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ROBUSTIFICATION OF SHEWHART CONTROL CHART BY MEDIAN BASED ESTIMATORS: A STUDY ON MALAYSIA STOCK DATA

(Peneguhan Carta Kawalan Shewhart Menggunakan Penganggar Berasaskan Median: Sebuah Kajian Berpandukan Pasaran Saham Malaysia)

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ABSTRACT

Statistical control chart is vastly used in financial field, especially in assessing changes in stock returns. Control charts are becoming an important consitituent of the decision-making process in stock trading. However, in the presence of non-normality, the classical control charts may produce too many false trade signals and therefore, may no longer be reliable in stock trading. This study aims to construct robust control chart using median based estimators and subsequently, used it on real financial data. Median and trimean estimators were applied in the construction of the limits for the Shewhart chart as well as in computing the charting statistics. The practical application of the proposed robust charts were demonstrated using a real data set about Top Glove stock's open price. In analyzing the capabilities of the robust Shehwhart charts for stock trading against the classical Shewhart chart, the findings show that the classical chart yields too many trade signals which most are considered as false alarms unlike the robust charts. This paper shows that the robustification of the Shewhart structure via the median based estimators help to alleviate the impact of non-normality on the chart's performance.

Keywords: investments; robust estimators; Shewhart control chart; statistical process control

ABSTRAK

Carta kawalan berstatistik selalu digunakan dalam bidang kewangan terutama dalam menilai perubahan pulangan saham. Instrument kualiti ini menjadi komponen penting dalam proses membuat keputusan perdagangan saham Oleh itu, instrument kualiti ini popular digunakan bagi membantu membuat keputusan perdagangan saham. Walau bagaimanapun, sekiranya data tidak normal, carta kawalan berstatistik yang klasik mungkin menghasilkan terlalu banyak isyarat perdagangan palsu dan oleh itu, tidak lagi boleh dipercayai dalam perdagangan saham. Kajian ini bertujuan untuk membina carta kawalan teguh menggunakan penganggar berasaskan median dan seterusnya, mengaplikasikan pada data kewangan sebenar. Dalam kajian ini, penganggar median dan trimean digunakan untuk membangun had kawalan carta Shewhart dan juga bagi mengira plot statistik. Aplikasi carta kawalan teguh yang dicadangkan dalam kajian ditunjuk menggunakan data sebenar mengenai harga terbuka saham Top Glove. Dalam menganalisis kemampuan carta teguh Shehwhart untuk perdagangan saham berbanding carta klasik Shewhart, penemuan menunjukkan bahawa carta klasik menghasilkan terlalu banyak isyarat perdagangan yang kebanyakannya dianggap sebagai palsu. Kajian ini ini menunjukkan bahawa peneguhan carta kawalan Shewhart melalui penganggar berdasarkan median membantu mengurang kesan ketidaknormalan terhadap prestasi carta.

Kata kunci: pelaburan; penganggar teguh; carta kawalan Shewhart; kawalan proses berstatistik

1. Introduction

Pioneered by Walter A. Shewhart in 1931, control chart is among the popularly used quality tools (Montgomery 2013). Initially used in the manufacturing process to reduce variation and hence, improving process quality, control chart aims to differentiate between two types of process variations. They are; common cause variation and special cause variation. Briefly, common cause of variation always exists in a process and in this state, the process is said to be in-control. On the contrary, special cause variation is harmful to the process and thus, shall be addressed quickly as it leads to out-of-control process. Notably, changes in the process from an in-control state to an out-of-control state can easily be detected using control chart.

The process is considered to be in-control as long as the chart statistic is plotted within the limits of the charts. On the other hand, if one or more chart statistics falls beyond the limits, the process is said to be out-of-control (Montgomery 2013). A signal is given then by the chart, suggesting a presence of special cause. In this case, the process has to be stopped and corrective actions may be undertaken to bring the proces back into an in-control state. However, upon signaling an out-of-control situation and no special causes are found in the process, it simply means false alarm.

In real practice, the user of control charts does not have insight as to whether or not the signal is false alarm or true signals of an out-of-control condition. Nonetheless, the use of the 3-sigma control limits for the Shewhart chart, for instance, provides a reasonable quality tool that is able to balance the tradeoff between infrequent false alarms and a high probability of detecting a true out-of-control condition. The effectiveness of the Shewhart chart, however, relies on the normality assumption (Amin & Reynolds 1995). While this assumption is hardly attainable in real life (see for examples, Bono *et al.* 2017), application of the classical Shewhart chart, which is based on the sample mean, is still favorable in many areas of SPC.

Kovarik and Sarga (2014), for instance, used Shewhart control charts to observe changes in the stock data. Specifically, both changes in the mean and variability in terms of the discrepancies between an asset return and market return were determined via the application of the Shewhart charts and the outputs were deemed easier to comprehend than using the risk metric. Meanwhile, Golosnoy *et al*. (2010) and Schipper and Schmid (2001) applied exponentially weighted moving average (EWMA) and cumulative sum (CUSUM) type charts to detect substantial changes in stock returns series based on historical data. Dumičić and Žmuk (2015), however, emphasized that stock price data are non-normallly distributed based on the analysis performed on the Crotia's stock trading. The findings in their study led to the conclusion that the cotrol charts based on the sample mean may produce too many false signal which can be misleading in terms of buying, holding, or selling stocks. Nonetheless, if the non-normality issue can be resolved, the use of statistical control charts in financial areas would be highly valuable as pointed out by the authors.

As with many other sectors, financial markets have been greatly impacted by the COVID-19 pandemic (Yusof 2021). Meanwhile, Baker *et al.* (2020) emphasized that no prior outbreak of deadly illnesses, including the Spanish flu, had influenced the global stock market as much as the COVID-19 pandemic. Fernandes (2020), in his study, mentioned that most stock markets crashed and recorded the largest one-day fall on 22 March 2020 due to the effect of the COVID-19 pandemic. Genting Malaysia Berhad and Air Asia Group Berhad stocks were both top losers in large market capitalization and middle market capitalization, respectively, as they were affected by lockdown and interstate travel restrictions due to COVID-19 pandemic (Wong 2020).

Notably, for the first time in history, the benchmarking price of crude oil by the United States had been reduced tremendously on April 2020 due to the structural decline in the fossil fuels market (Ambrose 2020) . Hence, Petronas Dagangan Berhad and Tenaga Nasional Berhad stocks faced a surge due to slow down of power consumption and shutdowns (Zeren & Hizarci 2020). Stock market traders switched to trading gold during the pandemic (Zeren & Hizarci 2020). Noteworthily, the spike in the number of COVID-19 cases has had a positive impact on healthcare sector. TopGlove, Careplus and Supermax stocks from the healthcare equipment and services became top gainers in 2020. The accelerated demand for disposable rubber or nitrile gloves needed for the COVID-19 tests, diagnosis and treatments caused a positive impact to this glove manufacturing industries (Wong 2020). Notably, under these uncertainties, the decision about trading on the stock market, specifically in Malaysia, shall be pondered upon.

This study investigates the effectiveness of a statistical control chart namely the Shewhart chart, in making decisions about trading on the Malaysia stock market during COVID-19 pandemic. To accomplish that, the average prices of stocks from Bursa Malaysia were observed. Taking into account that the underlying distribution of financial data are typically non-normally distributed (the fact that soon be proven in this study), median based estimators were used as the location estimators in place of the mean estimator when constructing the Shewhart control chart.

2. Literature Review

2.1. *Works on robust control charts in SPC*

Application of control charts on real data usually defies the assumption of normality. On that account, many researchers proposed to use rob ust statistics in the design structure to mitigate the effect of outliers which is the common cause of non-normality. Robust estimator is less perturbed by outliers, that is, more robust as opposed to the classical estimators, due to its higher breakdown point (*BP*). The *BP* measures the tolerance of an estimator to data contamination caused by outliers (Rousseeuw & Hubert 2011). For instance, in comparing between the mean and the median, both have 0% and 50% of *BP*, respectively (Hodges 1967). Therefore, the median is more robust than the mean. As such, using median-based estimators would be more efficient since not every data value is taken into the calculation; therefore, the calculation is not easily affected by outliers. Despite the strengths of robust estimators', work done related to robust control charts in terms of real data application is somewhat limited.

In a robust work by Abu-Shawiesh and Abdullah (1999), the researchers constructed a Shewhart chart based on Hodges Lehman (*HL*) which is a robust location estimator. This estimator was used in computing the plotting statistic as well as in constructing the 3-sigma limits of the Shewhart chart whereby it was paired with a robust scale estimator, that is, the Shamos-Bickel-Lehmann (*SBL*). Notably, this newly constructed robust chart performs well under non-normality as shown via a simulation study. Likewise, Abdul Rahman *et al.* (2018a) conducted a simulation study in assessing the performance of a newly constructed control chart in quality control. Specifically, a CUSUM chart was employed whereby the process parameters were estimated using median based estimators. The location parameter was computed based on the median and also *HL* where both were then paired with the median absolute deviation about the median (*MADn*) in estimating the dispersion parameter. To mitigate the effect of false signals caused by outliers in the subgroups, the authors chose to replace the sample mean with the aforementioned robust location estimators. While demonstrating a mediocre power to detect the out-of-control situations, the in-control performances of both charts remain unaffected in the presence of outliers.

Comparison via a simulation study on the effect of robust location estimators on the performance of robust estimators in the EWMA control chart by Zwetsloot *et al.* (2016) attested to usefulness of employing robust estimators instead of the classical estimators in quality control. While median-based estimators such as median and trimean made the statistical control chart robusts against dire contamination, their useful failed to be discussed in terms of real data application. Similarly, a more recent study by Abdul Rahman *et al.* (2018b) via a newly constructed EMWA chart based on modified one-step *M*-estimator (*MOM*) merely focused on the simulation performance. It is worth to note that the integration of *MOM*, which is a median based estimator with highest *BP*, into the EMWA structure led to reliable and improved performance of the SPC chart under extremely skewed and heavy-tailed distributions.

The general consensus among researchers in quality control field is that the integration of robust estimators in control charts may substantially lessen false signals under in-control state. This has been proven by Abdul Rahman *et al*. (2018a; 2018b), Zwetsloot *et al*. (2016), and Abu-Shawiesh and Abdullah (1999) in their simulation studies. With in-control robustness deemed to be the main key in designing and implementing a control chart, as without it, the capability of the chart in detecting actual shifts will be rendered useless (Human *et al.* 2011), robust control charts can be used confidently to detect changes in real data.

2.2. *Control charts in stock market trading*

Roberts (1959) was one of the primary researches who suggested the use of statistical process control tools to study the market price levels and changes. Hubbard (1967) studied post-war stock prices using Moody's Composite 200 Stock Average from the year 1950 to 1967. Hubbard utilized logarithmic monthly values in constructing the control charts to identify the price trends and later compared it with gross national product and personal income trends. Most importantly, he discovered indicators to look for when buying or holding stocks. Small price discrepancies edging above and below the centre line, according to Hubbard (1967), have no discernible pattern, and hence contain no relevant information for assisting an investor in deciding whether to purchase or sell stocks. On the other hand, significant deviations from the centre line indicates stock price overvaluation or undervaluation. Žmuk (2016) applied three types of residual-based control charts namely I-chart, EWMA and CUSUM. The empirical application was designed to improve the decision making process in short-and long-run stock trading using CROBEX10 index stocks on the Zagreb Stock Exchange.

3. Methodology

In this study, a secondary data set was obtained in illustrating the performance of the Shewhart control charts in finance.

3.1. *Real data collection*

Based on the website named The Edge Markets, five top gainers and five top losers on Bursa Malaysia 2020 were identified (Wong 2020). Bursa Malaysia is the lead regulator of Malaysia's capital markets to ensure a fair and organized market for securities and derivatives traded through its infrastructure. The stocks were identified from three different market capitalization values namely Large-cap, Mid-cap and Small-cap. Table 1 lists the stocks along with their relevant codes. Large-cap companies usually have a market valuation of $10 billion or more. Mid-cap companies commonly have a market valuation in the range of $2 billion to $10 billion. Companies classified as small-cap have a market capitalization worth of between $300 million to $2 billion. The stock codes enable identification of the stock in terms of a quotation scheme. Market capitalization defines a company's worth by referring to its composite market value of its outstanding shares.

The daily historic open prices of the stocks for a duration of 74 weeks from the 6th of Jan until the 6th of June 2021 were then obtained from Yahoo Finance. Yahoo Finance quotes historical data regarding stock trading on its website which are accessible to all. Data available for each stock are trading date, open price, highest price, lowest price, close price, average price, and volume of stock traded on each trading date. However, investors were mostly only interested in two variables which are the open price and the average price (Dumičić & Žmuk 2015). Open prices are the prices at which securities trade for the first time on a trading day when an exchange opens. In this study, open price was chosen as this variable is important as investors usually use it as a benchmark or reference point in evaluating performance over a set period of time. As such, open prices of stocks may aid in confirming trading ideas or eliminate biases.

Table 1: The name, sector, code and capitalization value of stocks chosen.

Company Name	Top Gainer / Loser	Sector	Code	Capitalization Value
Top Glove Corporation Berhad	Gainer	Healthcare Equipment & Services	TOPGLOV(7113)	Large-cap
Careplus Group Berhad	Gainer	Healthcare Equipment & Services	CAREPLS(0163)	Mid-cap
Telekom Malaysia Berhad	Gainer	Telecommunications	TM(4863)	Large-cap
Supermax Corporation Berhad	Gainer	Healthcare Equipment & Services	SUPERMX(7106)	Large-cap
Mr DIY Group	Gainer	Semiconductor	UNISEM(5005)	Mid-cap
Genting Malaysia Berhad	Loser	Leisure, Hospitality & Properties	GENM(4715)	Large-cap
Air Asia Group Berhad	Loser	Travel, Leisure & Hospitality	AIRASIA(5099)	Mid-cap
Pos Malaysia Berhad	Loser	Transportation & Logistics Service	POS(4634)	Small-cap
Tenaga Nasional Berhad	Loser	Electric Utility	TENAGA(5347)	Large-cap
Petronas Dagangan Berhad	Loser	Petroleum, Gas & Multiutilities	PETDAG(5681)	Large-cap

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3.2. *Robust location estimators*

In this study, two median based estimators were employed in monitoring changes in the mean of the stock data via the Shewhart control chart. The estimators are median and trimean which are explained below.

3.2.1. *Median*

Median (*MED*) is basically the middle value of the data set. The median formula is as follows:

$$MED = (\frac{n+1}{2})^{th} \; item. \tag{1}$$

where n is the number of observations (i.e., sample size) when the data set is odd. Meanwhile, for the even data set is given by

$$MED = \frac{(\frac{n}{2})^{th} \; item + (\frac{n}{2}+1)^{th} \; item}{2}. \tag{2}$$

With 50% breakdown point, median attains the highest possible breakdown point for location and thus, is highly unperturbed by outliers (Rousseeuw & Croux 1999).

3.2.2. *Trimean*

Trimean (*TM*) measures central tendency and is basically the mean weighted average of the median and the two quartiles of a set of values. The *BP for* trimean is 0.25 where the estimator can be computed as (Tukey 1977):

$$TM = \frac{(Q_1 + 2Q_2 + Q_3)}{4} \tag{3}$$

where *Q1* and *Q3* are the lower and upper quartiles, respectively. Meanwhile, *Q2* is the median.

The monitoring of location as based on the aforementioned estimators with Shewhart chart yields two robust charts, namely, Shewhart *MED* chart and Shewhart *TM* chart. In the remainder of this paper, each of the charts will be referred to by its respective location estimator. The next section discusses the Shewhart control structure.

3.3. *Robust Shewhart control charts*

Notably, in applying the proposed Shewhart control charts on TopGlove stock data, control limits for each chart had to be estimated in Phase I. The estimated control limits were then used in Phase II for monitoring changes in the open stock prices. Mathematically, the Shewhart control chart consists of plotting some measurement of quality characteristic denoted by θ_t against the the upper control limit (UCL) and lower control limit (LCL) defined as follows:

$$UCL_t = \mu_0 + 3\frac{\sigma}{\sqrt{n}}. \tag{4}$$

$$LCL_t = \mu_0 - 3\frac{\sigma}{\sqrt{n}}. \tag{5}$$

where μ_0 and σ are the location and dispersion parameters of the process, respectively. In real practice, the parameters are usually unknown and thus, be estimated in Phase I. Typically, the mean of the sample means ($\overline{\overline{X}}$) is used as the location estimator and the mean of the sample standard deviation ($\overline{S}$) is used as the dispersion parameter. If we let X_{it} , with $i = 1, \ldots, n$ and $t = 1, \ldots, m$ denote the Phase I observations, then

$$\overline{\overline{X}} = \frac{1}{k}\sum_{t=1}^{k} \overline{X}_t. \tag{6}$$

$$\sigma_1 = \frac{\overline{S}}{c_4(n)}. \tag{7}$$

where

$$\overline{S} = \frac{\Sigma_{t=1}^{k} S_t}{k}. \quad (8)$$

It should be noted that the constants c_4 depends only on the sample size *n* and are tabulated for normal distribution in various statistical textbooks. See for example, Montgomery (2013, pp. 702).

Notably, the aforementioned classical estimators, i.e. $\overline{\overline{X}}$ and $\overline{S}$, are easily perturbed by outliers. Hence, in this paper, the two robust estimators discussed in Section 3.2 were also considered in obtaining μ. Meanwhile, for fair comparison on the effect of location estimator on the performance of the Shewhart chart, σ_0 is assumed to be known. However, considering the intractability of the sampling distribution of the chosen robust estimators, the standard error for the robust estimators was simulated in this study. The value was determined based on 1×10^6 samples of size *n* from the normal distribution.

3.4. *Implementation procedure*

TOPGLOV(7113) was chosen to illustrate the application of the robust Shewhart chart control charts on real data. It should be noted that as the same procedure can be extended for the other nine stocks in this study via the same steps.

3.4.1. *Phase I procedure*

The sample size, *k* was decided to be thirty-seven (37) and the *n* was fixed at five (5). Phase I analysed data for 37 weeks from the 6th of January 2020 – 13th of September 2020. Daily open prices for stock TOPGLOV(7113) were listed on a weekly basis. For instance, 5 daily open prices for dates 6th of Jan 2020 – 13th of Sept 2020 were listed under Week 1. This was repeated for the other 36 samples for Phase I. The, μ was obtained based on the chosen robust estimators. Meanwhile, the mean estimator was included to provide a basis for comparison.

3.4.2. *Phase II procedure*

In Phase II, data was analyzed for 37 weeks from the 14th of September 2020 – 6th of June 2021. The open prices for the duration was used to calculate θ and subsequently, be plotted against the UCL and LCL of each respective chart.

4. Results and Discussion

Descriptive analysis, correlation and normality tests were done to compare and contrast the open prices of stocks to support the implementation of robust control charts.

4.1. *Descriptive analysis*

The descriptive analysis shows that all the stocks have 348 open prices that is adequate to represent the distribution of the data and fair unbiased comparison. PETDAG(5681) had the highest minimum and maximum open prices compared to the other stocks. CAREPLS(0163) had the lowest minimum open price compared to the other stocks which was at RM0.16. Table

3 reveals that SUPERMX(7106) had the highest standard deviation in comparison with the other 9 stocks.

Table 3: Descriptive analysis of ten selected Bursa Malaysia stocks

	N	Mininum	Maximum	Mean	Standard Deviation
TOPGLOV(7113)	348	1.53	9.59	5.44	2.42
CAREPLS(0163)	348	0.16	5.58	1.88	1.21
POS(4634)	348	0.53	1.58	.98	0.20
GENM(4715)	348	1.88	3.36	2.57	0.37
TM(4863)	348	3.10	6.75	4.69	0.96
AIRASIA(5099)	348	0.52	1.73	0.87	0.25
TENAGA(5347)	348	9.54	13.24	11.14	0.97
PETDAG(5681)	348	17.12	23.80	20.49	1.18
SUPERMX(7106)	348	0.64	11.81	5.12	3.19
UNISEM(5005)	348	1.55	9.18	4.52	2.48
Valid N (listwise)	348				

Therefore, the open prices of SUPERMX(7106) were more spread out from the mean. POS(4634) stock's standard deviation was the lowest which was at RM0.20. Low standard deviation implies that the open prices for stock POS(4634) were clustered around the mean open price. The higher the standard deviation, the higher the variability of the open price from its mean.

Meanwhile, Figure 1 shows 10 boxplots constructed with the open prices of stocks from 6th of January 2020 until 6th of June 2021. The box plots are simple yet powerful visual maps in outlier analysis. According to Figure 1, it is shown that stocks POS(4634), AIRASIA(5099) and PETDAG(5681) had outliers. In this case, an outlier comes to being when an open price of any stock deviates larger than three standard deviations from the average open price. The boxplot for SUPERMX(7106) stock was right-skewed. There were more data points on the left of the median than on the right. Hence, this means that there were more lower open prices than higher ones. POS(4634) stock's boxplot had the least spread whereas SUPERMX(7106) boxplot had the largest spread. This suggested that POS(4634) stock's overall open prices did not deviate far much from each other. However, SUPERMX(7106) had more variation in the overall open prices.

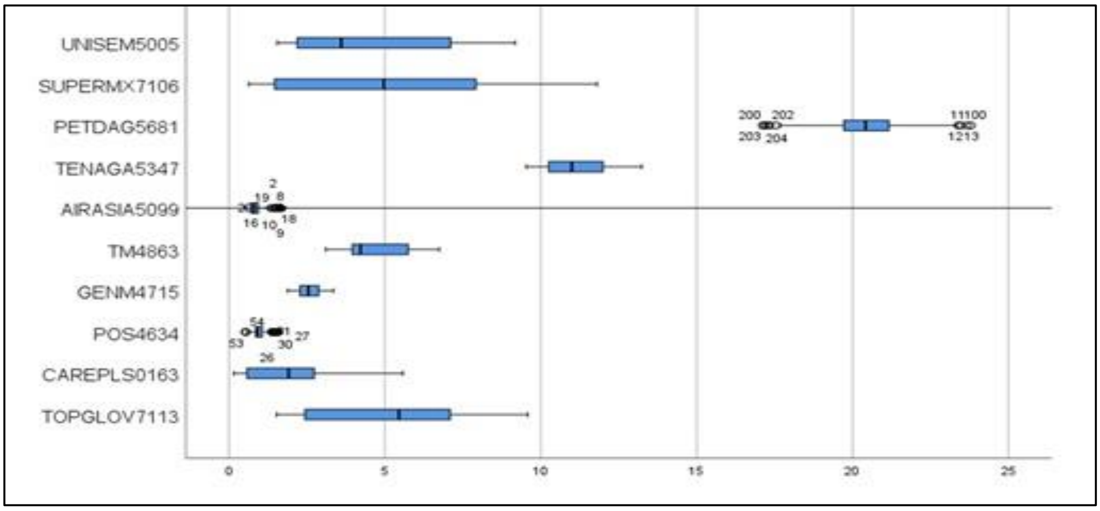

Figure 1: Boxplots of the selected stocks

4.2. *Correlation analysis*

According to Table 4, it is known that SUPERMAX(7106) and TOPGLOV(7113) had the most significant positive correlation, which is at 0.982. Thus, showing that, at a significance level of 5%, there is a strong linear relationship between the two stocks. Next, the stock pairs TOPGLOV(7113) and CAREPLS(0163), together with SUPERMAX(7106) and CAREPLS(0163), also have a statistically significant positive relation, which is at 0.944 and 0.941, respectively. The analysis also showed that stocks GENM(4715) and AIRASIA(5099) with UNISEM(5005) and TENAGA(5347) have a strong positive relationship whereby the correlation coefficients are at 0.845 and 0.829, respectively. The strength of the association between the two variables is represented by the absolute value of the correlation coefficient. The Pearson correlation coefficient between these stock pairs indicates that there had been a propensity that the stocks' prices vary in the same direction as one another. Therefore, if the price of one stock rises, the price of the other stock is likely to increase as well. Stocks TM(4863) and TENAGA(5347) had a correlation coefficient of 0.721, which indicated a strong negative correlation. Consequently, open price of TM(4863) inflates when the open price for TENAGA(5347) deflates, and vice versa. Likewise, at a particular time, it is advisable to invest in safe. In this study, the correlation analysis helped define a particular degree of risk to ensure that it is kept at a desirable rate.

Table 4: Pearson Correlation analysis of ten selected Bursa Malaysia stocks

	TOPGLOV7113	CARPLS0163	POS4634	GENM4715	TM4863	AIRASIA5099	TENAGA5347	PETDAG5681	SUPERMX7106	UNISEM5005
TOPGLOV7113	1	.944**	-.357**	-.406**	1.91**	-.634**	-.656**	-.429**	.982**	.334**
CARPLS0163	.944**	1	-.319**	-.382**	.217**	-.604**	-.686**	-.457**	.961**	.392**
POS4634	-.357**	-.319**	1	.587**	-.099	.726**	.463**	.653**	-.302**	-.151**
GNM4715	-.406**	-.382**	.587**	1	.438**	.845**	.121*	.406**	-.393**	-.342**
TM4863	.191**	.217**	-.099	.438**	1	.035	-.721**	-.346**	.183**	.941**
AIRASIA5099	-.634**	-.604**	.726**	.845**	.035	1	.494**	.613**	-.613**	-.069
TENAGA5347	-.656**	-.686**	.463**	.121*	-.721**	.494**	1	.705**	-.648**	-.829**
PETDAG5681	-.429**	-.457**	.653**	.406**	-.346**	.613**	.705**	1	-.402**	-.477**
SUPERMX7106	.982**	.961**	-.302**	-.393**	.183**	-.613**	-.648**	-.402**	1	.354**
UNISEM5005	.334**	.392**	-.151**	.342**	.941**	-.069**	-.829**	-.477**	.354**	1

4.3. *Normality test*

Q-Q plot is a graphical method of deciding if sample values are normally distributed. A straight line indicates a reasonably normal distribution. Whenever the bottom end of the Q-Q plot deviates from the straight line, but the upper end does not, the distribution is deemed to b e left-skewed. However, when the upper end of the Q-Q plot deviates from the straight line when the lower end does not, the distribution is right-skewed. According to Figure 2, all the Q-Q plots do not follow a straight line. Hence, this represents that the distributions of all the stocks' open prices were non-normaly distributed. The finding justifies the use of robust approaches in the implementation of the Shewhart chart as demonstrated next.

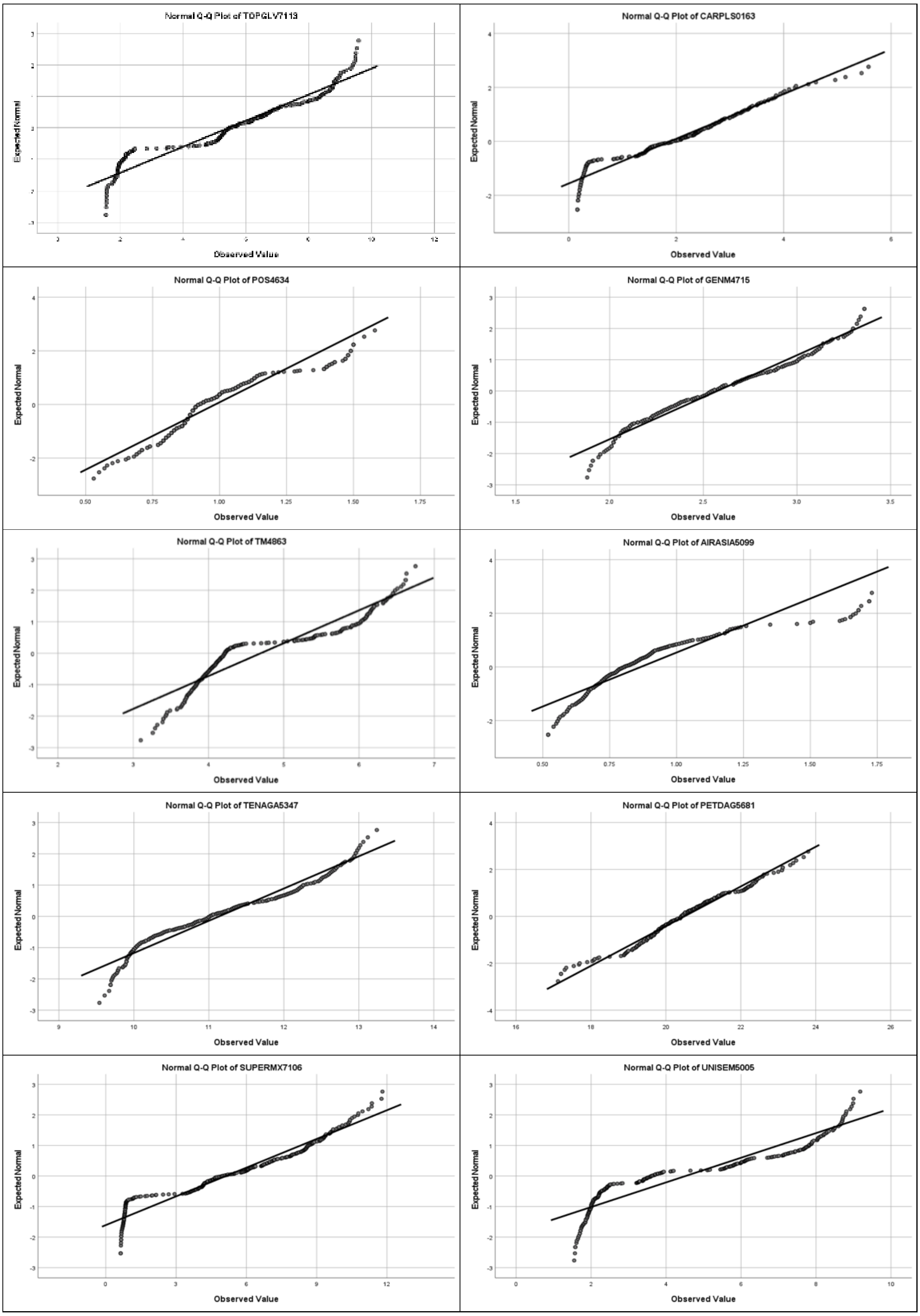

Figure 2: Q-Q plots of the ten selected stocks

4.4. *Implementation of robust Shewhart control charts*

Figure 3 shows the classical Shewhart $\overline{X}$ chart in modelling the open prices of TOPGLOV(7113) stock. The control chart signals from Week 1-16. The Shewhart $\overline{X}$ chart stays in-control from Week 24 until Week 31. The chart also signals an out-of-control point during Week 32.

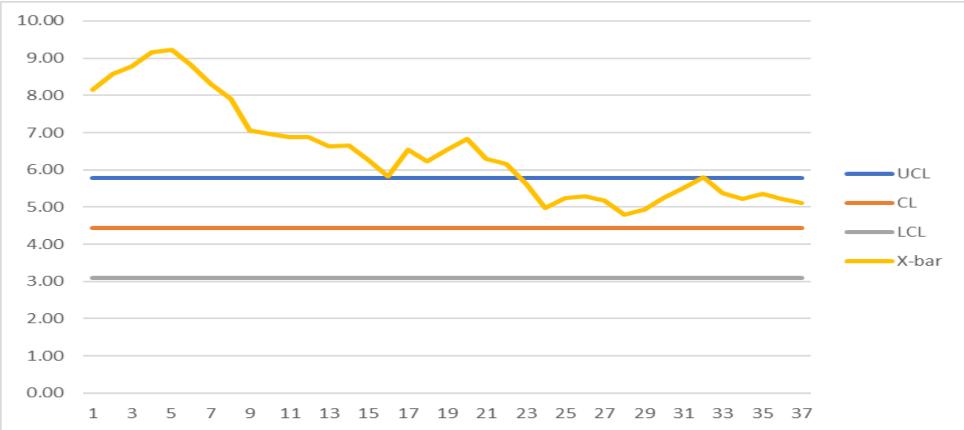

Figure 3: Shewhart $\overline{X}$ control chart

Figure 4 depicts the robust Shewhart control chart, which employed median as the location parameter. The control chart from Week 1-15 signals similarly to that of the Shewhart $\overline{X}$ control chart. Nonetheless, during Week 16, the chart did not signal as the robust trimean control chart. Likewise, contradictory to Week 32 in Shewhart $\overline{X}$ chart, the Shewhart *MED* chart does not signal. The points plotted for Week 23 to Week 37 are in-control as they are within the control limits.

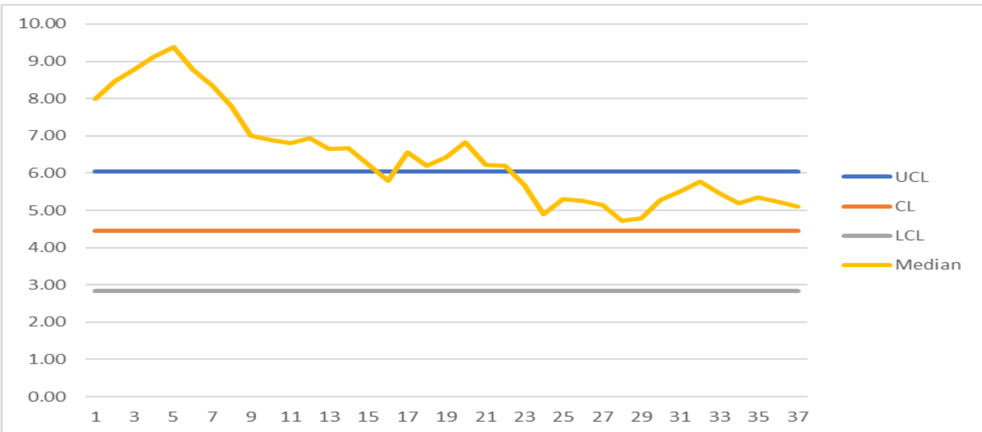

Figure 4: Shewhart median control chart

Figure 5 shows the Shewhart *TM* control chart. The chart shows out-of-control points from Week 1-15 similarly as the Shewhart $\overline{X}$ control chart. On the contrary, the chart does not signal during Week 16. Nonetheless, the open price plot for Week 32 was in control, and the chart failed signal. The plotted statistics for Week 23 to Week 37 are shown to be in-control as the points fall within the LCL and UCL.

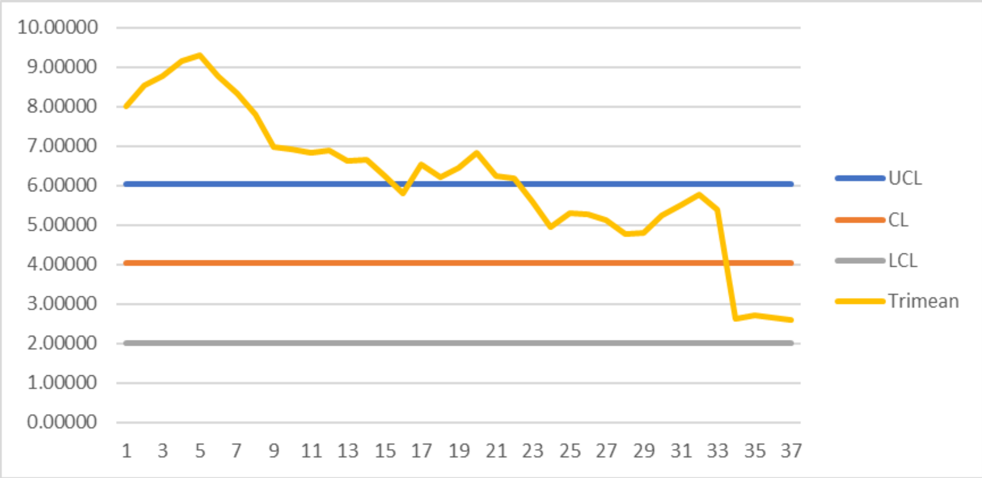

Figure 5: Shewhart trimean control chart

The downward trend in the control charts from Week 23 were due to the drop in average selling prices of nitrile gloves as much as 20% in the Top Glove's third financial quarter that ended on the 31st of May 2021. The decline in the selling prices was due to reduction in the sales volume to the United States and the reduction in the cost of raw materials used in the production of the gloves (Tan 2021).

Notably, there were slight surges in the control charts from the period of Week 24 to Week 25 and Week 27 to Week 32. Owing to the fact that the global glove prices increased in accordance with the resurgence of global COVID-19 cases in the first quarter of 2021 (Mahalingam 2021).

The slight decline in the control charts from Week 13 to Week 17 due to the unexpected event that the company's whistle-blower was sacked before a huge COVID-19 outbreak happened in its factories. According to the The Strait Times newspaper, the employee took pictures of the of his co-workers crowding and not adhering to standard operating procedures (SOPs) which resulted in Malaysia's largest cluster at that time having more than 5 000 infections in its factories and dormitories in Klang. The Malaysian government opened 19 investigations upon Top Glove companies to investigate the infringement of the Workers' Minimum Housing and Amenities Act.

Noteworthily, in Week 32, the two robustified charts showed IC unlike the Shewhart $\bar{X}$ chart. Hence, it is unlikely that the open price of TOPGlOV(7113) is actually out-of-control. Therefore, the Shewhart *TM* control chart and the Shewhart *MED* control chart are more reliable compared to the classical Shewhart control chart thus becoming a trustable supportive tool to gain trading signals.

These *MED* and *TM* control charts were proposed as their use is simple and straightforward for an ordinary investor. Furthermore, the proposed control charts might provide immediate alerts to an investor, which is crucial. Proposed robustifid control charts gives proper trading signals without pointing ot too may signals to buy or sell stocks. Since the charts use trimean and median as the pointing statistics and in the construction of control limits, the control charts will only signal when there are significant departures from the control limits. Hence, signalling overvaluation or undervaluation of stock price. No extra attention will be needed as long as the points fall within the limits unless there are points suddenly hurled outside of control limits.

5. Conclusion

Integration of robust location estimators in the design of Shewhart control charts captured the outliers in the decision-making process for trading the selected Bursa Malaysia stocks. When manufacturing processes result in contaminated data when for instance, there is a breakdown of machines, the financial market data might have contaminated data due to unexpected stock market surge or crash.

Besides, this, in a statistical context, means that the open price of the stocks varies more than three standard deviations from its mean at a particular time of the study. The open prices which deviate too far from the mean values will result in outliers, as depicted in Figure 1 of descriptive analysis. Outliers may have such an impact on traditional techniques that the resultant fitted model is unable to identify the deviating data. This is known as the masking effect. Furthermore, some excellent data points may seem to be outliers, a phenomenon is known as swamping (Rousseeuw & Hubert 2011). In order to prevent these effects, robust statistics aim to obtain a fit that is similar to that of the design structure if the outliers had not been present. The outliers may then be identified by their significant departure from the robust fit.

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