

# Random Matrix Theory Analysis of Impact Of Covid-19 On Exchange Rate Of Indian Currency

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## Abstract

In the present work, the time series of exchange rates of 5 dominant global currencies in terms of the Indian currency rupee is analysed. The time series of the exchange rate of EURO, GBP, JPY, SGD and USD in terms of Rupee from 2015 to 2021 are considered in present study. The Indian currency is taken as the base currency to analyse impact of various critical events on it and to identify safe heaven currencies. The technique of random matrix theory (RMT) is applied in static periods. For static period, 8 time windows of one year length starting from 2015 were considered. The static analysis identifies highly correlated and weakly correlated currencies during local critical events such as Covid-19 and Demonetisation in India. The study shows impact of such events on correlations among global currencies.

**Keywords:** Covid-19, Currency exchange rates,

## 1. INTRODUCTION

Recently a lot of research is being carried out to study the impact of global pandemic Covid -19 on various sectors. The unemployment and a steep pull back in development projects due to nationwide lockdown have adversely impacted the Indian economy. The augmentation of medical infrastructure was carried out during the initial lockdown. Even then, the Covid-19 impacted almost every sector. The different mathematical and physical approaches have already been applied to study the impact of such blackswan events on the financial indices and currency exchange rates [1-4]. Acosta et al. [5] examined the effect of the global pandemic by providing some primary evidence on the global dairy sector. He used a longitudinal qualitative analysis framework in which collective use of questionnaires, group discussion, media research, semi-structured interviews, and secondary evidence reviews was presented. The results indicated that both supply and demand of the global dairy sector was affected by the global pandemic and also accelerated the structural changes in the dairy sector. Ezeaku et al. [6] investigated the effect of supply of oil and global demand stocks in the Covid-19 times on the volatilities of the international commodity prices in agriculture and metal commodity market prices by utilising SVAR model.

Sipior et al. [7] discusses deployment of AI application and its importance in the fight against Covid-19. A careful planned study related with the development and use of AI for better solutions is required. Elnahass et al. [8] investigated the effect of ongoing pandemic Covid-19 on the global banking stability. He examined the impact by considering 1090 banks from 116 countries for three-month time during 2019–20. The results showed that the pandemic affected the financial performance of the banks and their financial stability. Shahzad et al. [9] examined the cross-sectoral volatility connections in the stock market of China and studied the specific asymmetries in appreciated volatility connectedness due to ongoing global pandemic. From the observed results it was evident that asymmetries have good and bad impact on volatilities that were time-varying and considerably impactful during Covid-19 pandemic. It was also concluded that good volatility spillover shocks was dominated by bad volatility spillover shocks. Maghyreh et al. [10] considered the transfer entropy processes to investigate the info distribution between the selection implied volatility & realized volatility and the revenues of six financial assets in the times of COVID 19 outbreak. Thus it was determined that the expectedness of the volatilities resultant from option pricing models has upgraded during the pandemic. The studies [11-20] have also studied the impact of covid-19 on various fields.

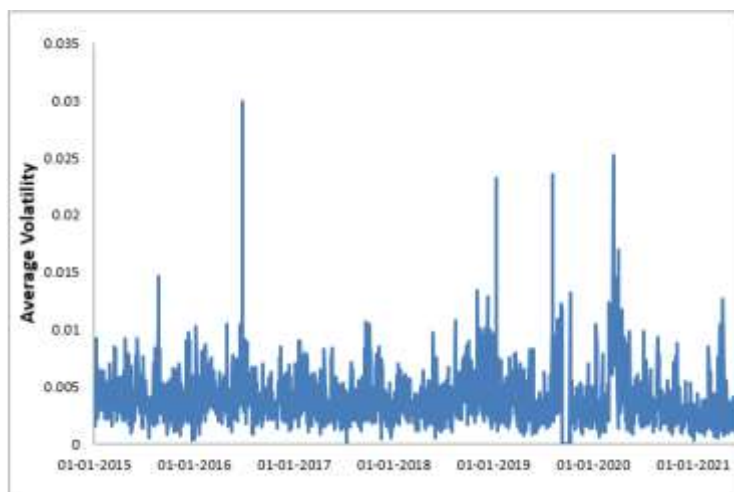
In present analysis global currency exchange rates data taken at a frequency of one day is analyzed. The daily data of 5 currencies have been taken and Indian currency i.e. rupees is taken as reference currency. Three word code symbolizations for currency has been used as per ISO standards. The random matrix theory is used to test the non –randomness of the considered data. As per authors’ knowledge no such analysis has been carried out on currency exchange rates to detect the impact of covid-19 on currency exchange rates. The organization of the chapter is as follows: in section-II, we discuss the analysed data. We discuss the methodology used in the analysis in section-III. The results are discussed in the section-IV. In section-V, summary of the findings is represented.

## 2. DATA ANALYZED

The times series of 5 global currency exchange rates in Indian Rupees is downloaded from <https://finance.yahoo.com/>. The global currencies used in the analysis are listed in Table -1. We have computed the volatility which is a measure of market fluctuations as shown in Fig.1.

**Table-1:** Currency exchange rates of 37 currencies in US Dollars.

| S.No | Acronym | Description      |
|------|---------|------------------|
| 1    | SGD     | Singapore Dollar |
| 2    | JPY     | Japanese Yen     |
| 3    | GBP     | Pound            |
| 4    | USD     | US Dollar        |
| 5    | EUR     | Euro             |



**Fig.1:** Average volatility of the global currency exchange rates computed for moving time window of one year.

## 3. METHODOLOGY

To analyze the time series of global currency exchange rates, we have applied the technique of RMT. The exchange rates of all the currencies are in taken in Rupees.

### 3.1 Random matrix analysis of currency exchange rates

Let  $E_i(\tau)$  denote the daily closing value of the exchange rate of currency ‘i’ in terms of USD at time  $\tau$ . The logarithmic returns  $R_i(\tau)$  are defined as

$$R_i(t) \equiv \ln E_i(\tau) - \ln E_i(\tau - 1)$$

Then the normalized returns for the stock ‘i’ is defined as

$$NR_i(\tau) = \frac{R_i(\tau) - \langle R_i \rangle}{\sqrt{\langle R_i^2 \rangle - \langle R_i \rangle^2}} \quad \text{where } \sigma_i = \sqrt{\langle R_i^2 \rangle - \langle R_i \rangle^2} \text{ is the standard deviation of } R_i \text{ and } \langle \dots \rangle$$

represents the time mean over the span of period.

The correlation matrix is computed using the normalized returns, having elements  $C_{ij} \equiv \langle r_i(\tau)r_j(\tau) \rangle$  lying in the range [-1, 1]. The values of elements represent perfect anti-correlation ( $C_{ij} = -1$ ) to perfect correlation (1). The Wishart matrix from random time series of the same length as that of empirical time series is generated and its eigenvalue distribution is compared with the cross-correlation matrix of empirical data. In the limiting values of N and T ( $n \rightarrow \infty, T \rightarrow \infty$ ) with ratio  $X = \frac{T}{N} \geq 1$ , the probability distribution of eigenvalues ( $\zeta$ ) of Wishart matrix is given by,

$$P(\lambda) = \frac{X}{2\pi} \frac{\sqrt{(\zeta_+ - \zeta)(\zeta - \zeta_-)}}{\zeta}, \quad \text{where maximum/minimum eigenvalues } (\zeta_+ \text{ and } \zeta_-) \text{ are given by,}$$

$$\zeta_{\pm} = \left[ 1 \pm \left( \frac{1}{\sqrt{X}} \right) \right]^2.$$

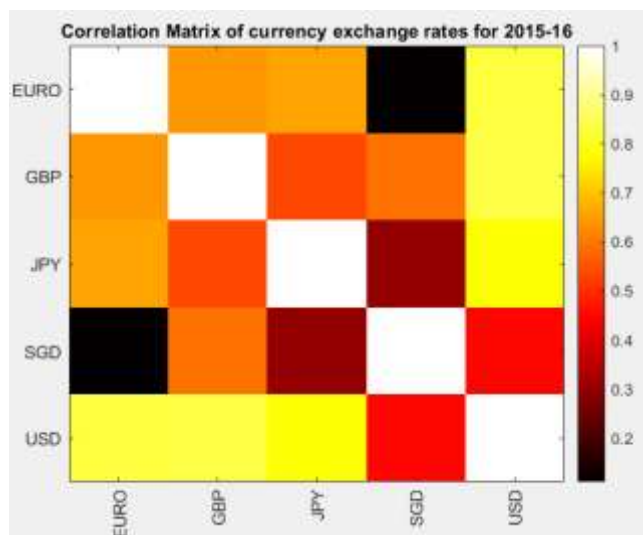
The eigenvalues within the range  $\zeta_+ \leq \zeta \leq \zeta_-$  i.e. RMT predictions represent the random behaviour of the time series and do not have economic meaning, whereas the eigenvalues beyond the RMT predictions have profound information.

So for financial indices having no correlations, the eigenvalues of correlation matrix lies between RMT predictions, i.e.  $[\zeta_+, \zeta_-]$ . The results of RMT analysis are listed in Table 2. From RMT results, we find that the dominant eigenvalues of CCM in all periods of crisis are out of the RMT predictions and thus provides the important information about the collective dynamics of the market.

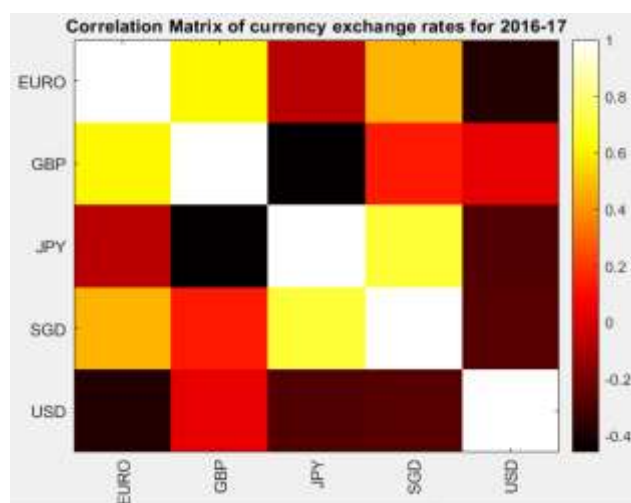
**Table 2:** RMT results for CCM of currency exchange rates.

| Time Window | $\lambda_{max}$ of Correlation Matrix | $\lambda_{min}$ of Correlation Matrix | $\lambda_{max}$ Wishart Matrix | $\lambda_{min}$ Wishart Matrix |
|-------------|---------------------------------------|---------------------------------------|--------------------------------|--------------------------------|
| 2015-16     | 2.4724                                | 0.4015                                | 1.296                          | 0.7423                         |
| 2016-17     | 1.5792                                | 0.5001                                | 1.296                          | 0.7423                         |
| 2017-18     | 1.8371                                | 0.6029                                | 1.296                          | 0.7423                         |
| 2018-19     | 2.4053                                | 0.3477                                | 1.296                          | 0.7423                         |
| 2019-20     | 2.5443                                | 0.3317                                | 1.296                          | 0.7423                         |
| 2020-21     | 2.8561                                | 0.2057                                | 1.296                          | 0.7423                         |
| 2021-22     | 3.2051                                | 0.1924                                | 1.296                          | 0.7423                         |

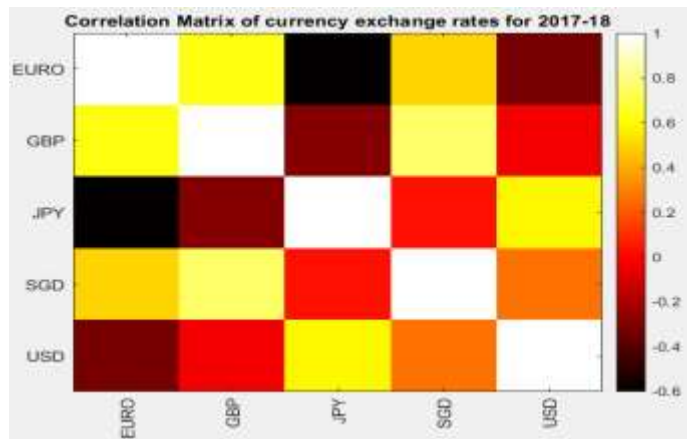
From the results of RMT predictions and empirical CCM of 5 global currency exchange rates, we find that the interaction among the global currencies is not random. The LEV deviated from the RMT predictions reflect that empirical correlation matrix contains important information. The individual values of the CCM are graphically represented by colors using color maps, which are useful to display a general view of data, not to extract specific information. The color maps and probability distribution of eigenvalues in different periods are shown in Figs.2-8.



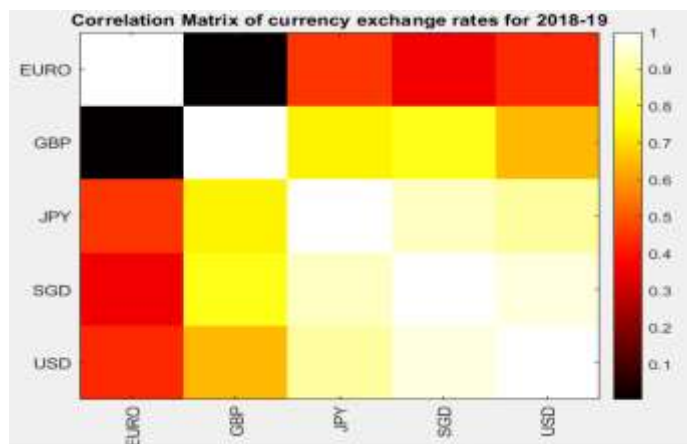
**Fig.2:** Color map of correlation matrix of 5 global currency exchange rates for 2015-16.



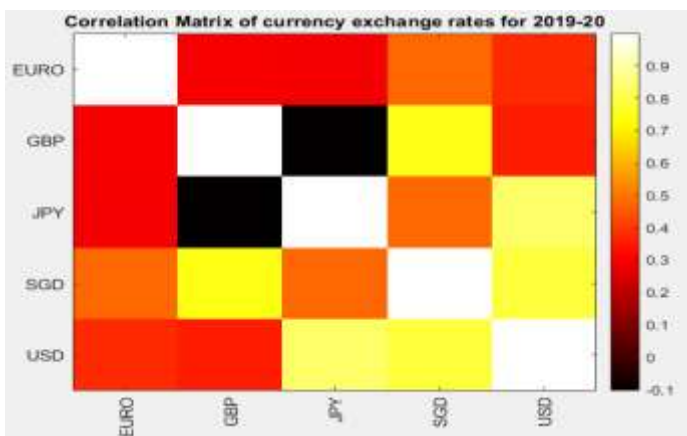
**Fig.3:** Color map of correlation matrix of 5 global currency exchange rates for 2016-17.



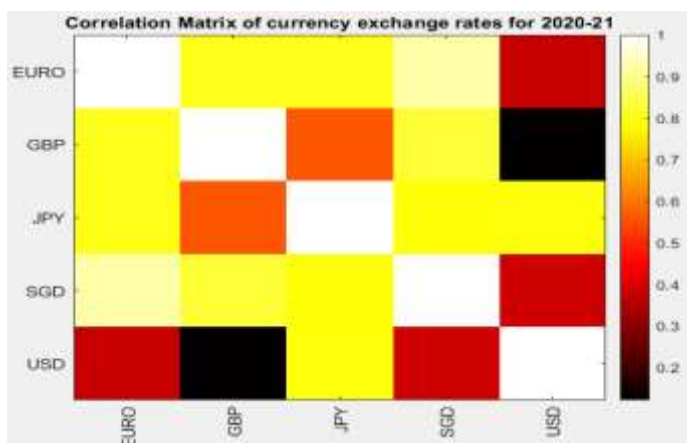
**Fig.4:** Color map of correlation matrix of 5 global currency exchange rates for 2017-18.



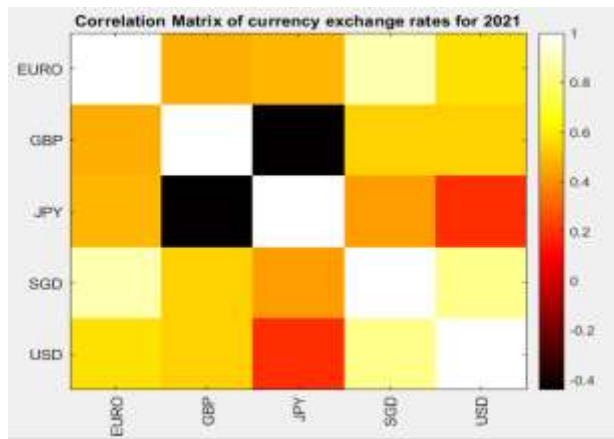
**Fig.5:** Color map of correlation matrix of 5 global currency exchange rates for 2018-19.



**Fig.6:** Color map of correlation matrix of 5 global currency exchange rates for 2019-20.

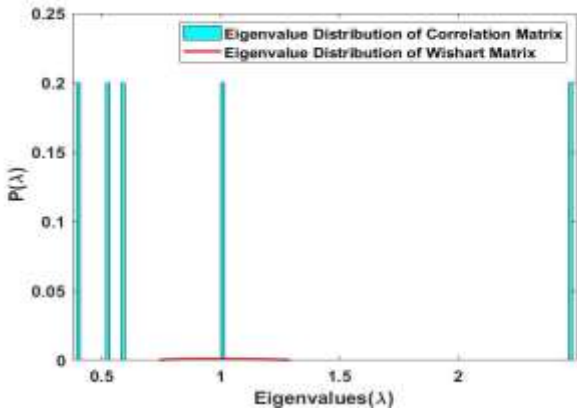


**Fig.7:** Color map of correlation matrix of 5 global currency exchange rates for 2020-21.

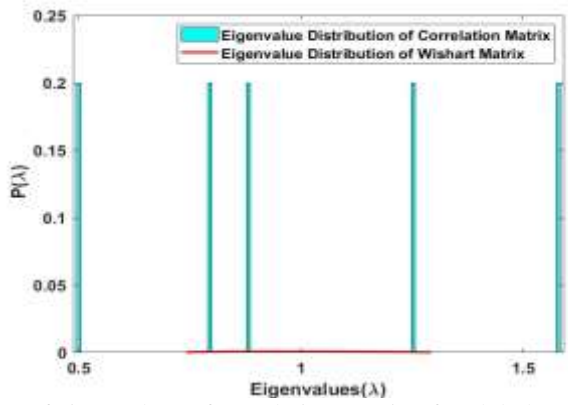


**Fig.8:** Color map of correlation matrix of 5 global currency exchange rates for 2021-22.

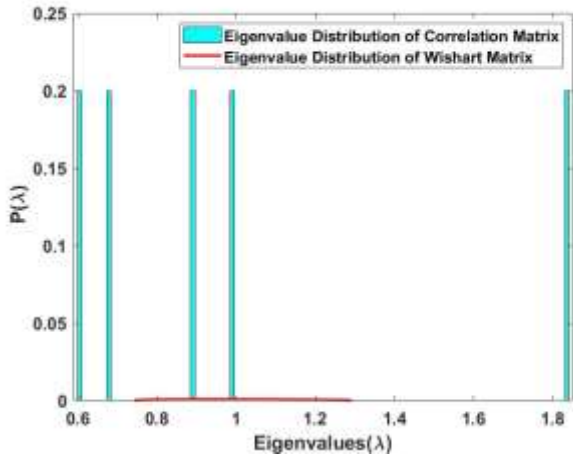
The probability distributions of eigenvalues in different periods are shown in Fig.9-15.



**Fig.9:** probability distributions of eigenvalues of correlation matrix of 5 global currency exchange rates for 2015-16.



**Fig.10:** probability distributions of eigenvalues of correlation matrix of 5 global currency exchange rates for 2016-17.



**Fig.11:** probability distributions of eigenvalues of correlation matrix of 5 global currency exchange rates for 2017-18.

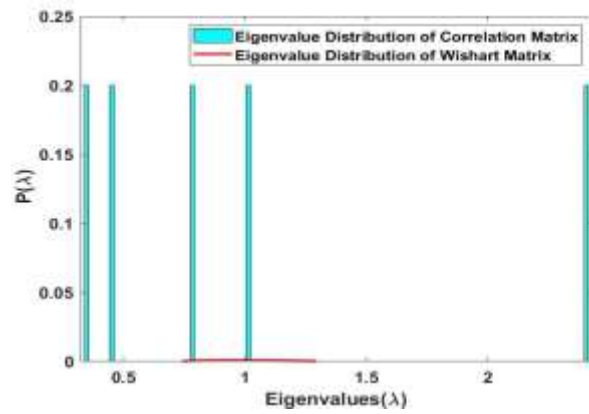


Fig.12: probability distributions of eigenvalues of correlation matrix of 5 global currency exchange rates for 2018-19.

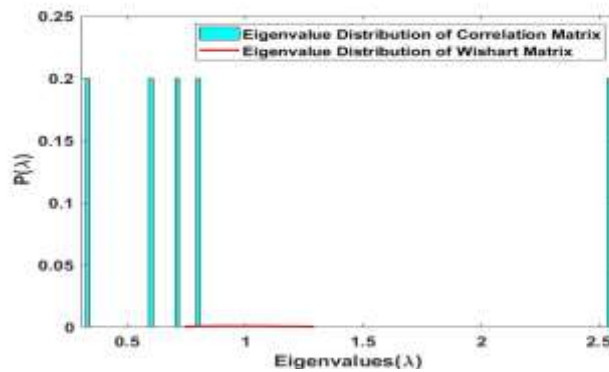


Fig.13: probability distributions of eigenvalues of correlation matrix of 5 global currency exchange rates for 2019-20.

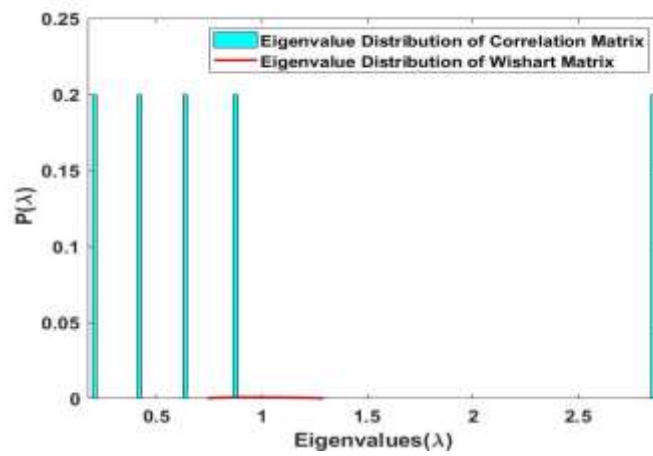


Fig.14: probability distributions of eigenvalues of correlation matrix of 5 global currency exchange rates for 2020-21.

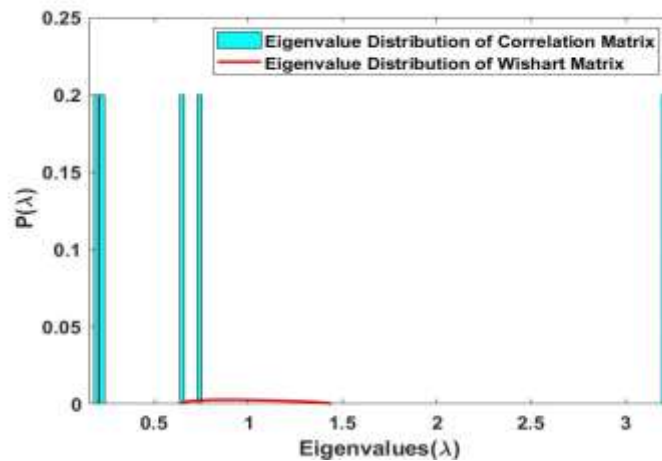


Fig.15: probability distributions of eigenvalues of correlation matrix of 5 global currency exchange rates for 2021-22.

## 4. RESULTS AND CONCLUSIONS

The static analysis of global currency exchange rates in terms of Indian Rupees is presented using well known statistical and physics approaches. The static analysis shows high correlation during the occurrence of extreme events. In the present work of analyzing the exchange rates of 5 currencies, we have constructed the CCM of the returns. Most of the calculated eigenvalues of CCM in different periods of crisis are out of bound of Wishart matrix (i.e. RMT predictions), which shows that the interactions among the global currency exchange rates are not random but informative. Heat maps of correlation matrices in different periods are shown in Figs.2-8. The heatmaps in the period of demonetization and Covid-19 represent high correlation among currencies. The largest eigenvalues in different periods of time are different and outside RMT predictions. More precisely, we have made an attempt to recognise particular currencies which have a dominant or dependent role. Since exchange rates are expressed as the price of one currency compared to another currency, so identification of dominant currencies is a difficult task. The analysis performed in this paper may be helpful in the development of different indicators of systemic risks in India.

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