

The Impact of Regional Policy and Population Growth on Environmental Kuznets Curve for Agricultural Sector in Indonesia: A Provincial Dynamic Panel Data Analysis

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Abstract

This paper aims to determine the impact of regional policy (RAD GRK) and population on GHG emission reductions in the Environmental Kuznets Curve (EKC) hypothesis of land-based agriculture (food crops, horticulture, and plantations) in Indonesia. This study uses provincial-level panel data and is processed using the GMM system method. The conclusion of this study proved the occurrence of the EKC hypothesis of the land-based agriculture sector in Indonesia with turning points of Rp. 44,201,600 /capita and Rp. 43,888,800/capita. The results of the study show that regional government policies and population growth in Indonesia has reduced the level of GHG emissions in the land-based agriculture sector.



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Introduction


The challenges of agricultural development today are not only to meet food needs, but also must be more environmentally friendly. Food demand is expected to continue to increase with an increasing population.^{1,2} The increasing need for food both from food crops, horticulture, plantations, and animal husbandry spurs productivity in the agricultural sector which

triggers an increase in greenhouse gas (GHG) emissions in the agricultural sector.³⁻⁵ In Indonesia, the agricultural sector's GHG emissions are dominated by the land-based agriculture subsector (food crops, horticulture, and plantations) compared to the livestock subsector. Data from Kementerian Lingkungan Hidup dan Kehutanan (The Ministry of Environment and Forestry)⁶ in 2017 emissions from

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the land-based agriculture sector reached 98,956.86 GgCO₂eq, while emissions from the livestock sector only amounted to 21,070.52 GgCO₂eq.

To reduce the rate of GHG emissions in 2009 the Indonesian government issued a policy called Rencana Aksi Pengurangan Emisi Gas Rumah Kaca (RAN-GRK) (Decree for GHG Emission Reduction) where Indonesia is committed to reducing GHG emissions by 26% with domestic effort and by 41% using international assistance based on estimates from BAU (Business as Usual).^{7,8} Agricultural sector emissions are targeted to decrease by 21 MtCO₂eq/year until 2030.¹⁰ At the regional (provincial) level, each Provincial Government is required to issued Rencana Aksi Daerah Penurunan Emisi Gas Rumah Kaca (RAD-GRK) (Regional Action Plans for Emissions Reduction) which allows regional governments to participate in national action plans for reducing GHG emissions.¹¹ Participation at the provincial-level is by calculating mitigation potential, developing emission reduction strategies, selecting local level mitigation actions, and identifying key stakeholders/institutions and financial resources.¹² The agricultural GHG emission reduction policy in Indonesia is consistent with the global GHG emission reduction scenario policy,¹³ stated that although after the Paris Agreement in 2015 which globally had a target of reducing emissions by 1 GtCO₂eq/year in 2030, the target must still ensure global food security. RAD-GRK policies at the regional level and RAN-GRK at the national level are part of Nationally Appropriate Mitigation Actions (NAMAs) that are continuously reported to the UNFCC.^{8,14,15}

With the population reached 267.3 millions in 2018 and its growth about 1.2%/year in the past 5 year, Indonesia is one of the countries with the largest population in the world. The increased human activity due to population growth is one of the causes of greenhouse gas (GHG) emissions.¹⁶ In the agricultural sector, GHG emissions will increase along with economic growth, an increase in agricultural production and increase in population.¹⁷ The agricultural sector which is conducted in densely populated areas will produce agricultural cultivation that is not environmentally friendly. This is due to the use of chemical fertilizers which are increasingly inefficient so that they produce more GHG emissions.¹⁸⁻²⁰ In fact, the combination of income

growth and population pressure on agricultural land is the main driver for the use of chemical fertilizers.²¹ In Indonesia, the development of an environmentally friendly agricultural sector, especially food crops, is constrained by the inefficiency of chemical fertilizers, especially in rice cultivation which has traditionally been the main emitter.¹²

Some scientists^{22,23} explicitly refer to GHG emissions as an externality resulting from economic activities. One hypothesis about the relationship between environmental damage and economic growth is the Environmental Kuznets Curve (EKC). The basis of the EKC hypothesis is that economic growth or per capita income will increase environmental damage and then decrease in an inverted U curve pattern.²⁴ In the early stages of economic growth, pollution abatement was almost non-existent because people did not yet have a preference for environmental quality.²⁵ The relationship between economic growth in the agricultural sector and GHG emissions is varied. The study from²⁶ shows that Agriculture Value Added has a positive relationship with emissions in high- and upper-middle-income countries, but in low-middle-income countries an increase in Agriculture Value Added will reduce CO₂ emissions. While the study by Balsalobre-lorente *et al.*,²⁷ shows that the GDP of the agricultural sector is influential in increasing emissions in BRICS countries.

EKC theory is an adaptation of the research conducted by³³ initially to find out the relationship between economic growth and income inequality. Kuznets curve research has continued to develop since the 90s through various studies by³⁴⁻³⁶ to seek the relationship between environmental damage and economic growth. The various studies have become the initial milestone in the development of the EKC hypothesis.

With the increasing anxiety about climate change, environmental degradation variables are then measured using GHG emission variables. Initial EKC research using GHG emissions as a variable for environmental damage was carried out, among others by³⁶⁻³⁸ by using panel data. EKC research using panel data is growing, recent studies using panel data include;^{39,40} confirmed EKC hypothesis in the countries of Europe;⁴¹ confirmed the EKC hypothesis in 14 African countries;⁴² searched in

MIKTA countries (Mexico, Indonesia, South Korea, Turkey, and Australia) the results where the EKC hypothesis was rejected in this study;^{43,44} conducted an EKC hypothesis study in ASEAN countries, the results of in the research from⁴³ EKC hypothesis was accepted and research from⁴⁴ the EKC hypothesis was rejected. For EKC research with panel data in one country, among others, conducted by;⁴⁵ examined the EKC hypothesis in China where the EKC was confirmed in the eastern region and the central region and rejected in the western region;^{46,47} confirm the occurrence of EKC in China in all regions; while⁴⁸ confirm the EKC hypothesis in the United States.

Increasing global awareness on the issue of climate change and global warming has led many countries to tighten environmental regulations. The study of policies or regulations in relation to the EKC hypothesis is conducted among others;⁴⁹ in European countries shows that with strict legal rules the number of turning points obtained will be lower so that the goal of environmental preservation will be more easily achieved; study from 50 concluded that energy regulation policies can reduce GHG emissions;⁵¹ in his studies in the European Union, Middle East, and Africa countries, concluded that the more stable political conditions, the quality of regulations and the more effective governance will be able to reduce GHG emissions;⁵² testing the policy in Taipei in the form of regulations fee for disposal of plastic waste has proven to be able to preserve the environment; while studies from^{47,53} in China shows that strict environmental regulations can reduce GHG emissions. A study from⁵⁴ in 8 OPEC member countries concluded that good governance policies would reduce GHG emissions. Conversely, bad governance due to a high corruption index, it will affect horribly the quality of the environment.⁵⁵⁻⁵⁷ Generally, countries with high populations will produce large emissions. Population growth increases the number of consumers and the level of consumption thereby driving growth in GHG emissions.⁵⁸ In the EKC hypothesis population variables are used in various forms including; the population density variable used by^{59,60} who concluded that the population density variable increases GHG emissions; urbanization variable used by⁶¹⁻⁶⁴ who concluded that urbanization increases emissions except in research by⁶⁴ who

concluded that urbanization will actually reduce emissions; the total population variable is used by⁶⁵ where this variable increases emissions in the long run, but has no effect in the short run; population growth variable used by^{31,66} who concluded that the variable population growth increases CO₂ emissions. This study aims to determine the impact of regional and population policies in reducing GHG emissions in the EKC hypothesis of the land-based agriculture sector (food crops, horticulture, and plantations) in Indonesia. The EKC hypothesis research in the land-based agriculture sector in Indonesia also uses regional economic growth variables as endogenous variables. This research provides a novelty in the form of a special EKC hypothesis in the land-based agriculture sector (food crops, horticulture, and plantations). The use of population growth variables, comparison of emissions for the island of Java as the main producer of rice in Indonesia, to regional policies on reducing GHG emissions in the agricultural sector are a novelty addition in this study. Various studies on GHG emissions using the EKC hypothesis in Indonesia have been conducted before,²⁸ used coal consumption as the dependent variable while the urbanization and trade openness variables were used as exogenous variables;²⁹ searched the effect of renewable energy on EKC;³⁰ examined the effects of energy consumption, financial development and international trade on EKC;³¹ examined the EKC hypothesis with energy consumption and population growth regressor variables. Various results of these studies concluded that the EKC hypothesis occurred in Indonesia. While research from³² concluded that there is no evidence of the EKC hypothesis in Indonesia.

Data and Methodology

Data

Data obtained by various sources, data on CO₂ emissions from the land-based agriculture sector were obtained from the Ministry of Environment and Forestry⁶, labor data were obtained from the Ministry of Agriculture⁶⁷, data on economic growth in the agricultural sector using the value of Gross Regional Domestic Products (GRDP) and population growth data obtained from the Central Statistics Agency (BPS).⁶⁸ Provincial government policy data on reducing greenhouse gas emissions were obtained from the Badan Perencanaan Pembangunan Nasional (National Development Planning Agency)

(Bappenas).⁶⁹ Following the availability and reliability of the data, only 31 Provinces of 34 Provinces in Indonesia were used from 2009 - 2017.

Methodology

The econometrics model in this study uses the approach taken by Dinda.⁷⁰ The focus of this research is to get the effect of population growth and provincial-level GHG emission reduction policies based on the EKC hypothesis. The equation used in this study is:

Model 1

$$CO2_t = f (GRDP_t, GRDP_t^2, PG_t, Djawa_t) \dots (1)$$

To find out the effect of GHG emission reduction policies, equation (2) is made, which is :

Model 2

$$CO2_t = f (GRDP_t, GRDP_t^2, PG_t, Djawa_t, DP_t) \dots (2)$$

Equations (1) and (2) are converted into equations (3) and (4) based on the Generalized Method of Moments (GMM) two-step system equation developed by 71to check the EKC hypothesis as previously used by^{53,72}:

Model 1

$$CO2_{it} = \alpha_1 CO2_{it-1} + \beta_1 GDRP_{it} + \beta_2 GDRP_{it}^2 + \beta_3 PG_{it} + \beta_4 Djawa_{it} + v_i + \varepsilon_{it} \dots (3)$$

Model 2

$$CO2_{it} = \alpha_1 CO2_{it-1} + \beta_1 PDRB_{it} + \beta_2 PDRB_{it}^2 + \beta_3 PG_{it} + \beta_4 Djawa_{it} + \beta_5 DP_{it} + v_i + \varepsilon_{it} \dots (4)$$

where i is the province (i = 1,2,, 31) and t is the time period (t = 2009 - 2017), v is the effect of the panel level and ε is the term for random error. CO₂ is the carbon emission of the land-based agriculture sector (food crops, horticulture, and plantations) of Indonesia per capita labor (kgCO₂eq/capita), with explanatory variables consisting of; GRDP and GRDP2 is the value GRDP of the land-based agriculture/laborcapita(Rp/capita(base year 2010)). PG is Population Growth (%), this variable in previous studies affected on emissions.^{31,66} Djawa is a dummy for the island of Java (1 for the province in Java Island and 0 for outside Java), Java was chosen because it has the largest number of agricultural land-basedworkers. DP is the Dummy Policy for the year in which the Regional Action Plan for Reducing Greenhouse Gas Emissions Reduction (RAD GRK) was established (0 before the regulation was passed and 1 after the regulation was passed). The statistical description of the variables used in this study can be seen in table 1.

Table 1: Descriptive statistic of variable

	CO2	GRDP	GRDP2	Population growth
Mean	2,555.342	23,101,591	7.08x1014	1.84170
Median	2,624.137	21,009,033	4.41x1014	1.64787
Maximum	7,761.663	84,642,640	7.16x1014	14.73295
Minimum	18.19486	4,933,820	2.43x1014	-13.44776
Std. Dev.	1,587.721	13,213,300	9.90x1014	2.066913
Observations	279	279	279	279

In general, based on research by Dinda ⁷⁰ the estimation model examines the significance of the β_i coefficient. Possible hypotheses are :

- If $\beta_1 = \beta^2 = 0$ then there is no relationship between x and y
- If $\beta_1 > 0$ and $\beta_2 = 0$, a linear and increasing

relationship exists between x and y

- If $\beta_1 < 0$ and $\beta_2 = 0$, a linear and descending relationship exists between x and y
- If $\beta_1 > 0$, $\beta_2 < 0$, there is an inverse U relationship between x and y, so EKC occurs
- If $\beta_1 < 0$, $\beta_2 > 0$, U-shaped curve occurs.

where the turning point of gross regional domestic product per capita is expected to be discovered through $PDRB = -\beta_1 / 2\beta_2$

The panel data used in this study has a large cross-section type, but with little time span. This causes stochastic disorders related to exogenous explanatory variables and endogenous explanatory variables.⁷³ So GMM is used to control the potential for the endogeneity of variables. To test the model according to criteria from⁷⁴ then the AR (1) and AR (2) tests, to examine the hypothesis of no serial correlation, are also presented. Also, the Sargan

test was also carried out to test the validity of the instrument.

Result and Discussion

Before conducting panel data regression using the system GMM estimator, a stationarity test must be performed on each variables⁷⁵⁻⁷⁷ use the unit root test both the common unit root test LLC (Levin, Lin, Chu) by⁷⁸ and individual IPS root unit tests by.⁷⁹ The stationary test is carried out on all variables except the dummy variable, the results of the stationarity test in table 2 show that all variables have been stationary at the level or at the first difference.

Table 2: Test the root unit for stationarity

Unit Root Test	LLC Test		IPS Test	
	Level	First Difference	Level	First Difference
CO2	-6.18599***	-12.1085***	-1.26940	-4.98097***
GRDP	-2.26481**	-11.0175***	1.89807	-3.58988***
GRDP2	-0.42284	-8.21927***	2.69801	-2.78396***
Population Growth	-31.3623***	-10.5477***	-10.6772***	-7.02487***

Source: Authors compilation

***, **, * : significant at 1%, 5% and 10% respectively

After obtaining that the variable used passed the stationarity test then the equation 1 model and model 2 were then tested according to the GMM System method. GMM test results in table 2 show that model 1 and model 2 can be seen from the autocorrelation test (AR (1) and AR (2)) and the Sargan test. In the first difference residuals test where the value of AR (1) is significant so H0 is rejected and the value of AR (2) is not significant so that H0 is accepted so that model 1 and model 2 do not experience autocorrelation problems. To test the validity of the models, the Sargan test is used where H0 states that the variables used that have over-identifying restrictions are rejected so that the validity of model 1 and 2 are accepted.

System GMM test results in both model 1 and model 2 show that the previous year's emissions also contributed to the current year's emissions. These results are consistent with similar studies using the GMM model in which the previous year's emissions had a positive and significant effect.^{53,80} In model 1,

an increase of 1 kg CO₂eq/capita in the previous period will increase current year emissions by 0.57 kg CO₂eq/capita. Whereas in model 2 an increase of 1 kg CO₂eq/capita in the previous period will increase current year emissions by 0.60 kg CO₂eq/capita.

The GMM model also shows that economic growth represented by the GRDP/capita has a very significant effect on GHG emissions in the agricultural sector. Economic growth through GRDP of Rp. 1,000/capita will increase agricultural sector GHG emissions by 0.1052 kg CO₂eq/capita in model 1 and 0.1027 kg CO₂eq/capita in model 2. Although not in the agricultural sector, the effect of economic growth on GHG emissions in Indonesia is according to previous research.^{28-30,32,81} As for research on the agricultural sector, economic growth also affects agricultural sector emissions in France, Spain, and Portugal,⁸² Bulgaria and the Czech Republic,⁸³ Iran⁸⁴ and China.⁸⁵ The GRDP2 results are negative and significant at model 1 and model 2 according to research from⁷⁰ the EKC hypothesis

was confirmed in the land-based agriculture sector in Indonesia. Confirmation of the EKC hypothesis of the agricultural sector in Indonesia is consistent

with previous EKC hypothesis research in Indonesia, although it is not specific about the EKC hypothesis of the agricultural sector.^{28–30,86}

Table 3: Result of System GMM estimation

Regressor	Coefficient	t Statistic	Probability	Coefficient	t Statistic	Probability
Model 1				Model 2		
CO ₂ _{t-1}	0.5721905***	37.52	0.000	0.6047943***	16.37	0.000*
GRDP	0.0001052***	32.68	0.000	0.0001027***	26.08	0.000
GRDP2	-1.19E-12***	-25.48	0.000	-1.17E-12***	-24.54	0.000
PG	-13.86256***	-3.50	0.000	-17.77709***	-3.49	0.000
DJawa	1,597.22***	11.67	0.000	1,258.212***	5.24	0.000
Dpolicy				-190.6635***	-6.57	0.000
C	-618.4133***	-9.74	0.000	-457.0439***	-2.87	0.004
AR (1)		-2.9712	0.0030		-3.0279	0.0025
AR (2)		-0.37937	0.7044		-0.33616	0.7367
Sargan test		27.65361	1.0000		27.42195	1.0000
N		248			248	
Turning Point		Rp. 44,201,680,67			Rp. 43,888,888.88	

Notes : *, **, ***10, 5 and 1 percent level of significance

The dummy policy variable in model 2 shows that this variable has a negative and significant effect on GHG emissions in the agricultural sector, this conclusion is consistent with previous research namely,^{47,49–53}.

This shows that the regulation on GHG emission reduction at the provincial-level (RAD GRK) can reduce GHG emissions in the agricultural sector. In the Decree for GHG Emission Reduction (RAN GRK) document, the Indonesian government is targeted to reduce GHG emissions in the agricultural sector by 21Mt CO₂eq/year by 20309. Data on agricultural sector emissions (including livestock and forestry) from 2009-2016 show that Indonesia has succeeded in reducing GHG emissions by an average of 6.33 MtonCO₂eq compared to Business as Usual projections.⁸⁷

Population growth in Indonesia has a negative and significant coefficient. In model 1 each increase in population growth by 1% will reduce agricultural sector GHG emissions by 13.86 kg CO₂eq/capita, whereas in model 2 each increase in population growth of 1% will reduce agricultural sector GHG

emissions by 17.77 kg CO₂eq/capita. This result is different from the research by Alam et al and Begu *et al.*,^{31,66} for the general sector where increased population growth will increase GHG emissions. For the Agriculture sector^{17,88} also gave different results with this study. The difference in the results of this study with previous research is possible because the focus of this study is only on the land-based agriculture sector. Beside the land-based agriculture sector in Indonesia, the increase in population and economic growth in Indonesia triggers the flow of agricultural land conversion. Many agricultural lands have turned into residential areas, industrial areas, and others. From 2000 - 2015 from 9 provinces with the largest paddy fields in Indonesia, the average land conversion was 96,512 hectares annually.^{89–91} The flow of land conversion caused by population growth has caused a decline in agricultural land in Indonesia.

The dummy variable for Java in both model 1 and model 2 shows that this variable influences emissions. This shows that there are real differences between the agricultural sector's GHG emissions

produced in Java and outside Java. According to data from Ministry of Environment and Forestry,⁶ emissions from rice cultivation and land management dominate GHG emissions from the land-based agriculture sector in Indonesia. Java Island has the most extensive rice fields compared to other islands in Indonesia. The area of paddy fields on the island of Java reaches 3,223,812 ha, equivalent to almost 40% of paddy fields in Indonesia.⁹² This can be an explanation for the significance of the Java dummy variable.

One of the main issues of research on the EKC hypothesis is the turning point. Turning points in this study will occur when the GRDP/capita at Rp. 44,201,608.67/capita in model 1 and Rp. 43,888,888.88/capita in model 2. Lower turning points in model 2 indicate that government policy or regulation variables can bend the EKC curve so that turning points are faster to obtain. By calculating GRDP using the base year 2010, the turning point value in model 1 is equivalent to 4,916.21 USD/capita and 4,881.42 USD/capita in model 2. The RAD GRK policy is also able to accelerate the achievement of turning points so that environmental aspects of sustainability are more quickly obtained. The turning points generated in this study are consistent with various previous studies. Whereas turning points in the EKC study in the agricultural sector have not been done much, but the results of this study are not much different from the study⁸⁴ obtained by the agricultural sector's turning point at 4,711 USD, 5,424 USD and 4,920 USD. In comparison, the turning point on the general sector EKC hypothesis in Indonesia is equal to 7,729 USD/capita.²⁹ In the ASEAN region a turning point is obtained at 4,685 USD/capita⁴³; Asian region obtained at 8,600 – 11,600 USD/capita⁹³; as well as developing countries obtained between 928.88 USD/capita – 8,910 USD/capita.^{94–96} The GRDP of the land-based agricultural sector in 2017 in Indonesia averaged Rp. 28,782,788.73/capita or equivalent 3,201.28 USD/capita, so the turning point in Indonesia has not been reached. The EKC hypothesis confirmed in this study shows that economic growth will increase agricultural sector GHG emissions in Indonesia. However, after turning points are exceeded, GHG emissions from the agricultural sector will decline. Therefore, the results of this study can provide an overview for policymakers to encourage economic growth

in the agricultural sector in Indonesia. In addition to encouraging the welfare of farmer's economic growth, also in the long run after achieving turning points emissions will decrease

Conclusion and Policy Implication

The results of this study indicate that economic growth affects the increase in GHG emissions from the land-based agriculture sector. Whereas population growth causes reduced GHG emissions from the land-based agriculture sector due to this variable causing the conversion of agricultural land. The land-based agriculture sector in Java is proven to produce greater GHG emissions than islands outside Java.

The government policy variables in the form of RAD-GRK at the provincial-level in this study proved to be able to reduce GHG emissions in the agricultural sector. In implementing RAD-GRK policies, it is evident that the agricultural sector is sufficiently prepared to implement various mitigation policies.⁹⁷ A study from⁹⁸ shows that in 2030 Indonesia is estimated to be able to reduce emissions in the agricultural sector by 47 Mt CO₂eq/year far greater than the target of 21Mt CO₂eq/year. Further study of the influence of RAD-GRK policy factors in each province will greatly help to provide a better figure.

The study also ensured that GHG emissions from the land-based agriculture sector produced by farmers in Java were greater than farmers outside Java. The large size of paddy fields in Java is the cause of the greater GHG emissions compared to other islands in Indonesia. The EKC hypothesis confirmed in this study shows that in economic growth will increase agricultural sector GHG emissions in Indonesia. However, after turning points are exceeded, GHG emissions in the agricultural sector will decline. Based on the results of this study, the Indonesian government needs to implement an abatement policy, especially for agriculture in Java. The results of this study indicate that the agricultural sector in Java produces more per capita emissions compared to outside Java.

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Conflict of Interest

The authors do not have any conflict of interest.

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