Identification of five time periods on the Indonesian stock exchange index historical data since 1997 to 2016

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Abstract. We are investigating the behavioural changes of the Indonesian financial systems in the last 20 years. Changes in the financial system behaviour were indicated by differences in the statistical properties of the daily log return distribution in two adjacent time windows. To measure how likely two distributions are differ, the Kolmogorov-Smirnov (KS) Test was applied. We have found that we can divide our time series data into five segments, where the KS probability values between two adjacent segments are maximum. This finding can be used to study the effect on the financial system imposed by, for example, the socio-economy and political policy by the government, by studying the changes in such factors in the identified time periods.

1. Introduction
In the field of financial economy, the stock market can be regarded as a complex system. The fluctuations of the stock price index are unpredictable and deemed to be dependent on a large number of different variables. They could be the qualitative ones such as social and political situations, from local to global, and the quantitative ones such as changes in currency rates and changes in the interest rates. Because of their complex nature, it is believed that the tools and methods in statistical physics can be very useful to describe and analyze the behavior of stock price fluctuation [1-5].

Efforts in using statistical physics to study the fluctuation in the Indonesian stock price (IHSG) was rarely conducted. One notable work was the investigation of the changes in IHSG fluctuations before and after the historical monetary crisis of 1997 [6,7]. As the findings from those studies, the IHSG index price fluctuations shows different statistical properties before and after the crisis. The differences in statistical properties, are further used to identify a principal change in the structure of Indonesia financial system, which in this case, was caused by the crisis.

Based on this study, we can draw as a general conclusion, that a change in the financial structure happen at certain time point, will separate two time-series where the stock price distribution from those different time regions possess different statistical properties. In some cases, the cause of such major change in apparent, like a global monetary crisis. But in other cases, identifying the factor that drives a major financial transformation is not straightforward. In principal, given a time-series data, we can perform a statistical procedure that will separate the data into two time-regions, such that the statistical properties of the data from each region are different. Therefore, when applied to a time series stock price data, we don’t necessary need the knowledge of external conditions, to find a change in the financial structure.
In this work, we are analyzing the IHSG stock price data from July 1997 to May 2016. In particular, we are looking at the distribution of the price return index, defined as:

\[ z_{\Delta t} (t) = \ln[Y(t + \Delta t)] - \ln[Y(t)] \]  

(1)

where \( Y \) is the index price value, and \( \Delta t \) is the time-step which was set to be 1 day. Many empirical studies show that the distribution of the price return index behave like a heavy tailed bell-shaped curve [8-10], and that it can be fitted to a Levy-stable distribution [6,7], this was first proposed by Mandelbrot [5]. Nevertheless, other types of distributions have also been used to describe the price return index, including the Gaussian function [6,7,11]. As a nice bookkeeping of different fitting approach to the price return index, as well as an effort to provide a standard, one can refer to Ref. [11].

Our goal was to determine whether there are separate time-regions where the statistical properties of the daily price return index distributions in each time-regions are different with each other, and if there are, we hope to locate where the time-points that separate those regions. The method to achieve this is purely statistical, without any assumption based on external situations. The results then can be related to any major events around the separating time-points.

2. Methods

The only statistical tool deployed in this work is the Kolmogorov-Smirnov (KS) test that would give the likelihood that two samples are drawn from the same continuous distribution [13]. In our first step, we formed two regions separated at a certain point in time, where we calculate the KS-test probability value between the daily price return index at the two regions. We move the separating point to the right, until the KS probability value is below a certain threshold. We held the left side time region to be fixed, and create new region splitting on the right side time region.

The first step of our procedure produces five time-regions (four separating points). In the second step, each of the four separating points are moved randomly, in both direction (left and right), in a certain time window. If the new sum of the KS probability values is less than the previous one, then new set of separating points is obtained. This procedure is iterated through until the sum of KS probability values does not get smaller.
In the final step, we perform a finer search for the separating points, where we scan through every position in time, around the previous separating points. This step is the most exhaustive ones since we are looking at about 100^4 possibilities. Once the whole procedures were performed, we obtained in total of five separated time periods. Location of the changing points are shown in Figure 1. Values of the Kolmogorov-Smirnov probability between different time periods are shown in Table 1.

Table 1. Kolmogorov-Smirnov Test probability values between distributions of the daily return index from two different time periods.

| time segment | i   | ii  | iii | iv  | v   |
|--------------|-----|-----|-----|-----|-----|
| i            | 1   | 6.63 x 10^{-7} | 8.80 x 10^{-14} | 3.95 x 10^{-4} | 6.22 x 10^{-15} |
| ii           | 6.63 x 10^{-7} | 1   | 3.81 x 10^{-8} | 1.08 x 10^{-4} | 5.64 x 10^{-7} |
| iii          | 8.80 x 10^{-14} | 3.81 x 10^{-8} | 1   | 2.50 x 10^{-6} | 1.64 x 10^{-3} |
| iv           | 3.95 x 10^{-44} | 1.08 x 10^{-01} | 2.50 x 10^{-06} | 1   | 6.90 x 10^{-07} |
| v            | 6.22 x 10^{-15} | 5.64 x 10^{-07} | 1.64 x 10^{-03} | 6.90 x 10^{-07} | 1 |

3. Result and Discussion

3.1. Fitting of the Distributions
To verify whether there are differences in the statistical properties of the price return index distributions from the five time periods, we fit the distributions to Levy-stable function, which has four parameters $\alpha$, $\beta$, $\gamma$, and $\delta$. The fitting is completed based on the Maximum-likelihood fitting of univariate distributions. $\alpha$ and $\beta$ are shape parameters, where they respectively govern the spread and symmetry of the distribution. A Gaussian distribution is a special case of the stable
distribution, with values $\alpha=2$ and $\beta=0$. While $\gamma$ and $\delta$ determine the scale and position of the distribution.

**Table 2.** Levy-stable fit parameter values of the daily return distribution from five time-periods.

| time segment | $\alpha$ | $\Delta \alpha$ | $\beta$ | $\Delta \beta$ | $\gamma$ | $\Delta \gamma$ | $\delta$ | $\Delta \delta$ |
|--------------|----------|-----------------|--------|----------------|--------|-----------------|--------|----------------|
| i            | 1.54     | 0.11            | 0.06   | 0.16           | 0.0155 | 0.0011          | -0.0041| 0.0015         |
| ii           | 1.63     | 0.05            | 0.18   | 0.10           | 0.0095 | 0.0003          | -0.0004| 0.0004         |
| iii          | 1.76     | 0.05            | -0.20  | 0.16           | 0.0073 | 0.0002          | 0.0022 | 0.0004         |
| iv           | 1.57     | 0.06            | -0.25  | 0.13           | 0.0108 | 0.0005          | 0.0015 | 0.0008         |
| v            | 1.62     | 0.04            | -0.33  | 0.08           | 0.0061 | 0.0002          | 0.0015 | 0.0002         |

The fit parameters of the distributions from all time segments are presented in Table 2. The fitting function plotted against the histogram of the distribution is shown in Figure 2. We noted that the parameter $\delta$ from all time segment does not depart very much from zero. On the other hand, variation of the $\gamma$ parameter can be removed by normalization. Therefore, we will be using only the shape parameters $\alpha$ and $\beta$ in characterizing the statistical properties of the index return distribution from each time segment.

![Figure 2](image)

**Figure 2.** Distribution of the daily index return from five time-periods (dotted) and their fitting function (line).

Since $\alpha$ governs the spread of the distribution, it can be related to the variance of the distributions. This number then will give us how far a closing index price in a certain day, can fluctuate from the previous day. In financial economy, such variable is closely related to the volatility of the market. Whereas for $\beta$, it controls the trend of the index price changes, either up, flat or down. The $\beta$ value that is far from zero, means that the index price has an increasing trend, if it is negative, and a decreasing trend, if it is positive.

### 3.2. Variance and Skewness of the Distributions

To further examine the statistical properties of the price return distribution from each time segment, we calculated the variance and skewness of the fitted distribution function. Ideally, a Levy-stable function possesses an infinite variance. A more useful finite variance is obtained by performing a cut on the range of the return variable. Here we put the cut at $z=\pm0.2$ for every time segment. The variances are plotted against the $\alpha$ value (Fig. 3), while the skewness is plotted against $\beta$ (Fig. 4). We found that the variance is related inversely and non-linearly to $\alpha$, while skewness is simply proportional to $\beta$. 
Table 3. Variance and Skewness of the Levy-stable fit function of five time periods.

| time segment | Var    | skewness |
|--------------|--------|----------|
| i            | 0.002776 | 0.78     |
| ii           | 0.000896 | 3.23     |
| iii          | 0.000321 | -4.32    |
| iv           | 0.001422 | -4.02    |
| v            | 0.000462 | -8.50    |

From the relation between the shape parameters with variance and skewness (Table 3), we can make sense the behavior of the daily index price evolution from the $\alpha$ and $\beta$ values. In time segment (i), $\alpha$ is small and $\beta$ is small, this manifested in a rather stationary evolution of the index price by day. In time segment (ii), $\alpha$ is large and $\beta$ is not too small. A positive $\beta$ value that is rather far from zero would be translated to a decreasing trend of the index price, but a large $\alpha$ allowed the fluctuation to take a large step opposite to the suggested trend, thus produces a quite constant behavior of the index price. In time segment (iii) and (v), $\alpha$ are rather small while $\beta$ are largely negatives. This condition manifest in a positive trend of the index price without too much disruption. And last, time segment (iv), both it’s $\alpha$ and $\beta$ are large, almost like in segment (i), but with much greater $\beta$. We notice that overall the index price in this time segment shows a positive trend, in agreement with the large $\beta$. But it undergoes a big jump in the process, as anticipated by the large $\alpha$.

Figure 3. Variance vs $\alpha$ (a) and skewness vs $\beta$ (b) of the Levy-stable fit function of five time periods.

4. Conclusion
In this study, we have identified five time-periods in Indonesia that systematically have different behavior in terms of stock market system. The differences are discovered by finding the minimum value of Kolmogorov-Smirnov Test probability between the distributions of daily return index from adjacent time segment. Furthermore, we have characterized the statistical properties of the index return distribution with two shape parameters of the Levy-stable distribution, $\alpha$ and $\beta$. Variation of $\alpha$ and $\beta$ from all time segment can then be used to explain the different behavior of index price fluctuation, of each time segment.

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