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COMPARING FUNCTIONAL FORMS OF AGGREGATION FOR SYNTHETIC INDICATORS OF WELL-BEING: THE ECUADORIAN CASE[1]

Diego Roldán M., Patricio Cárdenas, Francisco Roldán A., Pablo Beltrán, Doménica Ávila

Universidad de Cuenca

Abstract: *After the persistent criticism of the gross national income (GDP) as a measure of well-being, numerous proposals for synthetic indicators of different dimensions have emerged. The most notable was the Human Development Index (HDI), which although sponsored by the United Nations Development Program (UNDP) since 1991, was not free from criticism and has faced adjustments since then. Another alternative, previously proposed by Pena (1977), is the generation of indicators based on P2 Distance which have taken relevance lately. Both types of indicators allow a classification of geographical areas in general as provinces or countries. These indicators have been applied alternately with some modifications proposed by different studies generating different rankings that correlate to a greater or lesser degree.*

The results show that the two functional forms evaluated generate very similar classifications within the socioeconomic context of Ecuadorian provinces, justifying opting for the geometric mean since the complexity of P2 Distance does not contribute anything additional in the classification of the provincial welfare.

Keywords: HDI, P2-Distance, provincial ranking, well-being

Introduction

Measuring the level of well-being achieved by a country or region is important for assessing the efficiency of its policies as well as the efficiency of markets (Stiglitz, Sen, & Fitoussi, 2017). However, in order to achieve this goal, it is necessary to overcome certain obstacles

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such as determining the very concept of well-being (Michalska-ŻyŁa, 2014) which conditions the form of measurement.

According to the World Bank (2017), GDP per capita is a poor indicator of development or quality of life although it's use is widespread. Among its critics we can find its own inventor, Simon Kuznets, who asserts that this measure of national income hardly represents a measure of welfare. Thus, while GDP shows economic growth in many countries of the world, according to the Gini coefficient, the per capita income gap has increased between 1960 and 2009 (Heston, Summers, & Aten, 2013). This behavior is a trend with exceptions, for example in the United States between 2000 and 2013 it rose from 40% to 41%, while between 2000 and 2014 in Ecuador it decreased from 56% to 45% (World Bank, 2017).

Despite strong criticism, GDP per capita remains a widely-used option, possibly because of its availability in almost all countries with more complete time series than other indicators.

The Human Development Index (HDI) appeared in 1990 as a proposal by Pakistani economist Mahbub ul Haq sponsored by the United Nations Development Program (UNDP) as a more appropriate alternative. This index collects two additional welfare dimensions not addressed by GDP: a long and healthy life and access to knowledge, in addition to a decent standard of living.

Among the criticisms that this synthetic indicator has received, one refers to the functional form of integration of its components. In response, the functional form of the HDI has had several modifications. The most significant was in 2010; opting for the geometric mean of the normalized dimensional indicators (Kovacevic, 2011; Luque, Pérez-Moreno, & Rodríguez, 2016).

Although the HDI is recognized as a more devolved model than GDP to measure well-being, it also faces criticism about its functional form, its components and the arbitrary weighting of these. (Lind, 2010, p. 301). This has motivated researchers to propose adjustments in one or all of these issues. Changes in the dimensions of the index are frequently proposed, both in number and in classes (Ferrara & Nisticò, 2015). In other cases, researchers choose to propose different functional forms such as principal component analysis (Ferrara & Nisticò, 2015) or the P2 Distance of Pena[2] (Nayak & Mishra, 2012). P2 Distance functional form, according to the author, corrects some problems[3] of other synthetic indicators such as the arbitrary weighting of dimensions in the HDI.

On the other hand, some indicators seek to measure welfare, such as GDP, in monetary units. Others point to measure welfare ordinally (Drewnowski, 1972) as functional forms of the HDI and P2 Distance studied in this paper. In this case, the results obtained contain indicators that only make sense in a comparative way. These results are used for rankings of specific countries or regions classified by the same procedure or to monitor the development of the same space over time.

Nevertheless, the combination of several partial indicators into a synthetic indicator involves decisions on the type of combination (linear, non-linear) and on the aggregation method (i.e. simple average, geometric average) used in its construction (Davino & Romano, 2014). Despite starting from the same partial indicators, the different functional forms of each index can lead to classifications that may vary to a greater or lesser degree. This variance is the subject of this research.

The objective of this article is to determine the level of convergence that may exist between the HDI and P2 Distance functional forms applied to the same Ecuadorian socioeconomic scenario. This level of convergence may contribute to the determination of the functional form of aggregation that is most convenient for the Ecuadorian case.

The Ecuadorian Case

No consensus on the definition of quality of life allows for various approaches (Angelovič & Ištok, 2016). In the case of Ecuador and Bolivia, the quality of life is constitutionally based on *Sumak Kawsay* ("*Buen Vivir*", "Good Living"), a worldview of the Andean indigenous peoples.

In Ecuador, the policies adopted by the former government (Rafael Correa) are established in the National Plan of Good Living (PNVB). Three versions cover the current period since 2007, the third version being applied during the period 2013-2017. The last PNVB consists of 12 objectives subdivided into 93 goals with their respective target and

[2] Synthetic indicator P2 Distance was developed before HDI, by Pena Trapero (1977).
[3] This indicator uses a resource called *correction factor* to avoid the inclusion of redundant information commonly present within its partial indicators.

follow-up indicators that account for the impact and structural breaks (Senplades, 2013). Without denying economic growth as something desirable, the PNVB pays attention to its distributive and redistributive patterns (2013, p. 16).

The PNVB includes a system of monitoring and evaluation, comparing what was planned with what was done, seeking to measure the impacts of public management and establishing timely alerts for decision making (Senplades, 2013, p. 18). However, this development plan does not have any synthetic indicators to measure its results globally so some researchers are looking to develop this measurement resource. The University of Cuenca leads one of these projects in which a multidimensional socio-economic development indicator called IMDES was proposed. It is expected that this indicator will reliably show levels of development and provincial disparities, constituting a useful reference for the management of local and national governments in the framework of the PNBV.

The construction of a synthetic indicator like the one proposed (IMDES) requires overcoming some stages of design, one of them is the evaluation and selection of a functional form of aggregation of partial indicators. In our case, it is reduced to the two alternatives mentioned above: HDI and P2 Distance.

Luque *et al*. (2016) carry out a similar study using the information of the year 2011 of 187 countries maintaining the three dimensions of the HDI. They propose a new functional form of aggregation by introduction a modification to the normalization method. Comparing the official functional form of HDI and a modified version, their results show Spearman's correlation coefficients rho between 0.976 and 0.997.

In our study, we are interested in measuring the development of Ecuadorian provinces by means of a new proposed synthetic index explained below. In addition, we focus on the evaluation of the functional form of the HDI versus P2 Distance.

Multidimensional Socioeconomic Development Index (IMDES)

IMDES is a synthetic index under development. Some elements of different proposals have been eclectically taken, making adjustments to fit better in the Ecuadorian socio-economic context.

From the HDI, although its dimensions and partial indicators were not taken because they were inadequate for the Ecuadorian socioeconomic reality[4], its functional form of aggregation was taken for the IMDES.

The dimensions and partial indicators that make up IMDES correspond to the dimensions proposed in the Better Life Initiative of the Organization for Economic Co-operation and Development[5] (OECD) that measures well-being at national level. However, this organization does not use a synthetic indicator[6] (OECD, 2016). The aim of IMDES is to measure provincial welfare in the socioeconomic framework of Ecuador. Three dimensions (level 1) were included: Materials Conditions Index (I_{CM}), Quality of Life Index (I_{CV}) and Subjective Well-Being Index (I_{BS}).

In IMDES, there are three levels of indicators (see Table 1). Level 3 indicators are aggregated into the level 2 indicators by the arithmetic mean, like the methodology applied in the HDI and the OECD indicators. The Material Conditions Index (I_{CM}) adds income, jobs and housing. The Quality of Life Index (I_{CV}) adds education, health, safety and accessibility of services. Finally, the Subjective Wellness Index (I_{BS}) only includes the community.

Table 1 Dimensions and component indicators of the Multidimensional Index of Socioeconomic Development IMDES (Ecuador)

Dimension (Level 1)	**Topics (Level 2)**	**Indicators (Level 3)**	**Min**	**Max**
I_{CM} Material Conditions	**$I_{cm,i}$** Income	Household income [USD] (*) (i)	100	340
	$I_{cm,t}$ Jobs	Employment rate [%] (*) (i)	49.9	76.2
		Unemployment rate [%] (*) (i)	1.1	10.8
	$I_{cm,a}$ Housing	Number of rooms per person in a dwelling (*) (i)	0.6	1.0
I_{CV} Quality of	**$I_{cv,e}$** Education	Percentage of people with at least secondary education [%] (*) (i)	30	55

[4] The same organization recognizes that the HDI simplifies and captures only part of what human development involves (UNDP, 2017b).
[5] Se toma también como referencia el trabajo de Stiglitz *et al*. (2009).
[6] The OECD Better Life Index, in fact, is not an index, it is a tool that allows researchers to create their own index (national level) for OECD countries with weights of the dimensions assigned by the same researcher.

life	**$I_{cv,sl}$** Health	Life expectancy at birth [years] (*) (ii)	20	85
		Maternal mortality rate [per 100 000 births] (iii)	19	162
	$I_{cv,sg}$ Sefety	Assault rate [Per 1000 people]. (ii)	6	100
	$I_{cv,as}$ Accessibility of services	Percentage of households with internet broadband access [%] (*) (i)	10	50
I_{BS} Subjective Well-Being	**$I_{bs,c}$** Community	Percentage of the population that has confidence in the community [%] (*) (i)	10	68

(*) Indicators used by OECD. Data sources: (i) INEC-ENEMDU 2014. (ii) Sistema Nacional de Información (SNI) 2014. (ii) Nacimientos y Defunciones-INEC 2014.

Of the 10 partial indicators listed in the third column of Table 1, 8 are those selected by the OECD (those marked with one asterisk). We do not include environmental and life satisfaction indicators because we do not have data at the provincial level. Nor do we include the percentage that voted in the last elections since in Ecuador voting is mandatory. We use the maternal mortality rate instead of the age adjusted mortality rate because we believe it is a better component of the health indicator for the Ecuadorian case.

Coinciding with the OECD methodology, the labor ratio **$I_{cm,t}$** is the arithmetic mean of the standardized rates of unemployment and employment. The health index **$I_{cv,sl}$** is the average of the standardized life expectancy rates and the maternal mortality rate, replacing adjusted mortality.

In the case of the HDI, the UNDP also uses the arithmetic mean to add to this level the index of education through the standardized indexes of expected years of schooling and mean years of schooling (UNDP, 2016, p. 2). The safety ratio **$I_{cv,sg}$** uses the assault rate instead of the homicide rate due to the availability of the data.

The ranges used to standardize the IMDES partial indicators (see fourth column of Table 1) are mostly inconsistent with those used in the HDI and the OECD dimensions. These limits are based mainly on the provincial records available and the majority from the year 2014. They reduce the lower bound and increase the upper bound slightly from historical data, as suggested by Kovacevic (2011, p. 30). The main data source is the Survey of Employment, Unemployment and Underemployment of Ecuador (ENEMDU, 2014). The minimum level of income per household is that established in the HDI, but the maximum level corresponds to provincial records, since the one established by UNDP (75,000 USD) is very high for the economic reality of the provinces of this country. In the case of life expectancy at birth, we use the limits determined in the HDI of 2014.

Table 2 Provincial indexes of quality of life in Ecuador. 2014

Dimensions that make up the Socioeconomic Development Index (IMDES)

Province	Well-being dimensions of IMDES					
	Material Conditions		Quality of life		Subjective Well-Being	
	Index	Rank	Index	Rank	Index	Rank
Azuay	0.8404	1	0.7469	2	0.8738	13
Bolívar	0.5297	13	0.5373	15	0.8786	11
Cañar	0.5922	8	0.5320	17	0.9156	3
Carchi	0.5515	11	0.5127	19	0.9005	5
Chimborazo	0.7157	4	0.5543	10	0.8943	7
Cotopaxi	0.7032	5	0.4171	22	0.8791	10
El Oro	0.5987	7	0.6085	4	0.6612	20
Esmeraldas	0.2883	22	0.5437	13	0.8809	9
Guayas	0.5029	15	0.6003	5	0.5717	23
Imbabura	0.5764	9	0.5407	14	0.8386	16
Loja	0.5068	14	0.6855	3	0.8863	8
Los Ríos	0.3833	21	0.4740	20	0.6723	19
Manabí	0.4423	17	0.5554	8	0.8784	12
Morona Santiago	0.4035	19	0.5271	18	0.9300	2
Napo	0.4911	16	0.5560	7	0.9111	4
Orellana	0.4003	20	0.4371	21	0.8732	14
Pastaza	0.6335	6	0.5820	6	0.8426	15

Pichincha	0.8370	2	0.8065	1	0.6413	21
Santa Elena	0.2808	23	0.5468	12	0.7918	17
Santo Domingo	0.5612	10	0.5544	9	0.6217	22
Sucumbíos	0.4221	18	0.5502	11	0.9003	6
Tungurahua	0.7954	3	0.3851	23	0.7734	18
Zamora Chinchipe	0.5471	12	0.5351	16	0.9792	1

Rank is the order of provinces according to each dimensional indicator from highest to lowest. Does not include the island province Galápagos.

The HDI and P2-Distance functional forms

An important step in the design of such synthetic indicators is the choice of the functional form for aggregation of these dimensional indices (See Table 2). In this section, we review some strengths and weaknesses of the two options, HDI and P2 Distance, which are evaluated as alternatives to the IMDES. We must first answer: Is the complexity of the functional forms, geometric mean or P2 Distance, necessary in qualifying the well-being of the provinces of Ecuador compared to the arithmetic mean? In fact, this selection may lead to different classifications of the provinces[7].

HDI functional form

UNDP has used geometric mean instead arithmetic mean since 2010. (UNDP, 2016). According to this organization, geometric mean reflects poor performance better in any dimension. Also, it reduces the level of substitutability between dimensions (UNDP, 2017a). This functional form applied to IMDES is the geometric mean of the Index of Material Conditions (ICM), Quality of Life index (ICV) and Subjective Well-being index (IBS):

$$IMDES = \sqrt[3]{I_{CM} * I_{CV} * I_{BS}} \quad (1)$$

The HDI has received criticism for different aspects, as in its functional form that we will be particularly concerned with. One common critique is the redundancy of the information of the HDI components due to their high correlation. Other criticism is of the equal weights for the three components (Kovacevic, 2011, p. 15) although Ivaldi *et al*. (2016, p. 403) argue that, in the absence of dominance of one dimension over all others, the better option is to opt for equal weighting.

[7] According to Panigrahi and Sivramkrishna (2002), similar effects can also be used for the selection of different minimum and maximum levels for the normalization of the partial indicators.

Despite the criticism, HDI is widely used in different purposes. It is common to find HDI methodology applied with different types of modifications in some sub-national level studies and regions. Thus, for example, Devaraj *et al*. (2014) apply the HDI methodology in 92 counties of the State of Indiana (United States) under the same dimensions: Health, Education and Living standards. Additionally, they include new indicators to conform to these dimensions: life expectancy and years of potential life lost for health dimension, enrollment and attainment for education dimension, per-capita income and average monthly earnings for living standards dimension. The information corresponds mostly to the year 2010. Each dimension index is calculated by the geometric mean of its respective indicators, according to the HDI methodology of 2010. They stated that their analysis presented in the study was far from being conclusive, but suggests that there are tremendous disparities and inequalities in various counties of Indiana (Devaraj, Sharma, Hicks, & Faulk, 2014, p. 11).

Luque *et al*. (2016) try to overcome the problem of trade-offs between components by providing two innovations for the computation of the HDI: a different normalization and an alternative aggregation formula that provides a variety of composite indexes with different degrees of substitutability.

P2-Distance functional form

The second option as functional form for IMDES is the P2 Distance developed by Pena Trapero (1977). P2 Distance attempts to overcome the correlation problems differently to the principal components analysis[8], used as a synthetic multidimensional indicator of well-being. This functional form is an evolution of the model of Ivanovic (1974) based on the distance of Fréchet.

P2 Distance indicator synthesizes the information contained in a set of socioeconomic indicators allowing for inter-spatial and inter-temporal comparisons. The objective of Pena's indicator is to solve the problems of aggregation of variables with heterogeneous units of measurement, the application of arbitrary weighting and the inclusion of redundant information[9] (Somarriba & Pena, 2008, p. 83).

In this model, the aggregation is performed by the arithmetic sum of the distances $\boldsymbol{d_{ij}}$ of its indicators $\boldsymbol{x_{ij}}$ in relation to a reference limit $\boldsymbol{x_{i*}}$, coinciding in this sense with the

[8] On the use of PCA in well-being indicators see Ogwang and Abdou (2003) and Lee *et al*. (2016).
[9] On the description of this model see Somarriba and Zarzosa (2016, pág. 27) and Somarriba and Pena (2008).

numerator of the normalizations used in the HDI functional form. Applied to the Ecuadorian case, the index P2 Distance of the province ***j*th** is determined by:

$$DP_2(j) = \sum_{i=1}^{n} \left\{ \left(\frac{d_{ij}}{\sigma_i} \right) \left(1 - R^2_{i,i-1,\dots,1} \right) \right\} \quad (2)$$

with $d_{ij} = |x_{ij} - x_{i*}|$; $i = 1,2,\dots,n$; $j = 1,2,\dots,m$

n the number of variables (3 dimensions)

m the number of provinces (23)

σ_i the standard deviation of ***i***th variable (dimension).

x_{ij} the value of the ***i***th variable (dimension) in the ***j***th province.

$X_* = (x_{1*}, x_{2*}, \dots, x_{n*})$ Reference base. The worst situation of each dimensional indicator.

$R^2_{i,i-1,\dots,1}$ the coefficient of determination in the regression of X_i over X_{i-1} , $X_{i-2, \dots,}$ X_j , already included. And $R^2_i = 0$.

Thus, the synthetic indicator measures the distance from a base reference, corresponding to an imaginary province with the worst possible scenario for all the simple dimensional indicators.

According to Somarriba and Zarzosa (2016, p. 28), $\boldsymbol{d}_{ij}$ is divided by σ_i, to deal with the problem of heterogeneity in relation to the measuring units of the variables (partial indicators) and express in abstract units.

As each partial indicator is added into the synthetic indicator by an iterative algorithm, R^2 measures part of its variance explained by the linear regression of the previous variables added. As a result, according to Pena's model (1977), in each iteration the *correction factor* ($1-R^2$) prevents redundancy produced by the new partial ***i***th dimensional indicator aggregated into information already contained in the previous partial indicators. "In this way, the synthetic indicator only includes the new information from each variable [dimension]" (Somarriba & Zarzosa, 2016, p. 28).

Although P2 Distance method was published in 1977, no major references were found until the 2000s, possibly because of the HDI's dominance since 1990. The only observation found is in Cuenca García *et al*. (2010, p. 474) who stated that a further aspect to be considered is that the result varies when the order of entry of the partial indicators changes.

In any case, Cuenca García *et al*. (2010, p. 474) stated that P2 Distance fulfills all the properties defined in Pena (1977) for a good composite indicator: existence and determination, monotony, uniqueness, homogeneity and transitivity.

We found some studies at the subnational level using P2 Distance. Zarzosa (2009) applies this functional form to the analysis of poverty in the autonomous communities in Spain. Zarzosa and Somarriba (2013) use P2 Distance to measure social welfare in Spanish provinces and Canaviri (2016) performed a first approach to measuring well-being in Bolivia at subnational levels (municipalities). The socio-economic contexts of the previous study and ours coincide in many characteristics, in addition to being based on the same constitutional concept of well-being: the worldview of Sumak kawsay (Buen Vivir).

Statistical measure of the ranking convergence of the HDI and P2-Distance functional forms in the Ecuadorian socio-economic framework

Applying both HDI and P2-Distance functional forms to the provincial data for the year 2014, the results are the indices and rankings indicated on Table 3.

Table 3 Multidimensional Development Index IMDES

Provincial classification. Ecuador 2014

Provinces		IMDES			
		HDI	Rank	P2-Distance	Rank
1	Azuay	0.8186	1	9.7772	1
2	Bolívar	0.6300	11	5.7377	10
3	Cañar	0.6607	6	6.4106	7
4	Carchi	0.6338	10	5.8266	9
5	Chimborazo	0.7079	3	7.2535	3
6	Cotopaxi	0.6365	9	5.7013	12
7	El Oro	0.6222	13	5.0274	17
8	Esmeraldas	0.5169	21	4.2423	18
9	Guayas	0.5568	19	3.5561	21
10	Imbabura	0.6394	8	5.7344	11
11	Loja	0.6753	5	7.1033	4
12	Los Ríos	0.4962	22	2.3994	23
13	Manabí	0.5998	15	5.3422	14
14	Morona Santiago	0.5827	17	5.2527	15
15	Napo	0.6290	12	5.9466	8
16	Orellana	0.5346	20	3.8657	20

17	Pastaza	0.6773	4	6.5458	6
18	Pichincha	0.7565	2	8.3515	2
19	Santa Elena	0.4954	23	3.4623	22
20	Santo Domingo	0.5783	18	3.9158	19
21	Sucumbíos	0.5935	16	5.3454	13
22	Tungurahua	0.6188	14	5.0877	16
23	Zamora Chinchipe	0.6594	7	6.6904	5

As can be seen in Table 3, provinces 1, 3, 16 and 18 maintain their positions in the two ranks, 8 provinces differ only in one position, 4 provinces differ in 2 positions, 4 provinces differ in 3 positions and the major differences are in provinces 7 and 15, which differ by four. In an intuitive way, we can observe that the two classifications do not present significant differences based on actual provincial data. As can be seen in Figure 1, these ranks have a monotonic relationship.

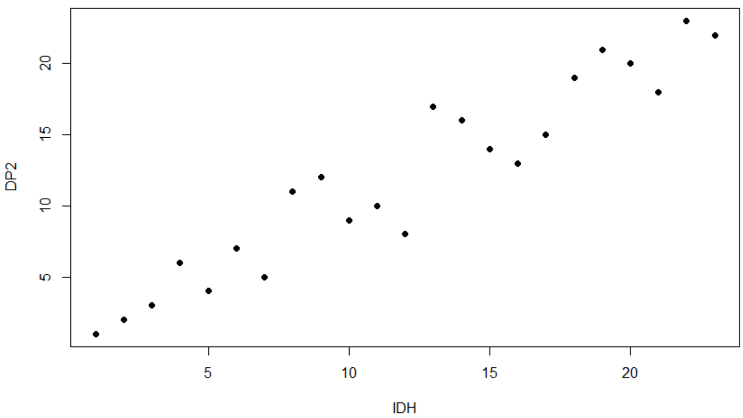

Figure 1 Monotonic relationship. Correlation between provincial rankings. HDI vs P2 Distance. Ecuador 2014

For measure the level of convergence between both functionals forms we are evaluating, we can calculate the correlation between the two given classifications based on Spearman's □, a nonparametric measure of rank correlation. Spearman's □□is defined by:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \quad \text{with} \quad d_i = r_{i2} - r_{i1} \tag{3}$$

Where

r_{ij} Ordinal of the ***ith*** object in the ***jth*** ranking

Spearman's correlation between HDI and P2 Distance ordinal variables will be high correlation of 1 when results show an identical provincial rank, and low correlation of -1 when ranks of HDI and P2 Distance are completely opposed.

Measuring the correlation of these two ranking classifications[10] using Spearman's □ gives a value of 0.9526 (0.0000). This value shows that the correlation between HDI and P2-Distance rankings is very strong and which was expected according to the relationship observed in Figure 1.

Conclusions

Since the IMDES is an indicator under construction, it is necessary to select a suitable functional form for the aggregation of its partial indicators. This analysis is simplified if the functional forms that are compared do not differ significantly in the ranking classifications they can generate.

In the specific case of the IMDES indicator, the pros and cons of the two functional forms used in the HDI and P2 Distance were analyzed in this paper. As the goal of this indicator is to establish a ranking of provinces, we should verify firstly if these two functional forms can differ significantly in their ranking results.

Based on these results, it can be concluded that it is not necessary to invest additional efforts in the analysis of differences of these options. Given the practical causes, we can opt for the simplest functional form, in this case the geometric mean used by the HDI.

Particularly for our case study, we can say that the strengths of the P2-Distance functional form described by its author Pena Trapero, in practice do not lead to significantly different results than the simpler form used by the HDI, the geometric mean. however, these results could be more robust if we extend the analysis through larger series of data.

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