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Implications of Population Growth and Oil Production on CO_2 Emissions: Empirical Evidence from Nigeria

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Abstract

This study analyzes the impact of rapid population growth, oil production on CO2 emissions in Nigeria within the framework of the error correction model, using annual time series data from 1970 - 2010. The study reveals that C02 emission in Nigeria and its hypothesized determinant are generally I (1) series, with two co-integration equations existing among their linear combinations. Our results show that, the variables in the model, population, oil production and per-capita gross domestic product are positively related to increase emissions in the country. Overall the variables account for 64% of the variation in $C0_2$ emission and it is highly significant at 5% as shown by the F-statistic ($p < 0.05$). The coefficient of the ECM behaved, having its expected negative sign and is significant at 5%. However, the speed of adjustment is low. In order to mitigate $C0_2$ emissions, the following recommendations are made: diversification of energy sources, proper funding of the sector, and adequate maintenance of energy infrastructure among others.

Introduction

Over the years, there has been rapid world population growth due largely to net increase in birth rate precipitated by advancement in technology, improved health facilities and better living standards. Goujon et al (1995) asserts that increasing population has the possibility of exerting pressure on demand for energy for transport, power, industry, deforestation, that would ultimately lead to increase in carbon-dioxide (CO_2) or greenhouse gases (GHG) emissions. Carbon-dioxide emissions hold the sun radiation in the atmosphere and regulate the temperature of the earth/globe. Besides emission of CO_2 makes it impossible to achieve sustainable development – a situation where the needs of the present are met, without compromising the ability of future generation to meet their own needs. Thus, rapid population growth is likely to put more people at greater risk from climate change.

Global carbon-dioxide emissions due to human activities have grown since the industrial revolution in the 18th century, and have continued to increase at an excessive level into the 21st century. Precisely, global CO_2 emissions increased from 20 to 30 between 1970 and 2009. However, much of the focus on anthropogenic CO_2 emissions has been on the developed world and emerging economies in Asia. which together account for over 80% of the cumulative CO_2 emissions and growth (Raupach et al., 2007). Available data has shown that in Nigeria Co_2 emissions rose from 5,874 thousand metrics tons in 1970 to 95,756 thousand metric tons in 2008. During the same period, the population of Nigeria grew at about 2.3 percent, while oil production increased by about 672,565.1 barrels on the average (World Bank 2009). The literature is replete with studies that examine the impact of climate change on sustainable development in Nigeria. (Omojolaibi, 2011. Oniemola, 2011). However, very few studies have examined the impact of rapid population growths, oil production on carbon-dioxide (co_2) emissions. Thus, this study will contribute and extend the literature in this respect. Specifically, this study examines whether rapid population growth and oil production have a long-run impact on $C0_2$ emissions in Nigeria. Furthermore, the historical trend of growth in population, oil production and emission of carbon-dioxide (CO_2) in Nigeria are scrutinized in the study.

The rest of this paper is structured as follows: section 2 is on review of empirical literature, while section 3 focuses on some stylized facts on population growth, oil production and $C0_2$ emission. Conceptual framework and methodology are the focus of the exposition in section 4. Results and discussion are presented in section 5 while section 6 is on the policy recommendations and conclusion.

2. Empirical Literature Review

The relationships between population growth and carbon-dioxide emission have been a subject of discussion in the literature. Erlich and Holdren (1971) suggest a suitable framework to analyse the determinants of environmental impact known as the equation IPAT: I=PAT where I represents environmental impact, P is the population size, A is the affluence and T denotes the level of environmentally damaging technology. The impact of human activity in the environment is viewed as the product of these three factors. Initially, this formulation was purely conceptual and could not be directly used to test hypotheses on the impact of each one of the factors on emissions mentioned above.

The IPAT model can be expressed as an identity where A could be defined as consumption per capita and T as pollution per unit of consumption. As stated in MacKellar et al. (1995), the IPAT identity is a suggestive approach that shows how environmental impact is not only due to a single factor. However, these authors outline the limitations of testing this identity in relation to the choice of variables and the interactions between them. They compare households (H) with total population levels, as the demographic unit used to forecast future world CO_2 emissions and they show how each choice lead to different predictions in all the regions of the world, always being higher the impact on emissions for the I=HAT model, where households replaces population.

Cole and Neumayer (2004) refer to the utility of the tautological version of the IPAT model for decomposition purposes but also highlight its limitations to estimate population elasticities. For such estimation they use the model proposed by Dietz and Rosa (1997). Starting from the idea of Ehrlich and Holdren (1971), Dietz and Rosa (1997) formulated a stochastic version of the IPAT equation, with quantitative variables containing population size (P), affluence per capita (A) and the weight of the industry in economic activity as a proxy for the level of environmentally damaging technology (T). These authors designate their model using the term STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology). Their results corroborate the Malthusian thesis in the sense that population growth has a more than proportional impact in CO_2 emissions. On the other hand, the study conducted by Cramer (1998), based on a similar model, shows a contamination-population elasticity less than unity for the five pollutants analysed in several areas of the USA. This discrepancy could be explained by the exclusion of carbon dioxide from among the pollutants considered by this author.

Dietz (2003) studied the impact of population on carbon dioxide emissions and energy use within the framework of the IPAT model. The results from these studies indicate that the elasticity of CO_2 emissions and energy use with respect to population are close to unity. The unity assumption for the population elasticity was embedded in the original IPAT formulation of Ehrlich and Holdren (1971) but not in the stochastic version of the IPAT (STIRPAT) formulated by Dietz and Rosa (1997). Using panel data, Shi (2003) finds a positive relationship between population changes and carbon dioxide emissions in 93 countries over the period 1975 to 1996. He finds that the impact of population on emissions varies with the levels of affluence and had been more pronounced in lower-income countries than in higher-income countries. In the same vein, Cole and Neumayer (2004) considered 86 countries during the period 1975 to 1998 and reveal a positive link between CO_2 emissions and a set of explanatory variables which include population, urbanization rate, energy intensity, and smaller household sizes. The authors assume that the effect of population and urbanization is equal for all income levels.

In addition, several studies have discussed and tested the existence of an Environmental Kuznets Curve (EKC) where the relationship between pollution and income was considered to have an inverted U-shape. These models frequently take emissions per capita for different pollutants as an endogenous variable, assuming implicitly that the elasticity, emission population, is unitary. A few of them considered population density as an additional explanatory variable (see, Cole et al., 1997 and Panayotou et al., 2000). However, their tests were not based on an underlying theory, and testing variables individually was subject to the problem of omitted-variables bias. According to Stern, (1998) and (2004), the results obtained within this framework were far from homogeneous and their validity had been questioned in the literature. Most of the criticisms are related to the use of non-appropriate techniques and the presence of omitted-variables bias. As Perman and Stern (2003) admitt, when diagnostic statistics and specification tests are taken into account and the proper techniques are used, the results indicate that the EKC does not exist. Borghesi and Vercelli (2003) consider that the studies based on local emissions present acceptable results, whereas those concerning global emissions do not offer the expected outcomes. Therefore the EKC hypothesis cannot be generally accepted.

Also decomposition methods have been applied to an increasing number of pollutants in developed and developing countries (for an extensive discussion on this, see, Hamilton and Turton, 2002; Bruvoll and Medin, 2003; Lise, 2005). Emissions are typically decomposed into scale, composition, and technique effects. Scale effects are measured with income and population variables, composition effects refer to changes in the input or output mix, and technique effects are proxied by energy intensity (the effect of productivity on emissions) and global technical progress. Hamilton and Turton (2002) conclude that income per capita and population growth are the two main factors increasing carbon emissions in OECD countries, whereas the decrease in energy intensity is the main factor reducing them. Bruvoll and Medin (2003) cover 10 pollutants and determine that in all cases, technique effects were dominant in offsetting the increase in scale. The authors conclude that, whereas structural change explains the increase in energy intensity during the period from 1913 through 1970, technical change was the main factor reducing energy intensity after 1970. Shifts in the fuel mix are the main factor explaining carbon emissions per unit of energy used. Stern (2002) use an econometric model to decompose sulphur emissions in 64 countries during the period 1973 to 1990 and reveals that the contribution of input and output effects on changes in global emissions is very modest, whereas technological change considerably reduced the increase in emissions.

3. Stylised Facts on Population Growth and $C0_2$ Emission.

It is currently acknowledged that global C02 emission has continued to increase. The United Department of Energy's Carbon Dioxide Information Analysis Centre (2010) notes that global C02 emission rose from 29,888,121 in 2008 to 33,508,901 in 2010. The top 10 countries in the world emitted 67.07% of the world total global C02. As shown in Table 1 below, as at 2010, China has the highest $C0_2$ emission with a value of 8,240,958 thousand metrics tones, followed by United States with 5,492,170 and India, Japan and Mexico with 2,069,958, 1688,688 and 1,138,432 thousand metrics tones respectively. Although Africa, particularly Nigeria, is not among the top ten countries emitting C02 in the world, available statistics has shown that C02 emission in Nigeria has continued to rise (see fig.1 below).

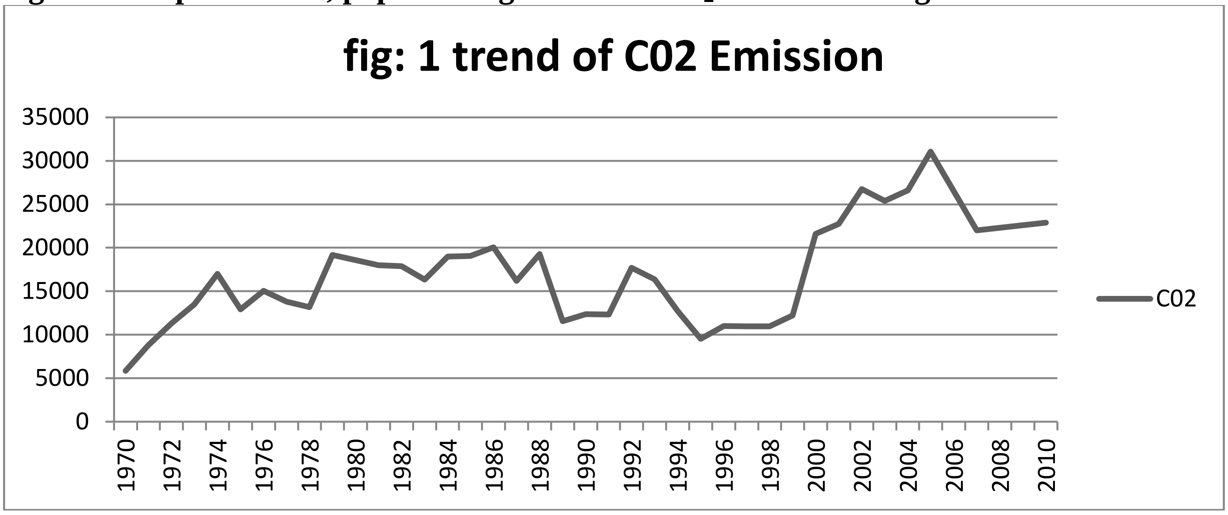
Table: 1 $C0_2$ emission and population growth

Country	C02 Emissions	Population
China	8, 240,958	1,339,724,852
India	2,069,738	1,210,193,422
United states	5,492,170	312,793,000
Indonesia	476,557	237,424,363
Brazil	419,537	190,732,694
Russia	1,688,688	142,946,800
Japan	1,138,432	128,056,026
Mexico	466,131	112,322,757
German	762,543	81,799,600
Iran	574,667	75,330,000
France	362,556	65,821,885
United Kindom	493,158	62,262,000
Italy	407,924	60,681,514
South Africa	451,839	50,586,757
South Korea	563,126	48,875,000
Saudi Arabia	493,726	27,136,977
Nigeria	224,872	158,259,000

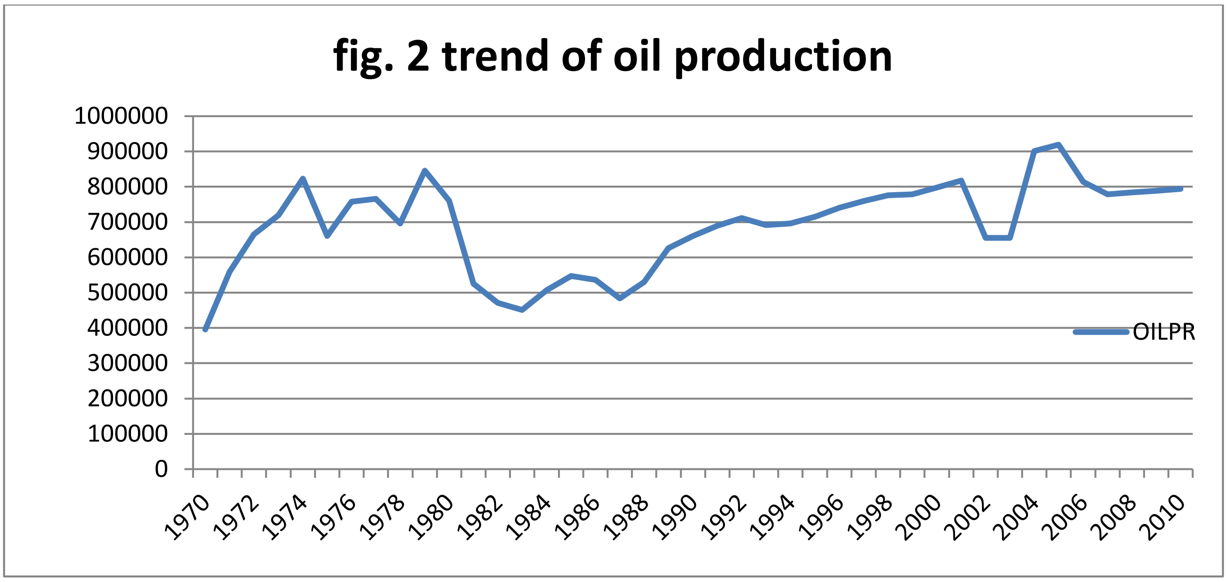
Source: United Department of Energy's Carbon Dioxide Information Analysis Centre (2010)

The details of carbon-dioxide emission in Nigeria for the period 1970 to 2010 are shown in Figure 1 below. C02 in Nigeria ranged from 5,874 thousand metrics tones in 1970 to 21,593 thousand metrics tones in 2000 and 224.872 thousand metrics tones in 2010. In the same vein, oil production has simultaneously risen. (See Figure 2 below). A major reason for this might not be unconnected with the gas flaring in the production of oil. Although the Nigerian government have put up the Gas Master Plan policy to avoid gas flaring, a large amount of gas is still flared. If this is not controlled, there is the evidence that $C0_2$ emission in Nigeria will continue to rise drastically in the years ahead.

Figure: 1 oil production, population growth and $C0_2$ emission in Nigeria.



Source; CBN (2010)



Source; CBN (2010)

3. Conceptual Framework and Methodology

We may intuitively state that mankind's activities and oil production influence the level of CO_2 emissions in the atmosphere. However, it is more difficult to determine what specific factors represent mankind's activities and to what extent each of them contributes to the increase or decrease in CO_2 emissions.

Following the IPAT equation: I= PAT by Erlich and Holdren (1971), and the STIRPAT model formulated by Dietz and Rosa (1997), we specify a linear version of the STIRPAT model. In order to test whether the factors considered in the STIRPAT model influence the level of CO_2 emissions. Thus the initial specification is given by the following equation:

$$\mathbf{I} = \alpha \mathbf{P}^{\delta} \mathbf{A}^{\beta} \mathbf{T}^{\gamma} \mathbf{e} \quad \text{...} (1)$$

Where I = carbon-dioxide emissions, P = population, A = gross domestic product per capital expressed in 1990 constant price and T = energy production since it required more technology to produce energy. α, δ γ β are parameters to be estimated and e is the random error. We form the empirical model by taking logarithms of equation 1 Thus:

$$\log \mathrm{I_t} = \alpha + \delta \log \mathrm{P_t} + \beta \log \mathrm{A_t} + \gamma \log \mathrm{T_t} + \varepsilon_{\mathrm{t}} \quad \text{.....................................} (2)$$

Where P, T, A remain as defined above. On apriori, we expect δ γ β > 0. Since the model is specified in natural logarithms, the coefficients of the explanatory variables can directly be interpreted as elasticities.

Before estimating the models, the dependent variable and independent variables are separately subjected to stationarity tests using the unit root test, since the assumptions for the classical regression model require that both variables be stationary and that the errors have a zero mean and constant variance. The unit root test is evaluated using the Augmented Dickey-Fuller test, which can be determined as:

$$\Delta Y_t = \alpha + \beta\tau + \delta Y_{t-1} + \sum_{t=1}^{m} \Delta Y_{t-1} + \varepsilon_t \quad \text{…………………………………….....} (3)$$

Where α represent the drift, t represent deterministic trend and m is a lag length large enough to ensure that ε is a white noise process.

If the variables are integrated of order one I (1), we test for the possibility of a co-integrated relationship using the Johansen Co-integration Technique. The study employs the error correction model (ECM) because it is an appropriate estimation technique that captures the short run and long run effect of the differenced variables. It connects the short run and the long-run behaviour of the dependent and independent variables. The proposed long-run is in equation 2 above.

If the Y_t and X_t are found to be co-integrated, then there must exist an associated Error Correction Model (ECM), according to Engel and Granger (1987). The usual ECM may take the following form:

$$\Delta Y_t = \alpha_0 + \beta_\iota \sum_{t=1}^{m} \Delta X_{t-1} + \delta_i \sum_{t=1}^{m} \Delta Y_{t-1} + \gamma_1 \varepsilon_{\tau-1} + \psi_t \quad \text{………………….......…} (4)$$

Where, Δ denotes first difference operators, ε_{t-1} is the error correction term, m is the number of lags necessary to obtain "white noise" and ψ_t is another random disturbance term. If /δ/ is significantly different from zero, then Y_t and X_t will have longer run relationship. The (ECM) error correction term (ε_{t-1}) depicts the extent of disequilibrium between Y_t and X_t. the ECM, reveals further that the change in Y_t not only depend on lagged changes in x_t but also on its own lagged changes. The estimate of the parameters of the ECM are generally consistent and efficient (Hendry and Richard, 1983). Inference about the long run Granger causality can be drawn from the ECM model. The presence of co integration will indicate at least, unidirectional long run causality from ΔX_{t-j}, If statistically significant will indicate a short run causality from ΔX_{t-j}, to ΔY_{t-j} . The statistically significant non-Zero co-efficient of ΔY_{t-j} will indicate feedbacks to ΔY_t from its own lagged values. It may be noted that even in the absence of co-integration, the error correction model may be estimated to detect if there is any short run granger causality.

The study used annual time-series data. The data of interest are amount of CO_2 emissions in tons, population, Gross Domestic Product (GDP) per capita expressed in 1990 constant price and oil production. These data are sourced from the Central Bank of Nigeria (CBN) statistical Bulletin (2010).

5. Results and Discussion

As a preliminary step to analyzing the result, we carried out the unit root test using the Augmented Dickey Fuller (ADF) test, since research has shown that regression coefficients with non-stationary variables may lead to spurious and misleading conclusion. The results of the unit root test are presented in Table 2 below.

Table 2: Result of ADF unit root test.

UNIT ROOT TEST FOR VARIABLES					
Variables		ADF test stat	1%	5 %	Order of integration
$LOGC0_2$	Level	-2.22784	-4.2092	-3.5279	I(1)
	1st diff	-4.11647	-4.2165	-3.5312	
PG	level	-2.0418	-4.2165	-3.5312	I(1)
	1st diff	-5.5128	-4.2242	-3.5348	
LOGPGDP	Level	-1.7624	-4.2165	-3.5312	I(1)
	1st diff	-4.2350	-4.2242	-3.5348	
LOGOILP	level	-2.9307	-4.2092	-3.5279	I(1)
	1st diff	-5.7855	-4.2165	-3.5312	

Source: Authors result using E-views 7

The result in Table 2 above indicates that the individual series for the variables are stationary at first difference i.e. they are integrated of order one, I(1) Thus, we proceeded to carrying out the co-integration test using Johansen Co-Integration test; this is presented in Table 3 below.

Table 3: Result of Co-integration test.

Hypothesize No. of CE(s	Eigenvalue	Trace Statistic	0.05 Critical Valu	Prob.**
None *	0.733100	84.36141	47.85613	0.0000
At most 1 *	0.515885	34.16786	29.79707	0.0147
At most 2	0.154676	6.601449	15.49471	0.6244
At most 3	0.005671	0.216110	3.841466	0.6420

Source: Authors result using Eviews 7

The co-integration result is presented in Table 3 above. As shown in the table, the null hypothesis of no co-integration is rejected as the trace test reveals that, two co-integration equation exists among linear combinations of C02 and its hypothesized determinants for test at 5% level of significance. The implication of the foregoing is that even though C02 emission in Nigeria and its hypothesised determinants are generally I(1) series, some stable long-run equilibrium relationship exists among the series, which could be given some error correction representations (Engle and Granger, 1987). It also shows that the possibility of the estimated relationship being spurious is ruled out.

Table 4: Estimated short –run result with ΔC02 emission as dependent variable

Regressors	Co-efficient	Standard error	T-stat	P- Value
C	-0.007479	0.034206	-0.218640	0.8282
ΔLOGPGDP	0.495414	0.244025	2.030180	0.0502
ΔLOGPG	1.018706	0.424438	2.400129	0.0214
ΔLOGOILP	0.499518	0.237375	2.104340	0.0428
ECM(-1)	-0.246429	0.119619	-2.060122	0.0471
R-squared	0.758770			
R-Bar-Squared	0.630754			
F-stat	3.430990 prob(F-statistic = 0.018477)			
DW-statistic	1.868567			

Source: Authors result using Eviews 7

The result of the short run determinant of carbon-dioxide emission is presented in Table 4 above. The results indicate that all of the variables included in the model are statistically significant (although at different level) and conforms to their expected signs. With respect to the estimated elasticities, the population elasticity is slightly higher than one, in line with previous research. The implication of this is that the reduction of global emissions will become a more challenging task as most developing countries are experiencing rapid economic growth. Rising per-capita gross domestic product, as revealed in this study, are associated with upward trend in emissions. From the result oil production also has a positive effect on CO2 emissions. However, estimated coefficient for oil production indicates a slight higher effect than per-capita gross domestic product on emissions. A reason for this might be the high amount of gas flaring during oil production in the previous years.

An examination of the F-statistic and the adjusted R^2, suggest that the variables in the error correction model significantly explain changes in carbon-dioxide emissions at $p < 0.05$, accounting for 63% of the short-run variation in the series. The coefficient of the ECM term captures the adjustment towards the long-run equilibrium. The coefficient of ECM also reveals the proportion of the disequilibrium in the differenced dependent variable in one period that is corrected subsequently during the next period. The result indicates that the speed of adjustment is low as only 0.2464(25%) of the error is corrected.

5. Conclusion and Policy Recommendation

In this study an error correction modelling of the determinants of carbon dioxide emissions in Nigeria during the period 1970 to 2010 was conducted. Following the STIRPAT model by Dietz and Rosa (1997), we specify a model which expresses carbon-dioxide emissions as a function of population (PG), per capita gross domestic product and oil production. The results showed that the variables in the model significantly affect the dependent variable as showed by the R^2 and F-statistic. The coefficient of the ECM is well behaved and significant; however, the speed of adjustment is low. On the basis of apriori expectation, the entire variables have their expected signs. On the basis of the result, the following policy recommendations are made:

- ✓ Increase energy efficiency of economic production in the country. As revealed in this study, oil production significantly contribute to C02 emission, thus, an increase in energy efficiency will lower the amount of C02 emissions. Alternatively, the use of clean energy should be encouraged.
- ✓ Proper maintenance of and additional energy infrastructure**:** This involves increment in energy infrastructure (particularly gas infrastructure). This will help drastically to reduce emission of $C0_2$ and will increase gas production and consumption which will, all things been equal, lead to economic growth. Also, there is the need to cultivate maintenance culture to avoid existing energy infrastructure from damaging.
- ✓ Diversification of energy sources**:** over the years, fossil fuels have been a major source in the provision of energy in Nigeria. However, because of the damage it cause policy makers and analysts everywhere in the world have shifted attention towards clean energy. It is necessary, therefore, for the Nigerian government to begin to encourage the use of this non-fossil fuel to drastically reduce $C0_2$ emission.
- ✓ Proper funding of the sector: The energy sector is capital intensive in nature, as a result, it requires huge amount of investments. Thus, the public and private sector could form a partnership to tackle investment problem. Also, government needs to increase the budgetary allocation to the sector particularly on clean energy infrastructure and make the release of funds as fast as possible without delays.

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