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Article

# Impact of Urbanization on Energy Intensity in Indonesia: Spatial Analysis

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***Abstract***

Urbanization is a phenomenon in developing countries that needs to be studied in depth because it has various impacts, including an increase in energy consumption. Energy consumption needs to be controlled to balance energy supply and demand in each province. In this study, energy intensity will be used to measure energy consumption, and regional elements are used to capture the diversity of characteristics in each province. The purpose of this study is to 1) Is there a spatial correlation in energy intensity in Indonesia; and 2) What is the spatial (direct, indirect, and total) impact of urbanization on energy intensity in the Indonesian region, Eastern Indonesia Region (KTI), and Western Indonesia Region (KBI). The research method used is a spatial analysis using Moran Test, Spatial Durbin Model, and advanced decomposition analysis on the spatial spillover effect. The result is a spatial correlation to the energy intensity that occurs in each province. Urbanization shows a significant negative impact on energy intensity on the direct effect on KTI and KBI and also on the indirect effect and the total effect in the territory of Indonesia and KBI.

**Keywords:** Energy Intensity; Spatial Analysis; Spillover effect; Urbanization.

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# I. Introduction

## 1.1. Background of Problem

Urbanization is a phenomenon that occurs in developing countries, including Indonesia. Urbanization is not only related to population but also invades into other sectors such as political, social, cultural and economic. Based on the population census conducted in 2010, Indonesia's population reached 238 million people with a population composition of 118.5 million people living in urban areas (49.8%) and a population living in rural areas of 119.5 million people (50.2%). The number of population movements in 2010 greatly increased compared to 1970, where the population living in urban areas was only 17.5% and in rural areas by 82.5%.

Urbanization increases energy consumption through demand from housing, infrastructure, transportation and energy-intensive activities. The increase in energy consumption cannot be separated from economic factors that occur in society. In a study conducted by Li et.al (2018), during the economic transition, the factor that drove energy consumption to increase significantly is urbanization in which there is a rapid movement of a population from rural areas to urban areas. Urbanization has a positive relationship with energy consumption because of production activities (Bakirtas & Akpolat, 2018). Referring to Sarminta & Simamora (2018), population movement is dominated by economic influences which make it very difficult to control. The impact of urbanization won't affect energy consumption in the area itself, but it will also affect the surrounding area. When an area has a high level of urbanization, energy consumption in the surrounding area will also increase along with the economic growth and industrialization in the affected area. Referring to (Liu et.al, 2018), adjacent areas will be influenced by agglomeration effects in the economic sector and other sectors which result in many similarities compared to areas that are far apart.

Economic development in Indonesia is not the same from one region to another. This is used as the basis for Presidential Decree (Kepres) No. 13 of 2000 concerning the Council for the Development of Eastern Indonesia. In this Presidential Decree, it is explained that the Eastern Indonesia Region (KTI) is an area that has a low stage of development while the Western Region of Indonesia (KBI) has a higher development stage. KTI covers Nusa Tenggara, Kalimantan, Sulawesi, Maluku and Papua. Meanwhile, KBI covers Sumatra, Java and Bali. In 2010 the total GRDP for the KTI region was 1300 trillion rupiah and for the KBI region it was 5500 trillion rupiah.

Based on research conducted by Wang et.al (2018), besides energy consumption, increasing urbanization also positively affects energy consumption. It has a direct impact on the rise of consumption of fossil energy and carbon dioxide ($CO_2$) emissions. Energy intensity is one of the useful indicators in knowing carbon emissions and energy consumption (Wang, 2017). Furthermore, research conducted by Huang et al (2017) explains that energy intensity is one of the most efficient and effective ways to reduce energy supply shortages caused by urbanization. According to Fitriyanto & Iskandar (2019), energy intensity is a proxy for measuring the level of energy efficiency. Energy intensity is an indicator that measures how much energy is used from the total energy consumption equivalent to barrels of oil divided by gross domestic product (Heidari et al, 2017).

Several studies on the relationship between urbanization and energy intensity have not been carried out in Indonesia, but the energy intensity can be proxied through energy consumption that has been analyzed. Research conducted by Agung, P. et al (2017) concluded that urbanization has a significant relationship with energy intensity. Another study conducted by Kristen & Soetjipto (2019) explains that urbanization on energy consumption has a positive impact on Western Indonesia, but has a negative impact on Eastern Indonesia.

### 1.2. The Problem

Based on several studies mentioned previously, there is no research that examines the impact of urbanization on energy intensity and economic diversity in each province, and this research answers these challenges using spatial analysis. The use of a spatial approach is used to analyze the differences in energy growth rates between provinces that may affect energy intensity in the province and its surroundings. Factors related to the economy are the most important causes of urbanization and urban development. The studies that have been published have only analyzed panel data without including spatial elements as an indicator. The use of spatial analysis will provide an overview of the heterogeneity of energy growth and the dependence of the implementation of energy efficiency from each province. In addition, the use of spatial analysis will show the spillover effect from urbanization.

In this study, the Spatial Durbin Model (HR) will be used which will increase the accuracy of predictions and contributions from the provincial level into the national level. In addition, to make depth analysis for the spillover effect between provinces, the study will decompose the results of HR into direct, indirect and total effects. The direct effect is the effect of changes in independent variables (such as urbanization) in a province that can affect the energy intensity of the province. Indirect effect is the effect of changes in independent variables (such as urbanization) in a province that can affect the energy intensity of other provinces nearby. The total effect is a combination of direct and indirect effects. Therefore, this study was conducted to answer research questions, namely: (1) Is there any spatial correlation of energy intensity in Indonesia? and (2) What is the spatial impact (direct, indirect and total) of urbanization on energy intensity in the regions of Indonesia, KTI, and KBI.

The purpose of this study is to determine whether there is a spatial correlation of energy intensity in Indonesia. In addition, this study also wants to know the spatial impact (direct, indirect and total) of urbanization on energy intensity. The hypothesis in this study is that there is a spatial correlation on energy intensity in Indonesia. In addition, the second hypothesis is that there are variations in the spatial impact of urbanization on energy intensity on direct, indirect and total effects within Indonesia, KTI and KBI.

### 1.3. Logical Framework

Research on the impact of urbanization on energy intensity is analyzed using spatial analysis. Each province will have a direct or indirect impact on energy intensity. It will prove that there is a spatial dependence between provinces where the energy intensity of one province will affect the energy intensity of another province. Factors that affect energy intensity between provinces can be delivered through urbanization, in short, the level of urbanization from one province can affect the energy intensity of other provinces. In addition, direct and indirect impacts on energy intensity will also be examined on other independent variables such as income per capita, energy consumption, number of rural and urban populations and energy prices, which are several variables related to urbanization.

## II. Data and Methodology

### 2.1. Data Set

The spatial relationship of energy intensity becomes the main focus of the spatial panel model by combining the spatial effects that occur in each province. According to Floch & Le Saout (2018), the use of the spatial panel model can provide an overview of the spatial dependence on energy intensity and spatial heterogeneity between provinces, products, companies and individuals. In using the spatial panel data model, it is necessary to do the Moran's I test first to verify whether there is a spatial dependence on energy intensity. After the Moran's I test, Moran Scatter Plots (MSP) were used to provide a visual description of the spatial dependence between provinces on energy intensity. In general, Moran's I see the relationship between the values of xi and xj, where i and j represent province i and province j. Here is the mathematical definition of Moran's I index:

$$I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij}(x_i - \underline{x})(x_j - \underline{x})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij}} \tag{1}$$

where x_i (x_j ) is the energy intensity in province i (j). _ij is a spatial weight matrix that contains binary numbers and represents the distance between provinces. Moran's, I have an index with a range between -1 to 1. If the value of I > 0, it indicates that there is a positive spatial correlation where provinces with high scores will be surrounded with high scores and vice versa. However, if I < 0 then there is a negative spatial correlation where provinces with high scores are surrounded by provinces with low scores and vice versa. In this study, the distance used is 700 km so that all provinces have at least one neighbor. The chosen distance is different from that suggested by Vidyattama (2014) which is as far as 200 km, it is because of the difference of a map ratio that is used in conducting spatial analysis. Provinces that are still within the radius will be considered neighbors and given a value of 1, while for provinces that are outside the radius it will be given a value of 0.

After the Moran's I test, a test will be conducted to determine the spatial econometric model that will be used. Based on the reference model of previous research by Lv et.al (2019), the following is the Spatial Durbin (HR) model that will be used:

$$lnEI_{it} = \rho \sum_{j\approx1}^{N} \omega_{ij} \times lnEI_{jt} + \beta_1 lnurbanization_{it} + \theta_1 \sum_{j\approx1}^{N} \omega_{ij} \times lnurbanization_{jt} + \beta_c lnX_{it}^{c} + \theta_c \sum_{j\approx1}^{N} \omega_{ij} \times lnX_{it}^{c} + \varepsilon_{it} \tag{2}$$

where: EI is the energy intensity. X indicates independent and control variables, namely Urbanization, GRDP per capita, Industrialization, FDI and Energy Prices. _1 and _c is a coefficient that represents the spatial spillover effect of urbanization and other control variables on energy intensity. The HR model was chosen because this model can capture the spillover effects (direct, indirect and total) impacts of urbanization on energy intensity that occurs between provinces.

After calculating the general spatial spillover effect, a more detailed calculation is needed regarding the magnitude of the direct and indirect effects contained in the spatial spillover effect. Referring to Floch & Le Saout (2018), it is necessary to use spatial decomposition to calculate direct effects, indirect effects and total effects. The direct effect is used to measure how much the dependent variables of a province change when the independent variables of the province change. The indirect effect is to measure the average response of the dependent variable to changes because of the change of the independent variable from the surrounding province. The total effect is the sum of the direct effects plus the indirect effects. According to Elhorst (2017), the decomposition process in the HR model is carried out through partial derivatives of variable x (independent and control) to variable y (dependent). The following is the implementation of the model in equation (3.2) to be able to calculate direct, indirect and total effects through partial derivatives:

$$nEI = (I - \rho\omega)^{-1} \left(\left( I\beta_1 + \theta_1 \textstyle\sum_{j\approx 1}^{N} \omega_{ij}\right) lnurbanization_{jt} + \right.$$

$$\left.\left(I\beta_c + \theta_c \textstyle\sum_{j\approx 1}^{N} \omega_{ij}\right) lnX_{it}^{c}\right) + \varepsilon_{it} \tag{3}$$

For direct effect, the weight matrix value used is the diagonal, i.e. column i to row i. so the direct effect is as follows:

$$direct\ lnEI = \frac{\sum_{i=1}^{n} S(W)_{ii}}{n} \tag{4}$$

As for the indirect effect, the value of the weight matrix used is non-diagonal, namely column I to row j, so the indirect effect is as follows:

$$indirect\ lnEI = \frac{\sum_{i=1}^{n} S(W)_{ij}}{n} \tag{5}$$

For the total effect is the sum of the direct and indirect effect:

$$total = direct + indirect \tag{6}$$

The data in this study used secondary data in the form of time series and cross section. The data was obtained from various sources including the Center for Data and Information of the Ministry of Energy and Mineral Resources, the Directorate of Energy Conservation of the Ministry of Energy and Mineral Resources, Bappenas and BPS. The data to be used include: (1) Provincial Energy Intensity for 2010-2018; (2) Urbanization 2010-2018; (3) Per capita GRDP 2010-2018 and (4) % of GRDP to Industry 2010-2018; (5) FDI 2010-2018; (6) Energy Prices 2011-2018.

## III. Methodology

Table 1. contains the results of Moran's test for the energy intensity variable. In the table it can be concluded that all the results of the Moran test are positive with a significance level of 1% to 5%. This indicates that there is a positive spatial autocorrelation between provinces. The achievement of the energy intensity of each province is one proof of the effects of regional agglomeration (grouping), namely provinces with high energy consumption will be surrounded by other provinces with high energy consumption as well. Provinces that have low consumption will be surrounded by other provinces that have low consumption as well. The value of the Moran index in Table 3 fluctuates, this indicates that there is a very high spatial autocorrelation on energy intensity in each province. The positive value of spatial autocorrelation confirms that there is a spatial dependence on energy intensity between provinces which will have a spillover effect on other economic factors such as technology and consumption preferences.

This part analyses the regression results, focusing on the effects of the main independent variables on income inequality, including total and specific taxes such as income tax, VAT, and local tax revenues.

### 3.1. Total Tax Revenue's Effect on Income Inequality

Table 1 shows the regression results in Model 1, which examines the effect of total tax revenue on income inequality. Table 1 Column (1) contains the baseline model specifications, specifically those that relate the change in total tax revenue (ln total tax) to the Gini ratio with a province-fixed effect. Column (2) specifies the model by including a year-fixed effect, which accounts for shocks during the observation year. Furthermore, Column (3) is a specification that controls fiscal policy variables regarding government spending based on Martinez-Vazquez et al. (2012). Column (4) is the final estimation result that includes all control variables, as described in Chu et al. (2000), Borge and Rattso (2004), Martinez-Vazquez et al. (2012), Martorano (2018), Alavuotunki et al. (2019), and Nusiantari and Swasito (2020).

**Table 1.** Moran's Test for Energy Intensity and Urbanization Variables

| Year | ln(Energy Intensity) |
|---|---|
| | *Moran's I* |
| 2010 | 0,185** |
| 2011 | 0,157** |
| 2012 | 0,147** |
| 2013 | 0,167** |
| 2014 | 0,148** |
| 2015 | 0,113* |
| 2016 | 0,082* |
| 2017 | 0,110* |
| 2018 | 0,106* |

Table 2 shows the results of the analysis using the Spatial Durbin Model (HR). The three columns represent the calculation results of the spatial panel model on the data of Indonesia, East Indonesia and West Indonesia. Before carrying out these calculations, the Hausman test is carried out to determine whether HR will use a random effect approach or a fixed effect approach. The results of the Hausman test show that the right human resources to use are human resources using a fixed effect approach for all regions, including Indonesia, KTI and KBI. In Table 2 there are 2 parts, namely (1) direct effects or local effects and (2) spatial spillover effects (variables that use spatial lagged for example W x ln(Urbanization)). The spatial lag coefficient of energy intensity is significantly positive in the 3 regions and this is in accordance with the Moran's Index test. The spatial lag values of energy intensity from Indonesia, East Indonesia and West Indonesia are 0.39, 0.57 and 0.35. Referring to the spatial lag value of energy intensity, the KTI region (Kalimantan, Sulawesi, Nusa Tenggara, Maluku and Papua) has a high spatial relationship compared to the KBI region (Java, Sumatra, Bali). This implies the need for specific energy conservation policies for the KTI region. Cities in the KTI region have an unequal socioeconomic background as well as the existing infrastructure. This makes the Energy Intensity in the KTI region more spatially affected than in the KBI area.

**Table 2.** Empirical Results of the Spatial Model

| Energy Intensity | Indonesia (N=297) | KTI (N=144) | KBI (N=153) |
|---|---|---|---|
| n(PUrb) | -0,04 | -0,50* | 0,09 |
| | (0,33) | (0,30) | (0,58) |
| ln(PDRBKap) | -1,04*** | 0,80*** | 1,41*** |
| | (0,19) | (0,19) | (0,29) |
| ln(PIND) | 0,01 | -0,04 | -0,12 |
| | (0,04) | (0,04) | (0,12) |
| ln(PFDI) | 0,02** | 0,01* | 0,02 |
| | (0,01) | (0,01) | (0,01) |
| ln(HargaEnergi) | -0,64*** | 0,19** | -0,79*** |
| | (0,04) | (0,08) | (0,05) |
| W x ln(IE) | 0,39*** | 0,57*** | 0,35*** |
| | (0,05) | (0,06) | (0,08) |
| W x ln(PUrb) | -2,39*** | 0,07 | -4,35*** |
| | (0,80) | (0,74) | (1.60) |
| W x ln(PDRBKap) | 1,69*** | 0,53* | 2,56*** |
| | (0,33) | (0,35) | (0,48) |
| W x ln(PIND) | -0,08 | 0,03 | -0,10 |
| | (0,10) | (0,07) | (0,54) |
| W x ln(PFDI) | 0,04** | 0,02* | 0,04* |
| | (0,02) | (0,01) | (0,03) |
| W x ln(HargaEnergi) | 0,33*** | -0,22** | 0,37*** |
| | (0,07) | (0,09) | (0,11) |

**Source**: author's data processing

The urbanization coefficient for each province is significantly negative for KTI but not significant for Indonesia and KBI. When there is a 1% increase in urbanization, there will be a 5% decrease in energy intensity in KTI. These results are consistent with the results of research by Lin & Zhu (2017) which concludes that urbanization and energy intensity have a negative relationship. The results of the regression analysis of urbanization variables are 1) Indonesia's commitment to reduce GHG emissions by 26% since 2009 which imply government policies to include elements of energy conservation especially in urban construction. With the implementation of these energy efficiency policies, insignificant results in Indonesia and KBI on the impact of urbanization on energy intensity are normal; 2) significant negative results in KTI indicate that the area is implementing urbanization more slowly than KBI. According to Kristen & Soetjipto (2019), the average level of urbanization in KTI is only 36.49% compared to KBI which reaches 51.63%. For the spatial spillover effect of urbanization, the resulting value is significantly negative for the Indonesian region and KBI, but not significantly positive in KTI. This indicates that urbanization through an increase in the urban population of a province, as a result of urbanization, can reduce the energy intensity of other provinces. In KBI, urbanization is possible to have a negative impact through technology spillover, the transportation sector and increasing socio-economic interaction between provinces.

The coefficient value of GRDP per capita has a significant negative value in all regions, both Indonesia, KTI and KBI. This shows that an increase in GRDP of 1% will result in a decrease in energy intensity by 1.04%, 0.8% and 1.41%. This shows that the higher GRDP per capita in a region is not necessarily accompanied by an increase in energy consumption. The gradual increase in energy consumption can be triggered by stagnant energy consumption patterns and the awareness of energy conservation in the community. For the spatial spillover effect of GRDP per capita, it can be seen that all regions have a significant positive value. When there is an increase in GRDP per capita of 1%, there will be an increase in energy intensity of 1.69% in Indonesia, 0.53% in KTI and 2.56% in KBI. This indicates that the GRDP per capita of a province will be able to affect the energy intensity of other provinces due to spatial influences. When a province in Indonesia experiences an increase in urban population as a result of urbanization, there will be an increase in energy intensity in the province adjacent to the province. According to Lv. et al (2019), GRDP per capita on energy intensity in the short term will form a U-Shape curve but in the long term it will make energy intensity decrease.

The Industrialization variable is not significant for all regions as well as the results of the spatial spillover effect. This indicates that industrialization activities including services in a province have no effect on energy intensity for either the province itself or the provinces in the region. The results of this study are not in line with the results of research from Ma & Yu (2017) and Huang et.al (2017) which conclude that there is a significant and positive relationship between economic structure and economic development. Based on the results of this study, the economic structure does not affect the ups and downs of energy intensity although there have been many industrial transformations from the manufacturing industry to the service industry.

Another variable, namely FDI, has a significant positive value for Indonesia and KTI. When there is an increase in FDI by 10%, there will be an increase in energy intensity of 0.2% for the Indonesian region and 0.1% for the KTI region. Likewise for the spatial spillover effect, the FDI variable is significantly positive for all regions. When there is an increase in

FDI by 10%, there will be an increase in energy intensity by 0.4% in the Indonesian region, 0.2% in the KTI region and 0.4% in the KBI area. This result is not in line with research conducted by Ma & Yu (2017) which states that FDI has a negative impact on the local effect. The entry of FDI into a region will stimulate economic growth through increased economic activity. In addition, the entry of FDI will also trigger a structural shift in economic activity that will affect energy intensity.

The effect of the energy price variable shows a significantly negative value in the Indonesian region and KBI and a positive value in the KTI region. When energy prices increase by 1%, energy intensity decreases by 0.6% in Indonesia and 0.8% in KBI. For KTI, when energy prices increase by 1%, there will be an increase in energy intensity of 0.2%. From these results, it can be concluded that KBI is more responsive to price changes than KTI. For KBI, many areas have high economic growth so that when there is an increase in energy prices, the area is able to use energy efficiency tools and technology in order to reduce energy use. Referring to Lv.et.al (2019), a significant positive value could imply that KTI is a developing region and requires considerable energy to develop. The amount of energy demand for each province varies according to the energy resources owned by each province. For the spatial spillover effect, the territory of Indonesia and KBI has a significant positive value. This indicates that an increase in energy prices in one province will increase energy intensity in other provinces. Energy prices in other provinces have become very important due to the high demand for energy in the KBI Region. While in KTI it has a significant negative value where when there is an increase in energy prices by 1%, there will be a decrease in energy intensity by 0.22%. This is in line with research conducted by Thaler (2011) which shows that living standards, energy imports, and energy prices have a negative impact on energy intensity. An increase in energy prices will trigger people to consume less energy and adopt energy efficiency such as traveling less and using less power tools. This of course will affect the energy intensity value of neighboring provinces.

Referring to Table 3. Regarding the results of the decomposition of spatial effects, an in-depth analysis method will be carried out to determine the effect of the independent variable on the dependent variable. The negative significant effect of urbanization occurs in the direct effect for KTI and KBI, indirect effect for Indonesia and KBI and the total effect for Indonesia and KBI. This indicates that the implementation of urbanization policies has an impact on reducing energy intensity for both the province itself and the surrounding provinces. For a direct effect, when there is an increase in the value of urbanization by 1%, there will be a decrease in energy intensity by 0.5% and 0.2% in the KTI and KBI areas. As for the indirect effect, when there is a 1% increase in the value of urbanization, there will be a 3.7% and 6.2% decrease in energy intensity in Indonesia and KBI, respectively. Likewise for the total effect, when there is an increase in the value of urbanization by 1% in Indonesia and western Indonesia, there will be a decrease in energy intensity by 3.9% and 6.4%, respectively. From the decomposition results, it can be concluded that energy efficiency policies have had an impact on decreasing energy intensity caused by urbanization. Many energy efficiency policies have been implemented to control energy use to support urbanization phenomena, such as the Minister of Energy and Mineral Resources No. 15 of 2012 regarding saving the use of groundwater, Minister of Energy and Mineral Resources Regulation No. 01 of 2013 concerning Control of Oil Fuel Use and Minister of Public Works and Public Housing No. 02/PRT/M/2015 concerning Green Buildings. KBI is a collection of provinces that have evenly distributed infrastructure with high connectivity making it easier for each individual in western Indonesia to be able to mobilize between provinces. The negative significance value in the indirect effect for provinces in the KBI Region shows the dependence between provinces in the Region and has a high attractiveness for capital and human resource exchanges to occur. Moreover, KBI pays more attention to energy adequacy and environmental sustainability because it is supported by adequate funding for the development of efficient technology and absorbs the capabilities of the surrounding technology. In addition, the high level of urbanization, especially in KBI, triggers the increase in GRDP in KBI, thus lowering the value of energy intensity. Therefore, it is necessary for the government to control urbanization so that the value of energy intensity is lower for each province in the KBI region. The negative significant value of urbanization on energy intensity can be caused by factors such as economies of scale, agricultural modernization, structural changes in the economy, urban population density, consumption preferences for clean energy and the application of technology to energy conservation.

**Table 3**. Decomposition Results of Spatial Effects

| Energy Intensity | Indonesia (N=297) | KTI (N=144) | KBI (N=153) |
|---|---|---|---|
| Direct Effect | | | |
| ln(PUrb) | -0.26 | -0.52* | -0.20*** |
| | (0.35) | (0.37) | (0.62) |
| ln(PDRBKap) | -0.93*** | -0.79*** | -1.27 |
| | (0.19) | (0.20) | (0.27) |
| ln(PIND) | 0.01 | -0.03 | -0.11 |
| | (0.04) | (0.04) | (0.15) |
| ln(PFDI) | 0.02** | 0.02** | 0.02* |
| | (0.01) | (0.01) | (0.01) |
| ln(HargaEnergi) | -0.63*** | 0.16** | -0.78*** |
| | (0.04) | (0.07) | (0.05) |
| Indirect Effect | | | |
| ln(PUrb) | -3.66*** | -0.34 | -6.17** |
| | (1.20) | (1.59) | (2.45) |
| ln(PDRBKap) | 1.98*** | 0.16 | 3.01*** |
| | (0.50) | (0.72) | (0.67) |
| ln(PIND) | -0.11 | 0.03 | -0.15 |
| | (0.14) | (0.15) | (0.84) |
| ln(PFDI) | 0.07*** | 0.07** | 0.08* |
| | (0.02) | (0.03) | (0.04) |
| ln(HargaEnergi) | 0.13 | -0.25* | 0.13 |

| | | | |
|---|---|---|---|
| | (0.11) | (0.18) | (0.14) |
| Total Direct | | | |
| ln(PUrb) | -3.93*** | -0.87 | -6.38** |
| | (1.35) | (1.85) | (2.73) |
| ln(PDRBKap) | 1.05* | -0.63 | 1.74** |
| | (0.55) | (0.81) | (0.71) |
| ln(PIND) | -0.09 | 0.00 | -0.27 |
| | (0.17) | (0.18) | (0.97) |
| ln(PFDI) | 0.10*** | 0.10** | 0.11** |
| | (0.03) | (0.04) | (0.05) |
| ln(HargaEnergi) | -0.50*** | -0.08 | -0.64*** |
| | (0.12) | (0.20) | (0.16) |

**Source**: author's data processing

For the per capita GRDP variable, the direct effect shows a significant negative value in the Indonesian region and KTI, the indirect and total effect shows a positive significant value both in the Indonesian region and KBI. The result of the direct effect of per capita GRDP is when there is an increase of 1%, there will be a decrease in energy intensity of 0.9% in Indonesia and 0.8% in KTI. This indicates that an increase in per capita GRDP in a province in Indonesia reduces the energy intensity in the province itself. In addition, another implication is that the increase in regional revenue is not followed by an increase in energy consumption by the community or industry. Another possibility is the awareness to maintain environmental sustainability and the development of environmentally friendly technologies has been widely implemented throughout Indonesia. Another contributing factor can be due to the low energy consumption of the people in the KTI region even though the GRDP per capita is increasing due to the low ownership of energy-intensive electronic devices and the lack of community mobilization. For the indirect effect, a positive significant value implies that KBI tends to consume more energy when there is an increase in GRDP per capita in the surrounding province. The high level of inter-provincial mobilization in KBI has opened the door for capital transfers between provinces, which causes inter-dependence of changes in energy intensity between provinces caused by per capita GRDP. The results of this study are not in line with the research conducted by Lv. et.al (2019) which states that there is a negative relationship between energy intensity and per capita GRDP so that an increase in per capita GRDP will reduce energy intensity.

For the Industrialization variable, the value is not significant in all regions. This indicates that industrialization activities including services in a province have no effect on energy intensity for either the province itself or the provinces in the region. The results of this decomposition still show the same results as the results of the previous general regression. The results of this decomposition are different from the results of Huang et.al (2017), which states that there is a negative relationship between industrialization and energy intensity so that increasing industrialization in a province will reduce the energy intensity of the surrounding provinces. The factor that may cause the insignificant value is the development of tertiary industry in the KTI region due to the increasing tourism sector. This tertiary industry has the characteristics of producing high value added and consuming less energy than the secondary industry. Tertiary Industry development can be one way to reduce energy intensity by taking advantage of the spatial advantages of each province.

The next variable is FDI which shows a significantly positive value for all effects and regions. For direct effects, when there is an increase in FDI of 1%, there will be an increase in energy intensity of 0.02% for all regions. An increase in FDI of 1% will have the impact of increasing energy intensity by 0.07% for the territory of Indonesia and KTI and 0.08% for KBI. Likewise with the total effect where when there is an increase in FDI of 1%, there will be an increase in energy intensity of 0.1% in the entire region. This indicates that FDI contributes to the increase in energy intensity. The lack of FDI's role in reducing energy intensity might be caused by the flow of FDI is only limited to manufacturing and energy-intensive industries where both types of industry are limited in terms of technology spillover effects. Technology transfer as an effort to reduce energy intensity can be done in two ways, namely 1) directly through the presence of foreign companies that are more efficient to operate in Indonesia and 2) indirectly through technological spillover from foreign companies to domestic companies.

The energy price variable has a significant negative value in the territory of Indonesia, and KBI and positive significant value in the KTI for a direct effect. When there is an increase in energy prices by 1%, there will be a decrease in energy intensity by 0.6% in Indonesia and 0.8% in KBI and an increase in energy intensity by 0.2%. For the indirect effect, only KTI is significantly negative, while in the total effect, the territory of Indonesia and KBI is also significantly negative. In the indirect effect, when there is a 1% increase in energy prices, there will be a 0.25% reduction in energy intensity. While for the total effect, when there is an increase in energy price, there will be a reduction in energy intensity of 0.5% and 0.65%, respectively. A significant negative value in KBI indicates that government intervention in energy pricing policies has been implemented. In addition, the provinces in KBI are very concerned about the price issue so that when the energy price gets higher and causes other basic prices to increase, it will automatically make the cost of goods other than energy also increase. The increase in product prices makes consumers more efficient in using energy. For a direct effect that has a significant positive value, it is possible because energy needs are very much needed for KTI without paying too much attention to the energy price factor. This is because all provinces in all regions in Indonesia are experiencing economic development so that the need for energy cannot be reduced, especially for infrastructure development to catch up with KBI. The close relationship between energy prices and energy intensity is the same as the impact of economic price so that energy consumption decreases and lowers energy intensity. Differences in results from each region can be caused by differences in the energy resources they have (Lv et.al, 2019).

## IV. Conclusion and Recommendation

Based on the results of the analysis in this study, it can be concluded that there is a spatial correlation in energy intensity in Indonesia. Moreover, the result of the study also concludes that there is a negative spatial relationship between urbanization and energy intensity on the direct effect in the KTI region. For indirect and total effects, the territory of Indonesia and KBI also have significantly a negative value. A negative value for urbanization indicates that the implementation of urbanization policies has been successfully implemented. The urbanization policy has been considered regional diversity and environmental conservation. The KBI region should begin to reduce the pace of urbanization and focus more on improving the quality of development through effective, green and sustainable development. The KTI region must increase cooperation with the western region, especially in the adoption of energy-saving technologies and urban planning capabilities. The KTI region must be developed in terms of spatial planning, energy efficiency development and sustainable urban infrastructure systems.

GRDP has a significant negative effect on the direct effect for the entire region. For the indirect and total effects, significant positive values exist in the territory of Indonesia and KBI. With the majority positive results, it is necessary to further optimize energy efficiency policies in the KBI, such as the use of environmentally friendly and energy-efficient goods so that the duplication of GRDP effects does not automatically increase energy consumption. The industrialization variable is not significant for all effects, either direct, indirect or total effects. This indicates that the value added which is generated from the industry would not affect the level of energy intensity.

The FDI variable has a positive significant value for all regions. The role of the government is needed to provide a stimulus to the industrial sector to promote and innovate in order to attract FDI entering their provinces. Increasing the ability to transfer technology is also one way to optimize FDI by giving a maximum negative effect on energy intensity. The energy price variable has a significant negative effect in almost all regions. We recommend reducing price subsidies for energy, relaxing government regulations and increasing energy price flexibility in accordance with market demands.

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