Investigation of Uncertainty in Financial Time Series: An Application of Entropy and Permutation Entropy

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Abstract

Predictability in financial market is a major concern in view of investment. Market condition is linked to the social, political and economic issues. NIFTY and Gold Price data are investigated in the context of demonetization. Uncertainty in the time series is captured by empirical probability distributions and measured by entropy of various states. Further, the micro patterns are explained with the help of permutation entropy.

Key words: *Demonetization, Uncertainty, Entropy, Permutation Entropy*

Introduction

A common phenomenon in the financial market is uncertainty. Financial time series are random in nature due to the uncertainty in the market [1]. Uncertainty occurs due to various economic, political and social issues viz. currency devaluation, demonetization, bank failure etc. As countries GDP is dependent on the financial status of the market, therefore economic growth of a country is affected by the uncertain behaviour of the financial market. It is very important to analyse economic data for decision leading to the betterment of a country's economic status. Prediction of trends and forecasting, analysis of patterns, estimation of stock prices, analysis of risk and return etc., are of major interest to investors. Investors generally invest in shares, foreign currencies or tangible assets like gold etc[2]. An analysis related to such financial data is always beneficial for investment decisions.

Uncertainty and risk are prime concern of investors in the financial market[3]. An increasing research interest has been observed in the area of stock market and other economic data for measuring uncertainty and risk[2], [4], [5],[6], [7]. Lot of quantitative techniques are applied for investigation of financial time series in view of persistence, volatility, scale invariance etc. International business cycle has been discussed based on the correlation of the best traded stocks[8]. Empirical studies on price fluctuation, estimation of risk in portfolio management, investigation on long range correlation, self similarity etc., are some recent research trends[6],[7]. The volatility in the stock market and increased risk and uncertainty in return have induced the tendency of investment in commodity market. Gold being the precious metal, has attracted many to invest in the bullion market. The easy liquidity and less risk in Gold price has been the preferred option for investment. A lot of research work has been done for the characterization of Gold price data[11]–[13].

Recently, a lot of uncertainty crept in the financial market in India due to demonetization in 2016. The impact of demonetization was observed in various areas such as banks, financial institutes, stock markets etc. In this paper we intend to see the immediate effect of demonetization on the NSE index i.e. NIFTY and also on gold price. The archival data is collected from the website of NSE and MCX for 50 days prior to the declaration of demonetization and 50 days after demonetization in order to compare the transient effect of it. The time series of NSE index and gold price shows

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significant nonlinear fluctuation. The fluctuation in the time series makes it unpredictable and thus the inherent dynamics is not deterministic. This uncertain behaviour is captured by the probability distribution of the time series and explained by the entropy measure and permutation entropy[14]. This paper consists of four sections. Starting from brief introduction in section:1, followed by the methodology in section: 2, Section: 3 illustrates the uncertainty measure of financial data with detail computation and finally section:4 contains conclusion.

Methodology

If the observations in a time series takes discrete values which has a finite degrees of freedom, all possible states can be described by the corresponding probability distribution. Further, probability of each state may be considered to characterise the complex dynamics. Entropy is such a mathematical measure which takes the probabilities of each possible state into consideration and thus enables us to quantify the uncertain behaviour using Shannon entropy as:

$$H = -\sum_{i=1}^{n} p_i \log p_i$$

where, is the probability of each probable state. If 0, the time series is regarded as deterministic[15]. Entropy has been widely applied in characterizing a time series[16].

Complexity is further investigated by analysing micro patterns of the time series using symbolic dynamics (SD). The symbolic dynamics allows one to find different patterns that may exist in a time series. Ordering such patterns leads to a measure called Permutation Entropy (here after referred as PE). Following Bandt and Pompe [17], if a time series {a1, a2,...,an } is mapped to {1,2,...,n} such that ordering of both the series are same, then n! different patterns are possible to observe. Each pattern is denoted by . For instance three successive observations {1,2,3}, computing PE involves all possible ordinal patterns (123),(132),(231),(213),(321),(312) shown in Fig.1.

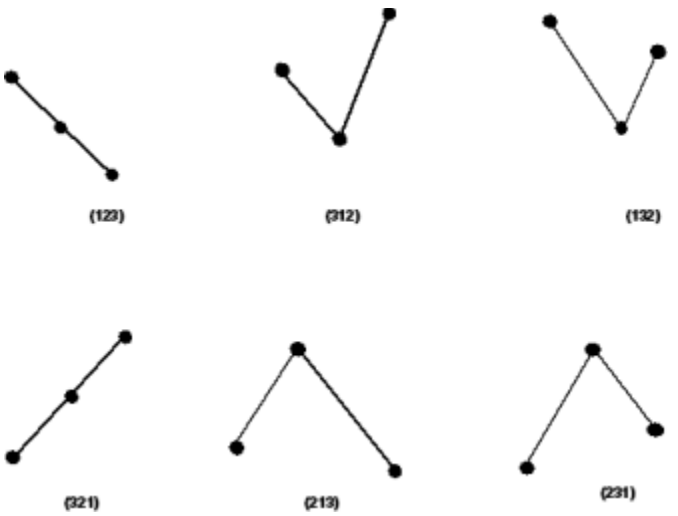

Fig.1: All possible ordinal patterns with three successive observations

For any time series, various motifs obtained as above may have the probability of occurrence given by where refers to motif. Therefore, uncertainty measure of a time series can be obtained by generalizing Shannon entropy as:

$$H_{PE} = -\sum_{i=1}^{M} P_{\Pi_i} \log(P_{\Pi_i})$$

Here, is termed as Permutation Entropy.

Uncertainty measure of the national stock exchange

The impact of demonetization is likely to have significant impact on the national stock exchange data as a good amount of financial transaction takes place every day. The data collected for the time period as mentioned in the previous section exhibits a highly fluctuating trend (cf. Fig.2). The average NSE data value is more for pre - demonetization as compared to the post-demonetization . Computed values of mean, standard deviation and coefficient of variation for pre and post demonetization are shown in Table :1.

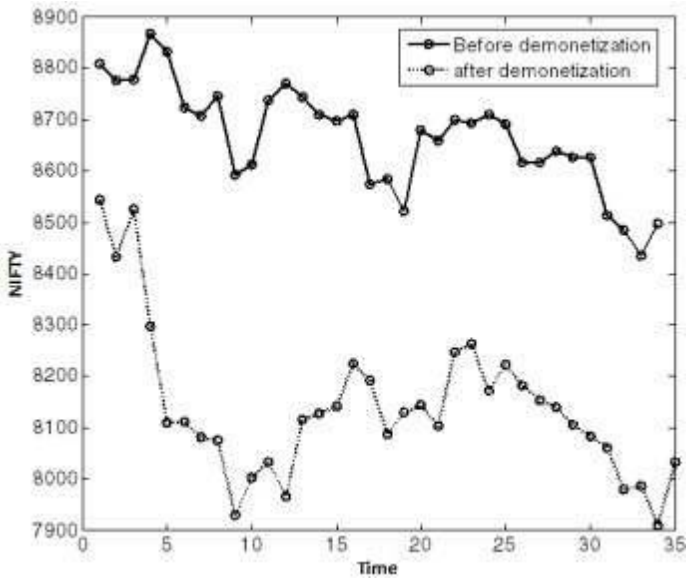

Fig.2: Time series of NSE data; blue line represents the data for pre demonetization and red line for post demonetization period of 50 days. Dates are shown in the time axis.

Table:1

NIFTY index	Mean	SD	CV	Entropy
Pre-demonetization	8.6665e+03	102.6487	0.0118	5.8710
Post - demonetization	8.1398e+03	144.8201	0.0178	6.1632

It is evident from Fig. 2 that the data is non linear and hence represented by its state of occurrences as indicated in the following histogram (Fig.3).

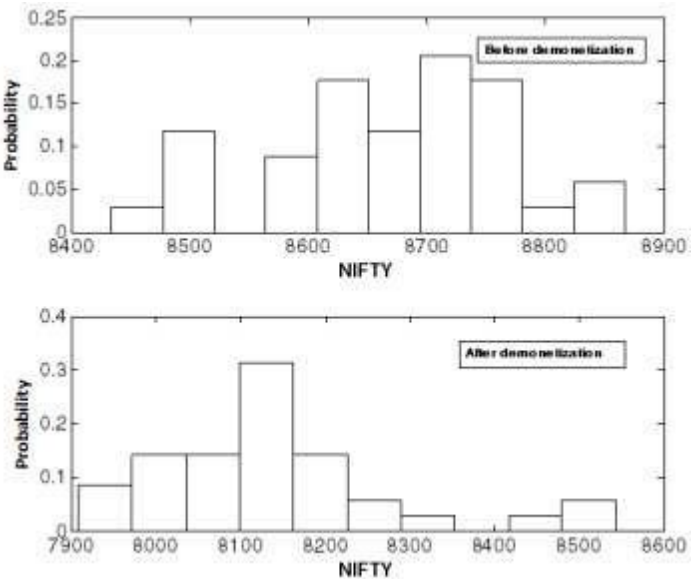

Fig.3: Histogram of NIFTY showing unimodal distribution of occurrence after demonetization

The histogram shows the probability of occurrence of all possible states of stock prices. In the period prior to demonetization, there are more than one state with almost same probabilities where as after demonetization, only one state with maximum probability is seen to occur. Entropy is computed for each case from the above histograms and the computed values are listed in Table: 2.Since the computed entropy is less for the period after demonetization, the NSE data is more ordered in post demonetization as compared to pre demonetization which is also depicted in the above figure (Fig.3) .

The impact of demonetization leads to observable effect in Gold market as it is believed to attract more investors in those days. We carried out the similar analysis for gold price rate in order to find a correlation of Gold price and NSE data. Our analysis shows that average gold price decreased after demonetization (Fig. 4). A higher coefficient of variation indicates less uniformity in the series after demonetization. This is further verified by computing entropy of both the data sets from their respective histograms(Fig. 5). The investigation is further carried out in view of micro pattern behaviour using the idea of PE. The ordinal patterns observed in both the data sets for each time period as mention in the previous section are displayed in Fig. 6 &7.

Ordinal patterns (321), (231) and (213), (132) are seen to appear with almost same probability in NSE data. The range of variations of their respective probabilities is nominal. On contrary, (123) is seen to appear with a significantly higher probability in Gold price data which indicates that for three consecutive days' price has a decreasing tendency i.e. first day shows the maximum price and third day, the lowest price. The scenario is quite different for post- demonetization period where no pattern is significantly dominant in gold data. The pattern (123) and (321) are seen to appear with same probability making the series more unpredictable for the buyers. At the same time (312), (231) and (123) are emerging with same probability for NSE data after demonetization.

Conclusion

The effect of demonetization on the micro pattern of NIFTY and Gold price is investigated. Uncertainty of the financial market is quantified by measuring entropy. Further micro patterns are analysed by permutation entropy. It is observed that the price of Gold on MCX was more uncertain in comparison with NIFTY after demonetization. Although transactions in NIFTY as well as Gold on MCX are cashless i.e. in both of these markets, payments are done from investors' account, price of Gold

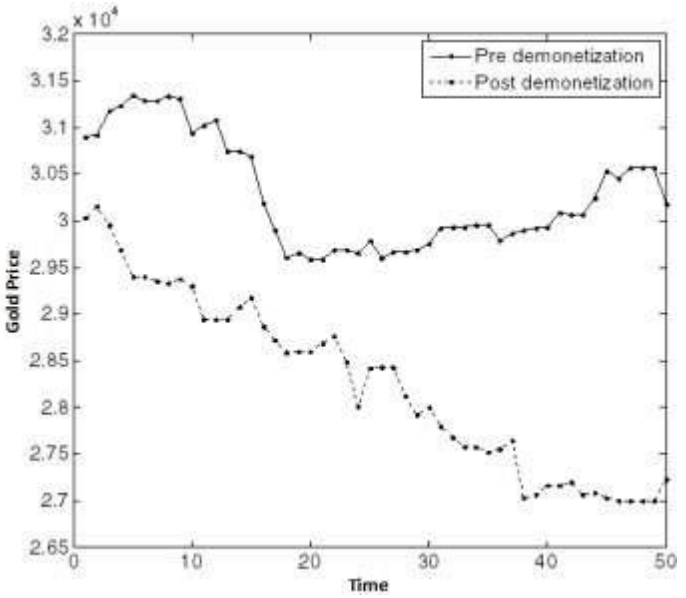

Fig. 4: Fluctuation in Gold price for a duration of 50 days before and after demonetization
All other statistical characteristics are measured and shown in Table 2.

Table:2

Gold Price	Mean	SD	CV	Entropy
Pre demonetization	3.0276e+04	591.1128	0.0195	7.2536
Post demonetization	2.8258e+04	954.2898	0.0338	7.8857

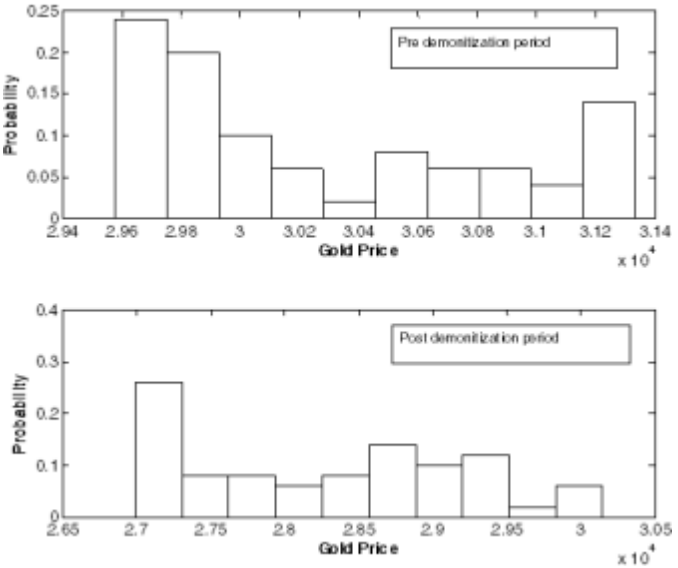

Fig.5: Various states of occurrence of Gold Price shown by histogram for a period of 50 days before and after demonetization

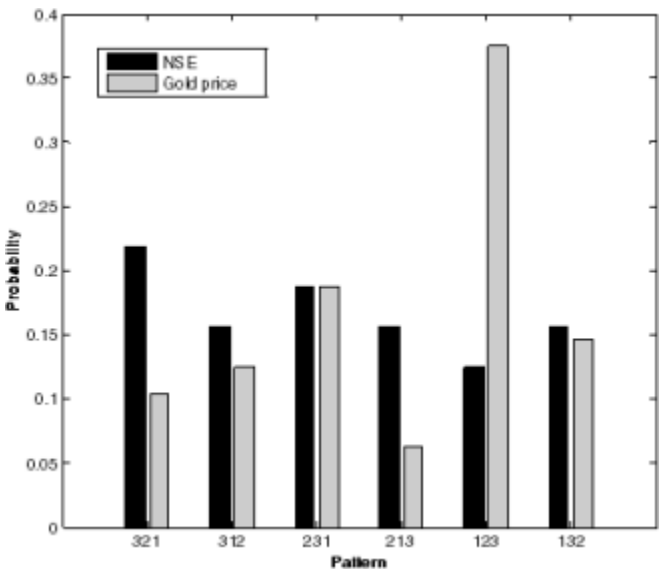

Fig.6: Ordinal patterns of NSE and Gold price data before demonetization

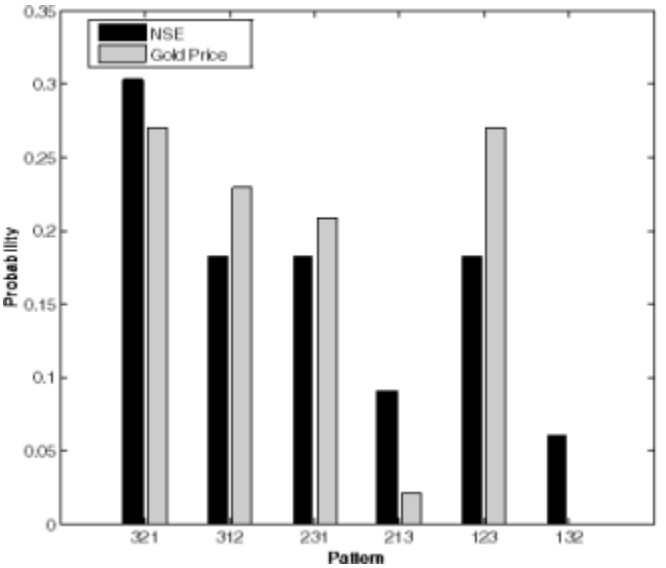

Fig.7: Ordinal patterns of NSE and Gold price data after demonetization

was found to be uncertain after demonetization as people started investing in Gold through offline market to purchase Gold in physical form. Investment in open market of Gold increased uncertainty in Gold Price on MCX.

The time varying stock market data is an indicator of economic stability of the financial market. Entropy measure provides a basis for understanding the uncertain behaviour of the data. Investigation of micro patterns of both data sets reflects the immediate impact of demonetization. Moreover, the price fluctuation patterns in both the data sets perhaps reveals anti correlation in investment trends during demonetization. However, study is conducted on small data set in order to see the immediate effect of demonetization, the result provides an insight into the status of the financial market in India.

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