Dynamics of Indonesian Coal Prices: Principal Component Analysis

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Abstract. Coal utilization is a major factor in the formation of energy resources. Therefore, changes in reference coal prices are quite interesting to observe, especially in recent years. The covid-19 pandemic and the surge in foreign demand have caused significant changes in coal prices. This study will evaluate the factors that influence the dynamics of coal prices from 2013 to 2022. The variables analyzed include coal production, domestic coal use, coal trade (exports and imports), and changes in coal prices. The method used in this study is Principal Component Analysis (PCA). The results of the study show that the variables of changes in coal prices, production, exports, imports and domestic consumption show roles that are not much different in the dynamics of coal in Indonesia. However, changes in coal prices are greatly influenced by the amount of coal exports. In addition, domestic consumption, production, and the variables that have the least influence on changes in coal prices are coal imports.

Keywords: Coal, Coal Prices, Price Dynamics, Principal Component Analysis

1 Introduction

Indonesia is a country rich in natural resources, one of which is coal. Coal is a fairly important natural resource commodity because the main use of coal is as an energy resource. The Ministry of Energy and Mineral Resources of the Republic of Indonesia stated that Indonesia's verified coal resources in 2022 were 92,139 million tons, while verified coal reserves were 33,377 million tons. In addition to being used for domestic needs, Indonesian coal is also exported abroad. However, Indonesia also imports coal for industrial needs [1].

In 2022, coal will contribute 42.38% of Indonesia's primary energy supply [1]. The supply of coal is the highest compared to other energy resources. Not only for power plants, coal is also used for the ceramics, cement, textile, fertilizer, paper and pulp, iron and steel, briquettes or other industries. The mineral and coal mining sector also has a very significant role in Indonesia's state revenue. The Ministry of Energy and Mineral Resources recorded that non-tax state revenue from the mining sector as of December 2022 was IDR 173.5 trillion. The achievement of non-tax state revenues was influenced by the very good prices of mining commodities [2].

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The phenomenon of coal price changes is quite interesting to see, especially in recent years. This is considering that around the time starting in 2020 there was a significant spike in coal prices. The Covid-19 pandemic caused the coal prices reference (CPR) to change significantly before and after the pandemic. Dewi & Yolanda (2021) [3] examines the relationship between coal selling prices from five companies in Indonesia and changes in stock prices by considering the number of Covid-19 cases. Changes in the number of Covid-19 cases have a positive effect on the relationship between coal selling prices and stock prices. However, Meyliawati et al. (2022) [4] stated that during the pandemic, coal consumption decreased and gave coal-effect on economic growth.

Recently, the soaring coal prices have also been driven by increasing demand, especially from India, China, and several European countries. The coal crisis that hit India caused the Indian government to increase the amount of coal imports due to tight coal supplies. China is recorded as increasing coal supplies for its industrial needs and implementing a policy of eliminating coal import taxes. The European Union issued a policy of banning coal imports from Russia due to the impact of the Ukraine-Russia war. In addition, European countries decided to reuse coal as a source of coal power plants considering that gas supplies from Russia had stopped [5].

Until 2022, CPR arranged by Regulation of the Minister of Energy and Mineral Resources 7/2017 on Procedures for Determining Benchmark Prices for the Sale of Metal Minerals and Coal and previously with Regulation of the Minister of Energy and Mineral Resources 17/2010 on Procedures for Determining Reference Prices for Mineral and Coal Sales. Changes in CPR during 2013–2022 can be seen in Figure 1.

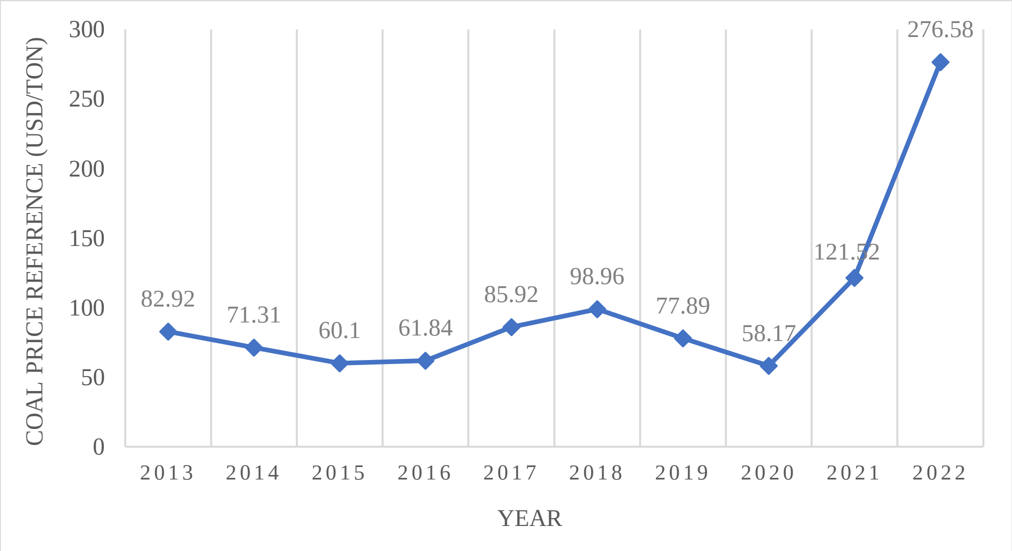

Fig. 1. Indonesia Coal Prices Reference (CPR) 2013–2022
(Source: Kementerian Energi dan Sumberdaya Mineral Republik Indonesia, 2023)

The dynamics of coal as a commodity are interesting to study considering that prices will be related to the dynamics of prices, production, exports, imports, etc. As a case study, coal commodity data will be reviewed during 2013–2022. Then what factors influence the dynamics of coal are expected to be evaluated. The factors analyzed are mainly coal production, domestic coal use, coal imports, and exports and the price of coal itself. Based on those reasons, this paper will show an analysis of the factors that influence the dynamics of Indonesian coal commodities using Principal Component Analysis (PCA) as an analysis tool.

2 Methods

Data in the form of coal prices were obtained from the Ministry of Energy and Mineral Resources. Meanwhile data on coal production, exports, imports and domestic coal consumption were obtained from reports from the Ministry of Energy and Mineral Resources in 2013-2022 [1]. To analyze these various factors, the Principal Component Analysis (PCA) method will be used. In this study, the PCA method will be used to reduce the number of existing variables and determine the influencing factors. PCA or its modifications have been used to see the dynamics of coal prices [6] [7]. Software Past4.02 is used for calculating, plotting process, and the whole data processing.

PCA can be used if the data to be analyzed basically has a large number of variables and has correlations between the variables. PCA calculations are based on calculating eigenvalues and eigenvectors that represent the distribution of data from a data set. By using PCA, the variables which originally numbered n variables will be simplified into k new variables called principal components, with the number k < n based on the linear combination of these variables [8] [9].

Jolliffe (2002) [9] stated that the purpose of PCA is to simplify and eliminate non-dominant and less relevant selection factors or indicators without reducing the intent and purpose of the original data of a random variable. In the calculation operation, a matrix can be made from the random variable. The *first* procedure carried out is to calculate the variance-covariance matrix of the existing data. Suppose x and y are random variables.

$$\mathrm{Var}(x) = \sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(Z_{ij} - \mu_j)^2 \quad \text{(i)}$$

$$\mathrm{Cov}(x, y) = \frac{1}{n-1}\sum_{i=1}^{n}(x_{ij} - \mu_{xj})(y_{ij} - \mu_{yj}) \quad \text{(ii)}$$

μx and μy is the sample average of variables x and y, while variables xi and yi are the values of the i-th observation of variables x and y. From the value data used, a covariance matrix of size n x n is obtained. *Second*, the calculation of the eigenvalues and eigenvectors of the covariance matrix is carried out.

$$(A - \lambda I) = 0 \quad \text{(iii)}$$

$$[A - \lambda I][X] = [0] \quad \text{(iv)}$$

Where A is an n x n matrix, λ is the eigenvalue and I is the identity matrix. The *third* step is to determines the value of the principal component proportion.

$$\mathrm{PC}\ (\%) = \frac{\mathrm{Eigenvalue}}{\mathrm{Variance.Covariance}} \,.\, 100\% \quad \text{(v)}$$

Fourth is the calculation of factor weights (factor loading) based on eigenvectors.

$$Ax = \lambda x \quad \text{(vi)}$$

Thus, a linear combination is obtained, namely:

a. $\lambda 1, \lambda 2, \lambda 3 \ldots \lambda n$ is the eigenvalue of matrix A

b. x1, x2, x3… xn is the eigenvector according to its eigenvalue (λn)

Before conducting PCA, there are several requirements that must be met to determine whether the data is suitable for further analysis. For this purpose, a data feasibility test is carried out in the form of the Bartlett Test of Sphericity and the Kaiser Meyer Olkin (KMO) correlation test – Measure Sampling of Adequacy.

Bartlett's test is a test to see if there is a correlation between variables. If there is no correlation, then PCA analysis cannot be performed. In other words, this test is to see if the correlation matrix is an identity matrix. Bartlet's test uses the following equation:

$$\chi^2_{stat} = \left\{(N-1) - \frac{(2p+5)}{6}\right\} \ln |R| \quad \text{(vii)}$$

Where:

N = number of observations

p = number of variables

|R| = correlation matrix determinant

Degrees of freedom (df) = $\frac{1}{2} p(p-1)$ .... (viii)

The hypothesis used are:

H_0: correlation matrix is an identity matrix

H_1: correlation matrix is not an identity matrix

using significant level α =0,05, if $X^2_{stat} \geq X^2\ (\alpha, \frac{1}{2}\ p(p-1))$ then H_0 rejected. Thus, it can be concluded that there is a correlation between variables in the data, or if H_0 is accepted, then it is concluded otherwise. The value of $X^2\ (\alpha, \frac{1}{2}\ p(p-1))$ is obtained from the standard table X^2.

The Kaiser Meyer Olkin (KMO) test is a test to see if the data is suitable for analysis with PCA. Data is declared suitable if the overall observation data and data for each variable have a KMO value of at least 0.5. The calculation uses the following equation:

$$KMO = \frac{\sum_{i=1}^{p}\sum_{j=1}^{p} r_{ij}^2}{\sum_{i=1}^{p}\sum_{j=1}^{p} r_{ij}^2 + \sum_{i=1}^{p}\sum_{j=1}^{p} a_{ij}^2};\ i,j = 1,2,\ldots p \quad \text{(ix)}$$

Where:

r_{ij} states the correlation coefficient value between variables i and j; and

a_{ij} states the value of the partial correlation coefficient between variables i and j.

3 Results and Discussion

As regulated by the Ministry of Energy and Mineral Resources, CPR depends on the price of the Indonesia Coal Index (ICI), Newcastle Export Index (NEX), and Newcastle Global Coal Index (GC). Thus, the coal price will be greatly influenced by the condition of the world economy, not only the condition of the national economy. The CPR during the last 2013-2022 can be seen in Table 1. It can be seen that before 2020 the price of bricks was around US$60–90 per ton. The price drop occurred when the pandemic started, reaching US$58 per ton. The decline in coal prices was due to the decline in global coal demand due to the Covid-19 pandemic and still unrecovered post-Covid-19 industry in Indonesia's coal importing countries, especially India [10]. However, after 2020, prices rose again quite drastically, reaching US$276 per ton, which was thought to be due to soaring demand overseas.

Table 1. Indonesia Coal Prices Reference, Production, Export, Import, and Domestic Consumption 2013–2022

Year	Coal Prices Reference	Production	Export	Import	Domestic Consumption
	(US$/ton)	(in thousand ton)			
2013	82.92	474,371.37	424,460.69	495.61	72,070.00
2014	71.31	458,096.71	408,238.48	2,260.00	76,180.00
2015	60.10	461,566.08	366,970.40	2,813.78	86,814.10
2016	61.84	456,197.78	369,596.75	3,573.82	90,550.00
2017	85.92	461,248.18	389,530.25	4,352.15	97,030.00
2018	98.96	557,772.94	429,061.65	5,357.78	115,080.00
2019	77.89	616,159.59	459,136.41	6,765.51	138,418.19
2020	58.17	563,728.26	406,882.43	7,279.90	131,886.64
2021	121.52	613,990.26	433,660.84	13,505.04	133,043.36
2022	276.58	687,432.38	464,499.71	10,743.19	215,813.24

Source: Kementerian Energi dan Sumberdaya Mineral Republik Indonesia, 2023

Data in 2022 shows that Indonesia produced 687.43 million tons of coal, which 215.81 million tons were consumed domestically and 464.49 million tons were exported. However, Indonesia also imported 10.74 million tons of coal for industrial purposes. The trend of production, consumption, exports, and imports has always increased every year and it can be seen through Figure 2. The soaring demand factor has also caused production to increase, reaching 8% and 12% in 2021 and 2022 (year on year). In addition, the ever-increasing price of coal has also caused a significant increase in production, especially to meet export needs. Although there was a decline in 2020 due to the Covid-19 pandemic.

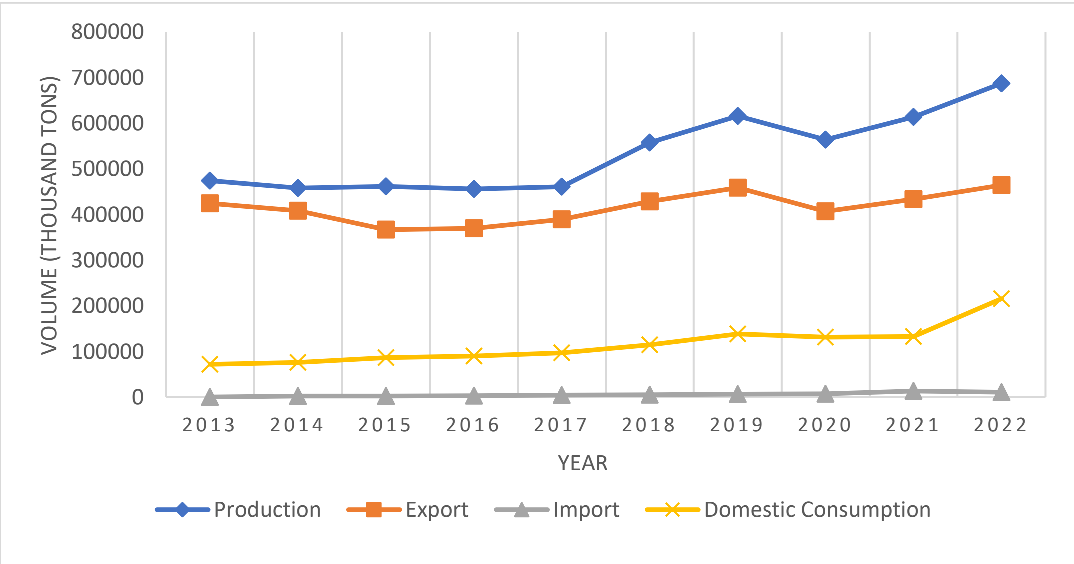

Fig. 2. Indonesia Coal Changes in Volume of Production, Consumption, Export, and Import 2013–2022

Bartlett and KMO tests were conducted to see whether the data used were sufficient to meet the requirements for PCA purposes. There are 5 variables used in this study, namely CPR (V1), production (V2), export (V3), import (V4), and consumption (V5). The result can be seein in Table 2, for the Bartlett test, it is known that N = 10, p = 5. Then to determine the determinant |R| a correlation matrix is made between the variables. From the correlation matrix, the value of |R| = 0.00078 is obtained. Thus, it can be calculated that X^2_{stat} = 46.47, while from the standard table with a significance level (α) = 0.05 and degrees of freedom (df) = 10, it is obtained that $X^2(\alpha,½\ p(p-1))$ = 18.30. In other words, $X^2_{stat} \geq X^2 (\alpha,½\ p(p-1))$, then H_0 is rejected. This means that it can be concluded that there is a correlation between variables in the data and further analysis can be continued.

Table 2. Correlation Matrix

	V1	V2	V3	V4	V5
V1	1	0.723729	0.635749	0.569129	0.844044
V2	0.723729	1	0.847447	0.845755	0.928977
V3	0.635749	0.847447	1	0.543920	0.697608
V4	0.569129	0.845755	0.543920	1	0.792319
V5	0.844044	0.928977	0.697608	0.792319	1

Source: Data Processing Result, 2024

The results of the KMO test show that the total value is 0.54. The KMO test value for each variable is V1 = 0.55; V2 = 0.52; V3 = 0.47; V4 = 0.56 and V5 = 0.54. The KMO values are all above 0.5 or close to 0.5 for V3, which means that the data can be used for factor analysis.

For the PCA analysis stage, the correlation matrix is utilized to determine the eigenvalues and eigenvectors as shown in Table 2. Meanwhile, Table 3 is the result of the calculation of eigenvalues and variance. The new variables (principal components) formed are based on eigenvalues greater than 1. There is only one principal component that has a value greater than 1, namely 3.99078. This one principal component explains 79.815% of the data diversity. This is also confirmed by the scree plot (Figure 3) which shows that the scree plot begins to flatten out when the initial variables are extracted into 1 factor.

Table 3. Eigenvalues and Variance Result

PC	**Eigenvalue**	**Variance**
1	3.99078	79.816
2	0.48126	9.6252
3	0.41651	8.3302
4	0.10180	2.0361
5	0.00964	0.1928

Source: Data Processing Result, 2024

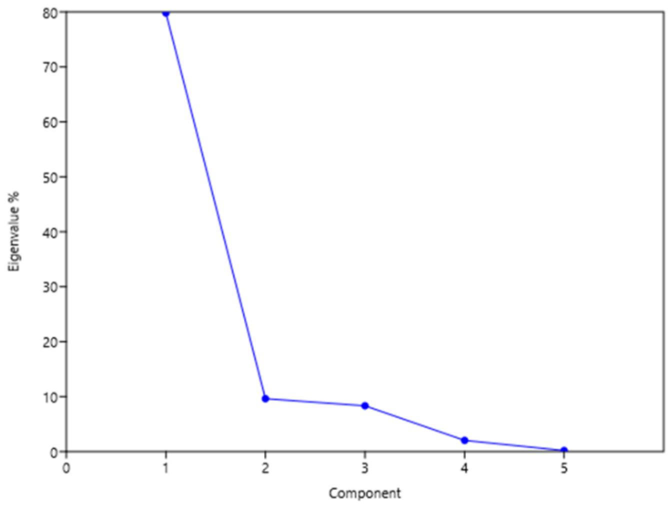

Fig. 3. Scree Plot Result
Source: Data Processing Result, 2024

Table 4 below explains the correlation between the original variables and the new variables (principal components) formed by PCA which are called loading values. The selected loading values are loading values above |0.5| which are considered capable of explaining the variables that affect the dynamics of coal trade. However, PC1 can explain 79.815% of the data diversity turns out to have a fairly low loading value. Only production and consumption factors are close to 0.5. This likely indicates that all of these variables have a relatively equal role in the dynamics of coal in Indonesia.

Table 4. Loading Value Result

Variables	PC1	PC2	PC3	PC4	PC5
CPR (V1)	0.42270	0.38079	-0.69256	0.40990	-0.16931
Production (V2)	0.48886	-0.083717	0.2561	-0.31132	-0.76909
Export (V3)	0.41706	0.54513	0.61292	0.22992	0.31679
Import (V4)	0.42173	-0.73838	0.093251	0.48435	0.18344
Consumption (V5)	0.48014	-0.07496	-0.26535	-0.66903	0.49581

Source: Data Processing Result, 2024

To find out how close the relationship is between variables, a PCA biplot is performed. Figure 4 shows a PCA plot for every year and a PCA loading plot that displays an arrow line on each variable that has a certain direction. The PCA plot for each data shows that on the left, there is data before 2018, while data from 2018 and above is on the right and more scattered. This likely confirms that the dynamics of changes in CPR, production, export, import, and consumption began to appear in 2018 and beyond.

In the PCA biplot, the smaller the angle formed between one line and another or the more they overlap, the stronger the positive correlation between the variables. If one line and another have opposite directions, then there is a negative correlation between the variables. The results of the PCA loading plot show that CPR and exports have the same direction and angle. This confirms that coal prices are highly correlated with the amount of exports. Statistical analysis conducted by Husodo and Vanany (2024) [11] on the Indonesian coal export in 2019-2022 indicated similar trend where CRP has significant partial influence on coal export.

This result in line with researches conducted by Pratama et al. (2016) [12]; Wijaya et al. (2018) [13] and Aristiyanti (2020) [14], stated that coal prices are highly correlated with export volumes and CPR has positive and significant effect on coal prices in Indonesia. Those studies also stated that the variables that significantly influence coal export performance are CPR and exchange rates. This is in accordance with the situation in the field that mining entrepreneurs will export coal in large quantities when prices increase. Interesting fact was also concluded by Situmeang & Setiawan (2022) [15] on Indonesia Coal Price in 2018-2020. Coal exports effect positively on coal prices, whereas coal production indicates a negative effect on coal prices. The similar indication is shown by the result of this study. As shown by the PCA biplot (Figure 4), the angle between CPR and export is smaller than the angle between CPR and production. Export is closely related to CPR rather than production to CPR.

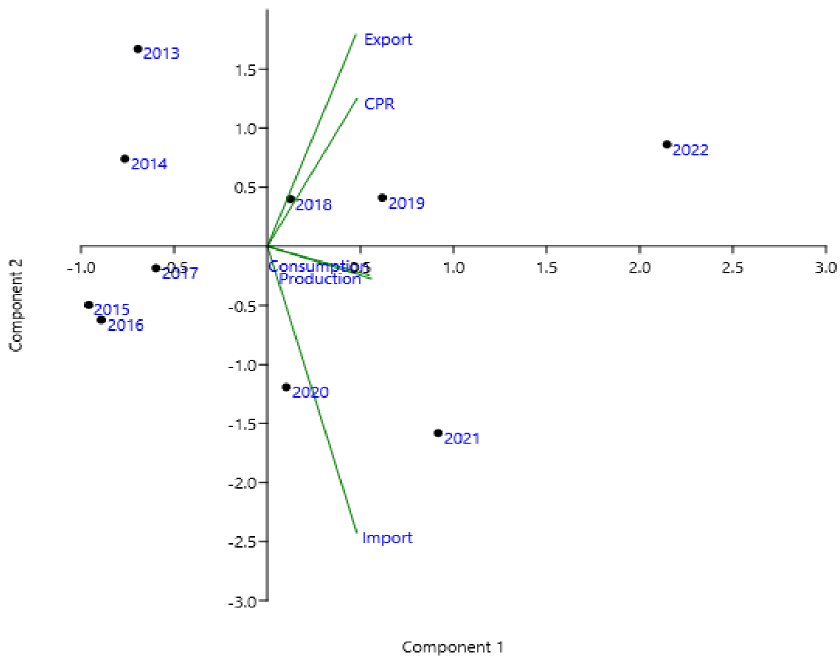

Fig. 4. Principal Component Analysis Biplot Result
Source: Data Processing Result, 2024

The PCA biplot results also show that domestic consumption and production have angles and directions that are close to each other. This pattern shows that the two factors are correlated. Domestic coal consumption increases along with increasing coal production. Ministry of Energy and Mineral Resources stated that there was increase of domestic coal demand for electricity and non-electricity sectors [16]. From 2015-2021 coal need for electricity increased 60% while for non-electricity increased 52%. To secure this demand, government regulates the Domestic Market Obligation (DMO) for coal company (recently 25% of production). Therefore, it is very logical that the production and consumption have very close relation because the increasing production of coal means increasing DMO volume which is consumed by various sectors.

However, CPR and exports as well as domestic consumption and production turned out to have different trend directions. This shows that the two groups of factors do not influence each other too much. The fact that there is an influence but not significant between domestic coal consumption and coal export volume was also found by Pratama et al. (2016) [12]. This shows that in reality exports and domestic consumption are not very related.

The PCA results show that the factor that has the least influence or that has a fairly far correlation is imports. This is indicated by the trend direction that is very far from the other trends. Indonesia's coal imports are so small that they do not affect other factors. This coal import is usually only to meet the needs of coking coal or metallurgical coal for steel factories [17]. This type of coal whose specifications are not available in Indonesia is very specific for metal industries so that the imported amount is small, even there was a slight increase of coal import in recent years following the increase of steel industries in Indonesia.

4 Conclusion

This study shows that from the variables in the data set, only one new variable is obtained that determines the dynamics of coal trade in Indonesia. With similar loading values, CPR, production, export, import, and domestic consumption likely indicate that all of these variables have roles that are not much different. However, CPR is very much influenced by the amount of coal exports. Domestic consumption and production are not factors that greatly influence CPR. The factor that has the least influence on CPR is coal imports.

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