The impact of macroeconomic indicators on carbon emission in Indonesia

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Abstract

The advancement of the industrial sector in economic activities can negatively impact the environment. Inefficient use of natural resources causes environmental damage in almost all countries. Environmental damage caused by economic activities becomes a crucial issue. Hence, the main purpose of this research is to estimate the impacts of macroeconomic indicators on increasing CO_2 emissions in Indonesia with time-series data from 1970 to 2016. The macroeconomic indicators used in this research were broad money, foreign direct investment, value-added manufacturing, and international trade. The analysis method was ARDL-ECM (*Autoregressive Distributed Lag-Error Correction Model*) for long-term and short-term analysis. The main findings in the long term value-added manufacturing and international trade have positive effects on the formation of CO_2 emissions. In contrast, foreign direct investments have significant but negative effects at the 10% significance level of CO_2 emissions. In the short term, only value-added manufacturing and international trade variables have significantly influenced the formation of CO_2 emissions in Indonesia. In contrast, foreign direct investments have been proven to be insignificant. Broad money in both the long and short term is insignificant to CO_2 emissions. Based on these findings and changing climatic conditions, it is necessary to have economic development policies that reduce emissions to preserve the environment and human civilization in the long term.

Keywords: *CO_2 emissions, Foreign direct investment, Value-added manufacture*

JEL Classification: F21, O4, Q5

INTRODUCTION

Economic activities around the world require energy as a raw material. Energy is used as the economy's foundation to stimulate investment and technological progress to create new job opportunities, strengthen the industry, and sustain economic growth (Tong et al., 2020). Industrialization is proven to grow the world economy but disrupts environmental sustainability. The use of energy in industrialization affects the environment, such as air pollution and global warming through carbon dioxide (CO_2) emissions. Azwar (2019) stated that the increase in CO_2 emissions is in line with industrialization. Both developed and developing countries face this condition, Bashir et al. (2019) mentioned that Indonesia is faced with maintaining economic growth by

minimizing environmental damage. As a country with abundant natural wealth, Indonesia has a high level of energy consumption as the use of natural resources in economic activities is limited to achieving economic development and environmental sustainability (Prawoto & Basuki, 2020). Ideally, economic growth is balanced with environmental preservation and renewable and non-renewable resources.

Several previous studies highlighted economic development but did not pay attention to the balance of nature. Chontanawat (2020) found cointegration and causality between CO_2 emissions, energy consumption, and ASEAN economic performance indicating environmental damage in ASEAN countries. Hdom and Fuinhas (2020) showed the negative impact of GDP, renewables, and hydropower on increasing CO_2 emissions in Brazil. A study in Indonesia by Azwar (2019) showed a positive effect of economic growth on CO_2 emissions, especially heat production and electricity. Tong et al. (2020) identified the relationship between CO_2 emissions and economic growth in E7 countries (Brazil, India, Indonesia, Mexico, People's Republic of China, Russia, and Turkey), showing no cointegration between energy consumption, CO_2 emissions, and economic growth in Indonesia, the People's Republic of China, Mexico, and Turkey. In line with a study by Shahbaz et al. (2020) in the UK, energy consumption and financial development contribute to environmental pollution, but CO_2 emissions can still be controlled through research and development expenditure.

The progress of the economic development sector is ideally balanced with the efficiency of energy use in the industrial sector because the challenges ahead will be more serious along with the increase in the use of power generation and transportation. The Indonesian government is serious about managing environmentally friendly industries and is committed to reducing CO_2 emissions (Bashir et al. (2019). According to World Bank data, CO_2 emissions (kg per 2010 US$ of GDP) in Indonesia continued to increase from 1970 to 2016, as did CO_2 emissions (metric tons per capita). This condition is directly proportional to the economic development in Indonesia.

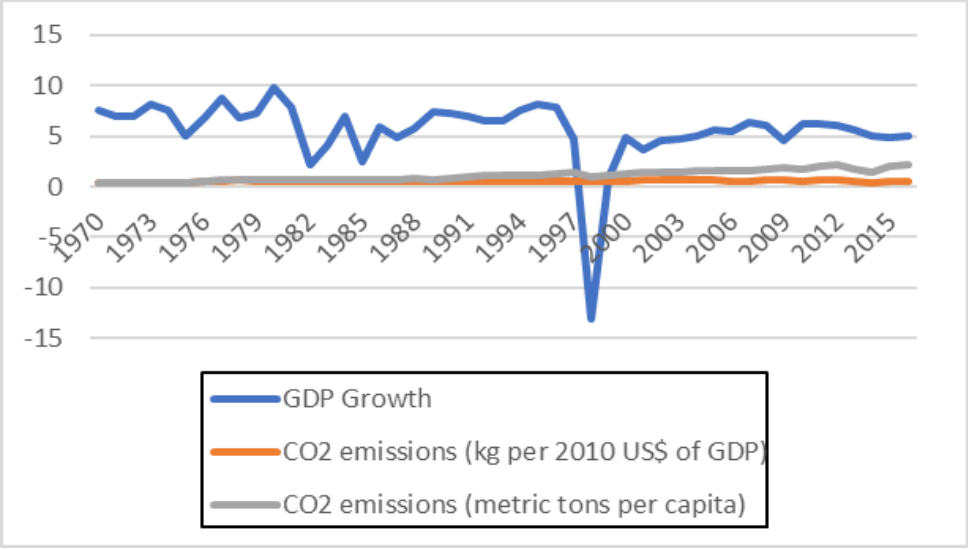

Figure 1. Indonesia's CO_2 emissions and economic growth
Source: World Bank, 2021

Environmental sustainability has now become an international concern. Improving the quality of human life through progressive development requires a better environmental quality. There are still few studies analyzing the effect of economic

activity as proxied by macroeconomic indicators with the risk of increasing CO_2 emissions. Hence, this study examined broad money, foreign direct investment, manufacturing value-added, and international trade on increasing CO_2 emissions in Indonesia from 1970 to 2016. This study contributed to the literature in estimating macroeconomic indicators on increasing CO_2 emissions in Indonesia with long-term and short-term analysis affecting policies in a long-term low-emissions economic development strategy.

METHODS

This study aimed to estimate the effect of macroeconomic indicators such as broad money, foreign direct investment, manufacturing value-added, and trade openness on CO_2 emissions in Indonesia for the period 1970 to 2016. The data used were secondary data from the World Bank. High economic activity is reflected in the success of the industrial sector in Indonesia and stable macroeconomic fundamentals. This study used the Autoregressive Distributed Lag-Error Correction Model (ARDL-ECM), where estimates were made in the short and long term. ARDL is a long-term econometric estimation approach to seeing the effect of variables by getting the effect value consistently through the lag of the dependent and independent variables.

The analysis begins with a data stationarity test where the ARDL estimation does not pay attention to whether the data is in I(0) or I(1). Then, the best lag determination, ARDL estimation, cointegration test, Bound Testing, long-term analysis, and short-term analysis. The last stage is to ensure robustness with Cusum and CusumQ tests. The test model used follows the study of Zubair, Samad & Dankumo (2020):

$$lnCO_{2t} = \beta_0 + \beta_1 BM_t + \beta_2 FDI_t + \beta_3 lnMVA_t + \beta_4 lnTRADE_t + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

CO_2 shows CO_2 emissions from liquid fuel consumption (kt) as the dependent variable. The independent variables used were BM (broad money, % of GDP), FDI (foreign direct investment, net inflows, % of GDP), MVA (manufacturing value-added, constant 2010 US$), and TRADE (exports of goods and services, constant 2010 US$). CO_2 emissions, manufacturing value-added, and trade were transformed into natural logarithms. As for the long-term estimation between CO_2 emissions and the influencing variables developed by Pesaran (2001) :

$$\begin{aligned}\Delta lnCO_{2t} = {} & \alpha + \beta_1 lnCO_{2t-1} + \beta_2 BM_{t-1} + \beta_3 FDI_{t-1} + \beta_4 lnMVA_{t-1} + \beta_5 lnTRADE_{t-1} \\ & + \sum_{i=1}^{p} \delta_{1i} \Delta lnCO_{2t-1} + \sum_{i=0}^{q} \delta_{2i} \Delta BM_{t-i} + \sum_{k=0}^{q} \delta_{3k} \Delta FDI_{t-k} \\ & + \sum_{m=0}^{q} \delta_{4m} \Delta lnMVA_{t-m} + \sum_{o=0}^{q} \delta_{5o} \Delta lnTRADE_{t-o} \\ & + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)\end{aligned}$$

Furthermore, the estimated Error Correction Model (ECM) can explain the imbalance between phenomena and actual events. Hence, adjustments need to be made due to differences in actual phenomena encountered between times. This study used the following model:

$$\Delta lnCO_{2t} = \alpha + \sum_{i=1}^{p} \theta_{1i} \Delta ln\, CO_{2t-1} + \sum_{j=1}^{q} \varphi_{1j} \Delta BM_{t-j} + \sum_{j=1}^{q} \varphi_{2j} \Delta FDI_{t-j} + \sum_{j=1}^{q} \varphi_{3j} \Delta lnMVA_{t-j} + \sum_{j=1}^{q} \varphi_{4j} \Delta lnTRADE_{t-j} + {}^{\gamma}ECT_{t-1} + \varepsilon_t \quad \ldots\ldots (3)$$

RESULTS AND DISCUSSION

The first stage in estimating the study model was the variable stationarity test. Stationarity testing is important for time series data considering that a variable is called stationary if the variable has long-term equilibrium. The stationary variable has a constant mean and variance within a certain value, and the covariance between two periods is only the difference between the two periods. Stationarity testing was carried out using the Augmented Dickey-Fuller test and the Phillips Perron test. The stationarity test is important to ensure cointegration between variables. The ARDL method does not recommend stationary data on I(2). Based on the results of the ADF test, CO_2 emissions, broad money, foreign direct investment, and trade openness were stationary at I (1), only the manufacturing value-added variable was stationary at I(0) and also I(1). Based on the Phillips Perron test, CO_2 emissions and manufacture value-added were stationary at I(0) and I(1), while broad money, foreign direct investment, and trade openness were stationary at I(1). Based on the results, all variables met the non-stationary criteria in I(2), so the ARDL test can be performed.

Table 1. Results of variable stationarity test

Variables	Augmented Dickey-Fuller				Phillips Perron			
	Level		1st Difference		Level		1st Difference	
	Intercept	Trend & Intercept	Intercept	Trend & Intercept	Intercept	Trend & Intercept	Intercept	Trend & Intercept
CO_2	-2.278	-3.060	-6.695	-7.113	-3.071	-2.848	-7.544	9.906
	(0.183)	(0.127)	(0.000)***	(0.000)***	(0.036)**	(0.188)	(0.000)***	(0.000)***
BM	-1.463	-1.167	-3.794	-3.878	-1.668	-0.904	-3.794	-3.888
	(0.543)	(0.905)	(0.006)***	(0.021)**	(0.440)	(0.946)	(0.006)***	(0.020)**
FDI	-3.192	-2.616	-8.864	-8.791	-3.205	-3.171	-8.841	-8.773
	(0.027)	(0.275)	(0.000)***	(0.000)***	(0.026)	(0.103)	(0.000)***	(0.000)***
LMVA	-3.852	-0.509	-4.295	-5.457	-3.664	-0.529	-4.294	-4.993
	(0.005)***	(0.979)	(0.001)***	(0.000)***	(0.008)***	(0.978)	(0.001)***	(0.001)***
LTRADE	-1.111	-2.758	--7.189	-7.145	-1.117	-2.917	-7.189	-7.150
	(0.704)	(0.219)	(0.000)***	(0.000)***	(0.701)	(0.167)	(0.000)***	(0.000)***

*Note: ***, ** and * are significant levels of 1%, 5% and 10%, respectively.*

In the second stage of ARDL testing, the best model was ARDL (2, 3, 4, 2, 4). Based on these tests, several independent variables were significant. Lag 1 of CO_2 and lag 2 of CO_2 significantly influenced CO_2 emissions with a p-value of 5%. Lag 2 and lag 3 of broad money significantly influenced the increase in CO_2 emissions with p values of 5% and 1%, respectively. Lag 3 of foreign direct investment also significantly influenced CO_2 emissions with a p-value of 5%. Manufacturing value added had a significant influence on CO_2 emissions, and lag 2 of trade and lag 4 of trade had a significant influence with a p-value of 5% and 1%. Based on the results, economic activity impacts environmental quality in Indonesia. CO_2 emissions in Indonesia tend to be high due to the continuous use of natural resources. It is also exacerbated by irresponsible land clearing for industrial purposes. This condition demands regulatory improvements in opening new industries to preserve Indonesia's nature to be utilized in the long term.

Table 2. ARDL estimation

Variable	t-Statistic	Std. Error
L CO_2 (-1)	2.559	0.161**
L CO_2 (-2)	-2.164	0.182**
BM	-1.102	0.006
BM(-1)	0.052	0.008
BM(-2)	2.643	0.008**
BM(-3)	-3.118	0.006***
FDI	0.788	0.012
FDI(-1)	-0.224	0.013
FDI(-2)	-0.503	0.013
FDI(-3)	-2.325	0.012**
FDI(-4)	-1.344	0.012
LMVA	2.684	0.280**
LMVA(-1)	-0.551	0.388
LMVA(-2)	-1.146	0.248
LTRADE	0.606	0.151
LTRADE(-1)	-1.794	0.137
LTRADE(-2)	2.725	0.155**
LTRADE(-3)	-1.590	0.126
LTRADE(-4)	3.481	0.106***
C	-4.398	1.297***
Adjusted R-squared	0.985	
S.E. of regression	0.059	
F-statistic	148.131	
Prob(F-statistic)	0.000	

Note: the lag optimal of ARDL is ARDL (2, 3, 4, 2, 4)
*Note: ***, ** and * are significant levels of 1%, 5% and 10%, respectively.*

Bound Test was used to see cointegration between variables. If the value of F-statistics is greater than the upper bounds I(1) value, then there is cointegration showing a long-run relationship among the variables. On the other hand, if the F-value is less than the lower bound I(0), there is no cointegration among the variables. In the table, the F-statistic was 7.9 or higher than the I1 Bound value, so it can be concluded that there was cointegration between CO_2 emissions, broad money, foreign direct investment, manufacturing value-added, and trade openness in Indonesia from 1970 to 2016.

Table 3. Bound testing

Test Statistic	Value	k
F-statistic	7.927	4
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.50%	3.25	4.49
1%	3.74	5.06

Based on long-term estimates (see Table 4), empirically, broad money had no influence on CO_2 emissions in Indonesia during the study. The three independent variables had a significant influence on CO_2 emissions during the study. Foreign direct investment had a significant and negative influence on CO_2 emissions in Indonesia. It means the increase in foreign direct investment will not have any implications for the formation of CO_2 emissions in Indonesia during the observation period. This condition

is different from a study by Zubair et al. (2020) that there is a two-way causality between CO_2 emissions and foreign direct investment in Nigeria. Manufacturing value added and trade openness had a positive and significant influence on CO_2 emissions in Indonesia. It proves empirically that industrialization and openness of the economy will trigger an increase in CO_2 emissions in Indonesia. This phenomenon indicates the need for management in the industrial sector and international trade, not only output-oriented but also low-emissions. Indonesia has a major trading partner contributing to increasing the country's foreign exchange reserves so that special incentives are needed to empower economic actors who care about the environment. Empirically, manufacturing value-added and international trade in the long term encourage the formation of CO_2 emissions to be addressed with economic policies considering the capacity and use of renewable resources by controlling the rate of environmental damage. Another finding in Indonesia by Azwar (2019) showed that the electricity sector and heat production as a driver of economic growth significantly and positively influenced CO_2 emissions in the long term.

Table 4. Long-Run estimation

Variables	t-statistic	Std.error
BM	-0.866	0.002
FDI	-1.896	0.024*
LMVA	2.933	0.087***
LTRADE	3.797	0.117***
C	-5.686	1.021***

*Note: ***, ** and * are significant levels of 1%, 5% and 10%, respectively.*

The environmental Kuznets curve explains the inverse U relationship between economic development and environmental degradation (Dasgupta et al. 2002). The Kuznets hypothesis explains the high probability of environmental damage due to activities to realize economic growth. It arises because the production process is a priority, so it does not focus on environmental aspects. Along with economic development, humans are made aware of environmental conditions, causing a turning point where economic growth is output-oriented and maintains quality and environmental sustainability (Shaharir & Alinor, 2013). Yandle et al. (2004) stated that economic development started in the agricultural sector, where pollution was still relatively low, then switched to the industrial sector requiring more people, capital, and natural resources, resulting in higher pollution and environmental damage. Furthermore, high economic growth makes people aware that wisdom is still needed to manage natural resources efficiently in order to remain sustainable.

Bimanatya & Widodo's (2018) study found unidirectional causality between coal consumption and economic performance in the short term and unidirectional causality between oil consumption on CO_2 emissions in the long term. Nugraha & Osman (2018) also identified energy consumption, industrial value-added, CO_2 emissions, and aggregate consumption had a significant influence on the output of the agricultural sector and the service sector in Indonesia. Bashir et al. (2019), using VECM, found a short-term causality between CO_2 emissions and energy consumption. No causality was found between human capital, state income, and energy consumption per capita on CO_2 emissions per capita. Still, an increase in CO_2 emissions was found due to energy consumption, human resources, and economic growth in Indonesia. Azwar (2019) found that high CO_2 emissions in Indonesia are caused by electricity and heat production. Prawoto & Basuki (2020) identified the effect of investment, exchange rates, the value

of trade, and industrial added value on Indonesia's economic growth in the long and short term, while CO_2 emissions and oil consumption in the long term influenced Indonesia's economic performance.

Based on the estimation results, in the short term, broad money and foreign direct investment had no influence on CO_2 emissions in Indonesia during the study period. However, manufacturing value-added and international trade had a significant and positive influence on CO_2 emissions in Indonesia in the short term. It means the higher the trade openness and industrial progress, the higher the CO_2 emission in Indonesia. It is in line with a study by Shahbaz et al. 2020) in the UK where environmental damage is caused by financial development. In contrast to Prawoto & Basuki's (2020) study in Indonesia, exchange rates, investment, trade, and industrial value-added influenced long-term and short-term economic growth, but CO_2 emissions and oil consumption did not influence economic growth in the long term. In Indonesia, Bashir et al. (2019), there was no influence of economic growth, energy consumption, and human resources on CO_2 emissions. Nuansa & Widodo (2018) also stated that environmental damage in Indonesia is caused by development only pursuing the economic sector. Negative and significant ECT (-1) had a coefficient value of 1.07297, showing the difference between CO_2 emissions with a balance value of 1.07297 so that it was adjusted within 1 year. As a developing country, Indonesia consistently continues to increase economic output, but ideally also pays attention to environmental aspects to create economic growth in line with maintaining environmental quality.

Table 5. Short-Run estimation

Variables	Coefficient	t-statistic	Std.error
D(BM)	-0.008	-1.613	0.005
D(FDI)	0.002	0.199	0.013
D(LMVA)	0.607	2.3197	0.262**
D(LTRADE)	0.399	2.916	0.137***
ECT(-1)	-1.073	-3.158	0.339***
C	-0.016	-0.670	0.024
Adjusted R-squared	0.268	0.268	
F-statistic	4.007		
Prob(F-statistic)	0.005		

*Note: ***, ** and * are significant levels of 1%, 5% and 10%, respectively.*

Chontanawat (2020) found increasing energy consumption in economic activities to increase CO_2 emissions. Hdom & Fuinhas (2020) found a two-way relationship between international trade and energy production in Brazil, where emissions of pollution and international trade positively influenced economic output. On the other hand, hydropower, GDP, and renewables negatively influenced CO_2 emissions in Brazil. Shahbaz et al. (2020) identified the impact of industrialization on the UK economy by analyzing R&D expenditures, economic growth, energy consumption, and financial development allegedly causing CO_2 emissions. It shows that the cointegration between CO_2 emissions and influencing factors with energy consumption and financial development is proven to disturb the environmental balance, while R&D expenditures can control CO_2 emissions. A study in the Philippines by Lim et al. (2014) showed a bidirectional causality between oil consumption and economic output, and a unidirectional causality between CO_2 emissions and the Philippines' economic performance. A study in E7 (Brazil, India, Indonesia, Mexico, People's Republic of China, Russia, and Turkey) by Tong et al. (2020) found no cointegration between

energy consumption, economic growth, and CO_2 emissions in Indonesia, Mexico, Turkey, and China. This study showed short-term causality between energy consumption and CO_2 emissions in all E7 members except Indonesia and causality between economic output and CO_2 emissions in Brazil, Mexico, China, and India. This study also showed causality between economic growth and energy consumption in India, Indonesia, Brazil, Mexico, and China, as well as causality between CO_2 emissions and energy consumption in all E7 member countries.

A robustness test for the ARDL method can be performed with the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ). Based on the Cusum and CusumQ tests, the variable had significance at the 5% confidence level, indicating parameter stability.

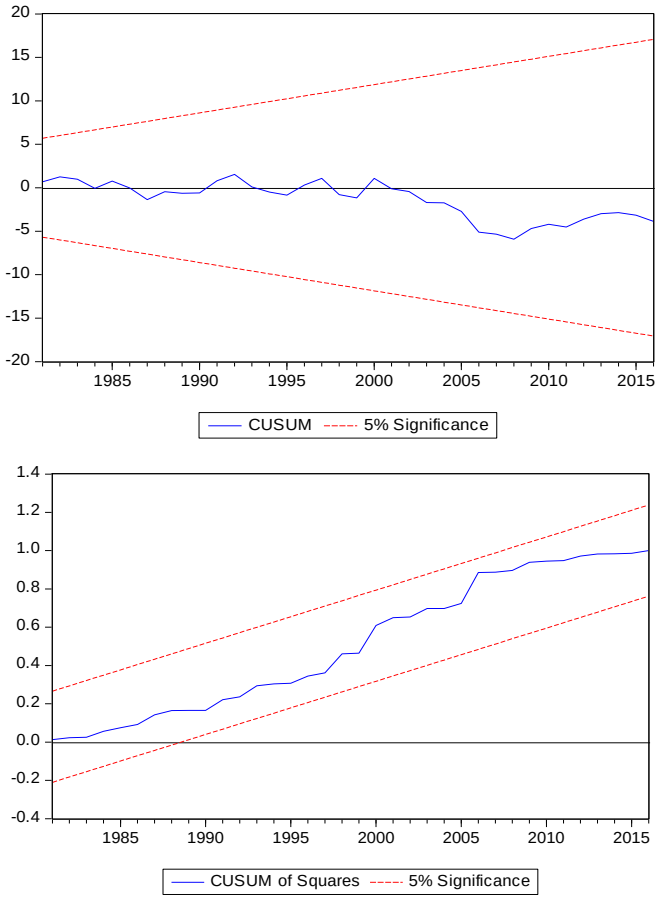

Figure 2. Cusum & CusumQ Test

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Industrial progress supports the economy in many countries globally, so it cannot be denied that environmental conditions are disturbed. Humans use natural resources as a factor of production and use technology that can negatively affect environmental sustainability. The use of renewable and non-renewable natural resources is at the heart of the economy. Global warming, air pollution, damage to ecosystems, to CO_2 emissions are evidence of environmental disruption. It is very important to study the

impact of economic activities on CO_2 emissions. This study found the positive influence of manufacturing value-added and international trade on CO_2 emissions in Indonesia's long term and short term. High economic activity causes environmental damage. Foreign direct investment negatively influenced CO_2 emissions in the long term, while broad money was insignificant. In the short term, foreign direct investment and broad money were insignificant. Based on Cusum and CusumQ tests, the model was stable and consistent.

Recommendations

The policy recommendations are: 1) the importance of regulations on the use of natural resources and environmentally friendly energy, 2) the synergy of relevant institutions in Indonesia to create clarity on sanctions for violating the law, 3) increase research and development related to CO2 emissions, 4) mitigation and energy-saving applications for sustainable development in Indonesia.

The limitation of this research is the use of CO_2 emission data is still limited nationally and does not include data analysis at the provincial or city level. Thus, for further research, it may be possible to conduct more comprehensive research that analyzes the impact of macroeconomics indicators on CO_2 emissions that represent the real conditions in regions of Indonesia.

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