Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 7, 733-753
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i7.8722

The relationship model between life expectancy at birth tuberculosis and PM2.5 developing and developed countries in Asia

Sri Hasnawati[1], Mustofa Usman[2], Edwin Russel[3*], Raihan Othman[4]

[1]Department of Management, Faculty of Economic and Business, Universitas Lampung, Soemantri Brojonegoro 1, Lampung, Indonesia; sri.hasnawati@feb.unila.ac.id (S.H.).

[2]Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Lampung, Soemantri Brojonegoro 1, Lampung, Indonesia; usman_alfha@yahoo.com (M.U.).

[3]Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Lampung, Soemantri Brojonegoro 1, Lampung, Indonesia; winrush08@gmail.com (E.R.).

[4]Department of Science in Engineering Faculty of Engineering International Islamic University Malaysia, Gombak, Kuala Lumpur, Malaysia; raihan@iium.edu.my (R.O.).

Abstract: Studies on environmental conditions, the health of a country's population, and life expectancy at birth (LEB) have attracted the attention of many researchers and raised awareness among governments in both developed and developing countries to improve the environment, such as reducing air pollution levels. Research examines the pattern of association between PM2.5 pollution levels and tuberculosis (TB) disease in both developed and developing countries in Asia. This study analyzes the relationship between pollution levels caused by PM2.5 and TB disease against LEB in these countries. The relationship model built between PM2.5, TB, and LEB is a linear model with dummy variables for developed and developing countries. The results showed that the relationship between PM2.5 and TB is significant; namely, the higher the PM2.5, the higher the TB cases in both developed and developing countries in Asia. The relationship between PM2.5 and TB with LEB is also significant, with a negative pattern: the lower the PM2.5 levels and the fewer TB cases in a country, the higher the LEB level, indicating better environmental conditions.

Keywords: *TBC, LEB, PM2.5, Developed countries, Developing countries, Asia.*

1. Introduction

In the last few decades, environmental pollution has been a global problem faced by all countries in both developed and developing countries and is feared to have a negative impact on human health. One of the environmental pollutants is air pollution, which is considered a dangerous factor for health [1] especially arising from transportation, industries and households [2, 3]. The type of air pollution that has the most severe threat to human health is particulate matter 2.5 (PM2.5), which has a diameter of less than 2.5 microns [4, 5] which can easily enter the human body through the respiratory tract and cause various respiratory and cardiovascular diseases [6]. Therefore, it is necessary to understand in depth about air pollution, especially related to PM2.5, which is used to formulate effective policies and mitigation and protect society from air pollution.

Several previous studies have examined the impact of air pollution (PM2.5) on the risk of being infected with tuberculosis (TBC) and worsening the condition of TBC sufferers [4, 7, 8] they examined the relationship between variations in PM2.5 concentrations in the surrounding environment and seasonal TBC in Beijing and Hong Kong, which showed that there was a significant correlation between the increase in the number of TBC cases reported in the current month and the increase in PM2.5.

History: Received: 5 May 2025; Revised: 14 June 2025; Accepted: 18 June 2025; Published: 9 July 2025
* Correspondence: winrush08@gmail.com

Notably, there was a significant correlation between the number of TBC cases reported during spring and summer. A study conducted by Min, et al. [7] in South Korea found that the areas with higher PM2.5 concentrations tended to have higher TBC recurrence rates. Based on the study conducted by Wang, et al. [8] using time series analysis, the result showed that higher PM2.5 levels were associated with a higher number of TBC cases in Shanghai.

Studies on the relationship between air pollution levels (PM2.5) and life expectancy (LEB) have been carried out by many researchers such as Apte, et al. [9] and Schwartz, et al. [10] where air pollution (PM2.5) has an influence on life expectancy. According to Apte, et al. [9] from his study about the impact of PM2.5 on life expectancy at birth (LEB), the result shows that the countries with higher levels of pollution have lower life expectancy at birth. Air pollution, including household air pollution and PM2.5, reduces the global life expectancy by an average of 1.65 years. This is in line with the research conducted by Hasnawati, et al. [11] in Qatar, which states that there is a relationship between LEB and air pollution (PM2.5). The impact of air pollution on life expectancy is quite large in countries with high death rates from cardiovascular disease. This study has provided strong evidence of a causal relationship between long-term PM2.5 exposure and mortality.

The aim of this research is to analyze the impact of air pollution, especially PM2.5 on tuberculosis (TBC) and life expectancy at birth (LEB) in several developed and developing countries in Asia. Besides, it is also hoped that this research can be used as a reference in making policies related to health and efforts to reduce air pollution levels.

2. Research Methodology

The relationship model built between PM2.5 and TBC is a linear model with dummy variables for each country. The variable relationship model can be defined as follows:

$$TBC_{ij} = C + \beta_1 PM_i + \beta_2 PM*PM + \gamma_1 D1 + \gamma_2 D2 + \gamma_3 D3 + \gamma_4 D4 + \varepsilon_{ij} \quad (1)$$

Where, TBC_{ij} denotes the observations of the i-th year and the j-th country, D1=1 if Azerbaijan and 0 otherwise;D2=1 if Indonesia and 0 otherwise; D3=1 if Malaysia and 0 otherwise; D4=1 if Philippines and 0 otherwise. The relationship model between TBC, PM2.5, and dummy variables for developing countries is defined as follows:

$$TBC_{ij} = C + \beta_1 PM_i + \beta_2 PM*PM + \gamma_1 D1 + \gamma_2 D2 + \gamma_3 D3 + \varepsilon_{ij} \quad (2)$$

Where, TBC_{ij} denotes observations for the i-th year and j-th country, D1=1 if Japan and 0 otherwise; D2=1 if Israel and 0 otherwise; D3=1 if Singapore and 0 otherwise. What is the relationship pattern between the level of pollution caused by PM2.5 and TBC on LEB in both developed and developing countries in Asia? The relationship model built between PM2.5, TBC and LEB is a linear model with dummy variables for developed and developing countries. The relationship model between LEB, TBC, and PM2.5, where dummy variables for developed and developing countries are defined as follows:

$$LEB_{ij} = C + \beta_1 TBC_i + \beta_2 PM_j + \beta_3 PM*PM + \gamma_1 D1 + \varepsilon_{ij} \quad (3)$$

With LEB_{ij} indicating the observations for the i-th year and j-th country, D1=1 for developed countries and 0 fordeveloping countries.

3. Results

3.1. Data Plot

In this research, we will discuss how the model of the relationship between TBC as a dependent variable is related to the environmental pollution factor PM2.5, both in developing and developed countries in Asia. The developed countries involved in this research are Japan, Israel, Singapore and South Korea, while the developing countries involved are Azerbaijan, Indonesia, Malaysia, the Philippines and Saudi Arabia. Next, we will build a model of the relationship between LEB as a dependent variable, whether it is influenced by TBC and PM2.5 levels in Asia, both in developed and developing countries. The relationship patterns above will be discussed in depth based on the results of modeling the relationships between the variables.

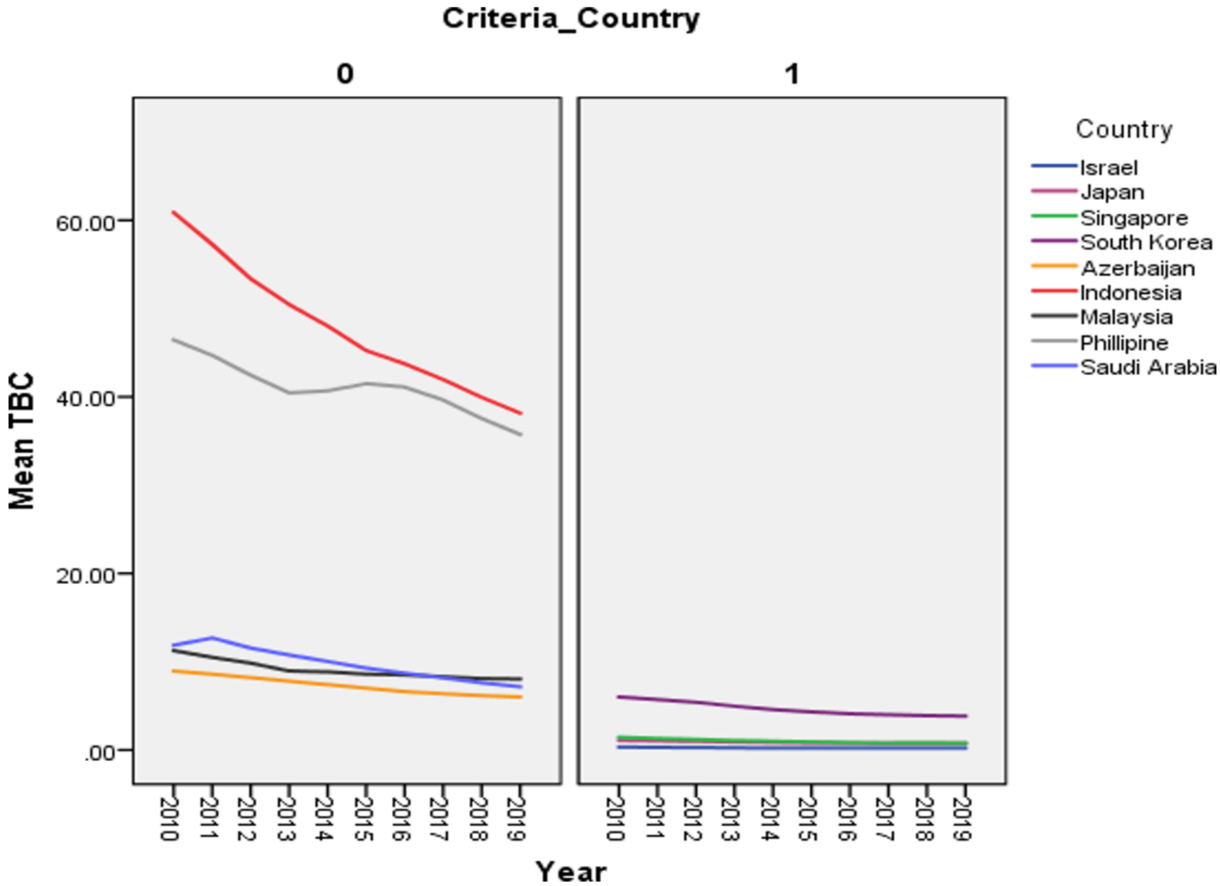

Figure 1.
Number of TBC diseases per 100,000 population in (a) developing countries Azerbaijan, Indonesia, Malaysia, the Philippines and Saudi Arabia, and (b) developed countries Japan, Israel, Singapore, and South Korea.

Figure 1 shows the TBC disease in developing countries and developed countries in Asia. Figure 1(a). The condition of TBC disease per 100,000 populations in developing countries shows that Indonesia and the Philippines are relatively high, namely in the range of 35 to 60 per 100,000 populations from 2010 to 2019. Figure 1(a). also shows that Indonesia is relatively the highest compared to the other four developing countries, Azerbaijan, Malaysia, the Philippines and Saudi Arabia. Meanwhile, the numbers of cases in Malaysia, Azerbaijan and Saudi Arabia are relatively low and range between 4 and 12 cases per 100,000 populations. Figure 1(a). shows that in all countries from 2010 to 2019, there was a downward trend in the five developing countries. Figure 1(b) shows the number of TBC cases in several developed countries in Asia from 2010 to 2019. The cases were in the range of 0.21 to 1.44 per 100,000 population. Figure 1(b) also shows that TBC cases in developed countries are lower than those in developing countries in Asia. In developed countries from 2010 to 2019, it shows a downward trend.

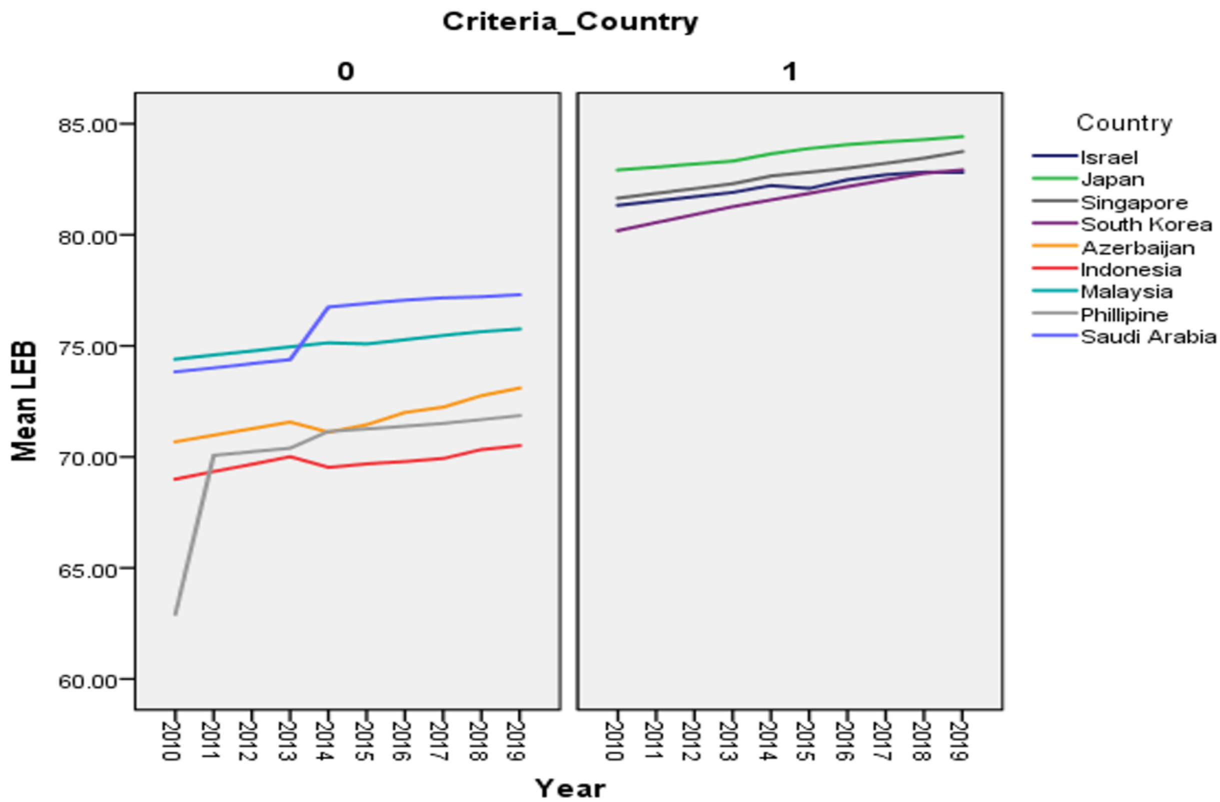

Figure 2.
Life expectancy at Birth (LEB) (a) developing countries Azerbaijan, Indonesia, Malaysia, the Philippinesand Saudi Arabia, and (b) developed countries Japan, Israel, Singapore and South Korea.

Figure 2 shows the LEB in developing countries and developed countries in Asia. Figure 2(a) shows that in developing countries, Malaysia and Saudi Arabia are relatively close and the LEB range from 2010 to 2919 is between 74.0 and 77.3 years. Meanwhile, the LEB levels of Indonesia, Azerbaijan and the Philippines are relatively close to each other, and the LEB values range from 62.9 to 73.1 years. Figure 2(b). shows that LEB in developed countries: Japan, Israel, Singapore and South Korea are relatively close to each other and the LEB values are between 82.2 and 84.4 years. Figure 2(a), 2(b) in both developing countries and developed countries in Asia, the LEB trend from 2010 to 2019 is increasing, which shows that life expectancy at birth in both developing countries and developed countries in Asia is increasing from year to year.

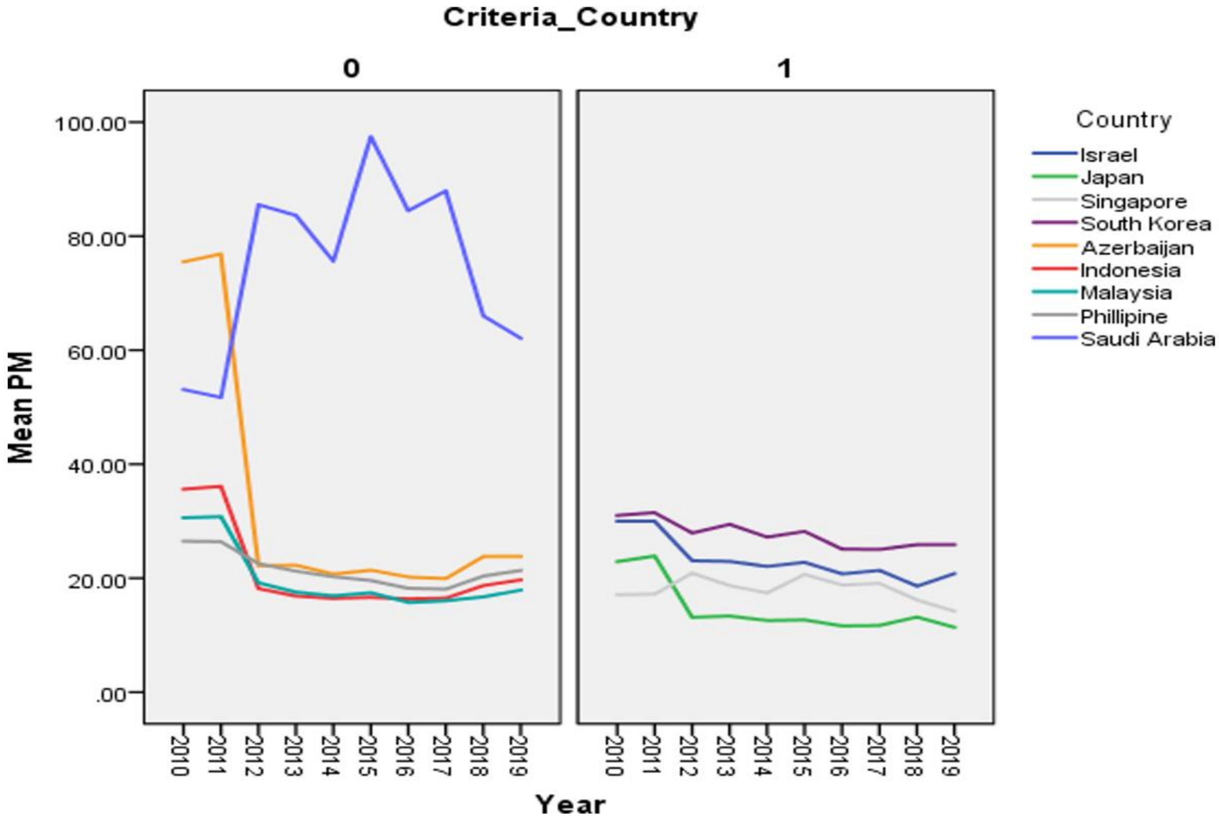

Figure 3.
PM2.5 in (a) developing countries Azerbaijan, Indonesia, Malaysia, the Philippines and Saudi Arabia, and (b) developed countries Japan, Israel, Singapore, and South Korea.

Figure 3 shows the PM2.5 conditions in developing and developed countries in Asia. Figure 3(a) shows the condition of PM2.5 in developing countries, where Saudi Arabia shows a relatively high level of PM2.5 compared to four other developing countries with a PM2.5 value range between 50 and 100. Meanwhile, four other developing countries, Azerbaijan, Indonesia, Malaysia and the Philippines, are relatively the same and low. Figure 3(b). shows PM2.5 conditions in developed countries in Asia. Figure 3(b) also shows that the PM2.5 conditions in ten years, 2010 to 2019, are stable, as shown by the graph with a flat trend. The results of this research support the research of Rentschler and Leonova [12]. High PM2.5 in developing countries generally with high populations and lower middle income. Apart from that, there are industrial activities that do not use environmentally friendly technology, environmental protection policies and law enforcement to reduce pollution.

3.2. Model of the Relationship between TBC and PM2.5 in Developing Countries

The relationship model between TBC, PM2.5, and the dummy variables for developing countries is defined as follows:

$$TBC_{ij} = C + \beta_1 PM_i + \beta_2 PM * PM + \gamma_1 D1 + \gamma_2 D2 + \gamma_3 D3 + \gamma_4 D4 + \varepsilon_{ij} \quad (4)$$

Where TBC_{ij} denotes the observations of TBC in the i-th year and the j-th country, D1=1 if Azerbaijan and 0 otherwise; D2=1 if Indonesia and 0 otherwise; D3=1 if Malaysia and 0 otherwise; D4=1 if Philippines and 0 otherwise. From the results of the analysis of variance.

Table 1.
Analysis variance for testing the model of developing countries model (1).

Source	DF	Sum of Squares	Mean Square	F Value	P-value
Model	6	15764	2627.31543	232.31	<.0001
Error	43	486.31274	11.30960		
Corrected Total	49	16250			

Note: R-square =0.9625.

Table 1 shows that model (1) is very significant with an F-value = 232.31 and a p-value <0.0001. Thus, this model can be used to explain the relationship between TBC and PM2.5 and also look at the relationship pattern in developing countries are discussed in this research. R-square=0.9625, this means that 96.25% of the variation of TBC can be explained by PM2.5. The analysis of variance for performing partial tests is presented in Table 2.

Table 2.
Analysis variance for the partial test of the model (1).

Variable	DF	Parameter Estimate	Standard Error	t Value	P-value
Intercept	1	-4.36576	4.00899	-1.09	0.2822
PM	1	0.51178	0.13859	3.69	0.0006
PM2	1	-0.00415	0.00126	-3.29	0.0020
D1	1	1.35196	2.20169	0.61	0.5424
D2	1	43.54862	2.56612	16.97	<.0001
D3	1	5.04304	2.61536	1.93	0.0604
D4	1	36.35782	2.54191	14.30	<.0001

Table 2 shows that PM has a significant effect on TBC with p-value = 0.0006, likewise for PM*PM it affects TBC with p-value = 0.0020. The pattern of the influence of PM on TBC for each country is presented in the following figure.

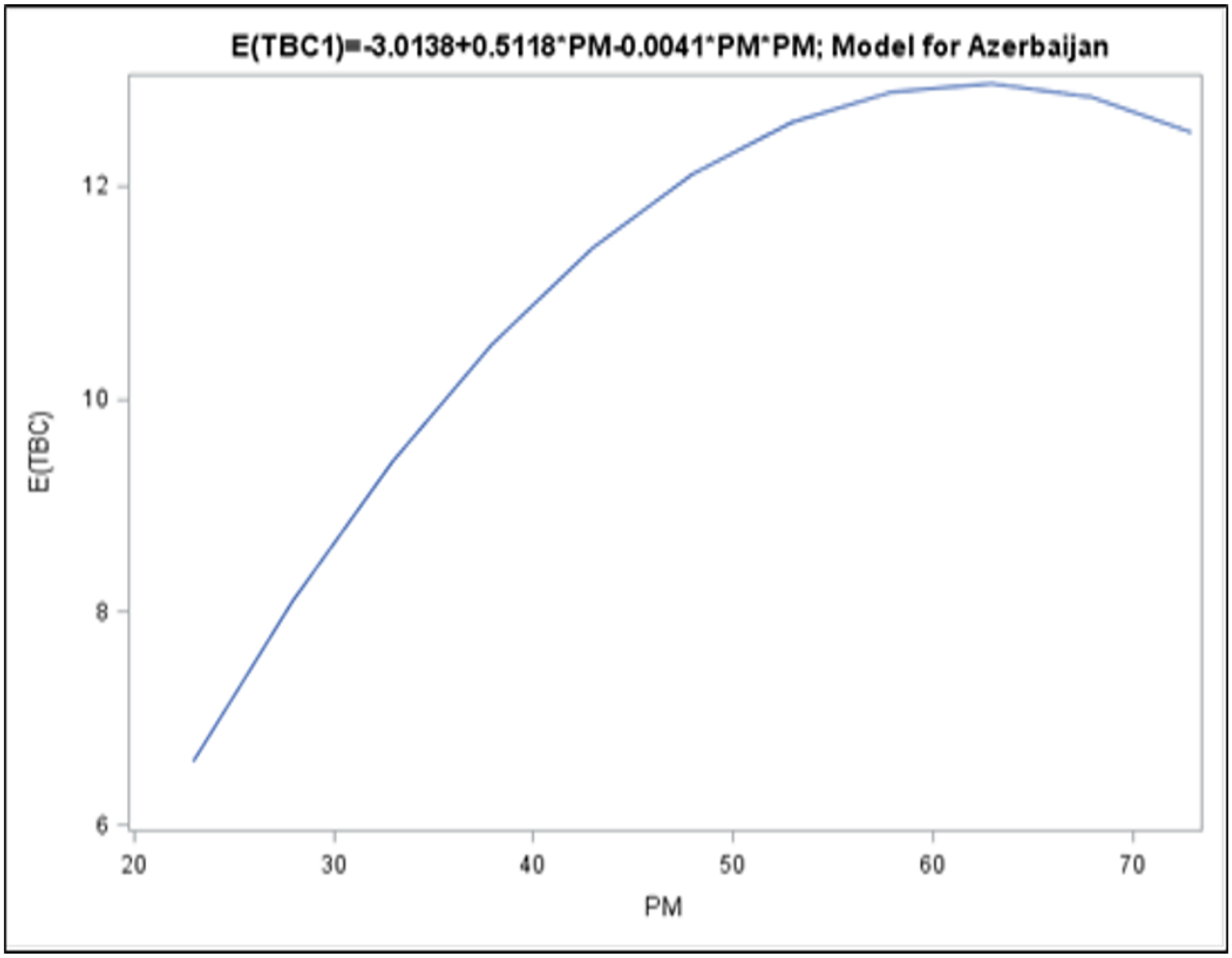

Figure 4.
Pattern of the relationship between TBC and PM2.5 for Azerbaijan with PM2.5 values ranging from 20 to75.

Figure 4. Shows the quadratic relationship pattern for the PM2.5 values from 20 to 75. The trend increases until PM2.5 is at 63. The level of exposure to TBC disease was relatively low in Azerbaijan from 2010 to 2019, namely in the range between 6 to 12 TBC cases per 100,000 populations.

ISSN: 2576-8484
Vol. 9, No. 7: 733-753, 2025
DOI: 10.55214/25768484.v9i7.8722

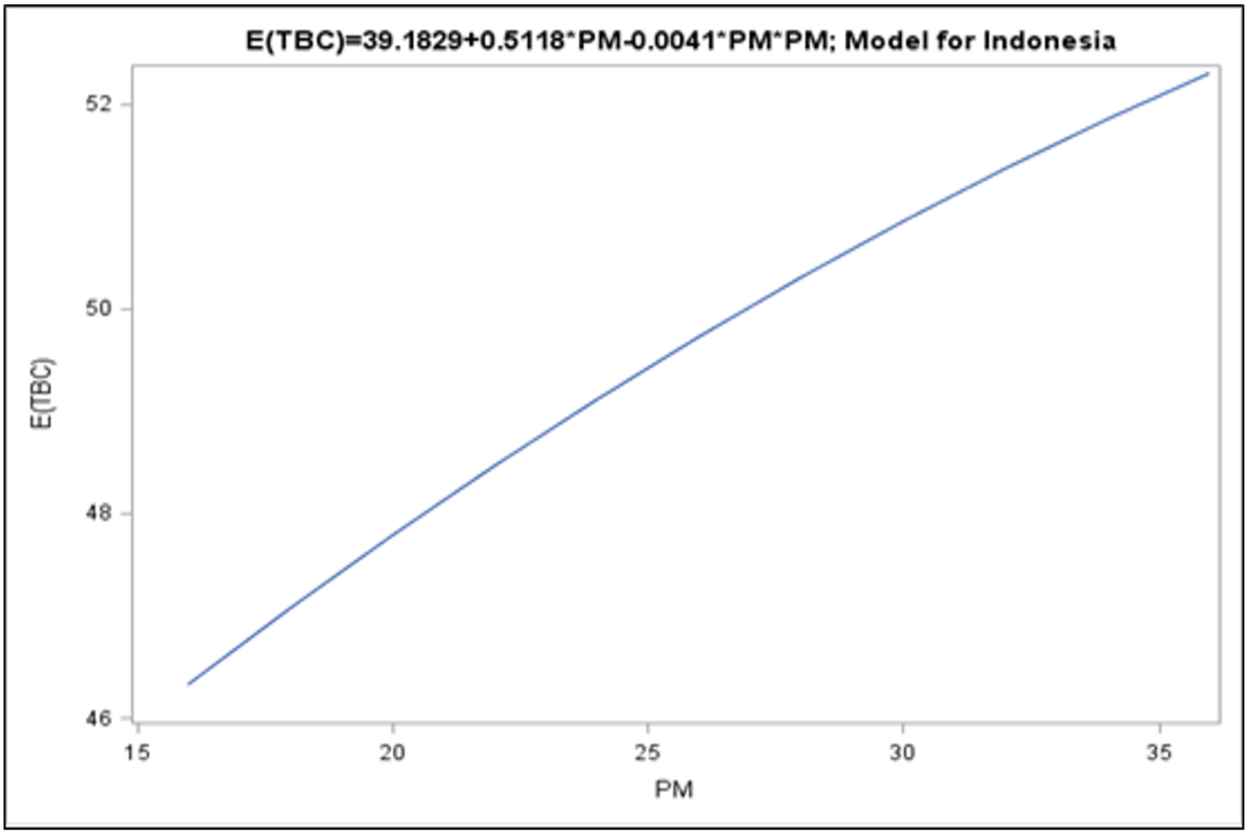

Figure 5.
Pattern of relationship between TBC and PM2.5 for Indonesia for the PM2.5 value range between 20 and 75.

Figure 5. Shows the quadratic relationship pattern for the PM2.5 values from 15 to 35. The trend increases until PM2.5 is at 35. Where the level of exposure to TBC disease is relatively high compared with the four other developing countries. In Indonesia from 2010 to 2019, the range was between 40 and 62 TBC cases per 100,000 populations.This condition certainly needs to get the government's attention in order to reduce the rate of TBC disease in Indonesia, which is relatively high compared to other developing countries.

ISSN: 2576-8484
Vol. 9, No. 7: 733-753, 2025
DOI: 10.55214/25768484.v9i7.8722

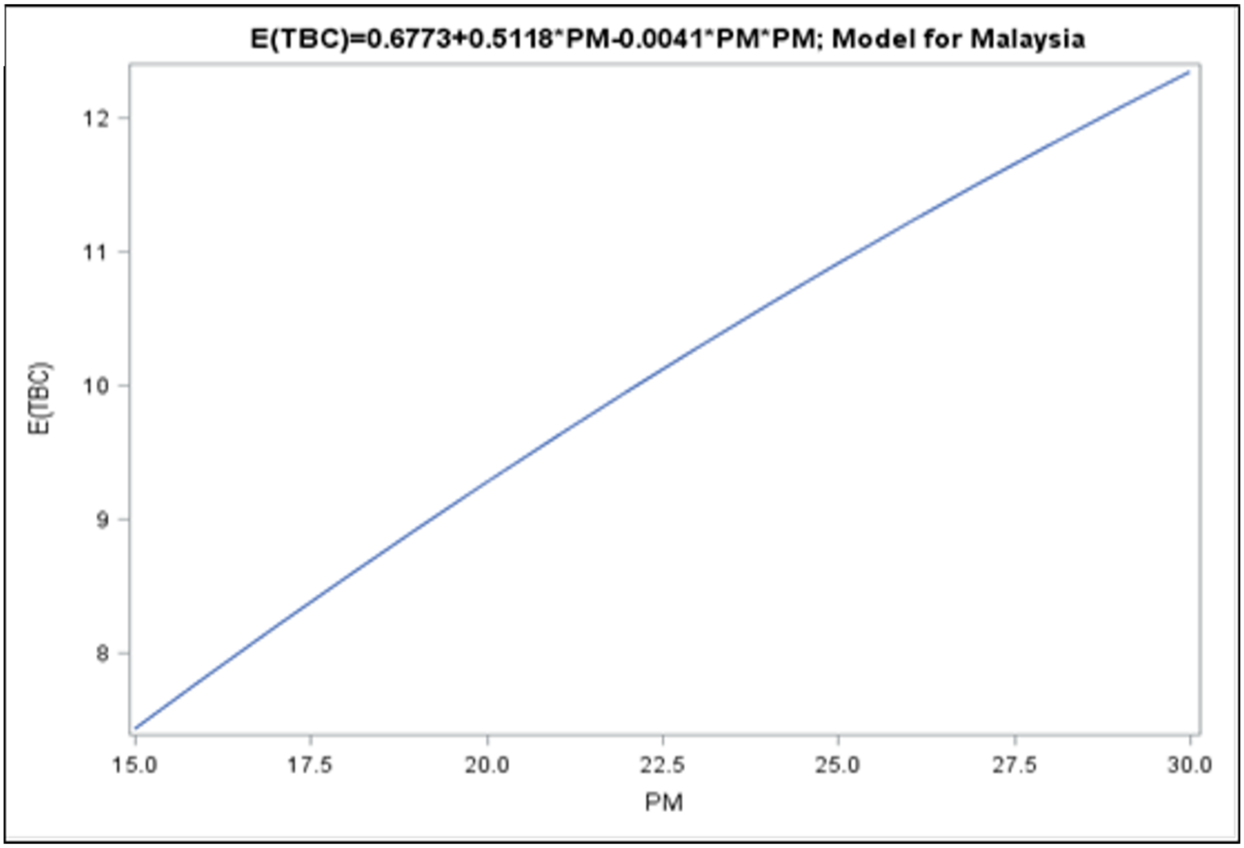

Figure 6.
Pattern of relationship between TBC and PM2.5 for Malaysia for the PM2.5 value range between 15 to30.

Figure 6. Shows the quadratic relationship pattern between TBC and PM2.5 for PM2.5 values from 15 to 30. An upward trend in TBC cases in Malaysia. Where the level of exposure to TBC disease is relatively low compared to four other developing countries, in the 10 years between 2010 and 2019, there were between 7 and 12 TBC cases per 100,000 populations in Malaysia.

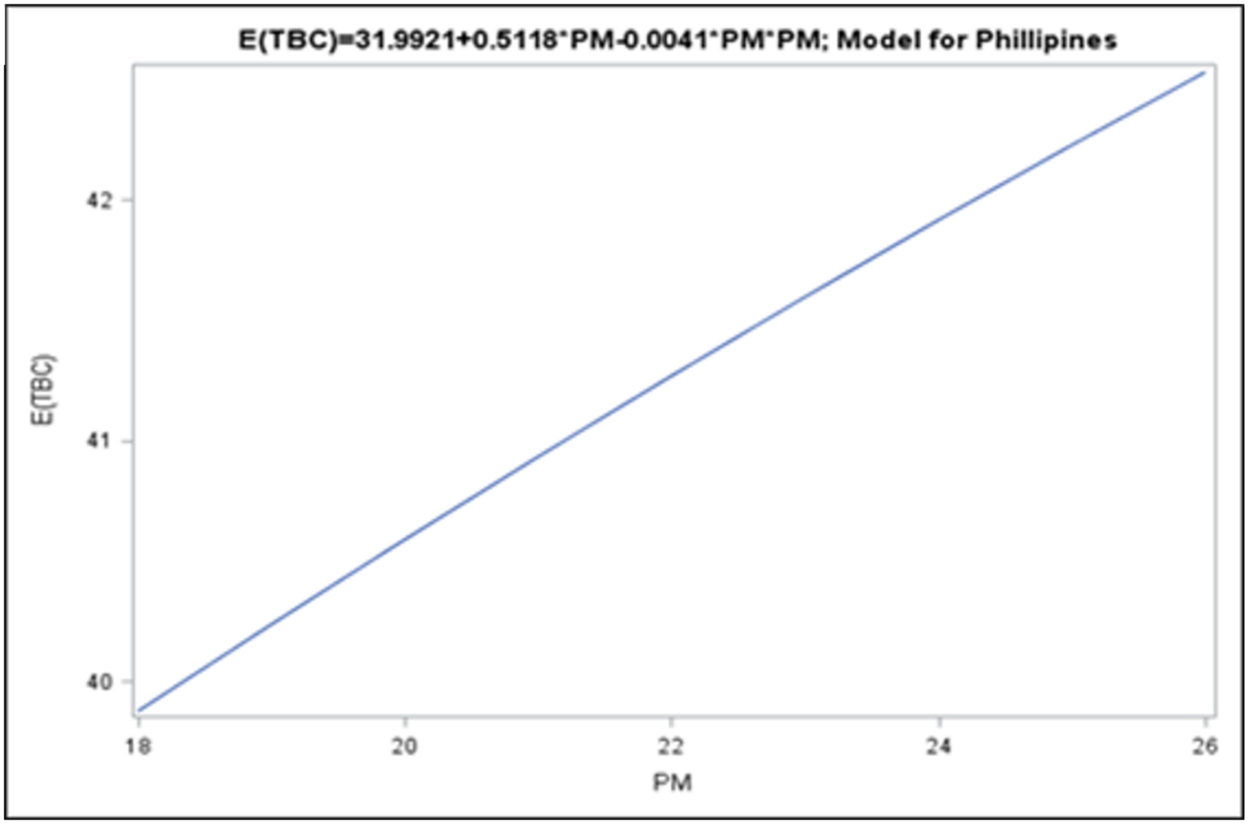

Figure 7.
Pattern of association between TBC and PM2.5 for Philippine for a range of PM2.5 values between 18 and26.

Figure 7 Shows the pattern of the quadratic relationship between TBC and PM2.5, where in the case of the Philippines the PM2.5 value is from 18 to 26. The trend increases until PM2.5 is at 26. Where the level of exposure to TBC disease is relatively high compared with the three other developing countries.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 7: 733-753, 2025
DOI: 10.55214/25768484.v9i7.8722

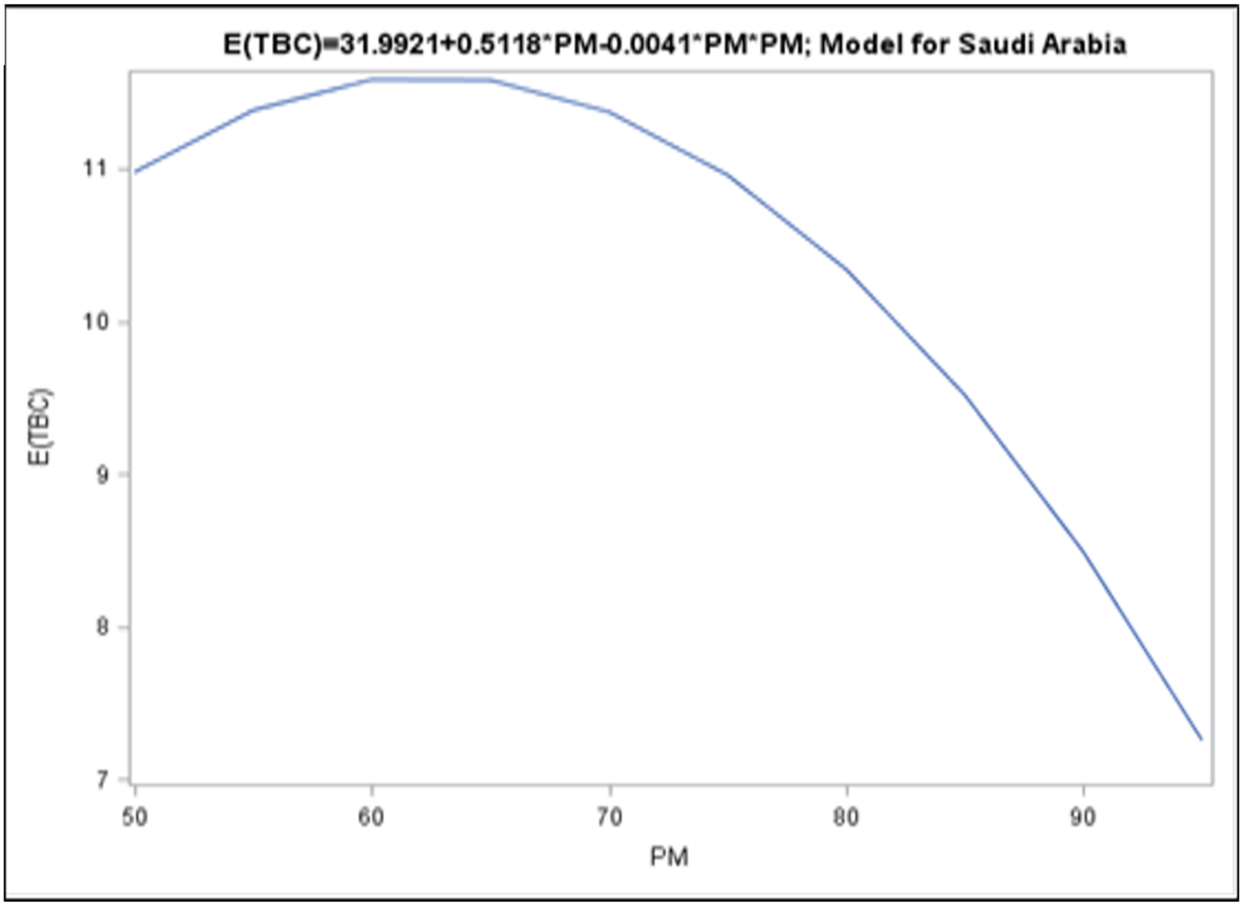

Figure 8.
Pattern of relationship between TBC and PM2.5 for Saudi Arabia for the PM2.5 value range between 50 to 90.

Azerbaijan, Malaysia and Saudi Arabia. In the Philippines from 2010 to 2019, that is in the range of 40 to 43 TBC cases per 100,000 populations. This condition is relatively similar to the conditions in Indonesia and still requires efforts to reduce the level of TBC cases.

Figure 8. Shows the pattern of the quadratic relationship between TBC and PM2.5 in Saudi Arabia, where in the case of Saudi Arabia the PM2.5 value is from 50 to 90, which is relatively high and dangerous according to the WHO criteria. The high PM2.5 value may be because Saudi Arabia is an area with lots of deserts. The trend increases until PM2.5 is at 63 and then decreases. Where the level of exposure to TBC is relatively low compared to three other developing countries, in Saudi Arabia from 2010 to 2019, namely in the range of 7 to 12 TBC cases per 100,000 populations. This condition is relatively low and the environmental conditions of Saudi Arabia, which contains many deserts, are relatively different from the environments of other countries.

The results of research on the relationship between TBC and PM2.5 in developing countries at the beginning of the research period showed a positive and continuing relationship in the four countries studied (Indonesia, Malaysia, the Philippines and Azerbaijan. These findings supported by the research of Jassal, et al. [13], Smith, et al. [14], Wang, et al. [8] and Min, et al. [7]. This is partly due to the increase in PM2.5 concentrations in developing countries. The high PM2.5 is due to the low technology and resources in an effort to reduce pollution, because of a growing economy that is not only able to cover primary needs. Meanwhile in Saudi Arabia, there is a negative relationship between TBC and PM2.5. This finding is supported by the research results of Min, et al. [7] and Wang, et al. [8] which states that there are efforts to reduce air pollution by mitigating black carbon and organic matter pollution, controlling nitrate emissions and increasing clean energy to prevent TBC recurrence.

3.3. Model of the Relationship between TBC and PM2.5 in developed countries.

The relationship model between TBC and PM2.5, where dummy variables for developed countries are defined as follows:

$$TBC_{ij} = C + \beta_1 PM_i + \beta_2 PM*PM + \gamma_1 D1 + \gamma_2 D2 + \gamma_3 D3 + \varepsilon_{ij} \qquad (5)$$

With TBC_{ij} indicating the TBC in the i-th year and j-th country observations, D1=1 if Japan and 0 otherwise; D2=1 if Israel and 0 otherwise; D3=1 if Singapore and 0 otherwise. From the results of the analysis.

Table 3 shows that model (5) is very significant with F value = 200.49 and p-value <0.0001. Thus, this model can be used to explain the pattern of the relationship between TBC and PM2.5 in developed countries in Asia and also look at the relationship pattern in the developed countries discussed in this research. R-square=0.9672, this means that 96.72% of the variation of TBC can be explained by PM2.5. Table 4 shows that PM2.5 has a significant effect on TBC with p-value=0.0290, likewise PM*PM affects TBC with p-value=0.0061. The pattern of the influence of PM on TBC for each country is presented in the following figures.

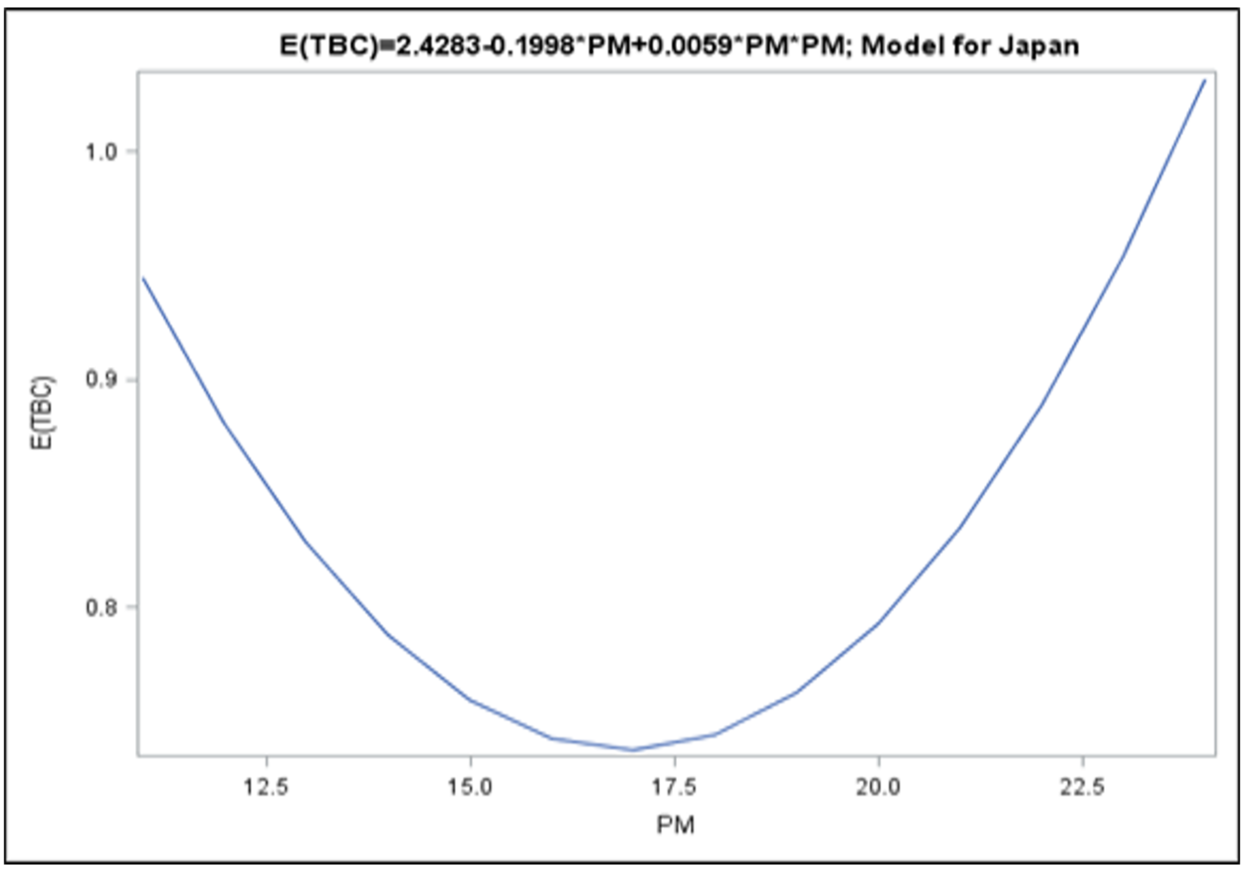

Figure 9.
Pattern of the relationship between TBC and PM2.5 for Japan with PM2.5 values ranging from 12 to 23.

ISSN: 2576-8484
Vol. 9, No. 7: 733-753, 2025
DOI: 10.55214/25768484.v9i7.8722

Table 3.
Analysis variance for testing partial of the model of developed country model (2).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	123.58227	24.71645	200.49	<.0001
Error	34	4.19153	0.12328		
Corrected Total	39	127.77380			

Note: R-squares= 0.9672.

Table 4.
Analysis variance for testing partial of model (2).

Variable	DF	Parameter Estimate	Standard Error	t Value	P-value
Intercept	1	5.66507	0.96044	5.90	<.0001
PM	1	-0.19985	0.08767	-2.28	0.0290
PM2	1	0.00589	0.00201	2.92	0.0061
D1	1	-4.03479	0.18465	-21.85	<.0001
D2	1	-3.23679	0.27771	-11.66	<.0001
D3	1	-2.98202	0.23802	-12.53	<.0001

Figure 9 shows the relationship pattern between TBC and PM2.5 in Japan with PM2.5 values from 2010 to 2019 between 12 and 23, which are relatively very small. The relationship between TBC and PM2.5 for PM2.5 values < 17 is negative (decreasing), and the value of TBC cases increases for PM2.5 values > 17.00 to 23. Furthermore, this relationship is very significant. However, the number of TBC cases in Japan is relatively small, namely less than 1 per 100,000 population.

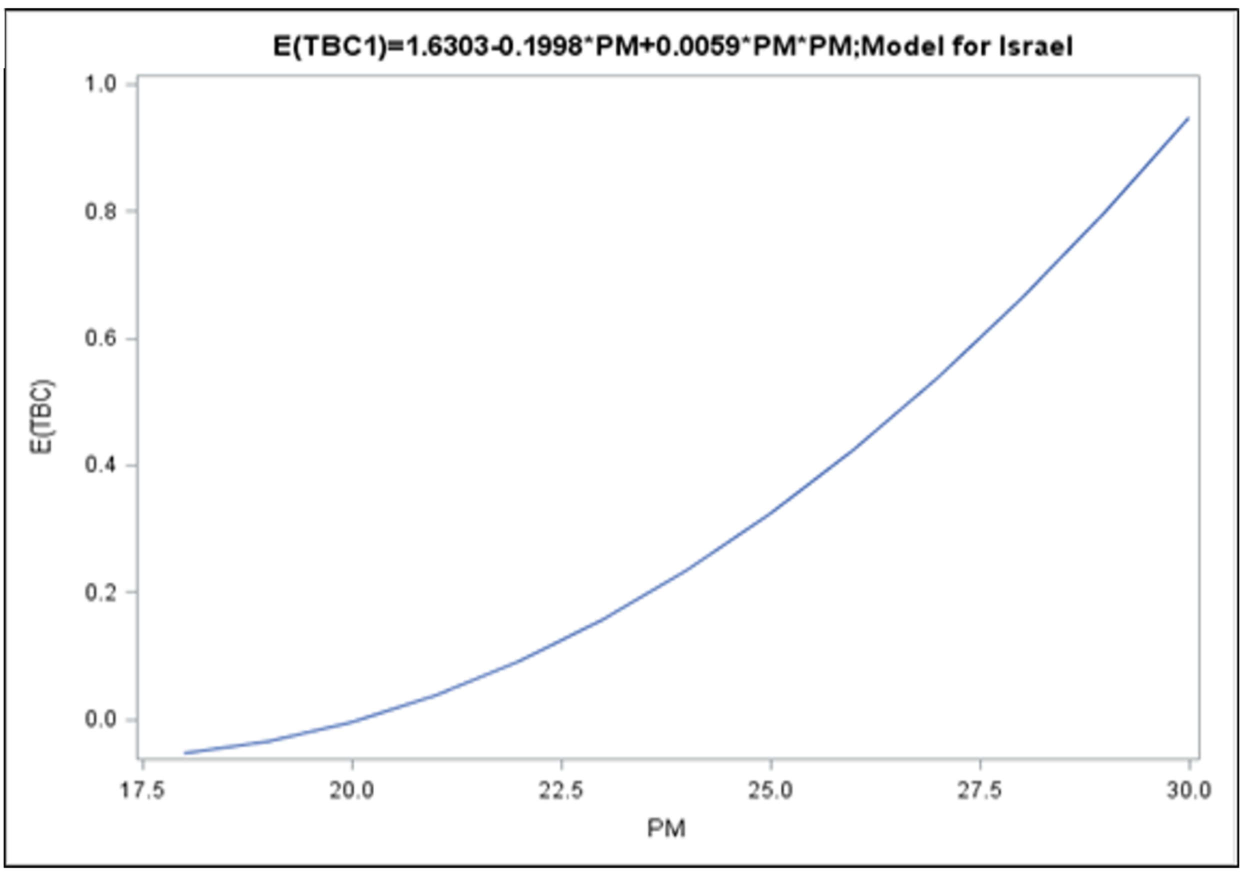

Figure 10.
Pattern of the relationship between TBC and PM2.5 for Israel with PM2.5 values ranging from 17.5 to 30.

Figure 10 shows the relationship pattern between TBC and PM2.5 in Israel, with the PM2.5 value from 2010 to 2019 being between 17.5 and 30, which is relatively very small. The relationship between TBC and PM2.5 for PM2.5 values from 17.5 to 30, the relationship is positive (increases). Furthermore, this relationship is very significant. However, TBC cases in Israel are relatively small, namely less than 1 per 100,000 populations.

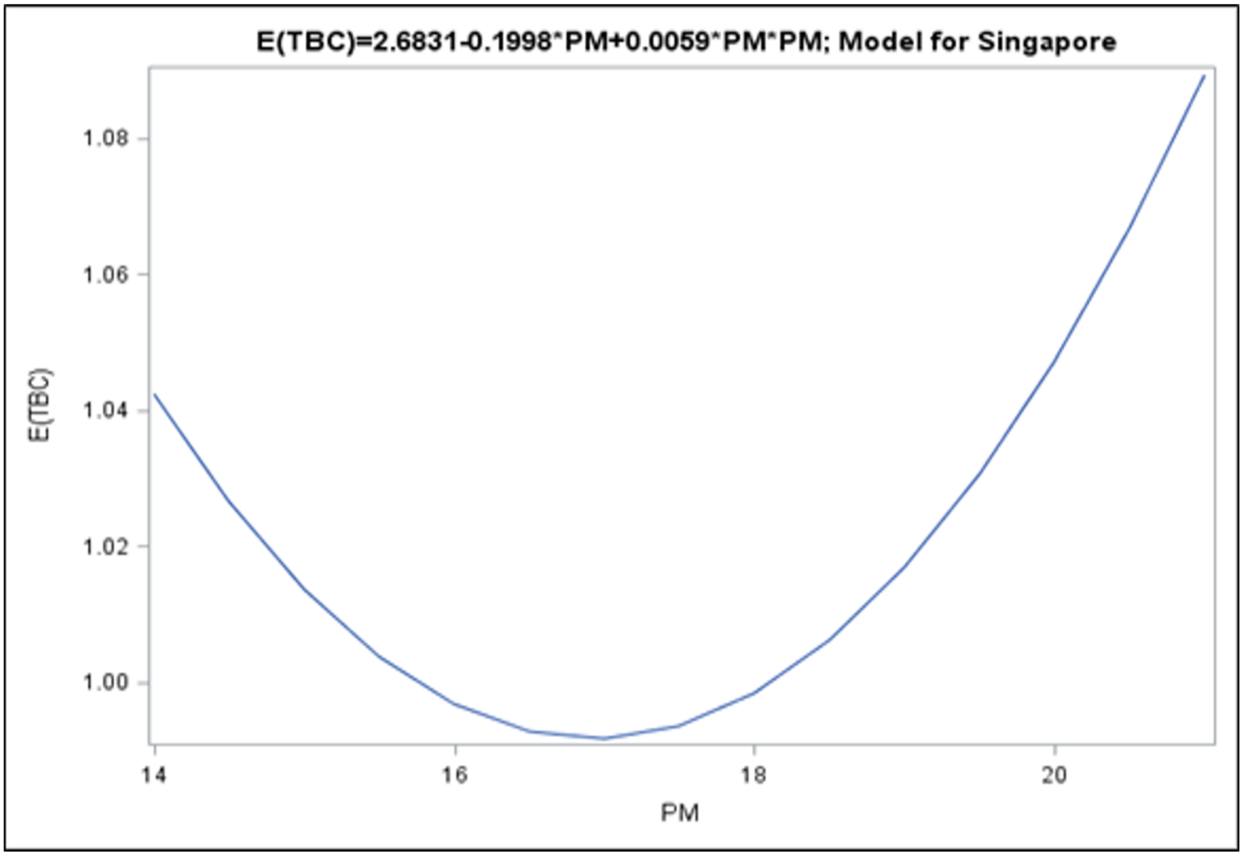

Figure 11.
Pattern of the relationship between TBC and PM2.5 for Singapore with PM2.5 values ranging from 14 to 21.

Figure 11 shows the relationship pattern between TBC and PM2.5 in Singapore with PM2.5 values from 2010 to2019 between 14 and 21, which are relatively very small. The relationship between TBC and PM2.5 for PM2.5 values <17 is negative (decreasing), and the value of TBC cases increases for PM2.5 values >17.00 to 21. And this relationship is very significant. However, TBC cases in Singapore are relatively small, namely less than 1.08 cases per 100,000 populations.

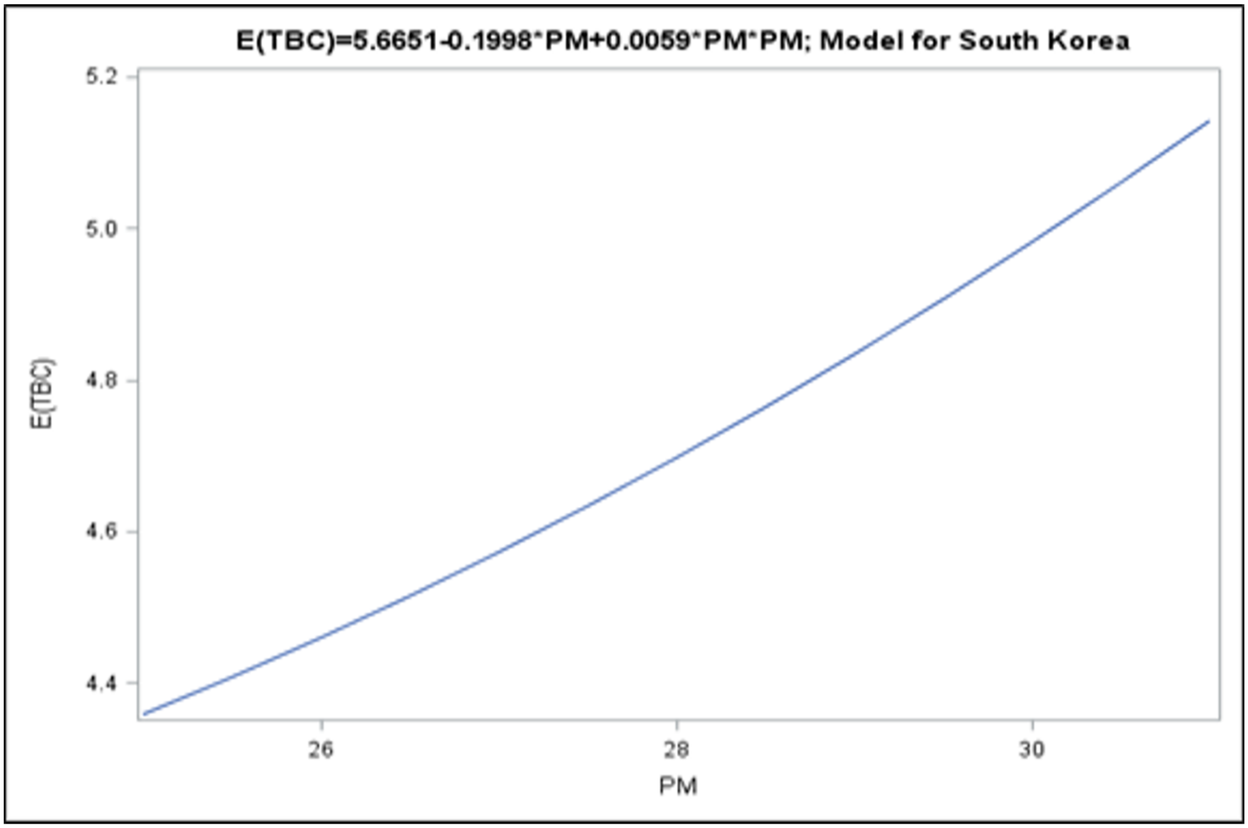

Figure 12.
Pattern of the relationship between TBC and PM2.5 for South Korea with PM2.5 values ranging from 25 to31.

Figure 12 shows the relationship pattern between TBC and PM2.5 in South Korea, with the PM2.5 value from 2010 to 2019 being between 25 and 31, which is relatively very small. The relationship between TBC and PM2.5 for PM2.5 values from 25 to 31, the relationship is positive (increases). Furthermore, this relationship is very significant. However, TBC cases in South Korea are relatively small, namely less than 5 cases per 100,000 populations.

The results of research on the relationship between PM2.5 and TBC in developed Asian countries are not different from the findings in developing countries in this study. That increasing PM2.5 will increase TBC cases Jassal, et al. [13], Smith, et al. [14], Wang, et al. [8] and Min, et al. [7] however, the high PM2.5 and TBC cases in developed Asian countries are smaller than in developing countries. Low PM2.5 in developed countries has better technology and resources so that TBC cases are automatically lower. Developed countries are investing in more environmentally friendly fuels and technology that limits carbon emissions.

3.4. Model of the Relationship between LEB, TBC, and PM2.5 in Developed and Developing Countries.

The relationship model between LEB and TBC, PM2.5, where dummy variables for developed and developing countries are defined as follows:

$$LEB_{ij} = C + \beta_1 TBC_i + \beta_2 PM_j + \beta_3 PM * PM + \gamma_1 D1 + \varepsilon_{ij} \qquad (6)$$

Where LEB_{ij} indicates the observations for the LEB in the i-th year and j-th country, D1=1 for developed countries and 0 fordeveloping countries.

ISSN: 2576-8484
Vol. 9, No. 7: 733-753, 2025
DOI: 10.55214/25768484.v9i7.8722

From the results of the analysis, Table 5 shows that model (6) is very significant with F value = 282.80 and p-value <0.0001. Thus, this model canbe used to explain the relationship pattern of LEB with TBC and PM2.5 in developed countries and in developing countries in Asia. R-square = 0.9301, which means that 93.01% of the LEB variation can be explained by TBC and PM2.5 in both developed and developing countries in Asia.

Table 5.
Analysis variance of model (6).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	2485.11731	621.27933	282.80	<.0001
Error	85	186.73766	2.19691		
Corrected Total	89	2671.85497			

Note: R-square = 0.9301.

Table 6.
Analysis variance for testing the partial model (3).

Variable	DF	Parameter Estimate	Standard Error	t Value	P-value
Intercept	1	76.76971	0.82370	93.20	<.0001
TBC	1	-0.10524	0.01243	-8.47	<.0001
PM	1	-0.13002	0.04256	-3.05	0.0030
PM2	1	0.00150	0.00042741	3.50	0.0007
D1	1	7.97335	0.45203	17.64	<.0001

From Table 6, the estimation model (5) is as follows:

$$LEB_{ij} = 76.7697 - 0.1052\, TBC_i - 0.1300\, PM_i + 0.0015\, PM * PM + 7.9733\, D1 \qquad (7)$$

For the developed country, D1=1, the estimate model is as follows:

$$LEB_{ij} = 84.7430 - 0.1052\, TBC_i - 0.1300\, PM_i + 0.0015\, PM * PM \qquad (8)$$

From Model (8), it appears that the relationship between TBC and PM2.5 is negative on LEB. This shows that if TBC cases and PM2.5 increase, then LEB will decrease, which means that the worse the environment and health, the LEB will decrease. This condition can be seen in Figure 13 below.

ISSN: 2576-8484
Vol. 9, No. 7: 733-753, 2025
DOI: 10.55214/25768484.v9i7.8722

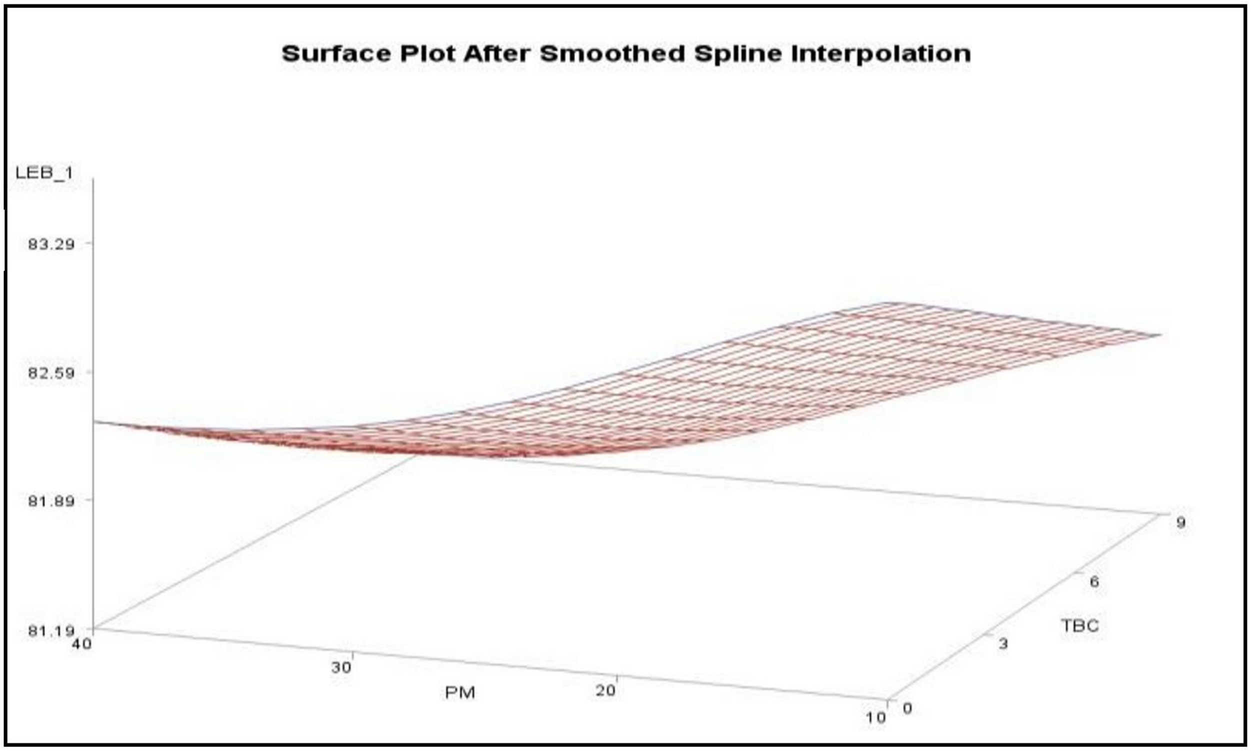

Figure 13.
Pattern of the relationship between LEB with TBC and PM2.5 for developed countries (Model 5).

Figure 13 shows that the environmental pollution caused by PM2.5 is relatively low (<50) which according to WHO, Figure 13 shows that the country has fewer TBC cases and the smaller the PM2.5, the higher the LEB, and Figure 13 also shows that the more TBC cases and the higher the PM2.5, the LEB decreases. These findings are supported by previous research by Kinney [15], Kusuma, et al. [16] and Hasnawati, et al. [11]:

Furthermore, for developing countries, the estimated model (D1=0), is as follows:

$$LEB_{ij} = 76.7697 - 0.1052\ TBC_i - 0.1300\ PM_i + 0.0015\ PM * PM \tag{9}$$

DOI: 10.55214/25768484.v9i7.8722

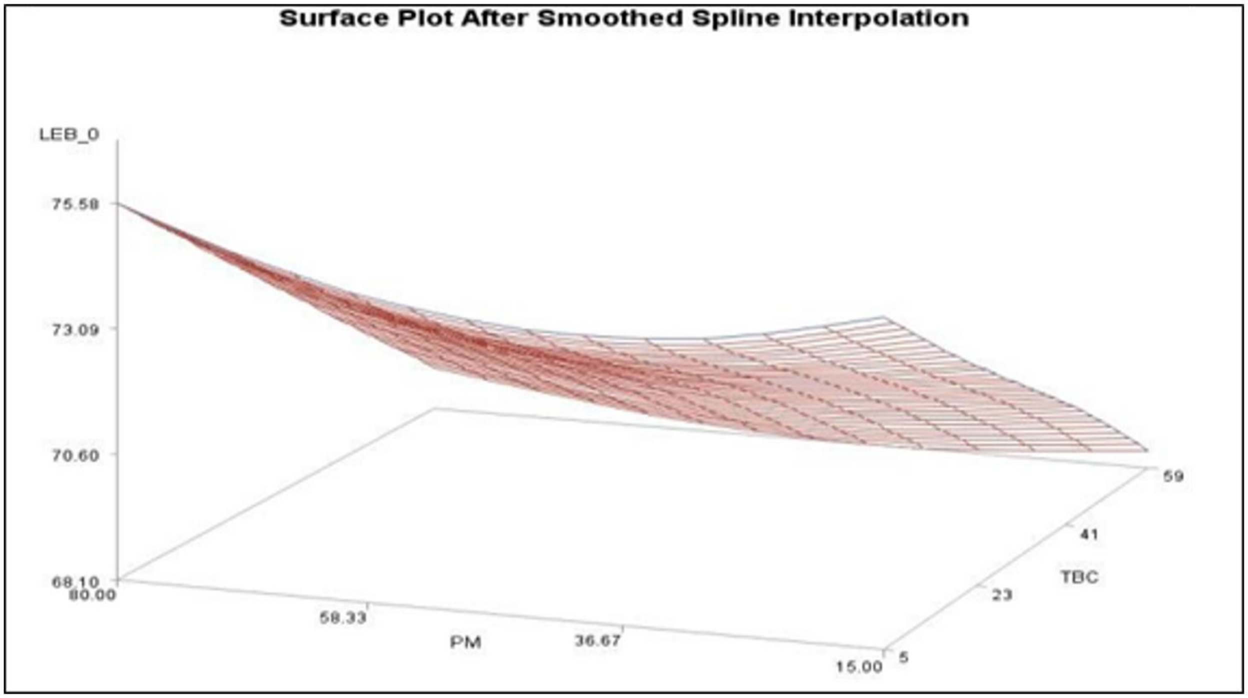

Figure 14.
Pattern of the relationship between LEB with TBC and PM2.5 for developing countries (Model 5).

Figure 14 shows that the environmental pollution caused by PM2.5 is relatively high in several developing countries. Figure 14 shows that the lower the level of TBC cases, the more significant the LEB is. Figure 14 also shows that the lower the PM2.5 and TBC cases, the higher the LEB.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 7: 733-753, 2025
DOI: 10.55214/25768484.v9i7.8722

Figure 15.
Observation value of the real data and predictions using Model (3).

Figure 15 shows the correspondence between the real and predicted values. The image shows that the real and predicted values are close together, indicating that the model fits the real data. Figure 15 also shows that LEB in developed countries is higher than LEB in developing countries in Asia.

4. Discussion

Based on the results of the analysis of the relationship between LEB, PM2.5, and TBC in the developed and developing countries, statistically the resulting model is very fit with the data in the developed and developing countries. The results show that the higher the PM2.5, the higher the TBC cases, and the higher the PM2.5 and TBC cases in a country, the lower the LEB. Based on this finding, it can be used as a basis for determining government policies to reduce the PM2.5 to improve the environment and to reduce TBC cases and increase LEB. Based on this model, it was also found that developing countries have higher levels of PM2.5, TBC and lower LEB compared to developed countries in Asia. Besides, it was found that the higher the PM2.5 and TBC, the lower the LEB. These results occur in developing Asian countries. On the other hand, low PM2.5 and TBC cases impact high LEB in developed countries.

5. Implications of Research Results

The implications of research results from related institutions, especially developing countries, can create policies that support low air pollution, especially to reduce PM2.5. Reducing PM2.5 can be achieved through the application of technology that produces low carbon, the use of environmentally friendly fuel, laws to enforce pollution reduction, reforestation, and bioremediation. Efforts to reduce TBC cases in any country must be made because it will have an impact on increasing LEB. The higher the LEB reflects the welfare of a country's people and a clean environment. Steps to reduce TBC cases include maintaining a clean environment and educating the public about healthy and clean living.

Funding:

This study has a financial support from HETI project Universitas Lampung for the academic year 2023-2024.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all the ethical practices during writing.

Copyright:

References

[1] World Health Organization, "Air pollution,". Retrieved: https://www.who.int/health-topics/air-pollution. 2021.
[2] L. Tohid *et al.*, "Spatiotemporal variation, ozone formation potential and health risk assessment of ambient air VOCs in an industrialized city in Iran," *Atmospheric Pollution Research*, vol. 10, no. 2, pp. 556-563, 2019. https://doi.org/10.1016/j.apr.2018.10.007
[3] Z. Safari, R. Fouladi-Fard, M. Vahedian, M. H. Mahmoudian, A. Rahbar, and M. Fiore, "Health impact assessment and evaluation of economic costs attributed to PM2.5 air pollution using BenMAP-CE," *International Journal of Biometeorology*, vol. 66, no. 9, pp. 1891-1902, 2022. https://doi.org/10.1007/s00484-022-02330-1
[4] Y.-F. Xing, Y.-H. Xu, M.-H. Shi, and Y.-X. Lian, "The impact of PM2.5 on the human respiratory system," *Journal of Thoracic Disease*, vol. 8, no. 1, pp. E69-E74, 2016. https://doi.org/10.3978/j.issn.2072-1439.2016.01.19
[5] J. Lelieveld, A. Haines, and A. Pozzer, "Age-dependent health risk from ambient air pollution: A modelling and data analysis of childhood mortality in middle-income and low-income countries," *The Lancet Planetary Health*, vol. 2, no. 7, pp. e292-e300, 2018. https://doi.org/10.1016/S2542-5196(18)30147-5
[6] T. Sukuman *et al.*, "Health impacts from PM2. 5 exposure using environmental epidemiology and health risk assessment: A review," *Applied Environmental Research*, vol. 45, no. 3, pp. 1-14, 2023.
[7] K.-D. Min, S.-Y. Kim, and S.-i. Cho, "Ambient PM2. 5 exposures could increase risk of tuberculosis recurrence," *Environmental Health and Preventive Medicine*, vol. 28, pp. 48-48, 2023.
[8] H. Wang, C. Tian, W. Wang, and X. Luo, "Temporal cross-correlations between ambient air pollutants and seasonality of tuberculosis: A time-series analysis," *International Journal of Environmental Research and Public Health*, vol. 16, no. 9, p. 1585, 2019.
[9] J. S. Apte, M. Brauer, A. J. Cohen, M. Ezzati, and C. A. Pope, III, "Ambient PM2.5 reduces global and regional life expectancy," *Environmental Science & Technology Letters*, vol. 5, no. 9, pp. 546-551, 2018. https://doi.org/10.1021/acs.estlett.8b00360
[10] J. D. Schwartz, Q. Di, W. J. Requia, F. Dominici, and A. Zanobetti, "A direct estimate of the impact of PM2.5, NO2, and O3 exposure on life expectancy using propensity scores," *Epidemiology*, vol. 32, no. 4, pp. 469-476, 2021. https://doi.org/10.1097/ede.0000000000001354
[11] S. Hasnawati, M. Usman, A. Faisol, and F. A. M. Elfaki, "Analysis and modeling gross domestic product, carbon dioxide emission, population growth, and life expectancy at birth: Case study in Qatar," *International Journal of Energy Economics and Policy*, vol. 13, no. 2, pp. 467-483, 2023. https://doi.org/10.32479/ijeep.14069
[12] J. Rentschler and N. Leonova, "Global air pollution exposure and poverty," *Nature Communications*, vol. 14, no. 1, p. 4432, 2023. https://doi.org/10.1038/s41467-023-39797-4
[13] M. S. Jassal, I. Bakman, and B. Jones, "Correlation of ambient pollution levels and heavily-trafficked roadway proximity on the prevalence of smear-positive tuberculosis," *Public Health*, vol. 127, no. 3, pp. 268-274, 2013. https://doi.org/10.1016/j.puhe.2012.12.030

[14] G. S. Smith, V. J. Schoenbach, D. B. Richardson, and M. D. Gammon, "Particulate air pollution and susceptibility to the development of pulmonary tuberculosis disease in North Carolina: An ecological study," *International Journal of Environmental Health Research*, vol. 24, no. 2, pp. 103-112, 2014. https://doi.org/10.1080/09603123.2013.800959

[15] P. L. Kinney, "Long-term effects of fine particles on mortality: Insights from 1984," *Risk Analysis*, vol. 41, no. 4, pp. 619-626, 2021.

[16] W. L. Kusuma, W. Chih-Da, Z. Yu-Ting, H. H. Hapsari, and J. L. Muhamad, "Pm2. 5 pollutant in asia—a comparison of metropolis cities in indonesia and taiwan," *International Journal of Environmental Research and Public Health*, vol. 16, no. 24, p. 4924, 2019. https://doi.org/10.3390/ijerph16244924