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The effect of economic agglomeration on water quality index (WQI) in Indonesia

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Abstract. Economic agglomeration is the concentration of many firms and industries in close proximity that is considered effective in urging growth across developing countries. Despite the advantages, limited studies are examining negative externalities as a result of economic agglomeration towards the environment, including on water quality. Indonesia as an island country has experienced notable economic growth in the last 20 years, but at the same time currently contains some of the worst polluted rivers in the world. Using the linear regression method, this study measured the effect of economic agglomeration on water quality index (WQI) across 34 provinces in Indonesia between 2013−2018 using random effect on panel data sourced from The Ministry of Environment and Forestry and Statistics Indonesia. The results reveal that economic agglomeration had a significant and negative effect on water quality by 0.2% on the index. The relationship was consistent even when controlled for other variables like population, sanitation access, foreign direct investment (FDI), the proportion of secondary industries, and gross regional domestic product (GRDP). Furthermore, there was also a significant effect of FDI on WQI. These results call for a sound regulatory framework to protect the water quality from economic agglomeration in order to avoid environmental degradation.

Keywords: Economic agglomeration; foreign direct investment; gross regional domestic product; negative externality; water quality index

1. Introduction

The relationship between economic growth and environmental is quite contradictory. The original Kuznets curve (1954) to examine how economic growth drives income inequality was later adopted to oversee the effects of the economy on the environment. In 1991, the environmental Kuznets curve suggested the relation of a bell-shaped curve between economic growth and environmental quality. During the initial stage of growth, the economy would tend to degrade the environment through the production of sulfur dioxide emissions. The environmental-polluting economy would continue until reaching a tipping point that would completely reverse the influence. Environmental quality improves as the economy grows and changes are made in environmental and industrial policies that drive water quality improvements, and improvements occur at the later stage of economic development [1].

Similarly, Indonesia faced rapid economic growth during the five-year development planning era (*Repelita*) in 1969–1994 aiming to strengthen industrialization and agriculture as its priority sectors. Throughout five planning periods, however, exploitation of natural resources was not responded with similar priority for water resource conservation regardless of water being the central input for industry and agriculture [2]. Now, the Ministry of Environment and Forestry is responsible for monitoring water quality and pollution control; while the mandate to protect public health, set drinking water standards, and monitor drinking water quality from water suppliers belong to the Ministry of Health. Since the decentralization reforms, local governments currently play a key role in setting targets for industrial discharges into water resources, based on the national regulations. These targets are classified between Class I to Class IV (from best to worst) quality and their eligible purposes. The drinking water quality are set into the four following categories: (1) Class I is used for drinking purposes; (2) Class II is used for recreations, fresh fish preservations, livestock, irrigation, and others; (3) Class III as tools or facilities for Class II water; and (4) Class IV is only for irrigation and other usage of similar quality.

Based on monitoring by the two ministries, more than half of the river water does not meet the drinking water criteria and are classified as poor. Indonesia ranks as the second-largest country emitting the highest riverine plastics in the world [3]. Furthermore, pollution is generated from economic activities including, predominantly, various food and beverage industries, textiles, mining, and drinking industries [4]. As a result, water quality drives the spread of water-related health hazards, including 7.5% of diarrhoea-related deaths annually [5]. Unfortunately, poor water sources lead to the use of bottled water as the primary drinking water in most households (31% according to Susenas, 2016) replacing other types of improved sources such as piped water and protected wells.

On the pollution causes, previous studies have found various socio-economic factors that compensate for the water quality. These factors include population and population growth, which cause overcapacity in wastewater management, land-use conversion from building facilities and infrastructures to support people's livelihood that subsequently decrease water absorption capacity [6]. Liu and Chen [7] found that although rainwater still supplies water from upstream Tarim River, Xinjiang, China, the flow itself has significantly decreased due to population growth, climate change, the expansion in cultivated land, and economic growth that degraded the water quality in the respective area. Similar results were found in Indonesia, where population and population growth negatively influence the quality of water [8].

Furthermore, related to economic activities, large-scale agriculture, urbanization, and industrialization also result in polluted water [9]. In Indonesia, several economic indicators such as manufacturing small and medium enterprises, group of workers, gross regional domestic product (GDRP) per capita, and foreign direct investment (FDI) also negatively influence the water quality. Uncontrolled generation of waste caused by those economic activities are more often do not meet the operational standards. On the other hand, degraded water quality correspondingly threatens urban development and population growth, especially in areas without a robust wastewater management system [10]. However, there has been very limited studies on the influence of economic agglomeration, as the combination of economic growth and urbanization, on water quality. In China, Zhou *et al.* [11] found positive spillover from agglomeration in reducing water pollution emissions. By assessing 339 cities across the country, data indicate that an increase in economic agglomeration by 1% reduced COD emissions by 0.117% and NH_3 emissions by 0.102%. By classifying the cities based on the level of agglomeration and emission to water, the study found that cities with high agglomeration and high emissions tended to concentrate, thereby requiring government intervention to reduce the spillover of this pollution.

Referring to the water quality index (WQI), two rivers in Indonesia have been ranked as the worst polluted river in the world, namely the Ciliwung River [12] and the Citarum River. On a different setting, Sutjiningsih [13] demonstrated WQI scores worsening across different water points around Universitas Indonesia's Depok campus, indicating that urbanization and land use degrade the quality of interconnected water sources over time.

Acknowledging the results of the aforementioned studies, this study examined the effects of agglomeration on water quality. In Indonesia, the Ministry of Environment and Forestry uses the WQI as one of the components within the environmental quality index (EQI) to measure environmental protection, an indication of pollution, and risks mitigation. Since 2009, the index has measured various organic and chemical parameters across several river water points to represent the river's water quality and subsequently denotes the district and provincial levels [14].

2. Research Method

2.1. Data

To examine the effect of agglomeration on water quality, data was collected from the Ministry of Environment and Forestry (*Kementrian Lingkungan Hidup dan Kehutanan,* KLHK) and Statistics Indonesia (*Badan Pusat Statistik,* BPS) across 34 provinces during 2013−2018. Being mandated to monitor the annual environmental status, the KLHK assesses the water quality index (WQI) as one of the parameters for the environmental quality index (EQI). KLHK assessment covers lakes and rivers nationally at random spots, which are collected as representatives of water quality at the district and provincial levels. The BPS conducts surveys that function as representative of the Indonesian population. The data collected from BPS were regional economic size as represented by gross regional domestic product (GDRP), region area, population size, sanitation access, and secondary industries.

This study used the WQI from KLHK as the dependent variable. The main independent variable in this study was economic agglomeration (EA). Previous studies have measured agglomeration by several methods. Indicators such as the Herfindahl Index, Gini spatial coefficient, and Theil index are often used to measure agglomeration at regional and national scales. In this study, the size of the regional economy per area of the region (provincial GRDP/km^2) was used as a proxy to measure the level of agglomeration [15]. The control variables were population, sanitation access, FDI project, the proportion of secondary industries, and GRDP.

The water quality parameters include dissolved oxygen (DO), pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), faecal coliform, total phosphorus, nitrate (NO_3), ammonia (NH_3), total suspended solids (TSS), and total dissolved solids (TDS). The determinants of WQI scores include: (a) the reduction of polluters and efforts to restore different water sources; (b) availability and fluctuation of water discharge influenced by changes in land use as well as local weather, regional and global climate factors; (c) water use; and (d) erosion and sedimentation levels. After analysing the parameters using weighting factors and sub-index values stated above, the assessment produced a scale of 0–100. The WQI scores were categorized into: (1) 0-25 as very bad, (2) 26-50 as bad, (3) 51-70 as moderate, (4) 71-90 as good, and (5) 91-100 as very good.

Economic agglomeration was calculated from the gross regional domestic product of a province divided by the area of the province. The data was obtained from the BPS.

2.2. Empirical model

This study used panel data regression analysis to see the variations in the effects of economic agglomeration, population, the percentage of households with access to sanitation, foreign direct investment (FDI) projects, the proportion of secondary industries, and GDRP on the water quality index in Indonesia. After several model-fit tests and classical assumption tests, the most fitted regression analysis for the hypothesis model was the random effect—panel data as presented in the following equation:

$$WQI_{it} = \beta_0 + \beta_1 + \beta_2 + \beta_3 sanitasi_{it} + \beta_4 + \beta_5\, propisek_{it} + \beta_6\, ln\_gdrp_{it} + e \qquad (1)$$

where *WQI* was the water quality index (scale of 1−100), *ln_ea* was the natural logarithm of economic agglomeration (as GDRP/km^2), *ln_pop* was the natural logarithm of population number, *sanitasi* was the percentage of households with access to sanitation, *ln_fdip* was the natural logarithm of FDI project number, *propisek* was the proportion of secondary industries to the total GDRP, *ln_gdrp* was the natural logarithm of the GRDP, *i* was the cross-section data out of 34 provinces, *t* was the period between 2013−2018, and *e* was the error term.

3. Results and Discussion

3.1. Water quality index and economic agglomeration

On average, the water quality index (WQI) in 34 provinces in Indonesia for six years period (2013 to 2018) scored at 52.4 on a scale of 0−100 (Table 1); higher index scores indicated better water quality. The highest water quality index was recorded by Southeast Sulawesi in 2017 with a WQI of 70, and the lowest was recorded by DKI Jakarta in 2016 with a WQI of 22.31. As the main independent variable, the highest economic agglomeration was set by DKI Jakarta in 2017 with an economic agglomeration of 2610 billion rupiah/km^2, while the lowest was set by Papua Province in 2013 with an economic agglomeration of 0.367 billion rupiah/km^2.

Table 1. Descriptive analysis of main research focus (WQI and EA).

Variable	Unit/description	Obs	Mean	Std. Dev.	Min	Max
Water quality index	Index of 1–100	204	52.41	7.98	22.31	70
Economic agglomeration		204	75.50	385	0.367	2610

The relation between the WQI and EA in Indonesia is presented as a scatter plot in Figure 1. The figure shows that the WQI (y-axis) decreased as the EA (x-axis) increased, which indicates that a higher level of EA would degrade water quality in the area. This condition occurred due to various economic activities that did not meet the environmental operational standards and polluted the water in the area as a consequence.

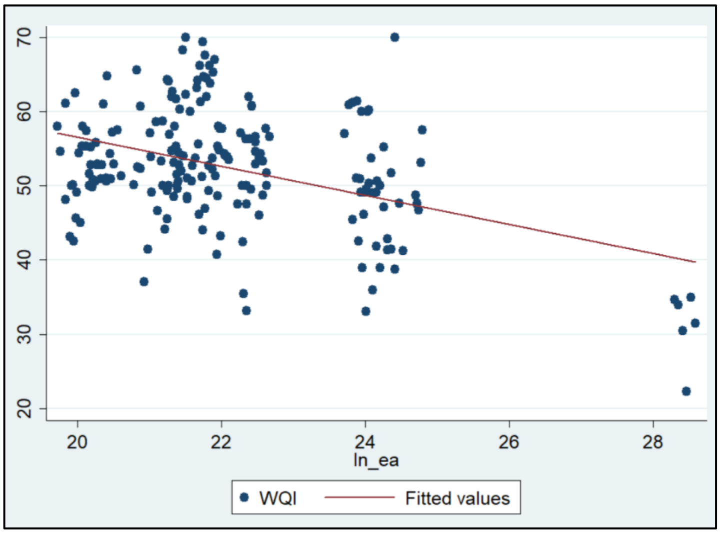

Figure 1. Scatter plot relation between WQI and EA.

After several model-fit tests and classical assumption tests, the most fitted regression analysis for the hypothesis model was the random effect—panel data. To find the best model to analyze the main independent variable (EA) effect to the dependent variable (WQI), this research would show several variable-test model robustness. Four regression estimation options were applied, consisting of different control variables run within the main model stated previously.

- Option 1 – Only one control variable was taken from each control variable proxy (ln_pop, ln_fdip, ln_gdrp).
- Option 2 – Two control variables on demographic of population were used as control variables (ln_pop, sanitation, ln_fdip, ln_gdrp).

- Option 3 –Two control variables on investment and industrialization were used as control variables (ln_pop, ln_fdip, propisek, ln_gdrp).
- Option 4 – All control variables were used (ln_pop, sanitasi, ln_fdip, propisek, ln_gdrp).

Considering the partial significance test, option 1 was the best model to explain the water quality index. The global model estimation shows Prob > |F| at 0.002 which was smaller than 0.01 meaning that all variables i.e. economic agglomeration, population, FDI projects, and GDRP had significant effects on the water quality index. This result was aligned with the partial significance test that shows there were three variables (EA, FDI projects, and GDRP) that significantly affected the WQI. The R-square value of 0.2332 indicates that 23.32% of the water quality index variable diversity could be explained by economic agglomeration, population, FDI projects, and GDRP, while the rest were explained by other variables outside the model.

The results of all options show a consistent significant level of the EA effects on WQI. The best model (option 1) shows that EA had a significant negative impact on WQI at 99% confidence level (P > |z| of 0.003), with β_1 (coefficient) of -2.305. Aligned with the research hypothesis, in Indonesia where agglomeration-led policies were made to boost the economic growth, such policies were expected to degrade water quality. Adopting the environmental Kuznets curve, the agglomeration effect in Indonesia was still in the environmental decay phase, waiting for the tipping point of bell curved-shape and starting to improve the environmental quality. The need for economic agglomeration activities to boost economic growth was still prioritized compared to regulating businesses to prevent any environmental negative externalities. This finding also adds to the list of studies such as Zhou *et al*. [11], de Bok and van Oort [16] and Verhoef and Nijkamp [17] that show a provincial level agglomeration would cause environmental degradation. In terms of the correlation prediction stated in the hypothesis, GDRP shows a consistent difference of correlation results on the four options. Based on the previous literature study, the higher the GDRP amount of a region, the bigger the region economic size, which resulted in a higher number of economic activities that would tend to degrade environmental quality.

As for other variables, the estimation result also shows that the population variable had no significant effect on the water quality index. On the other hand, FDI projects had a significant negative effect on water quality. In general, FDI was established as foreign businesses operated or acquired local assets. Most of the FDI projects were required to achieve certain return levels at cost of any local environmental degradation. Aside from the nature of the foreign investment source that made the FDI projects less attached to domestic environmental issues, this condition was also possible due to the lack of supervision of FDI project practices. With numerous ongoing FDI projects, the supervisors had limitations in checking whether the FDI waste treatment system had met the environmental treatment standard or they simply discharged the waste into rivers or other water flows in the region, at the cost of the water quality in the area.

3.2. Policy Implication
Since the decentralization reforms, the power of water quality management had been transferred from the central government to the autonomous regional governments [18]. The policy states that river management should be organized at the lower administrative level to completely enclose a water body in the district level if the river is located within one district and at higher governmental levels if the river is located within corresponding multiple districts. Therefore, the local government in these economic agglomerated areas should be able to identify which industries are mostly contributing to the pollution, then, incentivize by providing pollution abatement subsidies or impose a progressive wastewater discharge tax to those sectors [4]. Hence, industries could acquire possibly costly technologies to treat the waste before discharge to the water system. These policies can be imposed but monitoring and evaluation must be strictly conducted to enforce the policy and control the waste discharge [19].

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Tabel 2. Regression result analysis.

Var	Hypothesis	Corr.	Option 1		Option 2		Option 3		Option 4	
			Coeff.	**P > |z|**	**Coeff.**	**P > |z|**	**Coeff.**	**P > |z|**	**Coeff.**	**P > |z|**
ln_ea	H1: $\beta_1 < 0$	-	-2.305	0.003 ***	-2.692	0.001 ***	-2.718	0.005 ***	-2.531	0.002 ***
ln_pop	H2: $\beta_2 < 0$	-	-0.715	0.689	-0.039	0.982	-0.478	0.788	0.123	0.946
Sanitation	H3: $\beta_3 > 0$	+			0.074	0.217			0.066	0.271
ln_fdip	H4: $\beta_4 < 0$	-	-1.762	0.019 **	-2.148	0.008 ***	-1.761	0.018 **	-2.115	0.009 ***
Propisek	H5: $\beta_5 < 0$	-					0.118	0.164	0.110	0.185
Manufacture	H5: $\beta_5 < 0$									
ln_gdrp	H6: $\beta_6 < 0$	-	3.299	0.083 *	3.252	0.074 *	2.251	0.268	2.269	0.368
Cons			16.084		13.241		40.729		36.651	
Prob > Chi^2 (F-stat)			**0.0002**		**0.0001**		**0.0002**		**0.0002**	
Overall R^2			**0.2332**		**0.2626**		**0.2524**		**0.2743**	

*significant at p<0.1
**significant at p<0.05
***significant at p<0.01

4. Conclusion

The results of this study suggest that economic agglomeration has a significant negative effect on water quality, indicating economic agglomeration corresponds to the degradation in water quality. The growth in the economic sector wherein industries cluster within certain regions likely generate pollutant emissions and degrade the environment. Future research should include factors that determine the agglomeration at a provincial level, whether an investment is looking for proximity to natural resources as their main input (primary nature) or proximity to non-natural resources factors of production and consumer market (secondary nature). Due to the limited availability of WQI data at the city level, this study focused on provincial level agglomeration. Nevertheless, it was adequate to generate an agglomeration-related policy. However, the more detailed the unit analysis, the more accurate the estimation result should be, therefore, future research should accommodate smaller unit analyses, such as district level.

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