Distance-based Ranking Fuzzy Numbers Approach for measuring air pollution: the Malaysia case

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Abstract

This article discusses the effects of carbon dioxide emission on the economic environment. The major contribution of this study is by improvising the IPAT's fuzzy dilemma into a better model using the Distance-based Ranking Fuzzy Numbers Approach introduced by Ahmad Syafadhli Abu Bakar, Daud Mohamad, Nor Hashimah Sulaiman (2012). This study is a pioneer study using the Ranking Fuzzy Numbers Approach in modeling air pollution measurement in Malaysia. The time series data collected are from 1970 to 2011 where these data will be used to explain the relationship between carbon emission with the population, gross domestic product (GDP) and the manufacturing industry. All calculation and explanation with regards to economic perceptions are also provided. The forecasted value of carbon dioxide emission can be used to assist the government in future planning and development.
Keywords: air pollution, IPAT model, Distance-based Ranking Fuzzy Numbers Approach.

1 Introduction

Air pollutants can be either gases or aerosols, known as particles or liquid droplets suspended in the air. The change in the natural composition of the atmosphere can be harmful to humans and other living species. Moreover, this situation can cause damage to natural water bodies and the land. Anthropogenic is the pollution caused by human activities. Specifically in this study, it has been identified that the population, gross domestic product (GDP) and the

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manufacturing industry adapted from IPAT Model (I: Carbon Dioxide Emission Impact; P: Population; A: Affluence; T: Technology) are the major contributors to the emission of carbon dioxide. A change in economic structure, namely, the growth of the manufacturing industry has affected the amount of carbon emissions where this is happening when a particular economy shifts from subsistence to an agricultural economy and later, to an industrial economy. In this case, pollution levels increase due to the significantly rapid industrial activities as well as the instrumental changes in the manner of the production processes. Furthermore, the trade policy which is under the major activity in the gross domestic product (GDP) stipulates that the more open an economy, the greater the possibilities of importing and exporting pollution intensive commodities that affect the domestic pollution level.

Another matter that warrants attention is the condition that the economic scale is measured against, based on the magnitude of a population, i.e. the bigger the economy, the greater the pollution occurred while other determinants remains constant. Thus, this research will firstly investigate the impact of population density, gross domestic product (GDP) and the manufacturing industry with regards to the links between the growth of population and the environment.

Secondly, this investigation will contribute to the argument that the size of the population and other determinants must be taken into consideration in the forecasting of air pollutant emissions. This study is much likely related to the vast and dynamic literature related to the Environmental Kuznets Curve (EKC). The EKC states that pollution with regards to the environment increases and decreases along the rise in per capita income levels. This can be found in [1, 2] where the impacts of pollution on the environment was highlighted. Population often being included as a scale variable in EKC studies where there were very few systematic quantitative empirical studies on the relationship between population and pollution that were explicitly examined. Cramer [3] studied the effects of population magnitude on the level of air pollution in the US state of California where they came up with a conclusion claiming that some sources of emissions were closely related to the population while others were not.

However, the global implications of Cramer's work was not adequate; this was due to the fact that their attention were limited on one state in a developed country such as the US, hence their main result could be considered to be far from robust. Dietz and Rosa [4] together with York *et al*. [5] in their studies which focus on the emissions of CO_2 and energy used, investigated the roles played by the population, affluence and technology by adopting the Impact-Population-Affluence-Technology (IPAT) model. They found that the ratio of change between energy use and CO_2 emissions was bordering on unity. For example, it was estimated that an approximately one percent increase in CO_2 emissions was the result of a one percent increase in population. This study was later followed by [6] but no projections on the differences between the elasticity and the population levels had been made. Dietz and Rosa [6] later utilized the IPAT model by employing a group of cross-sectional and time series data for similar investigation. They found that the population elasticity for CO_2 to be around 1.41 and 1.65, but no investigation on how different population size

might affect the kind of result was provided. Even though, research done by [6] can be considered to be relevant, it can also have the potential to be severed in terms of their methodology and justification flaws due to [6] only being concerned with one pollutant, namely, CO_2.

For instance, the CO_2 emissions and per capita income, showed consistent increment from time to time. Thus, the covariance stationary condition required for non-biased and regression-stable outcomes were notified as nonexistent. Nonetheless, the validity of the estimated coefficients and elasticity were questionable because many economists have undertaken studies on "Environmental Kuznets Curve" (EKC) which included the population density as one of many of determinants of pollution concentrations [7]. Yet, those studies often produced inconsistent results and fuzzy [1]. The investigation on the population–pollution relationship and the wider effects of population levels against various other pollution related demographic factors or spatial density were extensively dealt with in those studies.

This research tries to provide an in depth analysis on the effects of population magnitude and factors such as gross domestic product (GDP) and the manufacturing industry on air pollution emissions. Adjustment on the flaws of previous studies outlined above is also investigated. This research is based on the works by Dietz and Rosa [6] and Sani [8] and seeks to improvise their studies in many ways. First, the previous studies mentioned earlier investigated only the direct relationship between CO_2 and energy used, neglecting the size of population and numbers of manufacturing industries. Then, this research will consolidate the discussion by forecasting the value and comparing the consistency of the given data. Findings of the irregularities that occur along the period will also be provided and analyzed. The justification of using the Distance-based Ranking Method is the ability to cope with the changes occurring from time to time. It also allows for a further research design that grants effective controlling of the 'latent country' effects. In addition, the comparison of the results with the adaption of ranking fuzzy approach can be achieved. Third, the researcher, using a first-differenced estimator, rectifies the methodological flaw of Dietz and Rosa's [6] investigation by keeping his variables are co-variance stationary. The researchers' estimated results are therefore consistent and not biased.

2 Theoretical background and literature reviews

The scope of the literature is limited to three variables based on the IPAT Model proposed by [6] and [9]. Most of the researchers claimed their models to be the best and came with minimum error. The IPAT model is based on the equation I = f (P, A, T), in which I represents environmental impact with *P*, *A* and *T* represents the variables population, affluence and technology respectively. Global population keeps increasing year by year; numerous literature found that there is a direct correlation between an increasing number of population that lead to high air pollution emission. Sanglimsuwan [10] came up with the empirical evidence that an increase in carbon dioxide emissions is positively associated

with global population change. The result was derived from analyzing the links between carbon dioxide emissions, population, and other related determinants.

He based his empirical study on cross-country data involving 83 countries from the year 1980 to 2007. The results obtained validated the notion that population dynamics affect the amount of carbon dioxide emissions. Sanglimsuwan [10] also added that the results had confirmed that population is an instrumental factor in the manipulation of carbon dioxide increase. In Malaysia, tools for transportation as motorcycles, cars, vans, omnibuses, trucks as well as heavy machineries such as tractors operate on fuel. Usually, the heavy ones operate on diesel. Light vehicles on the other hand, operate on petrol. Sanglimsuwan [10] posits that diesel consuming vehicles contribute more to air pollution. This is because there is more road dirt, and NO_2 and SO_2 and other particles are produced when compared to vehicles consuming petrol. The Department of Education measured that about 622,000 tonnes of air pollutants are released into the atmosphere. These pollutants, by and large are by products of vehicle fuel combustion [8]. 48.7 percent of the pollutants are carbon monoxide particles (CO), with the rest being SO_2 (31.3 percent), NO_2 (11.2 percent), hydrocarbon (6.0 percent) and unstable particles (2.8 percent) [8].

About 96 percent of hydrocarbons come from cars, motorcycles, aircraft and rail transport [11]. He also noted that transportation industry is also estimated to contribute to 70 percent of the total NO_2 generation by fuel combustion in Malaysia. According to the research conducted by Seldon and Song [11], he made numerous efforts to derive the EKC theoretically. The main theoretical explication is that when the number of GDP grew, the bigger the scale of production and this in turn, causes more pollution to take place. However, high income per capita, and the subsequent demand for better health and environmental wellbeing can translate into environmental checks. In this case, there will be agents for favourable shifts in the composition of output and in production techniques.

Malaysia, known to be a developing country throughout the world, enjoys a healthy economy growth, as can be seen from the thriving of many economic activities. The relationship between Malaysia's GDP and her Carbon Emission Index can only be justified by performing a certain test that will be explained in the next section. The paper by Vincent [12] has already provided a prelude into this matter. Vincent [12] chose Malaysia as the subject of his study because Malaysia has achieved a lot of economic progress, apart from of it being one of the fastest growing economies in the region as well as in the world for decades. Not only that, but according to him Malaysia also is good to study because it has more and quality data on environmental quality than perhaps any other country.

Vincent [12] considered his study to be groundbreaking on the matter of the pollution/income relationship over time for a developing country. In Malaysia too, a big portion of solid waste is disposed or discarded using the landfill system. The waste disposal sites, which often look like huge reactors, are normally filled up with waste. With the composting processes of the organic materials that occur as the microorganisms in the soil start to break down the waste, the process produces several gases including methane (CH_4), CO_2, CO,

H_2S and vinyl chloride as a result, which further worsens the air condition. Methane is the gas that is generated in the biggest amount. It is highly flammable [13] and in some instances may cause explosions and this somehow indirectly plays a major role in the air pollution mechanism.

3 Preliminaries

Fuzzy numbers are used as an important component in fuzzy set theory. The definition of fuzzy number can be given as follows.

Definition 1: Based on the research being done by Bakar *et al*. [14], a *triangular fuzzy number* A_i can be represented by the following membership function.

$$\mu_{A_i}(x)=(a_{i1},a_{i2},a_{i3})=\begin{cases}\dfrac{x-a_{i1}}{a_{i2}-a_{i1}} & \text{if } a_{i1}\le x\le a_{i2}\\ \dfrac{a_{i3}-x}{a_{i3}-a_{i2}} & \text{if } a_{i2}\le x\le a_{i3}\\ 0 & \text{otherwise}\end{cases}$$

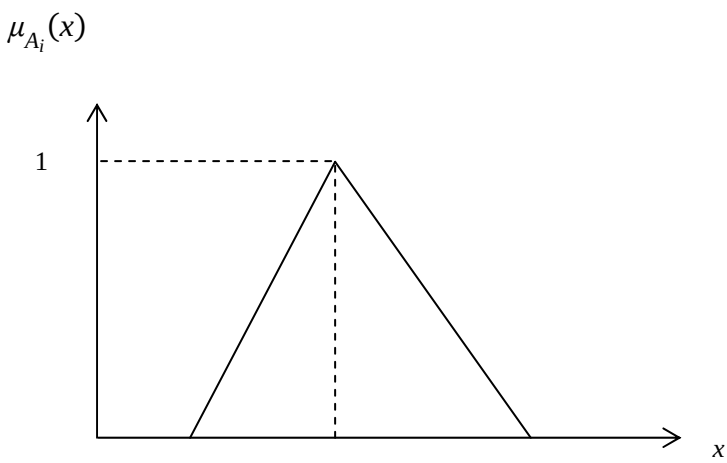

Figure 1: Triangular fuzzy numbers.

4 Methodology

In this case, we applied the Distance-based Ranking Fuzzy Numbers Method shown as

$$\Delta(\widetilde{A}) = x^{*}_{\widetilde{A}} \cdot h^{*}_{\widetilde{A}} \cdot \varphi^{*}(\delta_{\widetilde{A}\widetilde{B}}, \widetilde{A})^{\sigma^{*}(\widetilde{A})}$$

where

$x^{*}_{\widetilde{A}}$ is the centroid of fuzzy number A

$h^{*}_{\widetilde{A}}$ is the height of fuzzy number A

$\varphi^{*}(\delta_{AB}, A)$ is the similarity measure between fuzzy numbers A and B

$\sigma^{*}(\widetilde{A})$ is the spread of fuzzy number.

5 Result analysis

Based on the information provided in Table 1, it shows the result of fuzzy numbers' representation from the IPAT data. By using Distanced-based Ranking Fuzzy Numbers it will help the researcher to see the causal effect for each data interpretation. For example, for the data set number 5, the actual data is 4.608. In reality, does the data exist independently without being influenced by the past factors and form that actual data. From the actual data definitely it will create the continuous impact. Thus, the fuzzy number representation shows at the data set number 5, the value of the past is 3.343 and the future impact data is 9.216. In general, a triangular fuzzy number "a" can be written as (a − α, a, a + β), where α and β are the left and right spreads respectively. These types of numbers are alternately represented as ⟨a, α, and β). In this case, the problem of precision in terms of measuring the carbon emission index that caused air pollution in Malaysia can be determined.

Table 1: Fuzzy analysis.

Data No.	IPAT Data	Fuzzy Numbers Representation
1	1.177	[0.000, 1.177, 2.354]
2	1.474	[1.177, 1.474, 2.948]
3	1.931	[1.474, 1.931, 3.862]
4	3.343	[1.931, 3.343, 6.686]
5	4.608	[3.343, 4.608, 9.216]
6	4.532	[4.608, 4.532, 9.064]

The application of polynomial models is to estimate and predict the shape of response values over a range of input parameter values. Polynomial models are a great tool for determining which input factors drive responses and in what direction. These are also the most common models used for analysis of designed experiments. From Table 2, the value of SSE out of the ten samples is 8.028.

Table 2: Error computed between the actual data and the polynomial model.

Year(x)	Year	Actual Data	Polynomial	SSE
1	2000	49.549	48.799	0.75
2	2001	20.293	18.232	2.061
3	2002	22.650	22.000	0.650
4	2003	27.096	26.369	0.727
5	2004	34.046	33.434	0.612
6	2005	39.099	38.723	0.376
7	2006	46.271	45.671	0.6
8	2007	56.263	55.324	0.939
9	2008	67.812	67.232	0.58
10	2009	53.733	53.000	0.733
			TOTAL	$\left(\sum SSE\right) = 8.028$

Table 3: Error computed between the actual data and linear least square analysis model.

Year(x)	Year	Actual Data	Linear Least Square	SSE
1	2000	49.549	49.049	0.5
2	2001	20.293	19.049	0.5
3	2002	22.650	21.650	1
4	2003	27.096	26.096	1
5	2004	34.046	33.046	1
6	2005	39.099	38.099	1
7	2006	46.271	45.271	1
8	2007	56.263	55.263	1
9	2008	67.812	67.312	0.5
10	2009	53.733	52.733	1
			TOTAL	$\left(\sum SSE\right) = 8.5$

Linear least squares regression is by far the most widely used modeling method. It is what most people mean when they say they have used “regression”, “linear regression” or “least squares” to fit a model to their data. Not only is linear least squares regression the most widely used modeling method, but it has also been adapted to a broad range of situations that are outside its direct scope. It plays a strong underlying role in many other modeling methods. Based on Table 3, the value of SSE out of the ten samples is 8.5.

Table 4: Appearance of uncertainty condition over forecasting period.

Year	Carbon Emission Index	Condition
1994	40.070	IRREGULAR
1995	54.191	NORMAL
1996	42.102	NORMAL
1997	45.132	IRREGULAR
1998	30.150	NORMAL
1999	36.030	IRREGULAR
2000	49.049	NORMAL
2001	19.793	NORMAL
2002	22.650	NORMAL
2003	27.096	NORMAL
2004	34.046	NORMAL
2005	39.099	NORMAL
2006	46.271	NORMAL
2007	56.263	IRREGULAR
2008	67.312	IRREGULAR
2009	53.733	IRREGULAR
2010	70.775	NORMAL

Some consequences include the increase in pollution levels. For instance, with the outbreak of diseases that are caused by pollutants or the collapse of an ecosystem as one of its links ceases to perform. When occurrence conditions involve uncertainty, avoiding or preparing for such catastrophes is particularly difficult. In addition, to endorse the belief, the Distance-based Ranking Fuzzy Numbers Approach can quantity the uncertainty by showing several irregular signals for the years 1994, 1997, 1999, 2007, 2008 and 2009. It shows that there is uncertainty occurring which is not included in the model such as open burning outside from a foreign country and a haze issue with unjustified causes. For example, the haze cases in Southeast Asia that occurred in the period 1994 to 1997 had imposed threats to the environmental management and increased its citizens' awareness of the environment [15]. Furthermore, the major sources of pollution from stationary sources are basically from industries and solid waste combustion. Power stations accounted for 22.5 percent (1.7999 million tonnes) of the total annual use of fuel [8]. This also means that power plants released about 46.1 percent of SO_2 and the remaining 51.6 percent are shared by other industrial emissions [8]. Besides industries, wood burning also contributes to about 40 percent of total particulate emission [8]. Forest burning practices in Kalimantan and Sumatera, Indonesia (80, 180 hectares) in year 1997 is the single major contributor to the air pollution scenario then, which caused haze for months in our country [16].

6 Conclusion

The utilization of the fuzzy approach in analyzing the data was appropriate since the result obtained was relevant and consistent with previous studies.

Representation of our data in terms of the fuzzy numbers form was also appropriate since the fuzzy number was known to have the ability to deal with uncertain and fuzzy data value. Thus, the actual and forecasted data were well presented and analyzed. Again, based on the discussion on the significance of the study, to preserve the sustainability the environment's sustainability, various measures should be implemented. Emphasis should be accorded to the use of renewable alternative energy as well as the increasing of energy efficiency. The Government is therefore recommended to operate the Feed-in Tariff and alternative Energy Fund so as to stimulate the implementation of alternative energy projects. Guidelines, standards and laws that are not relevant and acceptable could also be launched and initiated to ensure efficient usage and management of the energy, and to primarily minimize the release of greenhouse gas into the air. A sense of responsibility alone is not adequate for a comprehensive effort on environment conservation. The Government should, therefore, promote economic opportunities that bring merits on conservation. Eco-tourism, for instance can generate income particularly for local communities to encourage the conservation of the country's flora and fauna. The Government will also need to promote environmentally friendly housing by introducing appropriate guidelines on the green rating system. Putrajaya and Cyberjaya should champion and flagship green townships. The Government should take the lead in adopting green building standards in the countries. New Government buildings should also be designed in a way that meets the green standards such as the development of the Diamond Building at Precinct 2.

References

[1] Cole, M. A., A. J. Rayner and J. M. Bates. (1997). "The Environmental Kuznets Curve: An Empirical Analysis," *Environment and Development Economics*, 2, pp. 401–416.

[2] Grossman, G. M. and A. B. Krueger. (1991). "Environmental Impacts of a North American Free Trade Agreement," NBER Working Paper No.3914, *Cambridge: National Bureau of Economic Research.*

[3] Cramer, J. C. (1998). Population growth and local air pollution: methods, models, and results. In W. Lutz, A. Prskawetz & W. C. Sanderson (Eds.), *Population and environment* (A supplement to Vol. 28). *Population and development review*, pp. 22–52. New York: Population Council.

[4] Dietz, T., & Rosa, E. A. (1997). Effects of population and affluence on CO_2 emissions. *Proceedings of the National Academy of Sciences*, 94(1), pp. 175–179.

[5] York, R., Rosa, E.A., & Dietz, T. (2003b). Footprints on the earth: the environmental consequences of modernity. *American Sociology Review*, 68(2), pp. 279–300.

[6] Dietz, T. and Rosa, E.A. (1994). *Rethinking the environmental impacts of Population, Affluence and Technology.* Human Ecology Review. Summer/Autumn, 1.

[7] Grossman, G. M. and A. B. Krueger (1994), "Economic Growth and the Environment," *Quarterly Journal of Economics*, 110, pp. 353–377.
[8] Sani, S., (1987). Urbanization and the Atmospheric Environment in the Low Tropics – Experience From The Kelang Valley Region Malaysia. *Universiti Kebangsaan Malaysia, Bangi*.
[9] Ehlirch, P.R., & Holdren, J.P. (1971). Impact of population and growth. *Science*, 171, pp. 1212–1217.
[10] Sanglimsuwan, K. (2012). The impact of population pressure on carbon dioxide emission: evidence from a panel-econometric analysis. *International Research Journal of Finance and Economic*s, 82 (2012), pp. 90–93.
[11] Seldon, T. and D. Song. (1994). "Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?" *Journal of Environmental Economics and Management*, 27, pp. 147–162.
[12] Vincent, J. R., (1997). Testing for environmental Kuznets curves within a developing country. *Environment and Development Economics* 2: pp. 417–31.
[13] Afroz, R., Hassan, M., and Ibrahim, N.K., (2003). Review of air pollution and health impacts in Malaysia. *Environmental Research*, 92, pp. 71–77.
[14] Bakar, A.S.A., Mohamad, D., and Sulaiman, N.H., (2012). Distance-Based Ranking Fuzzy Numbers. Advances in Computational Mathematics and its Applications (ACMA) 146 Vo. 1, No. 3, World Science Publisher, United States.
[15] Canter, L. W., (1985). Environmental Impact Assessment. University of Oklahoma, McGraw Hill Book Company.
[16] Horany, N.M., (1998). Kajian Pencemaran Udara: Kesan Jerebu Terhadap Masalah Kesihatan di Johor Bahru. *Universiti Teknologi Malaysia: PSM thesis*.