Trade, FDI, Growth and Biodiversity: an empirical analysis for the main OECD countries.

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Abstract

Whether the Environmental Kutznets curve relationship holds for biodiversity or not remains an open issue. While there are several studies investigating the EKC relationship for biodiversity, they suffer from some limitations and the empirical evidence is inconclusive. More specifically, with few exceptions, the previous EKC studies for biodiversity looked into the diversity of a particular species or a number of species rather than a broader measure of biodiversity. In addition, these studies do not control for some economic factors that could directly or indirectly affect the biodiversity stock such as trade and foreign direct investments (FDI). International trade, in fact, could influence the biodiversity trough the effects on economic growth, production specialization and technological innovation diffusion. The presence or not of FDI in a country could be of help in assessing the "pollution haven" hypothesis that has obvious feedbacks on biodiversity.

The innovative features of this paper are its attempts to estimate a ECK for biodiversity using an overall index of biodiversity terrestrial and marine and the inclusion in the traditional ECK equation of proxies for trade and FDI. According to our estimates for the main OECD countries in the period 1990-2010, the ECK hypothesis is partially verified. Rising incomes are first associated with increasing biodiversity then with decreasing biodiversity and eventually with increasing biodiversity again. This non-monotonic relationship could be explained by the fact that a certain level of income (production) there may be some biodiversity losses that cannot be continuously substituted with environmental-friendly production technology due to ecological threshold and the unique nature of the damage.

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INTRODUCTION

Since it first appeared as a formal concept in the early 1990s, the environmental Kuznets curve (EKC) hypothesis has engendered significant debate within academic and policy literature. The hypothesis states that environmental degradation will increase with economic development up to a point, upon which additional development will lead to a decline in environmental degradation.

The seminal papers on this issue were those of Grossman and Krueger (1991) concerning the potential environmental impacts of NAFTA and the Panayotou (1993) study for the International Labour Organization. They reached a similar conclusion: cross-country analyses showed that the relationship between some pollution indicators and income per capita could be described as an inverted-U curve. Panayotou for first coined it the “Environmental Kuznets Curve” (EKC) given its similarity to Kuznets’ hypothesis[1].

Whether the Environmental Kutznets curve relationship holds for biodiversity loss or not is a particularly challenging issue to investigate. In fact, there may be some biodiversity losses that cannot be continuously substituted with better production technology and thus the ECK hypothesis would be rejected.

The empirical literature investigating the EKC relationship for biodiversity is not particularly recent, suffers from some limitations and do not reach unique results. More specifically, with few exceptions, the previous EKC studies for biodiversity looked into the diversity of a particular species or a number of species rather than into a broader measure of biodiversity. In addition, these studies do not account for some economic factors that could directly or indirectly affect species diversity such as trade and foreign direct investments (FDI). International trade, in fact, could influence the biodiversity trough the effects on economic growth, on production specialization and on technological innovation diffusion. The presence or not of FDI in a country, on the other hand, could help in assessing the “pollution haven[2]” hypothesis that if verified has obvious feedbacks on biodiversity.

The innovative features of this paper are its attempts to estimate ECK for biodiversity using an overall index of biodiversity terrestrial and marine and including in the traditional ECK equation proxies for trade and FDI for the main OECD countries in the time period 1990-2010.

The paper is organized as follows. The first section conducts a critical survey of the most recent empirical literature, the second and the third sections describe the

[1] A Kuznets curve is the graphical representation of Simon Kuznets' hypothesis that as a country develops, there is a natural cycle of economic inequality driven by market forces which at first increases inequality, and then decreases it after a certain average income is attained

[2] The pollution haven theory posits that foreign investors from industrial countries are attracted to weak environmental regulations in developing countries. This principle says that a company would want to locate in a country with the lowest environmental standards.

empirical strategy, the equation and the dataset and the estimation results. Conclusions follow.

1. A SURVEY OF THE LITERATURE:

The EKC relationship has generated extensive debate and empirical investigation[3]. Various empirical EKC studies have employed different methods, and evaluated different environmental indicators resulting in a broad spectrum of findings. Based on a number of empirical findings supporting the EKC, some analysts argue that there exists a general inverted U-shape relationship between economic growth and the environment. On the contrary, others argue that there is no inverted U-shape relationship between income and overall environmental quality (e.g., Stern 1998; Stern and Common 2001; Harbaugh et al. 2002).

This debates on the relationship between growth and environmental quality is complicated further if we consider the fact that some environmental losses, as the loss of biodiversity, cannot be continuously avoided with an environmental friendly production technology.

Whether the EKC relationship holds for biodiversity loss, remains an open issue[4]. As in the broader EKC literature, most authors estimate a regression model with some measure of biodiversity as the dependent variable and per capita income or a higher order polynomial as the independent variable, in addition to some additional covariates that might be relevant. The most frequent additional covariates are population density or some related measure such as fraction of urban population, economic aggregates such as measures of trade intensity or the share of agriculture, and measures of civil and political liberties and/or political institutions.

The empirical evidence is assessed in terms of the statistical significance of the estimated coefficients on the income terms and the location of the 'turning point,' that is, the level of income at which biodiversity-income relationship changes from decreasing (increasing) biodiversity with increases (decreases) in income to increasing (decreasing) biodiversity with increases (decreases) in income. The studies investigating the EKC relationship for biodiversity, with few exception are subject to various limitations. More specifically, they looked into the diversity of a particular species or a number of species rather than into a broader measure of biodiversity. Different authors use very different measures of biodiversity[5.]

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[3] The empirical robustness of the inverted U-shape relationship remains a debatable issue. For an extensive survey see Jie He (2007).

[4] Table 1 in the appendix taken from Rothman and Khanna (2008) summarizes the empirical literature on the EKC for biodiversity.

[5] Maozumder et al (2006) investigate the EKC hypothesis for the overall risk of biodiversity loss by using the multivariate National Biodiversity Risk Assessment Index (NABRAI; Ryers et al. 1998, 1999) and several variants, which include genetic, species, and ecosystem diversity. McPherson and Nieswiadomy (2000) examined the EKC relationship for threatened birds and mammals and found an N-shape relation for threatened birds; the implication is that biodiversity loss ultimately increases with

The literature may be classified, for merely descriptive purposes, into two broad categories based on the measure of biodiversity used. The first category includes those studies where the authors argue that their measures of biodiversity are such that the loss in biodiversity is irreversible and cannot be recovered so that the relationship between their measure of biodiversity and per capita income is expected to be monotonic. (Asafu-Adjaye (2003) and Dietz and Adger (2003)). The second group of studies allows for the possibility of a non-monotonic relationship between biodiversity and per capita income. All the other studies fall into this category and employ a measure of biodiversity that can be expected to decrease as well as increase within a reasonable timeframe.

The evidence regarding the existence of an EKC for biodiversity is inconclusive. One key insight from this literature is the important role of non-income variables in explaining biodiversity change. Therefore, changes in biodiversity are associated with other socio-economic and political factors such as the structure of the economy, population density and urbanization, and the degree of civil and political liberties. This finding is very much in line with the wider literature on the EKC hypothesis.

2. EMPIRICAL STRATEGY, EQUATION AND DATASET

The EKC literature have hypothesized that the relationship between economic growth and environmental quality is not monotonic and may change sign from positive to negative when a country reaches a certain level of income. The same phenomenon may be drawn on the supply side by changes in input and output mix when the latter are correlated with domestic per capita income. This implies an inverted-U shape relationship between environmental degradation and income. For this reason, the standard EKC curve could be represented by a polynomial approximation as follows:

$$ES_i=a_1+b_1X_i+b_2X_i^2+b_3X_i^3+e_i \qquad (1)$$

Where: ES is the environmental stress level, Xi the per capita income of country i and ei is the error term.

Equation (1) allows testing hypotheses of ES -income relationships.

i) If b1 > 0 and b2= b3= 0 reveals a monotonically increasing relationship indicating that rising incomes are associated with rising level of ES;
ii) b1< 0 and b2=b3= 0 reveals a monotonically decreasing relationship indicating that rising incomes are associated with decreasing level of ES;

higher level of income. They found no evidence of an EKC relationship for threatened mammals. Naidoo and Adamowicz (2001) examined the EKC relationship for birds and mammals as well as for amphibians, reptiles, fishes, invertebrates and found a general U-shape relationship for amphibians, reptiles, fishes, and invertebrates. However, they find an inverted U-shape relationship for birds and mammals. Dietz and Adger (2001) examined the EKC hypothesis using species area-relationship in a number of tropical countries. They found no EKC relationship between income and biodiversity loss, but did find that conservation effort increases with income.

iii) b1> 0, b2< 0 and b3= 0 reveals a quadratic relationship representing an inverted U- shape EKC relationship. That is, rising incomes are associated initially with increasing ES and eventually with decreasing ES.
iv) b1 <, 0 b2 > 0 and b3= 0 also reveals a quadratic relationship representing a general U-shape relationship. That is, rising incomes are associated initially with decreasing ES and eventually with increasing ES.
v) b1> 0, b2< 0 and b3> 0 reveals a cubic relationship representing rising incomes are first associated with increasing ES then with decreasing ES and eventually with increasing ES again.
vi) b1< 0, b2 > 0 and b3 < 0 is another cubic relationship representing rising incomes are first associated with decreasing ES then with increasing ES and eventually with decreasing ES again. This relationship is a U-shape followed by an inverted U-shape relationship.

We intend to evaluate which of the above hypotheses best describes the income-biodiversity relationship. It is important to underline that, the biodiversity variable has to be interpreted in an opposite way with respect to the ES variable, since the increase of the variable correspond to a reduction of a certain environmental stress.

In this analysis, we modify the equation to take into account biodiversity instead of environmental stress and we include in the equation some economic variables. we consider trade, as Rock (1996) found a positive relationship between trade openness and pollution intensities. Foreign direct investment is included to test for the pollution haven hypothesis[6] (Suri and Chapman 1998). The equation is estimated for the OECD 34 countries; the time span is 1990-2010[7]. The estimated equation form is the following:

$$Bio_i = a_i + a_1 lnPCGDP_i + a_2 lnPCGDP^2_i + a_3 lnPCGDP^3_i + a_4 TRADE_j + a_5 URBAN_i + a_6 FDI_i + a_7 Co2_i \qquad (2)$$

Where:

i) Bio_i is the percentage of protected areas marine and terrestrial of country i (source: UN);

ii) $PCGDP_{i,}$ is the percapita GDP (source OECD)

iii) TRADE is the sum of exports and imports as percentage of GDP (source OECD)

[6] The pollution haven hypothesis states that increasingly stringent environmental regulation will move polluting activities from richer to poorer countries. However, previous studies provide little direct evidence in support of the pollution haven hypothesis

7 Summary statistics for the data are provided in table A2 in the appendix.

iv) URBAN is the percentage of urban population over the total population (Source : FAO)

v) FDI is the stock of inward FDI as percentage of GDP (Source: Unctad)

vi) Co2 is the emission of Co2 in thousand tons per capita(Source: OCSE).

vii) *ai* is the intercept measuring country specific time invariant effects.

From this specification, the turning point income at which biodiversity is at its maximum level is easily derived as:

$$PCGDP_{max} = \exp(-a_1/2a_2)) \quad (3)$$

where a_1 and a_1 are the parameters of levels and square of per capita GDP in equation (2).

As for the empirical strategy, we use a panel data technique[8.] A major motivation for this choice is the possibility to control for the correlated time invariant heterogeneity. We perform an Hausman specification test to check the presence of correlation between explanatory variables and individual effects. Results are reported in table 1: the null hypothesis of zero correlation is accepted, showing that for our purposes the REM provides more efficient estimates than FE estimators[9].

ESTIMATION RESULTS: IS THERE AN ENVIRONMENTAL KUZNETS CURVE FOR THE BIODIVERSITY?

According to our estimates, the ECK hypothesis (vi) is partially verified, indicating that rising incomes are first associated with increasing biodiversity (decreasing ES) then with decreasing biodiversity (increasing ES) and eventually with increasing biodiversity again (decreasing ES). This relationship interpreted in terms of ECK is a U-shape followed by an inverted U-shape relationship.

In terms of the control variables, Co2 emission and trade have not a significant impact on biodiversity while FDI inflows (and the percentage of urban population) have a negative and significant impact on biodiversity supporting the pollution haven hypothesis.

[8] The two most widely used panel data models are the random effect model (REM) and fixed effect model (FEM): both can control for heterogeneity. Their assumptions are different. REM models require that unobserved bilateral effects are ~ n.i.i. and orthogonal to the remaining part of the error term. regressors have to be uncorrelated to individual effects and error term for all cross sections and time periods. If the orthogonality conditions hold, the REM provides more efficient estimates than FE estimators. If explanatory variables are correlated with unobserved individual effects FEM is consistent.

9 The test statistic of 4.34 is greater than the chi-squared critical value with 7 degrees of freedom therefore the null hypothesis that the REM is consistent is not rejected.

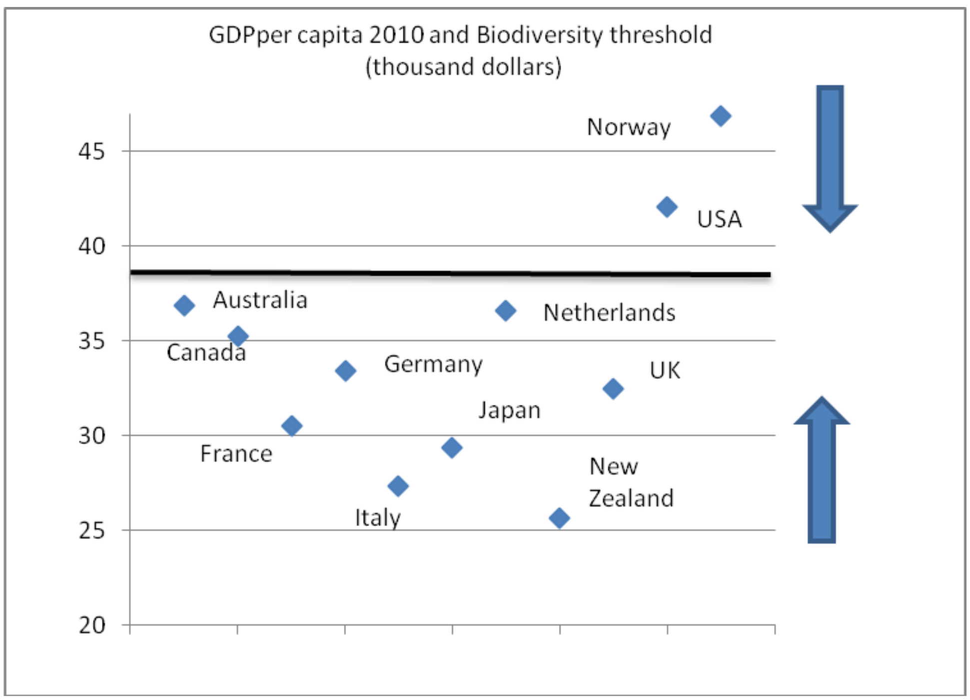
Table 1. The impact on biodiversity of growth, trade and FDI

N. of obs: 601 N. of bilat. relat. 34	Time sample : 1990-2010	
Bio		
	within	GLS
lnGdppc	0.37***	0.37***
lnGdppc2	-0.14***	-0.14***
lnGdppc3	0.02***	0.02***
Trade	0.01	0.01
FDI	-0.08*	-0.08*
Urban	-1.62***	-1.62***
Co2	0.69	0.77
Trend	0.03***	0.03***
Costant	-0.06	-0.07
	F test (8,559) =71.42 Prob>F= 0.00	Wald $\chi^2(8)$=570.73 Prob> χ^2= 0.00

*** significant at 1% , ** significant at 5%, * significant at 10%.

To sum up, according to our findings, at a certain level of income, there may be some biodiversity losses that cannot be continuously substituted with environmental-friendly production technology due to ecological thresholds and the unique nature of the damage.

Chart 1



Source: our calculation on OECD data

It is quite complicate to compare our results with prior EKC studies. Therefore, most of the empirical literature on ECK for biodiversity looked into the diversity of a particular species or a number of species rather than into a broader measure of biodiversity. Only the Mozumder et al paper, as far as we could check, uses an overall index for biodiversity. Mozumder et al fund no support for the EKC relationship for any of the three different biodiversity risk indices, however it has to be underlined that they did not use a panel data technique and the countries under consideration are different from those in this study.

According to our estimates the turning point GDP per capita at which biodiversity is at its maximum level is 37.5 thousand dollars. In 2010, GDP per capita for the average of the 34 OECD countries taken into consideration was 29.5 thousand dollars, therefore in 2010 on average the OECD countries were on the ascending part of the ECK curve.

In chart 1 is represented the position at country level of some OECD members with respect to the biodiversity turning point represented by the bold line. At the moment, it seems that only the USA and Norway were on the descending part of the ECK curve.

CONCLUSIONS

Whether the Environmental Kutznets curve relationship holds for biodiversity loss or not is a particularly challenging issue to investigate. In fact, there may be some biodiversity losses that cannot be continuously substituted with better production technology. According to our estimates for 34 OECD countries in the period 1990-2010 the ECK hypothesis is partially verified. Rising incomes are first associated with increasing biodiversity (decreasing ES) then with decreasing biodiversity (increasing ES) and eventually with increasing biodiversity again (decreasing ES). This relationship interpreted in terms of ECK is a U-shape followed by an inverted U-shape relationship.

This non-monotonic relationship could be explained by the fact that a certain level of income (production) there may be some biodiversity losses that cannot be continuously substituted with environmental-friendly production technology due to ecological thresholds and the unique nature of the damage.

Appendix

Table 1: Summary of Empirical Literature on the Existence of an EKC for Biodiversity

Author	Dependent Variable	Independent Variables	Data	Methodology	Results & Authors' Conclusions*
(Mozumder et al. 2006)	• National Biodiversity Risk Assessment Index – standard, adjusted, and upgraded	• GDP per capita • Trade as % of GDP • Number of Tourists • Gross Foreign Direct Investment as % of GDP • Per-capita Foreign Aid • Fertilizer Consumption • Urban Population (% of total) • Average Circulation of Daily Newspapers per 1000 people	Cross-country data: 62 countries for NABRAI; 104 countries for Adjusted and Upgraded NABRAI	OLS regression	The estimated coefficients on the GDP related variables are not significant for all of the biodiversity risk indices. No evidence in support of an EKC relationship
(McPherson & Nieswiadomy 2005)	• % of threatened bird and mammal species (as defined by the IUCN) in each country	• GDP per capita • % threatened birds (2000) • % threatened mammals (2000) • % endemic mammals • % endemic birds • Island dummy • persons per square kilometer • Political rights and civil liberties • Antigovernment demonstrations, per year • Civil law dummy • Common law dummy • Communist law dummy • Muslim law dummy	Cross-country Data: 113 countries	Spatial lag model (also known as the mixed regressive-spatial autoregressive model) Four models are presented for each species. Model 1 includes all of the variables. Since there is some multicollinearity among political liberties, demonstration, and the legal system dummies, they also present models that include only some of these variables to see if some of these variables are significant.	For mammals: linear and squared income variables are significant. The turning point is at approximately $12,000. For birds: linear and squared income variables are significant. The turning point is in the $12,000 to $14,000 range. The cubed income term was not significant in any of the models. For both mammals and birds, results indicate a possible EKC curve.
(Asafu-Adjaye 2003)	• Number of known mammal species/10000 km • Number of known bird species/10000 km • Number of known higher plant species/10000 km • % of bird and mammal species threatened with extinction	• GDP per capita; • Agricultural value added as percentage of GDP; • Economic freedom index; • Black market premium on exchange rates; • Population density; • Urban population growth; • % of land developed for agriculture and other uses; • % of protected land area; • Climate dummy	Cross-section data for 100 countries, including 50 low-income, 25 middle-income and 25 high-income countries.	OLS regression No GDP square in the model.	GDP has a significant negative effect on species density for mammals and birds, but not for higher plants. It appears to have adverse effect on indicator 5. The proxy for the composition of economic output is highly significant for indicator 5. Although economic growth has an adverse effect on biodiversity, the type or composition of this growth is also significant for biodiversity loss.

	• Average annual % change in the number of known mammal species 1989-1999				
(Dietz & Adger 2003)	• Predicted species richness in any year compared to the reference year 1970 • National parks and protected areas as a percentage of national land territory • Percentage of CITES reports submitted relative to those expected in 1999	• GDP per capita; • Population change; • Population density; • Linear time trend; • Forest area; • Democracy - the sum of political rights and civil liberty indices;	Panel data for first two indicators; cross section data for third indicator	Hyperbolic and linear in income equations for indicators (1) and (2) Linear in income equation for indicator (3) OLS, fixed effects and random effects	Income terms are significant, but the signs are opposite of what we would expect. Economic development is related to the area of state protected land but it is not the overriding determinant of the rate of designation
(Naidoo & Adamowicz 2001)	• Number of threatened species (plants, mammals, birds, amphibians, reptiles, fish and invertebrates)	• GDP per capita; • Number of species; • Number of endemic species; • Country area; • Percent area domesticated; • Percent area protected; • Percent original forest left	Global, cross-sectional data: 157 countries, 1996	Classified threatened species into several taxonomic groups and analyzed per-capita income relationships separately for each group. Negative-binomial regression for count data Three regression analyses: all countries, outlier removed, nonlinear effects of noneconomic variables.	When all countries were included in the analysis, income variables were significant predictors in all taxonomic groups except for mammals. The number of threatened plants increased linearly with log(GNP). The number of threatened amphibians, reptiles, fishes, and invertebrates all had a negative coefficient on log (GNP) and a positive quadratic term, indicating a general U-shaped relationship. The number of threatened bird species exhibited an inverted-U relationship with increasing log(GNP).
(Ehrhardt-Martinez et al. 2002)	• Average annual rate of deforestation	• GDP per capita; • Forest stock 1980; • Data reliability; • % urban; • Population pressure; • Rural-urban migration 1970-1990; • Labor in services 1980; • Secondary education 1980;	All developing countries with available forest cover estimates	OLS. The analysis proceeds in three steps: Structural modernization models, political modernization models and international political economy models. Structural modernization models:	Structural modernization models: the operative modernization variable is urbanization rather than GDP. Urbanization is the more central dynamic producing the EKC. Political modernization models: the urban polynomial remains significant throughout this series, indicating the stability of the
		• Protected areas 1991; • Government scope 1980; • Democracy 1980; • Debt level/GDP 1980; • Change in debt 1980-1990; • Forest exports/GDP 1980; • Forest export/Global forest exports; • Forest import/Global forest imports; • Imports/Exports 1980; • Semiperiphery dummy		Forest stock, data reliability, log GDP per capita and squared, % urban, population pressure, R/U migration, Population*Migration, Labor in services, services*urban; Political modernization models: Forest stock, data reliability, % urban, urban squared, secondary education, protected areas, government scope, democracy, scope*democracy; International political economy models: Forest stock, data reliability, % urban, urban squared, Debt level/GDP, change in debt, Forest exports/GDP, Forest export/Global forest exports, Forest import/Global forest imports, Imports/Exports	structural EKC. International political economy models: dependency and world systems theory have little net impact on deforestation once the ecological modernization theory is appropriately specified.
(Bhattarai & Hammig 2001)	• Annual % change in forest and woodlands area	• GDP per capita; • Time; • Political institutions; • Black market premium on foreign exchange; • External debt as % of GDP; • Change in Cereal yield; • Population growth; • Rural population density	Panel data for 66 countries in Latin America, Africa, and Asia, 1972-1991	Fixed effects model estimated by weighted least squares	The results confirm the existence of an EKC for Latin America and Africa. Quadratic income term is negative and cubed term is positive. The first turning point is around $6,000 for Latin America; $1,300 for Africa. EKC for Asia follows a different pattern from LA and Africa (opposite signs).
(Koop & Tole 1999)	• Changes in forest cover (deforestation)	• GDP per capita; • Change in GDP; • Population density; • Change in population	Panel data	Begin with a simple regression model, then consider fixed and random effects models, and a random coefficients model.	A significant environmental Kuznets curve exists in the simple regression, but it is gradually lost when the specification is freed up.

Source: Rothman and Khanna (2008)

Table 2 Summary statistics of the data

Variable	Obs	Mean	Std. Dev.	Min	Max
co2	652	472468.7	1167402	3156.395	7215899
biodiv	680	11.51103	7.816746	.5	40.2
trade	685	.7738568	.5581625	.1337163	3.874629
urban	684	26025.37	41531.88	231	255403
fdi	692	31.82356	30.01563	.1688624	208.9906
gdppc	700	25.62518	10.69039	6.590715	74.70427

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