ANALYSIS OF FINANCIAL STABILITY AND DETECTION OF UNPREDICTABLE UNKNOWNS USING POISSON TRANSFORM

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Abstract : Finance and economy refined for centuries without reference to advanced mathematics and signal processing. Stock market crashes are critical for the financial stability. Thus the resulting financial distress usually takes time to dissipate and it is usually modeled via Poisson processes with a predetermined fixed intensity. To model the rare events called "unpredictable unknowns"(UUs), a modified framework is proposed by using the Poisson processes with random intensity. US Dow Jones Industrial Average (DJIA), Japan Nikkei 225 and Turkish BIST 100 index are considered for the analysis since they are stable indices. From the experimental results it is explicit that in the stable stock markets, there are fewer unpredictable unknowns when compared to unstable ones. The modified method uses prediction of future values with linear predictor and moving average filter also analyses the effect of unknowns in the prediction. Simulation results show that prediction of financial data in the presence of UUs is impossible when compared to financial time series without UUs.

***Index Terms* – Financial Stability, Unpredictable Unknowns, Poisson Process, Linear predictive coding, Moving average filter.**

I. INTRODUCTION

With the expansion of economic globalization and progression of information technology, financial data are being generated and accumulated at an exceptional pace. . The subject of financial time series analysis has fascinated generous attention in recent years. At the same era, the field of financial econometrics has endured numerous unique developments, precisely in high frequency finance, software availability, and stochastic volatility. Financial statistics are regularly growing and are extremely distinguishable in daily reports on stock prices, currency exchange rates, gold prices, and interest rates. Many of these data are distinguished by a high degree of uncertainty, and variations have the possibility to generate extensive gain or losses. Still there is no exact and universally approved definition for the term "financial stability" and it is commonly used with reference to steady growth, reasonable distension, and low unemployment. Financial stability is a event in which the financial system, includes the key financial stock markets and the financial institutional system is disobedient to economic shocks and it is fit to evenly accomplish its key objectives: the management of risks, and intermediation of financial funds. So in the truancy of financial stability, high variations will be detected in the asset prices. Financial stability is one of the most extensively reviewed issue in today's economic literature. The purpose of analyses on financial stability was early identified during the international financial crises at the end of the 90s. The 2008/2009 financial crisis has had widespread effects on the financial sector in the first place, but also strong consequences on the real economic activity. Usually, in the years 2008 and 2009, financial conditions in the U.S. and the ultimate industrialized and open economies were described by high instability and elevated stress. When evaluating the stability of an institutional system, we examine the degree in which the whole system is suitable of opposing external and internal shocks. Still these shocks do not consistently results in financial crises. But it creates an unstable financial environment and can itself disrupt the normal development of the economy.

Different theories define the sources of financial instability; but their purpose may vary according to the period and countries drawn into the extension of analysis. These sources of financial crises turn up not only collectively, but also independently, or in a random sequence, and therefore the analysis of financial stability is an quite complex task. The target on individual branches distorts the global picture, so the issues need to be examined in their complexity in the course of interpreting financial stability. Modeling financial data in continuous time including uncertainty is a primary issue. The analogous driving process is usually assumed to follow a appropriate pattern. An event is said to be "unpredictable unknown" if it could not be predicted apriorily, caused a historically significant major daily collapse and reversion to the level just before the crisis, i.e., the recovery period is too long. Moreover, if the stock market shuts down after the occurrence of this particular event, without taking into the consideration of recovery period, it will be assumed as an UU. This paper reviews probability distribution such as Poisson transform which can be applied to problems arising in finance and examines some of these applications. So this study considers rare events that have serious destructive effects to financial stability. In order to model these UUs, a compound Poisson process is proposed in which its intensity is taken to be random, drawn from an exponential distribution with a very low positive parameter. In bull markets, the stock index tends to increase in a persistent but relatively slower manner compared to bear markets due to profit sales or prudent short sellers. Also for a stock index to be attractive, it has to promise a return considerably higher than the T-bill rate. Moreover, as short selling requires collateral small investors can only go long with stocks. Therefore, stock indices in the long run tend to have an upward trend. In a bear market, the situation is different. When huge sales begin, this will trigger more sales and stop orders become market orders. If a bear market starts with an UU, this usually hits the index on first day of its occurrence, together with a series of downfalls.

We begin with the basic concepts of financial time series and a brief introduction to the processes to be discussed throughout the paper. section 2 provides literature survey of previous methods for the analysis of financial stability. Section 3 focuses on modelling unpredictable unknowns using Poisson transform and also we introduce modified method which uses prediction of future financial values using linear predictor and moving average filter. . In section 4, results and comparison are discussed Section 5 concludes that prediction of financial time series without prediction error is possible if there is no UU occurs.

II.RELATED WORKS

A persistent rise in the stock prices together with a moderate volatility can be regarded as stable. In case of sudden, unpredictable and sharp breaks, stability deteriorates. Thus, not surprisingly many models have been proposed for the detection of breaks throughout the literature (for example [1], [2], [3], [4]). When the market's investment boundary becomes uniform, the market turns into unstable. In addition, Mandelbrot and Hudson (2004) introduce the idea of "mild" and "wild" randomness and claim that price changes are neither continuous nor follow a Brownian motion [5]. By the help of fractals they come up with the idea that markets are turbulent and highly risky, have flexible time, contain inevitable bubbles and are deceptive to technical analysis. As stated in [6], Poisson process is a fundamental example of a stochastic process with discontinuous trajectories. They give many examples why Poisson processes are good candidates for modeling financial breaks. In these models, although the exact timing and magnitude of the event is uncertain, the expected number of jumps for an interval is taken to be constant. Moreover, the jump size is either fixed [7] or tied to a specific distribution [8], [9]. Hence, although random, the average number and the size of the crisis are still known. However, financial markets are less predictable. It is therefore sensible to propose a more general framework for modeling breaks. So, in order to address this unpredictability, the intensity and the jump size should be generalized. Thus, this study aims to consider this need by introducing a Poisson process whose intensity is random. Moreover, the jump size is also taken as a function of this new random intensity parameter. [10] define "predictable surprise" as problems that at least some people are familiar of, getting poor over time and likely to explode into a crisis eventually, but are not prioritized by key judgment makers or have not evoked a response fast enough to avoid serious damage. They similarly regard the 2008 subprime meltdown as "predictable". Numerous studies are available regarding causality and the predictability of unpredictable events. They are all considered after the occurrence of the event in question. However, if an UU becomes predictable, then it will not be an UU anymore. A critique to [10] is the "Black Swan Theory" by [11] which is developed to explain surprises beyond the realm of normal expectations in history, science, finance, and technology whose probability is too low thus hard to compute. According to [11], an event is deemed to be a black swan if it is a surprise (to the observer), has a major effect and after the first recorded instance, it is justified by hindsight, as if it could have been expected; that is, the significant data available but unaccounted in risk reduction problems. Contrary to the affirmation of [10], this study follows the ideas of [11] and regard the September 11 attacks or 2008 financial crisis as unpredictable events. [12] uses a testing procedure to determine whether the coefficients in two linear regressions on different data sets are equal or not. In order to apply Chow test [12], the suspected break point should priory be known. [13] extended the Chow test by proposing tests for parameter instability and structural breaks with unknown change points. [14] defined a recursive algorithm in which multiple structural breaks can be automatically detected from data. The modulus of continuity notion catches points beyond the possible paths of Brownian motion and regards them as jumps. [15] use this approach for the identification of breaks where in such a case a constant variance should be stated. Hence one can infer that there is not a single and universally accepted method for jump detection.

III.RESEARCH METHODOLOGY

This study tries to model the above mentioned UUs. The intensity of this event should be very low. If it is expected to occur more than its actual probability, then its impact will significantly diminish. Rareness can be thought as a measure of unpredictability. When rareness increases, the investors will be less aware of its probability and therefore will position themselves as if it would never happen. This ignorance is in fact the key to its highly detrimental impact to financial stability. The homogeneous Poisson process counts events that occur at a fixed rate called the intensity. The process is characterized by:

$$P\,[N(t+\tau) - N(t) = k] = \frac{e^{-\lambda\tau}(\lambda\tau)^k}{k!},\ k=0,1\ldots.. \qquad (3.1)$$

Where $N(t+\tau) - N(t) = k$ is the number of events in time interval $(t,\ t+\tau]$, λ being the expected number of jumps that occur per unit time. The mean and variance of the Poisson process given in (3.1) is $E(x) = Var(x) = \lambda t$. When a specific portion of τ is considered, then mean will be less than λt. Thus if a very rare event is considered for a specific part of the time domain we must have $0 < \lambda < 1$.

Contrary to the existing literature, this study takes into account a Poisson process which has a random intensity. This is quite different from non-homogeneous Poisson process with an intensity parameter $\lambda(t)$ where the rate is assumed to be time dependent. [16] consider the arrival rate function as of the form $\lambda(t) = a + bt$, $a, b \in R$ within the interval $[0,T]$ where $0 \le t \le T$ and estimate the parameters a and b. They concentrate on telecommunication applications where ordinary Poisson process is widely used for modeling. [17] proposes a model where $\lambda(t)$ is itself a stochastic process. In this study the intensity parameter is neither fixed nor time dependent. It also does not follow a stochastic process. Here, the parameter is drawn from an exponential distribution with probability density function of the form:

$$f(x;\lambda) = \begin{cases} \lambda e^{-\lambda x} & if\ x \ge 0 \\ 0 & if x < 0 \end{cases} \ldots\ldots \qquad (3.2)$$

with a rate parameter λ which is very close to zero. λ is taken infinitesimally small in order to model the rareness and unpredictability of UUs as discussed before. Moreover, if λ is taken to be fixed or follow a particular pattern this will again lead to a different kind of predictability which will contradict the nature of UUs.

This paper concentrates on rare events by the help of a randomly drawn intensity from an exponential distribution. Since this is usually close to zero, its probability of occurrence is very close to zero as well. The Flow chart of the proposed method is shown in Fig 3.1.

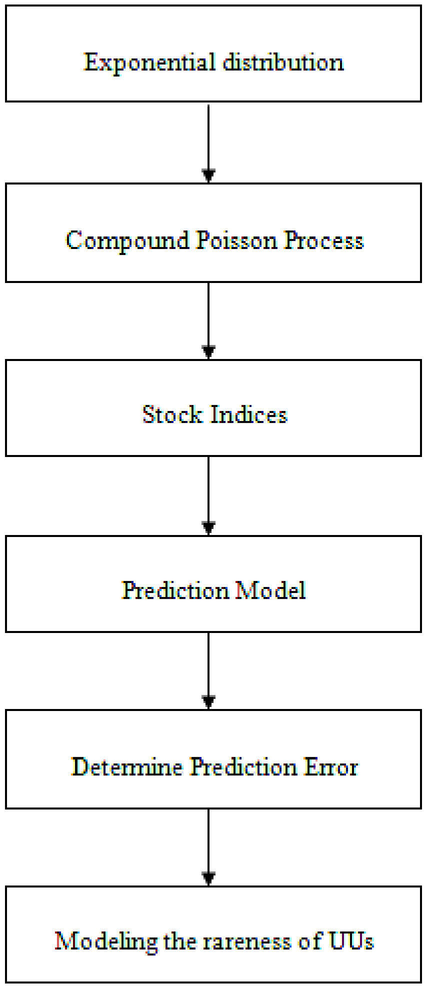

Fig.3.1 Flow chart of the Proposed Method

It is clear that the magnitude of the crash has a mean and a variance which tend to infinity when λ approaches to zero. Thus, although the probability of encountering an UU is very low, if it happens, a severe deterioration in financial stability becomes very high. On the other hand, although a high impact is highly probable, it is not certain. Therefore, the model respects the unpredictable nature of these rare events in every possible way. Due to its memorylessness property exponential distribution has been chosen. As a summary, this new model takes into account a compound Poisson process, to predict structural breaks. The compound Poisson process has a random intensity drawn from an exponential distribution whose λ is very close to zero for modeling the rareness of UUs. On the other hand if a UU happens, this UU it will hit the stock market with a magnitude which is drawn from an exponential distribution with a rate parameter λ. Hence, the more rare this event, the more its expected impact will be.

The most commonly used model for time series data is the autoregressive (AR) process. The AR process is a difference equation determined by random variables. The distribution of such random variables is the key component in modelling time series. If the time series considered is the first order autoregressive equation, then it is called AR(1) process. Hence, it is sensible to compare AR(1) process (since it is a proxy of OU process) with the new model [18]. The aim is to detect the probability of an UU for 100 days ahead. In the first step Poisson process is used to determine the probability of UUs occurs in the three major stock indices, namely Japan Nikkei 225, US Dow Jones Industrial Average and Turkish BIST 100. The intensity is generated from an exponential distribution with a very low rate parameter. Then a compound Poisson process is formed by taking this randomly chosen intensity. Whenever the probability of UU tends to zero, it is highly probable that its impact tends to infinity. However, this is also not certain since the magnitude of the impact is also random.

Here we analyses the effect of unpredictable unknowns in the case of financial time series prediction. For the prediction of financial data, two methods are considered and they are linear predictor and moving average filter. Block diagram of the proposed prediction model is shown in Fig. 3.2

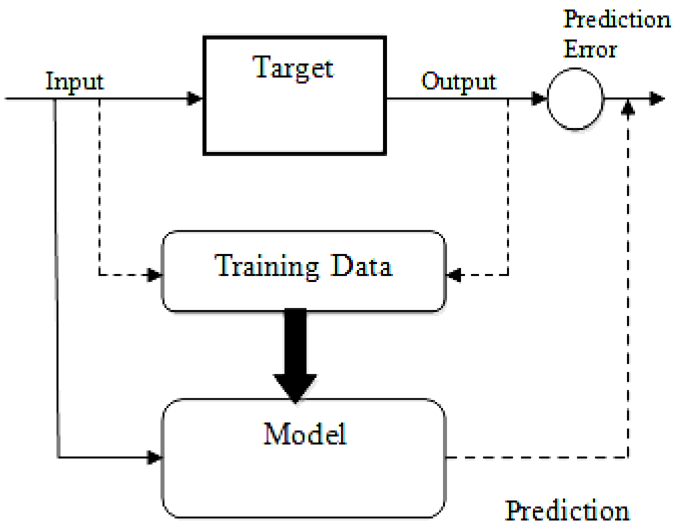

Fig.4.2 Flow chart of the Prediction Model

. Here the prediction is depends on the model we used in Fig. 4.2. The algorithm used for linear predictor is as follows:

1. Start
2. Read the database (financial time series for the three stock indices)
3. Perform preprocessing to remove not a number.
4. Set estimated data equal to the original data.
5. Set prediction order, p.
6. Find the coefficients using p
7. Set the number of values to be predicted.
8. Find the each predicted value by multiplying each coefficient with the estimated data.
9. Update the estimated value with the value obtained in previous step.
10. Update the coefficients using estimated data.
11. Find the prediction error
12. Stop

IV. RESULTS AND DISCUSSION

Experiments were conducted on three stock indices, namely Japan Nikkei 225, US Dow Jones Industrial Average and Turkish BIST 100 and are done on MATLAB platform.

4.1 Simulation of BIST 100 index

From the database, we detected 5 UUs for approximately 5000 days. Since, in order to foresee 100 days ahead $\lambda\tau$ = 0.1. The probability that there will be an UU within this period can be computed from (3.1) by setting k = 1 which is 9%. The probability of having more than one UU is found to be too low (0.5%).

4.2 Simulation of DJIA index

For DJIA we detected 3 UUs for approximately 8000 days, therefore $\lambda\tau$ = 0:0375. The probability that there will be an UU within this period can be computed from 3.1 by setting k = 1 as 3.6%. Probability of having more than one UU is now 0.07%.

4.3 Simulation of Nikkei 225 index

For Nikkei 225 only 1 UU is observed for approximately 8000 days, therefore $\lambda\tau$ = 0.0125. The probability that there will be an UU within this period can be computed from 3.1 by setting k = 1 as 1.2%. Probability of having more than one UU now becomes 0.008%.

4.4 Simulation of AR(1) model

An AR(1) process typically has the following possible trajectories as depicted in Fig. 4.1. With the incentive to express the change in the prices of stocks, the starting value of simulated index is taken to be 100. This period can be extended or shortened as preferred. Simulation is done via Mat Lab.

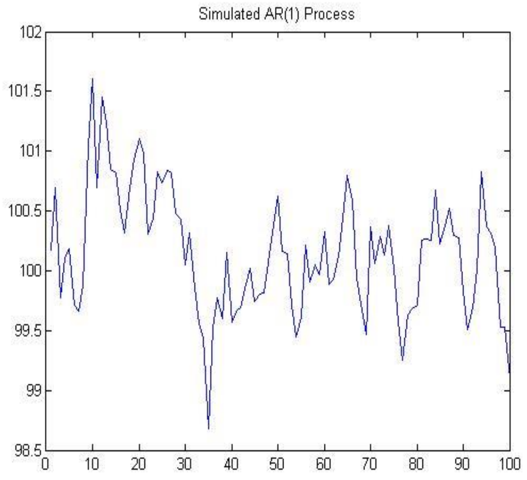

Fig.4.1 Possible Trajectory of an AR(1) Process

4.5 Simulation of Linear Predictor

Prediction of NIKKEI 225 using LPC is shown in Fig.4.5. Thus it is clear that linear prediction can be used for the prediction of financial time series data.

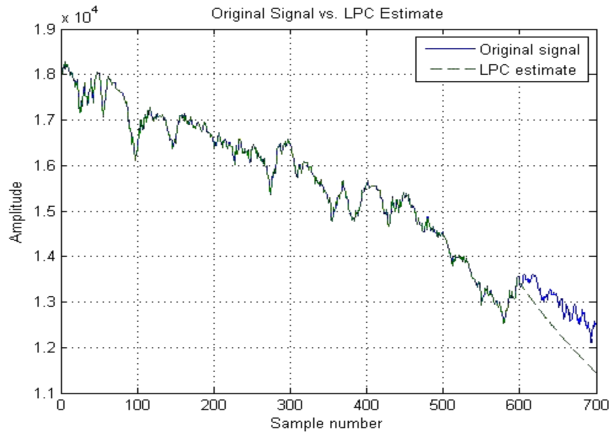

Fig.4.2 Output of Linear Predictor

4.5 Simulation Moving Average Filter

Now we have to compare the results of linear predictor with moving average filter. The algorithm used for moving average filter is same as linear predictor except that the estimated value is obtained by averaging the each predicted value. In moving average filter prediction the coefficients is set to one. It can be changed so that we have to design weighted moving average filter. Results of linear predictor and moving average filter are shown Fig. 4.3. Hence it is clear that accuracy of linear predictor is more when compared to moving average filter.

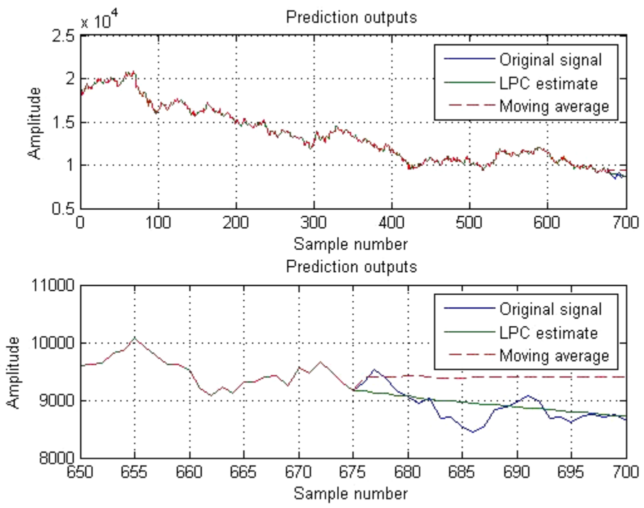

Fig.4.3 Comparison of LPC with Moving Average Filter

For the analysis and comparison, we designed a Mat lab application which shows the financial time series prediction and also the probability of UU in the predicted interval. GUI for financial time series data prediction is shown in Fig. 4.4.

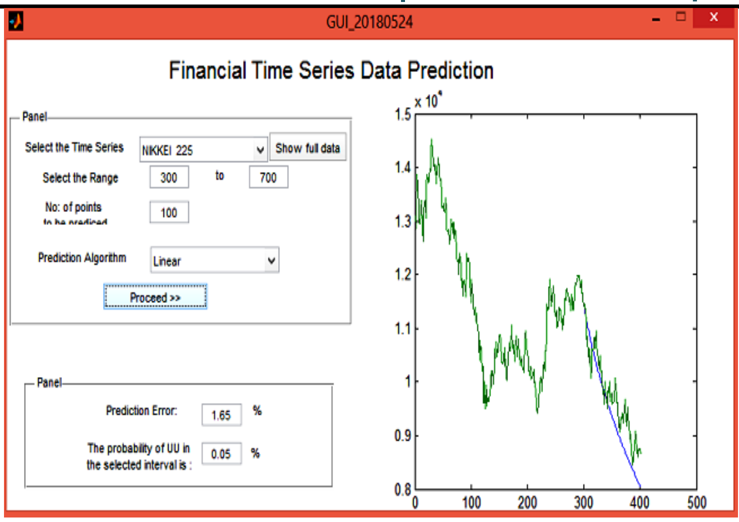

Fig.4.4 GUI for the Analysis of Financial Time Series

From the experimental results it is clear that prediction of financial time series data is possible with linear predictor only when there is no unpredictable unknown occurs. If we select the region with UUs, then the prediction is better with moving average filter and also prediction error is less compared to linear predictor.

Table 4.1: Comparative Study of NIKKEI 225 Index

Prediction Methods	Prediction Error without UUs(in percentage)	Prediction Error with UUs(in percentage)
Linear Predictor	1.17	7.29
Moving Average Filter	3.17	3.24

During the experiments all the predicted cases were taken for finding out the accuracy of the financial time series data prediction system. Table 4.1 shows that prediction error without UUs using moving average filter is 3.17% which is more than same using linear predictor which is 1.17%. Prediction error with UUs using linear predictor is 7.29% which is more than same using moving average filter which is 3.24%.

V. CONCLUSION

This paper offers with rare events that have severe harmful outcomes to financial stability. In order to model those UUs, a compound Poisson process is proposed in which the intensity is taken to be random and drawn from an exponential distribution with a totally low effective parameter. When this parameter receives in the direction of 0, in case of occurrence, its impact becomes the reciprocal of the aforementioned parameter. Right here the purpose is to strain the reality that every time the unknown event is more unpredictable its effect is expected to be a lot more potent. It is observed that every time the stock marketplace becomes more solid, the possibility of an UU considerably diminishes. If one of these rare event takes place, it's miles particularly probably that its effect can be very excessive. in view that, the viable impact is negatively correlated with rareness. So we concluded that prediction of financial time series data is possible only when there is no unpredictable unknown occurs.

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