there is not much empirical support for such a prediction. Furthermore, the child mortality rate has been meager during the pandemic, which, in turn, decreased the fertility rate. During the virus outbreak, extended school closures and physical distancing led to a quick return to home-schooling. While this takes up more parents' time, the imposed lockdown has reduced intended fertility and pregnancy postponements. In the Malaysian context, how parents divided the time spent on childcare during the mandatory lockdown has significantly impacted fertility rates. Moreover, substantial economic losses were inflicted by shutting down many businesses. Millions of households were affected, and high-income nations faced an economic recession. Due to the irrevocable nature of childbirth and the high costs of raising children, fertility rates inevitably decreased due to unemployment.

## 3. METHOD

### 3.1. Data collection

During the meticulous data collection phase, an extensive search was conducted across various sources, including websites, news outlets, and social media platforms. This rigorous methodology guaranteed that the most recent and diverse data was included. Notably, one of the primary sources used was (https://www.macrotrends.net), which was chosen specifically for its provision of highly current and comprehensive data on global population statistics, with a particular focus on Malaysia's population from 2016 to 2020, as detailed in the site's complete Table 1. The data collection procedure included an in-depth examination of several demographic indicators, socioeconomic trends, and population statistics, providing a comprehensive, nuanced understanding of Malaysian population dynamics throughout the chosen period. The dataset compiled by cross-referencing information from many trustworthy sources provided a broad and multifaceted perspective on Malaysian demographics, societal developments, and significant trends. Furthermore, this phase prioritized raw data collecting, verification, and validation to assure correctness and reliability. The credibility of the acquired data was extensively confirmed by rigorous scrutiny and cross-verification with several reliable sources, reinforcing the integrity of the findings and succeeding analyses. The information generated by this robust approach serves as a solid platform for in-depth analysis and detailed insights into Malaysia's population trends and demographics throughout the given period. This complex data aggregation from many sources is a critical foundation for additional study and analysis, allowing for a more comprehensive understanding of Malaysia's changing sociocultural landscape and demographic transitions.

Table 1. Number of populations in Malaysia from 2016 to 2020

| Years | Number of populations in Malaysia |
|---|---|
| 2016 | 30,683,654 |
| 2017 | 31,104,646 |
| 2018 | 31,528,033 |
| 2019 | 31,949,777 |
| 2020 | 32,365,999 |

### 3.2. Data computation

This study used Matrix Laboratory (MATLAB) to conduct data computation of the population growth rate in Malaysia from 2016 until 2020. Using the population growth rate model, $N(t) = N_0 e^{rt}$ where $N(t)$ is the number of individuals in the population at time t, $N_0$ be the initial condition at t=0. T be the time (year), we rearrange the formula to become $r = (\ln(\frac{N(t)}{N_0}))/t$ to compute the rate of population growth, r. From the derivation of the model, the numerical solution was used, the Forward Euler scheme, also known as the Euler method $N^{n+1} = N^n + (\Delta t)(r)N^n$ where $N^0 = N_{0,}\ n = 0,1,\ldots,N_t - 1$ to estimate the population of Malaysia for another z years. To write a program for Euler's Method:

```
1.  Define N^n.
2.  Input N^0 = N_0, n = 0,1,...,N_t − 1.
3.  Input step size and the number of steps, n.
4.  For j from 1 to n, do
 a)  m=N^0
 b)  N^1 = N^0 + (Δt)(r)N^0
 c)  t1=t0+Δt
 d)  Print N^1
 e)  t0=t1
 f)  N^0=N^1
    5.  End
```

The study's primary goal was to use Euler's Method as an approximation technique to create answers for estimating Malaysia's population growth over a given period. This method enabled a systematic way to assess and forecast population trends within the period chosen, demonstrating the use of mathematical and computational tools in comprehending demographic shifts.

### 3.3. Data analysis

A graphical analysis of Malaysia's population growth rate from 2016 to 2020 was conducted to explore the patterns within the data. The data were presented using MATLAB by plotting the graph, allowing for a visual representation of the population's growth trends over the specified time frame. Based on the graphical plotting and the observed trends in population growth rates, a predictive model was employed to estimate the expected population in Malaysia for the subsequent five years, providing valuable insights into the country's demographic trajectory and aiding in future planning and resource allocation.

### 3.4. Data interpretation

The figures were rigorously checked with Malaysian population data using the population growth rate model and the Euler method. This comparison enabled a thorough examination of the population growth rate and its underlying tendencies. The ensuing investigation found that the COVID-19 pandemic had a perceptible impact on Malaysia's population growth rate, providing vital insights into the implications of the global health crisis on demographic trends within the country.

## 4. RESULTS

The data analysis conducted using various tables and figures unveiled intriguing insights into the population growth trends in Malaysia from 2016 to 2020. The data analysis results were obtained using the analysis program as shown in Figure 4 and Table 2. Figure 4 and Table 2 demonstrate an even distribution of the population in Malaysia, which kept rising every year. However, the population growth rate declined from 2017 until 2020. The population growth rate from 2016 until 2017 showed a slight increase, with rates from 1.3574% to 1.3595%. However, from 2017 until 2020, it started to show a decreasing trend of 1.3595% in 2017 to 1.3520% in 2018 and continued to decline in 2019 with a growth rate of 1.3288%. The data showed a massive growth rate decreased from 2019 1.3288% to 2020 with only 1.2943%.

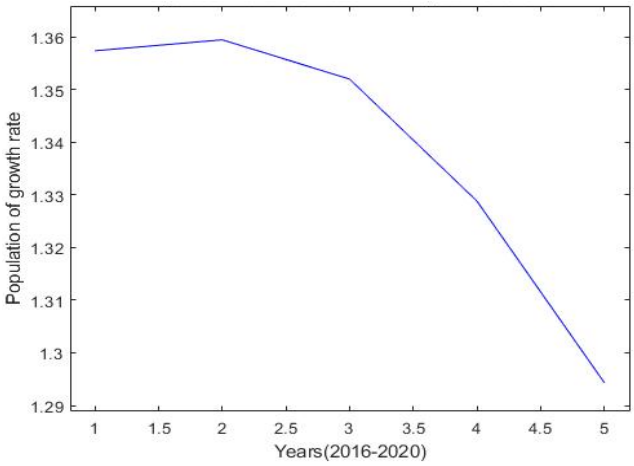


Figure 4. Population growth rate in Malaysia from 2016 to 2020

Table 2. Population growth rate in Malaysia from 2016 to 2020

| Years | Number of populations in Malaysia | Population growth rate in Malaysia (%) |
|---|---|---|
| 2016 | 30,684,654 | 1.3574 |
| 2017 | 31,104,646 | 1.3595 |
| 2018 | 31,528,033 | 1.3520 |
| 2019 | 31,949,777 | 1.3288 |
| 2020 | 32,365,999 | 1.2943 |

Figure 5 and Table 3 show that the predicted population in Malaysia calculated using the exact solution derived from the population model is more accurate than the numerical method since the solution by Faithful has the closest value to the actual population data. However, the focus is on 2020, when COVID-19 began to hit Malaysia. Malaysia's predicted population in 2020 for the numerical method is 32,362,706, while the exact solution is 32,374,228. By comparing the actual population back in 2020, which is 32,365,999, with the predicted population using the same key, it is evident that the expected population number is higher than the actual people in Malaysia. Based on Figure 6 and Table 4 above, the estimation for the annual population size and growth starting from 2021 to 2025 is evenly increasing. These values were obtained using the numerical method, the Euler method, and the exact solution. This formula designates the population model $N = N_0 e^{rt}$. Based on the results in the previous section, the population model formula provided a more accurate value than the numerical method since it has the closest value to the actual population in 2020.

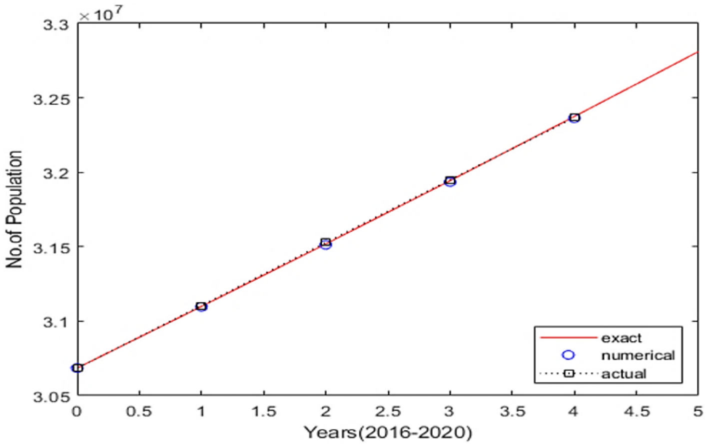


Figure 5. Projected and factual number of populations in Malaysia from 2016 to 2020

Table 3. Projected and factual population in Malaysia from 2016 to 2020

| Years | Predicted population (by Numerical-Euler) | Predicted population (by population model $N = N_0 e^{rt}$ ) | Actual population |
|---|---|---|---|
| 2016 | 30,684,654 | 30,684,654 | 30,684,654 |
| 2017 | 31,095,828 | 31,098,596 | 31,104,646 |
| 2018 | 31,512,512 | 31,518,121 | 31,528,033 |
| 2019 | 31,934,780 | 31,943,307 | 31,949,777 |
| 2020 | 32,362,706 | 32,374,228 | 32,365,999 |

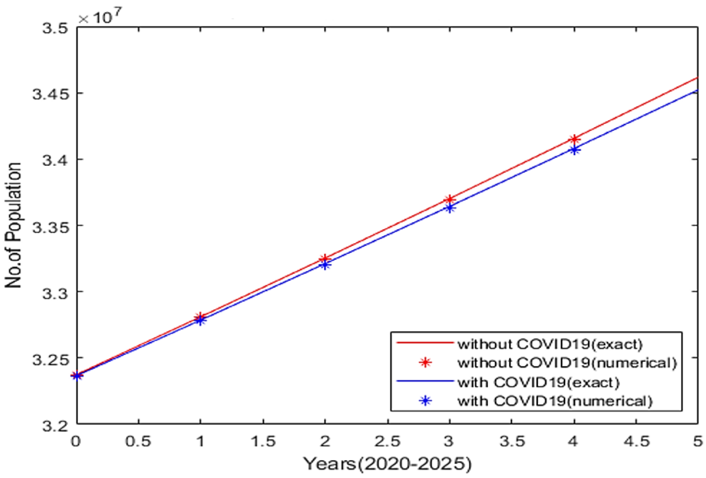


Figure 6. Projected population number of Malaysia for the next five years

Table 4. Projected population of Malaysia in the next five years

| Years | Predicted population with COVID-19 (by Numerical-Euler) | Predicted population with COVID-19 (by population model $N = N_0e^{rt}$ ) | Predicted population without COVID-19 (by Numerical-Euler) | Predicted population without COVID-19 (by population model $N = N_0e^{rt}$ ) |
|---|---|---|---|---|
| 2021 | 32,783,520 | 32,786,225 | 32,808,042 | 32,810,962 |
| 2022 | 33,206,427 | 33,211,907 | 33,247,670 | 33,253,588 |
| 2023 | 33,634,790 | 33,643,115 | 33,693,189 | 33,702,185 |
| 2024 | 34,068,679 | 34,079,923 | 34,144,677 | 34,156,833 |
| 2025 | 34,508,165 | 34,522,402 | 34,602,216 | 34,617,615 |

## 5. INTERPRETATION AND DISCUSSION

The data showed that Malaysia experienced a gradually slow population growth rate annually. Population aging is one of the factors that affect the population growth rate. As stated by the Department of Statistics Malaysia, 7.2% of Malaysia’s 31 million population is estimated to reach 65 and above in 2020, with a declining number of children aged 15 and below. Since 2015, fertility rates have fallen below replacement rates, which has led to lower birth rates. One of the reasons for the decrease in fertility is that women are beginning to participate actively in the labor market. Improvements in women’s education play an essential role in changing the structure of women’s employment, thereby leading to the shift of women’s work towards modern sectors. This indicates that an average mother’s age at the first birth increased in 2017 from 27.7 to 27.8 in 2018 at a rate of 0.1 years. The increase in the average age of mothers at first birth generally indicates a shorter period of reproduction in women.

Based on the economic point of view, due to an increase in industrialization and urbanization, which, in turn, increased literacy and living standards and enhanced medical practices. This has forced the majority of married couples in Malaysia to practice family planning, which would automatically affect the birth rate. The virus affected the birth rate considerably because many families postponed having children and couples avoided getting married, along with an increased number of terminations of early pregnancies and many families had decreased sexual desire and frequency of sexual intercourse due to COVID-19 due to many affected social and economic sectors that were the most affected by this pandemic. Based on the obtained data regarding Malaysia’s estimated population, it has been confirmed that if the COVID-19 pandemic had not hit the country, a higher population rate would have been achieved compared with the results. Regarding the projected population over the next five years, a long-term effect of this pandemic is expected to be present on the population growth rate in Malaysia. Although economic development and the eradication of poverty have received much attention during COVID-19, several potential effects of the pandemic on future generations are a significant cause for concern.

Based on the analyzed data, the COVID-19 situation, which started with the first case in January 2020 and continued to rise, affected the population growth rate as compared to the population data in Malaysia during 2020 using the previous year’s data, which was before the COVID-19 pandemic - the population rate was higher compared to the actual population data during the pandemic. Therefore, COVID-19 significantly affected the population as the population growth rate decreased from 2019 to 2020. As for the estimated population for the following five years after 2020, the results showed a noticeable variation in the estimated number of Malaysia’s population, which was affected by the occurrence of the COVID-19 pandemic, and the estimated population without the event of COVID-19. For example, considering the estimated population in 2021, the difference was 0.0377% between the value of the estimated population with and without the COVID-19 incidence. The difference in these values increases year after year. For these years, including 2022, 2023, 2024, and 2025, a distinction can be found between the importance of the estimated population number with and without COVID-19’s occurrence at 0.0627%, 0.0877%, 0.1127%, and 0.1377%, respectively. Therefore, the coronavirus pandemic significantly affected the growth of the population in Malaysia according to the variation in the values of the estimated population.

## 6. CONCLUSION

The global-scale outbreak of the COVID-19 pandemic, which was caused by SARS-CoV-2 virus infection in Wuhan, a city in China, in December 2019, had a significant impact on people’s daily lives and plans. The virus has affected everyday life, reaching out to different categories, such as healthcare and wide-scale economic and social impacts. This study investigated the effect of the COVID-19 pandemic on the population growth rate in Malaysia. The results established that the coronavirus pandemic has impacted the Malaysian population growth rate. However, this pandemic has not directly affected Malaysia’s mortality rates, as the country’s recovery rates were higher. Instead, the virus has affected the birth rate considerably because many families postponed having children and couples refrained from getting married, along with an increased number of terminations of early pregnancies due to huge, inflicted impacts in the social and economic sectors, which were the most-hit sectors by the global pandemic. Based on the plotted data of this study's estimated population, it has been confirmed that if the COVID-19 pandemic did not occur, there would be a higher population rate than the obtained results. Regarding the projected population over the next five years, a long-term effect of this pandemic is expected to be present on the population growth rate in Malaysia. Although economic development and the eradication of poverty have directed much attention during COVID-19, several potential effects of the pandemic on future generations mirror a significant cause of concern.

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