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Carbon Emissions, Economic Growth, Forest, Agricultural Land and Air Pollution in Indonesia

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ABSTRACT

This study specifically analyzes the effect of motor vehicle emissions, economic growth of forest area, and agricultural area on air pollution in 33 Indonesian Provinces during the year 2010-2017 using the panel data regression approach. The results showed that (1) Carbon emissions and agricultural area in all regions in Indonesia had a negative and significant effect on the air quality index (2) Based on the regions of Sumatra Island, Java Island, and Kalimantan Island, GDP had a positive and insignificant effect on air pollution (3) Forest area in all regions in Indonesia, as a whole, has a positive and significant effect on the air quality index.

Keywords: Air Pollution, Carbon Emissions, Economic Growth, Forests, Agriculture
JEL Classifications: Q50, Q53

1. INTRODUCTION

Air pollution is the biggest threat to global health (Alvarado et al., 2019; Wang et al., 2019; Martinez et al., 2018; Cohen et al., 2017). The world health organization (WHO) estimates that there were 4.9 million of premature deaths that caused by ambient air pollution in 2017 (Health Effects Institute and Project, 2019). This condition continues to increase every year at an alarming rate around the world, especially in low and middle-income countries (Pinder et al., 2019; Gulia et al., 2020; Antoine et al., 2019). Over the last two decades, Indonesia has experienced very significant changes in its air quality during the period 1998 to 2016; Indonesia is one of the twenty most polluted countries in the world (Greenstone and Fan, 2019). National air quality in 2018 is classified as good with a value of 84.74. As many as 32 provinces experienced a decrease in air quality index (AQI) except DKI Jakarta and South Sulawesi which experienced an increase of 13.07 points and 4.90 points respectively (Ministry of Environment and Forestry, 2018).

The main cause of increasing air pollution is the number of motorized vehicles (Wang et al., 2019) which significantly impacts motor vehicle pollution causing 8.9 million deaths globally (Burnett et al., 2018). Indonesia tends to experience a decrease in air quality in several areas due to increased usage of transportation, this is evidenced by an increase in particles (PM_{10} and $PM_{2.5}$) and ozone oxidant (O3) (Ministry of Environment and Forestry, 2018). Jakarta is the main contributor to motor vehicle pollution, namely 35 percent of $PM_{2.5}$ in all cities in Indonesia in 2008-2009 (Greenstone and Fan, 2019). According to WHO, the impact of $PMexposure_{2.5}$ causes an increased risk of respiratory disease, cancer, irritation and phenomena, and even death, in addition to these health problems it will have an impact on visibility and environmental damage (Samet et al., 2000; Puett et al., 2014). People who live near highways have a higher risk of exposure to air pollution and its side effects on health (Krzyzanowski et al., 2005; Venn et al., 2000).

Increasing usage of agricultural land will lead to poorer environmental quality, this condition is related to agricultural activities such as the use of many chemicals in the agricultural process, the types of plants that are modified (genetically) and the types of land (peat) used will cause environmental conditions, namely climate change, deforestation, pollutants and genetic pollution (Agbogidi, 2011; Onu and Ikehi, 2016). In line with that, the negative impact of agricultural activities especially agricultural land use, such as forest conversion will cause degradation of soil quality, soil pollution, aquifer and surface water (Phairuang et al., 2019). The relationship between the agrarian sector and air pollution is bilateral in nature, the cause of air pollution, namely agricultural activities related to deforestation, exploitation of natural plant resources such as forestry (Olsen et al., 2020, Phairuang et al., 2019). Clearing forests for use as plantations or agro-industry has a significant impact on increasing air pollution (Phairuang et al., 2019; Rosales-Rueda and Triyana, 2018) one of the impacts of using forests as plantations or agro-industry is forest fires (Phairuang et al., 2019; Rosales-Rueda and Triyana, 2018; Chaiyo and Garivait, 2014) the impact of causing a decline in health and causing various respiratory diseases (Cheong et al., 2019).

The key to reduce pollutants is by expanding land cover (Sun et al., 2016). Increasing land cover in urban areas can affect pollutant concentrations and will reduce the spread with an impact on energy demand and biogenic emissions in the surrounding area (Sun and Zhu, 2019; Xian et al., 2007; Nowak et al., 2000). The interaction of land cover on environmental quality, especially air quality, will have an environmental impact on the sustainable atmosphere (Vadrevu et al., 2017).

The relationship between economic growth and the environment is contradictory; generally the increasing of economic growth will cause environmental degradation in accordance with the Environmental Kuznets Curve (EKC) (Ali and Oliveira, 2018). Policies in developing countries have entered the stage *clean economy* while developing countries are still experiencing the impact of pollution simultaneously as a result of increasing economic growth (Andrée et al., 2019; Zheng et al., 2015)

2. LITERATURE REVIEW

The relationship between economic growth and the environment is questionable whether limited resources or increased income can improve environmental conditions (Griffin and Schiffel, 1972; Grossman et al., 1991; Panayotou, 1994). Economic progress has had a significant impact, especially on the increasing motorized vehicles which have an effect on air pollution (Greenstone and Fan, 2019; Burnett et al., 2018). In general, motorized vehicle emissions contribute greatly to urban air pollution worldwide (Health Effects Institute, 2010; Lyons et al., 2003). This linkage is discussed in the literature review in terms of transportation and air pollution. The main sources of air pollution are related to transportation, namely the number of motorized vehicles, traffic, and congestion (Brugge, 2019; Burnett et al., 2018). Exposure to air pollution caused by transportation traffic has a significant impact on health conditions (Burnett et al., 2018) and at an advanced stage will have an impact on children's health (Frondelius et al., 2018). In response to it, the need for economic policies must be based on environmental policies (Bo, 2011; Crespo et al., 2017). One of the policies that can reduce pollution is to expand land cover (Sun et al., 2016).

The implications of economic growth for environmental policies are related to the interpretation of the U-shape model which confirms that developing or lower-middle-income countries must carry out strict regulations regarding land cover. It because economic growth is not sufficient to restore the condition of natural forests lost (Andrée et al., 2019; Crespo et al., 2017; Panayotou, 1993). In addition, there is a need for policies to increase trees, especially in urban areas, because most of the elimination of pollution occurs in rural areas that still have trees and forests (Nowak et al., 2014).

3. METHODS

This research is focused on analyzing the effect of motor vehicle emissions, forest area, and economic growth on air pollution in Indonesia. This study uses secondary data in the form of panel data, namely a combination of time series data and cross-section data in the period 2010-2017 of 33 provinces in Indonesia. The data source is obtained from the official website of the Ministry of Environment and the Indonesian Central Bureau of Statistics by taking data on indicators of developments in environmental conditions. The variables used can be seen in Table 1:

The analytical approach used is a panel data regression analysis model with the following specifications (Greene, 2012):

$$Y_{it} = x_{it}^{'}\beta + z_{j}^{i} + \varepsilon_{it}$$

$$Y_{it} = x_{it}^{'}\beta + c_{i} + \varepsilon_{it}$$

There is a K regressor in x_{it} which is not included in the constant term. Heterogeneity or the individual effect $z_i' \alpha$ where z_i contains the term and one individual or group variable. If z_i is all individuals observed in the model it can be treated as an ordinary linear model and suitable for use in the OLS model. There are several types of models that can be estimated in panel data estimation. However, the most common is the model Pooled Least Square, Random Effects Model, Fixed Effects Model.

This model will use Natural Logarithms to get a higher level of significance (Gerdes, 2011; Croissant and Millo, 2008) so the model equation can be written as follows:

Table 1: Research variables, data units, and data sources

No.	Variable	Unit	Symbol	Source
1	Air Quality	Index	IKU	IKLH (Ministry of Environment)
2	Number of Motor Vehicles	Unit	JKM	Indonesian Statistics (Central Statistics Agency)
3	Gross Regional Domestic Product	Million Rupiah	PDRB	Indonesian Statistics (Central Statistics Agency)
4	Forest Area	Thousand Acres	LH	Indonesian Statistics (Central Statistics Agency)
5	Plantation Area	Thousand Acres	LAP	Indonesian Statistics (Central Statistics Agency)

$$LNIKU_{it}=\beta_0+\beta_1\ LNJKM_{it}+\beta_2\ LNPDRB_{it}+\beta_3\ LH_{it}+\beta_4\ AP_{it}$$

To decide which model to estimate, we performed the Breusch-Pagan Lagrange multiply (LM) test for fixed effects and the Hausman test for options using the fixed-effect model or the Random Effect Model and heteroscedasticity test.

4. RESULTS AND DISCUSSION

4.1. Summary Statistic of Air Pollution Indicator

Table 2 describes the regional air pollution conditions in Indonesia which are classified by islands namely Sumatra, Java, Bali and Nusa Tenggara, Kalimantan, Sulawesi and Maluku, and Papua Islands. Java is an area in the red category or classified as having exposure to unhealthy air pollution. Meanwhile, the islands of Kalimantan, Sulawesi as well as Maluku, and Papua have the healthiest air quality in Indonesia. The indicators that determine air quality in Indonesia are inseparable from motor vehicle emissions, economic conditions, forestry, and agricultural activities.

Motor vehicle emissions are the main cause of high air pollution in Java and the lack of green open space as seen from the low forest area when compared to the eastern region of Indonesia which the low use of motorized vehicles and the high availability of green open space. Andrée et al. (2019) explain empirically that the economy of a region cannot protect it from the impact of environmental damage. In line with that, the concentration of the Indonesian economy located on the island of Java is not in line with environmental conditions, this condition is a stage where a good economy is a threat to the environment (Meadows et al., 1972).

4.2. Analysis of Panel Regression

Statistical tests based on the Chow, Hausman and Breusch-Pagan Lagrange multiply (LM) tests which are classified by region in Table 3 which shows the variation of the model:

Table 4 shows the results of panel data regression estimation where panel A shows the Common Effect Model, Panel B Fixed Effect Model and Panel C the Random Effect model. Regionally, it shows that the number of motorized vehicles in all regions in Indonesia has a negative and significant effect on the air quality index, which means that any increase in the number of motorized vehicles will reduce air quality. These results are consistent with previous literature studies that the main sources of air pollution are related to transportation, namely the number of motorized vehicles, traffic and congestion (Brugge, 2019; Burnett et al., 2018; Health Effects Institute (HEI), 2010; Lyons et al., 2003).

Areas that are not an economic concentration or the region's low GDP contribution to Indonesia's gross regional domestic product (GRDP) such as Bali Island and Nusa Tenggara, Sulawesi, Maluku and Papua have negative coefficients, this shows that an increase in GDP will reduce air quality, consistent with the theory of Environmental Kuznet Curve (Kuznets, 1955). In line with it, air pollution has a profound impact on low-income areas resulting from increased economic growth (Andrée et al., 2019; Ali and Oliveira, 2018; Zheng et al., 2015).

Table 2: Descriptive statistic by region (2010-2017)

Region	Air Pollution	Vehicle	GDP	Forestry	Agriculture Area
Sumatra Island (n = 80)					
Minimum	52	28353	28353	382	67
Maximum	100	487531	487531	9456	3167
Mean	88	184420	184420	2540	1160
Std.Deviation	10	134853	134853	2028	890
Java (n = 48)					
Minimum	13	881 155	64 679	0	17
Maximum	115	20,730,267	1,635,367	117 135	1361
Mean	48	9,407,229	810 705	19 967	552
Std.Deviation	23	5680953	489 436	20 486	477
Bali and Nusa Tenggara (n = 24)					
Minimum	77	908 897	43 847	2958	131
Maximum	100	4931597	144 945	49 128	1809
Mean	89	2345225	83 219	20 965	988
Std.Deviation	7	1330154	30315	13 396	692
Kalimantan (n = 32)					
Minimum	77	846 469	56 531	5887	1567
Maximum	100	2966407	469 646	172 163	15300
Mean	90	2045534	181 079	37 082	9559
Std.Deviation	6	627837	155153	37283	5147
Sulawesi (n = 48)					
Minimum	77	846469	56531	5887	1567
Maximum	100	2966407	469646	172163	15300
Mean	90	2045534	181079	37082	9559
Std.Deviation	6	627837	155153	37283	5147
Maluku and Papua (n = 32)					
Minimum	28	39 756	14984	2401	2515
Maximum	92	956547	148823	38363	42225
Mean	62	548234	53423	12708	12850
Std. Deviation	17	301089	43303	7601	13252

Table 3: Diagnostics panel test

Region	Test			Best Model
	Chow	Hausman	LM	
Sumatra	3.179 (0.0030)	20.99 (0.000)	51.39 (0.000)	FEM
Java	3,412 (0.021)	13.64 (0.008)	3,795 (0.0514)	FEM
Bali and Nusa Tenggara	4,027 (0.0371)	0.000 (1,000)	2,818 (0.0932)	FEM
Kalimantan	1.21 (0.3253)	10,661 (0.0306)	16,658 (0.000)	FEM
Sulawesi	1,919 (0.117)	8,887 (0.064)	54.44 (0.000)	CEM
Maluku and Papua	2,080 (0.194)	2.9714 (0.5626)	0.523 (0.4694)	REM

Table 4: Air pollution indicator

Panel A: Common effect model by region						
Region	C	Vehicle	GDP	Forestry	Agriculture Area	Adj
Sumatera	2.078*** (0.00)	0.0596* (0.06)	–0.0797*** (3.17)	–0.0275 (0.21)	–0.0051 (0.21)	0.23
Java	4.253*** (2.62)	0.102 (1.68)	–0.125 (0.62)	0.007 (0.05)	0.016 (0.25)	0.21
Bali and Nusa Tenggara	8.35*** (12.08)	–0.021*** (7.79)	0.13 (0.15)	–0.087*** (17.58)	–0.058 (2.46)	0.36
Kalimantan	6.057*** (6.58)	–0.086 (0.65)	–0.005 (0.056)	0.017 (0.23)	–0.059 (0.38)	0.21
Sulawesi	4.89*** (66.2)	–0.0168*** (4.33)	–0.011*** (4.106)	0.003 (0.454)	–0.004 (1.57)	0.06
Maluku and Papua	5.286*** (25.8)	–0.036*** (2.80)	–0.084*** (2.500)	0.075*** (2.87)	–0.019 (0.275)	0.28
Panel B: Fixed effect model by region						
Region	C	Vehicle	GDP	Forestry	Agriculture Area	Adj
Sumatera	2.716*** (16.5)	–0.2046*** (2.8)	0.055 (0.51)	0.0778*** (4.2)	–0.00493*** (18.3)	0.47
Java	–486.24*** (7.01)	–0.295** (2.154)	0.1796 (0.596)	85.23*** (6.91)	–0.0144 (0.415)	0.36
Bali and Nusa Tenggara	–21.69*** (2.07)	–0.119*** (2.95)	–0.356*** (2.67)	5.046*** (3.85)	–0.113*** (3.86)	0.48
Kalimantan	5.90*** (6.55)	–0.253*** (3.12)	0.197 (1.48)	0.030 (0.454)	–0.0499 (0.763)	0.42
Sulawesi	6.074*** (7.22)	0.052 (0.79)	–0.2006 (0.344)	0.009 (0.34)	–0.0304*** (3.53)	0.16
Maluku and Papua	5.090*** (4.16)	0.013 (0.237)	–0.161 (0.2514)	0.110* (1.912)	–0.002 (0.266)	0.36
Panel C: Random effect model by region						
Region	C	Vehicle	GDP	Forestry	Agriculture Area	Adj
Sumatera	2.1141*** (12.02)	0.0512 (0.4)	–0.0799*** (3.3)	–0.022 (0.54)	–0.0048*** (3.16)	0.20
Java	4.253*** (3.65)	0.102*** (0.10)	–0.125 (0.77)	0.007 (.073)	0.016 (0.38)	0.05
Bali and Nusa Tenggara	7.103*** (3.65)	–0.027 (0.203)	–0.138 (0.888)	–0.041 (0.954)	–0.1408	–0.03
Kalimantan	5.172*** (9.56)	–0.197 (0.238)	0.050 (0.487)	0.013 (0.63)	–0.129 (0.617)	0.13
Sulawesi	4.973*** (18.82)	–0.030 (1.01)	–0.014** (2.02)	0.011 (0.357)	0.005 (0.867)	0.07
Maluku and Papua	5.295*** (41.4)	–0.036*** (9.12)	–0.073** (2.176)	0.067** (2.359)	–0.027** (2.405)	0.21

*0.1, **0.05, ***0.01

In contrast, areas that have the concentration of GRDP in Indonesia namely Sumatra, Java and Kalimantan, show positive coefficient results but the effect is not significant, which means that an increase in GDP does not directly affect the improvement of air quality. It is consistent with the results of Ali and Oliveira (2018) that economic growth has a positive effect but the effect is indirect but depends on the decomposition of economic growth itself. Hettige et al. (2000) explained that economic growth does not directly determine the quality of air pollution but is determined by three main factors, namely the contribution of industry to national output, the contribution of pollution and the intensity of pollution.

The impact of forestry in all regions in Indonesia, as a whole, has a positive and significant impact on air quality, meaning that any increase in forest area will improve air quality. The forest will directly reduce air pollution in all regions in Indonesia. The results of this study are consistent with Crespo et al. (2017), Sun et al. (2016) and Bo (2011) found that policies to reduce pollution are to expand land cover by expanding natural forest areas, especially in the City of Jakarta as the main contributor to air pollution in Indonesia.

The coefficient value of agricultural area in all regions in Indonesia has a negative value, which means that agricultural area has a negative effect on air quality in Indonesia. This study is consistent with previous literature such as Olsen et al. (2020), Phairuang et al. (2019) Rosales-Rueda and Triyana (2018), Onu and Ikehi (2016) Agbogidi (2011) and Chaiyo and Garivait (2014) who found a significant impact on agricultural activities, especially land use such as agro-industry and forest exploitation will increase air pollution. There are two regions in Indonesia, namely Java and Kalimantan, where statistically agricultural areas do not have a significant impact on decreasing air quality. This condition is due to the small number of agricultural areas in the two areas, which causes an indirect effect on air quality.

5. CONCLUSION

This study analyzes the effect of motorized vehicle emissions, economic growth of forest area and agricultural area using panel regression in each region in Indonesia. In accordance to Brugge (2019), Burnett et al. (2018), Health Effects Institute (2010), Lyons et al. (2003) it can conclude that motor vehicle emissions will increase air pollution. Consistent with the theory (Kuznets, 1955), economic growth in low-income areas namely Bali and Nusa Tenggara, Sulawesi, Maluku and Papua islands, has a negative effect on air quality. In contrast to high-income regions such as Sumatra, Java and Kalimantan, it has a positive effect on improving air quality in Indonesia. In particular, forest areas in all regions in Indonesia have a positive impact in improving air quality in contrast to agricultural areas which have a negative impact on air quality in all regions in Indonesia.

Empirical analysis evidence in both low-income and high-income regions of Indonesia finds that motor vehicle emissions are a determining factor for declining air quality. It needs an environmental regulations and policies related to the concentration of motor vehicle emissions (Ouyang et al*.,* 2019; Ali and Oliveira, 2018). Government can make intervention to raise the demand for national electric vehicles and public transportation, also reduce the use of private transportation especially for vehicles that have high vehicle emission levels (Baayoun et al*.,* 2019; Connolly et al*.,* 2019). In addition, motor vehicle emissions and conversion of agricultural land causes air pollution to increase (Olsen et al*.,* 2020; Phairuang et al., 2019). Air pollution can be overcome by managing agricultural land and reducing agro-industrial activities (Phairuang et al., 2019; Török et al., 2016).

It empirically proves that forest area will reduce exposure to air pollution in Indonesia (de Mello et al*.,* 2020) thus it need forest restoration as well as forest conservation and maintaining plant diversity (Lillo et al., 2019). Economically there is an inequality of income in every region in Indonesia, therefore to create a sustainable environment it need government intervention related to inequality (Lillo et al., 2019) and reduce income inequality in the Eastern Indonesia region also creating social sustainability such as poverty alleviation (Scherer et al*.,* 2018; O'Neill et al., 2018).

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