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# Modification of Earnings Quality Capability Measurement Indices by adding the Centralized Tendency Factor

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## Abstract

Previous studies on earnings quality from the perspective of estimation error only focused on the dispersion degree of estimation errors. Due to market investors' aversion to estimation error, centralized tendency factor is added in this study to modify the earnings quality capability indices by Chang et al. (2012) and correspond to investment risks resulted from earnings quality. With the 1988~2010 data from the U.S. Compustat financial database, this study measures estimation errors by the regression model (Francis et al., 2005), and in turn, applies modified earnings quality capability indices to help investors in assessment of investment risks.

**JEL classification numbers:** M40, M41
**Keywords:** Earnings quality, Estimation errors, Dispersion degree, Centralized tendency, Investment risk

## 1 Introduction

From the perspective of risk aversion, how to choose the best investment portfolio to achieve maximum return on investment, with minimum investment risk, is important to investors. Investors always depend on personal preference as criteria for investment judgment and final decisions. In this case, they usually make judgments based on financial statement information; therefore, they must consider how to effectively assess business performance and interpret hidden information conveyed through the complex information of financial statements in order to select the best portfolio. However, investor's confidence in financial statements was hit hard during the outbreaks of major

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accounting scandals of internationally renowned companies so that the earnings quality of financial statements was questioned and the confidence was seriously affected.

According to the Statements of the Financial Accounting Concepts Bulletin No.1, as issued by the U.S. Financial Accounting Standards Board, the accounting concept of assessing business performance is mainly based on earnings of the accrual basis, which is more conducive to evaluate an enterprise's current operating performance and future ability to generate cash flow, as compared with cash-based information. However, Dechow et al. (1996) argued that the earnings quality of financial statements will be lowered, as accrued earnings items involve strategic speculative behavior and increased use of assumptions and estimates for subjective judgment regarding future operating results. Hence, accrual-based earnings are more uncertain than the cash-based earnings to increase the potential risk of investors.

Thus, the cash inflow from operating activities for a company would be very low or even nil when its net profit is high; the difference between these two is mainly due to errors caused by the enterprise in adopting accrual-based assumptions and estimates. Dechow and Dichev (2002) took advantage of the impact of the estimation errors caused by the difference between working capital and accrual-based net profit on earnings quality, and used the regression model to make the change of working capital corresponding to the cash flows of operating activities from previous, current, and future period. In that model, residual term was treated as the estimation errors, and standard deviation of estimation errors for each company was regarded as the proxy variable of earnings quality (hereafter DD1); DD1 was measured estimation errors by regression model based on a pooled sample, industry group, or even individual firm level. Subsequent discussions in that paper were mainly focused on firm level. McNichols (2002) modified the DD1 model by adding the concept of estimated discretionary accruals, as proposed by Jone (1991). Namely, the current change in net sales and gross value of properties and plant facilities were added to the DD1 model and then estimation errors was measured by pooled regression method (hereafter DD2). To increase the number of samples, Francis et al. (2005) replaced the combined calculation of the explained variables of the DD2 model by gross calculation. In other words, change of working capital was replaced by total current accruals in pooled sample regression model, and estimation errors and their standard deviation were obtained (hereafter DD3).

On the premise of investors' aversion to estimation errors, Chang et al. (2012) took the investors' tolerance of estimation errors from DD1 model into account, and developed the basic capability index of accrual quality (hereafter $C_{BAQ}$), which also corresponded to the investment risks caused by earnings quality factors. Finally, the pooled sample regression model was used to measure estimation errors and their standard deviation. Chang et al. (2013) further used $C_{BAQ}$ calculated by the DD3 model to discuss the relationships between organizational strategy, fixed asset investment, and earnings quality; the firm-specific regression method was used in that research to measure estimation errors and their standard deviation.

According to the aforementioned DD1, DD2, DD3 models, and studies by Chang et al. (2012) and Chang et al. (2013), firm level regression model was used only in DD1 model and in Chang et al. (2013), pooled sample regression model was applied in the remaining studies, and standard deviation of the estimation errors for each company was regarded as the proxy variable of the earnings quality. However, such measurement models only focused on the dispersion degree of estimation errors but overlooked centralized tendency of them. This study assumes that the ideal target value or theoretical target value of estimation errors to be 0, then the distance of centralized tendency away from target value should be also taken into account . Otherwise, one can be very frustrated with the difficult position to choose from one investment target with smaller standard deviation of estimation errors but longer distance of their centralized tendency away from target value; and the other with larger standard deviation of estimation errors but shorter distance of their centralized tendency away from target value. Perhaps the investment target with smaller standard deviation would be favored according to the DD1 model.

This study follows the assumption of Chang et al. (2012) on investor aversion to estimation errors and the DD3 model to measure estimation errors by modifying $C_{BAQ}$ to further add centralized tendency in estimation errors and make sure corresponding to the investment risk caused by earnings quality factors. All the efforts are devoted to illustrate the application of the modified capability index of accrual quality (hereafter $C_{MAQ}$) based on the data of American companies. The remainder of this paper is organized as follow. First, the study demonstrates how the $C_{BAQ}$ index be modified in Section 2. Then relevant statistics and data sources with estimation model are discussed in Section 3 and Section 4 respectively. Actual operational measurement indicators are presented in Section 5, and finally, conclusions are offered in Section 6.

## 2 Modified Basic Capability Index of Accrual Quality

### 2.1 The Development of $C_{BAQ}$

In 1930s, in order to take advantage of financial statement analysis to determine undervalued investment opportunities, investors began to study the concept of earnings quality. In 1971, O'glove and Olstein jointly founded the Quality of Earnings Report2, which specifically analyzes various financial reports of listed companies to assess their earnings quality. Cornell and Apostolou (1992) pointed out that accounting information has higher earnings quality if containing feedback value and predictive value. Bricke et al. (1995) argued that, if a company exposes more information that reflects the actual situation of the business, and its financial profitability, and uses consistent accounting principles and offers predictable earnings, it can be regarded as having higher earnings quality. In summary of the above studies, although earnings quality has been gradually taken seriously, there is no clear and consistent definition or measurement method.

Regarding measurement method, DD1 proposed the regression model to make the change of working capital corresponding to the cash flows of operating activities from previous, current, and future period, standard deviation of the estimation errors for each company was regarded as proxy variable of earnings quality. However, DD2 argued that the DD1 model should strengthen its control variables; therefore, the current change in net sales and gross value of property, and plant facilities, was added in the DD1 model to measure estimation errors. Both DD1 and DD2 adopted change of working capital as explained variable of the regression model; hence, the compromising items of working capital change should have no missing value, and the limitation of data composition will be

[2]O'glove.T(1987), in the book of "Quality of Earnings", proposed the accounting earnings in the real economic sense as the earnings quality analysis indicator, and summarized the report of earnings quality measurement.

relatively great. Therefore, by following the regression model of DD2, the explained variables of DD3 adopted the total current accruals to reduce the limitations on data selection and increase the number of samples.

As DD1, DD2, and DD3 did not consider the earnings quality problem from the perspective of investors' aversion to estimation errors, Chang et al. (2012) introduced the quality concept of process capability, by using the DD1 pooled sample regression model to measure estimation errors and 90% confidence interval of the estimation errors as the upper and lower tolerance limits. Investors would then be able to use it as the proxy variable of earnings quality to develop $C_{BAQ}$ for each investment target. The equation is shown as below:

$$C_{BAQ} = \frac{USL - LSL}{3.29\sigma_p} \quad (1)$$

where

*USL*: upper limit of working capital estimation errors

*LSL*: lower limit of working capital estimation errors

$\sigma_p$: standard deviation of working capital estimation errors for investment target

The basic concept of Chang et al. (2012) on investment target's investment risk is that it should at least be the same as the investment risk of all potential investment targets available on the market. In this case, $C_{BAQ}$ is expected to be equal to 1. We can see that the numerator in Eq. (1) is the tolerance of potential investment target (pooled sample) $\pm$ 1.645 standard deviation, while the denominator is tolerance corresponding to the selected investment target $\pm$ 1.645 standard deviation, thus, the range is 3.29 times of standard deviation.

According to Eq. (1), if investor sticks to the status quo on same investment decision within a period of time, with constant *USL* and *LSL*, $C_{BAQ}$ value and investment target $\sigma_p$ are reversely correlated. Hence, larger $\sigma_p$ value comes with smaller $C_{BAQ}$ value and vice versa. In this way, Chang et al. (2012) improved DD1 model by taking estimation error tolerance into account and constructed capability indices of investment target earnings quality from the perspective of investors.

To reduce the investment risk caused by lowered earning quality, Chang et al. (2012) constructed a mathematical relationship between $C_{BAQ}$ and investment risk (hereafter investment risk or $P_i$) caused by earnings quality for each investment target. $P_i$ can be represented by the following equation:

$$P_i = 2P(Z \le -1.645C_{BAQ}) \quad (2)$$

In Eq. (2), one can easy understand that larger $C_{BAQ}$ value and hence smaller $P_i$ means investment risk is lower; on the contrary, higher investment risk can be caused by smaller $C_{BAQ}$ value.

Although Chang et al. (2012) revised DD1 pooled sample regression model to better control the relationship of $C_{BAQ}$ index and investment risk, centralized tendency of estimation errors is still out of concern. According to the assumption that the expected value of the pooled sample residual term should be 0, target value of the estimation errors can also be assumed to be 0. From the perspective of the investor, target value of estimation errors at 0 is reasonable assumption. However, Chang et al. (2012) overlooked the fact that centralized tendency of estimation errors of investment target should be 0. Such relationship between centralized tendency of the distribution for estimation errors and target value is not considered even in the cases of DD2 and DD3.

## 2.2 Modified Capability Index of Accrual Quality $C_{MAQ}$

To correct the drawback of $C_{BAQ}$, this study refers to the concept of the Taguchi quality loss function [3] and consider the mean, standard deviation, and target value of the estimation errors for investment target to modify $C_{BAQ}$ into $C_{MAQ}$ and the deduction process is shown as below:

$$
\begin{aligned}
\tau^2 &= E[(x_p - T)^2] \\
&= \frac{1}{\mathrm{n}}\sum(\mathrm{x_p} - \mathrm{T})^2 \\
&= \frac{1}{n}\sum[(x_p - u_p) + (\mu_p - T)]^2 \\
&= \frac{1}{n}\sum[(x_p - u_p)^2 + 2(x_p - u_p)(\mu_p - T) + (\mu_p - T)^2] \\
&= \frac{1}{n}[(x_p - u_p)^2 + n(\mu_p - T)^2] \\
&= \sigma_p^2 + (\mu_p - T)^2 \qquad (3)
\end{aligned}
$$

where

$x_P$ :estimation error of investment target

$T$: target value of estimation errors for investment target

$\mu_P$ : mean of estimation errors for investment target

${\sigma_P}^2$: variance of estimation errors for investment target

With $\tau = \sqrt{{\sigma_P}^2 + (\mu_P - T)^2}$ , $C_{MAQ}$ can be given by

$$
\begin{aligned}
C_{MAQ} &= \frac{USL - LSL}{3.29\tau} \\
&= \frac{USL - LSL}{3.29\sqrt{\sigma_p^2 + (\mu_p - T)^2}} \\
&= \frac{USL - LSL}{3.29\sigma_p} \times \frac{\sigma}{\sqrt{\sigma_p^2 + (\mu_p - T)^2}}
\end{aligned}
$$

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[3]See Kaplan and Atkinson ( 2007)

$$= \frac{C_{BAQ}}{\sqrt{1+\frac{(\mu_p - T)^2}{\sigma_p^2}}} \tag{4}$$

However, as the target value is assumed to be 0, namely, T = 0, Eq. (4) can be simplified as:

$$C_{MAQ} = \frac{C_{BAQ}}{\sqrt{1+\frac{{\mu_P}^2}{{\sigma_P}^2}}},$$

$$\text{where } \sqrt{1+\frac{{\mu_P}^2}{{\sigma_P}^2}} \geq 1 \tag{5}$$

In Eq. (5), $C_{MAQ}$ must be smaller than $C_{BAQ}$ in normal circumstances. Only if when the mean of estimation errors for investment target is 0, $C_{MAQ}$ would be equal to $C_{BAQ}$. The relationship between $C_{BAQ}$ and $C_{MAQ}$ can be further modified as:

$$C_{BAQ} = C_{MAQ} \times \sqrt{1+\frac{{\mu_p}^2}{\sigma_p^2}} \tag{6}$$

Substitute the $C_{BAQ}$ in Eq. (6) into Eq. (2), we obtain relationship between $C_{MAQ}$ and $P_i$ as

$$P_i = 2P(Z \leq -1.645 C_{MAQ} \sqrt{1+\frac{{\mu_P}^2}{{\sigma_P}^2}}) \tag{7}$$

In Eq. (7), smaller $P_i$ is accompanied by larger $C_{MAQ}$ value; hence, investment risk caused by the earnings quality factors is lower. On the contrary, smaller $C_{MAQ}$ value and larger $P_i$ means investment risk caused by the earnings quality factors is higher. Therefore, when $C_{MAQ}$ value is known, $P_i$ can be obtained accordingly.

In this case, dispersion degree and centralized tendency of estimation errors are integrated into the construction of measurement index to not just remedy the deficiency of $C_{BAQ}$ but therefore develops $C_{MAQ}$ to better capture the earnings quality of investment target and correspond with the investment risk caused by earnings quality factors.

# 3 Discussion of Standard Deviation and other Statistics for Estimation Errors

## 3.1 Standard Deviation of Estimation Errors

Since sample data is used, estimators should be defined prior to follow-up calculation and analysis. According to Eq. (4), $\sigma_p^2$ and $x_P$ are two key factors to set up estimators. In general, $\bar{x}_p = \sum x_p / n$ is adopted as the estimator of $x_P$, and $s_p^2 = \frac{\sum (x_p - \bar{x}_p)^2}{n-1}$ is adopted as the estimator of $\sigma_p^2$. Then the estimator of $\tau^2$ in Eq. (3) can be shown as

$$\begin{aligned}\hat{\tau}^2 &= \frac{1}{n-1}\sum (x_p - T)^2 \\ &= s_p^2 + \frac{n}{n-1}(\bar{x}_p - T)^2\end{aligned} \tag{8}$$

It is worth noting that, Boyles (1991) pointed out that $\hat{\tau}^2$ is a biased estimator, $\tilde{\tilde{\tau}}$ is indeed the unbiased estimator of $\tau^2$, and the variation of $\tilde{\tilde{\tau}}^2$ is smaller than that of $\hat{\tau}^2$.

$$\begin{aligned}\tilde{\tilde{\tau}} &= \frac{1}{n}\sum (x_p - T)^2 \\ &= \frac{1}{n}\sum (x_p - \bar{x}_p)^2 + (\bar{x}_p - T)^2\end{aligned} \tag{9}$$

Therefore, to estimate the true value of $\tau^2$, $\tilde{\tilde{s}}_p^2 = \frac{\sum (x_p - \bar{x}_p)^2}{n}$ is used for the estimation of $\sigma_p^2$ with maximum likelihood method. As a result, $\tau^2$ estimation in Eq. (4) turns out to be

$$\tilde{\tilde{\tau}}^2 = \tilde{\tilde{s}}_p^2 + (\bar{x}_p - T)^2 \tag{10}$$

And then $C_{MAQ}$ estimation in Eq. (4) can be rewritten as

$$\hat{C}_{MAQ} = \frac{USL - LSL}{3.29\sqrt{\tilde{\tilde{s}}_p^2 + (\bar{x}_p - T)^2}} \tag{11}$$

However, as the target value is assumed to be 0, namely, T = 0, Eq. (11) can be simplified as:

$$\hat{C}_{MAQ} = \frac{USL - LSL}{3.29\sqrt{\tilde{\tilde{s}}_p^2 + \bar{x}_p^2}} \tag{12}$$

### 3.2 Application of Statistics

To verify the empirical application of $C_{MAQ}$ estimation on investment decision, the study conducts necessary statistical tests such as the overall $C_{MAQ}$ test of investment targets and pair-wise comparisons when investors need to determine difference among investment risks.

Under the premise that three investment targets[4] are of interest, $F_{max}$ method (Hartley, 1950) is used to test the homogeneity of $C_{MAQ}$'s. Null hypothesis and alternative hypothesis are $H_0$: $C_{MAQ1} = C_{MAQ2} = C_{MAQ3}$; $H_1$: at least one $C_{MAQi}$ is unequal. Test statistic is:

$$F_{\max} = \frac{Max\{\hat{C}_{MAQ1}, \hat{C}_{MAQ2}, \hat{C}_{MAQ3}\}}{Min\{\hat{C}_{MAQ1}, \hat{C}_{MAQ2}, \hat{C}_{MAQ3}\}} \tag{13}$$

In which, $F_{\max} \sim F_{\max[3,\bar{v}-1]}$ can be confirmed (Appendix A), and the average degree of freedom[5] is $\bar{v} = \sum v_i / 3$.

On the same token, when there are k $C_{MAQ}$'s of investment targets to be tested, then

$$F_{\max} \sim F_{\max[k,\bar{v}-1]} \; (\bar{v} = \sum_{i=1}^{k} v_i / k) \tag{14}$$

When $H_0$ is rejected by $F_{max}$ test, we believe that there are differences among $C_{MAQ}$'s, and pair-wise comparisons would be needed for further discussion. For the comparison of $C_{MAQ1}$ and $C_{MAQ2}$, whether confidence interval of $C_{MAQ1} / C_{MAQ2}$ includes 1 is to be answered. Refer to Eq. (A1-6), we can further construct mathematical equation as

$$\frac{\left(\dfrac{C_{MAQ1}}{\hat{C}_{MAQ1}}\right)^2}{\left(\dfrac{C_{MAQ2}}{\hat{C}_{MAQ2}}\right)^2} = \frac{\left(\dfrac{C_{MAQ1}}{C_{MAQ2}}\right)^2}{\left(\dfrac{\hat{C}_{MAQ1}}{\hat{C}_{MAQ2}}\right)^2} = \frac{\chi^2_{v_1} / v_1}{\chi^2_{v_2} / v_2} \sim F(v_1, v_2) \tag{15}$$

Thus, for a confidence level of (1-α)100%, the upper and lower limits of $(C_{MAQ1} / C_{MAQ2})^2$ can be represented by equations as

$$\text{UCI} = (\hat{C}_{MAQ1} / \hat{C}_{MAQ2})^2 \times F_{\alpha/2}(v_1, v_2) \tag{16}$$

---

[4]Investors may set the number of investment targets according to their own investment targets.

[5]See Appendix A1 for the calculation of degree of freedom.

$$\text{LCI} = (\hat{C}_{MAQ1}/\hat{C}_{MAQ2})^2 \times F_{1\text{-}\alpha/2}(v_1, v_2) \tag{17}$$

The upper and lower confidence limits of $(C_{MAQ1}/C_{MAQ2})$ are then

$$\sqrt{\text{UCI}} = (\hat{C}_{MAQ1}/\hat{C}_{MAQ2}) \times \sqrt{F_{\alpha/2}(v_1, v_2)} \tag{18}$$

$$\sqrt{\text{LCI}} = (\hat{C}_{MAQ1}/\hat{C}_{MAQ2}) \times \sqrt{F_{1-\alpha/2}(v_1, v_2)} \tag{19}$$

When confidence interval of $(C_{MAQ1}/C_{MAQ2})$ is greater than 1, we could conclude that $C_{MAQ1} > C_{MAQ2}$.When confidence interval is smaller than 1, then $C_{MAQ1} < C_{MAQ2}$. $C_{MAQ1}$ could be no different from $C_{MAQ2}$ when confidence interval includes 1.

Taking advantage of the aforesaid mathematical algorithm and test process, investors can more precisely determine the earnings quality of investment targets without interference from certain factors and in turn, reduce investment risk.

# 4 Data Sources and Measurement Model of Estimation Errors

## 4.1 Data Sources

Data collection process of this study is illustrated in Table 1. The sample data used here are from Compustat financial database during the 1988-2010[6] period. The study first collects data regarding cash flow, gross value of property, plant and equipment, change in net sales, change in current assets, change in current liabilities, cash change, change in current liabilities, and cash flow from operation due in one year, for a total of 78,860 samples. However, as operating cash flow of the previous and following periods are required for measurement model, this study matches up operating cash flow with the previous, current, and following periods and the number of 68,937 samples remains. Finally, 53,689 samples are selected after eliminating industries sample below 20 and companies blow 8 years and excluding finance and insurance industries.

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[7]To match up the data of previous total assets and the operating cash flow of the previous, current, and following, the period of collection is 1987~2011.

Table 1: Sample selection

Investment risk data- Companies (firm-year level)

| | |
|---|---|
| Cash flow, grow value of property, plant and equipment, change in net sales, change in current assets , change in current liabilities, cash change, change in current liabilities, and cash flow of operation due in one year-available samples | 78,860 |
| Matching operating cash flows with the previous, current ,and following periods | (9,923) |
| Companies with the previous, current ,and following periods operating cash flows | 68,937 |
| Annual sample of matching industries below 20 and companies blow 8 years | (6,804) |
| Annual samples of matching industries above 20 and companies blow 8 years | 62,133 |
| Excluding finance and insurance industries | (8,444) |
| Annual samples of 3420 companies in sustainable operation above 8 years | 53,689 |
| data source: Compustat | |

## 4.2 Measurement Model of Estimation Errors

The above $C_{MAQ}$ index and regression model proposed by Francis et al. (2005) are used to measure estimation errors. The famous accrual quality measurement model is

$$TCA_{i,t} = \alpha_0 + \beta_1 CFO_{i,t-1} + \beta_2 CFO_{i,t} + \beta_3 CFO_{i,t+1} + \beta_4 \Delta REV_{i,t} + \beta_5 PPE_{i,t} + \varepsilon_{i,t} \quad (19)$$

where

$$TCA_{i,t} = \Delta CA_{i,t} - \Delta CL_{i,t} - \Delta CASH_{i,t} + \Delta STDEBT_{i,t}$$

in which

$TCA_{i,t}$ : total current accruals for *i* company during year *t*

$\Delta CA_{i,t}$ : change in current assets for *i* company during year *t* (Compustat #4)

$\Delta CL_{i,t}$ : change in current liabilities for *i* company during year *t* (Compustat #5)

$\Delta CASH_{i,t}$ : cash change for *i* company during year *t* (Compustat #1)

$\Delta STDEBT_{i,t}$ : change in current liabilities due in one year for *i* company during year *t* (Compustat #34)

$CFO_{i,t-1}$ : cash flow from operation for *i* company during year *t-1*

$CFO_{i,t}$ : cash flow from operation for *i* company during year *t* (Compustat #308)

$CFO_{i,t+1}$ : cash flow from operation for *i* company during year *t+1*

$\Delta REV_{i,t}$ : change in net sales for *i* company during year *t* (Compustat #12)

$PPE_{i,t}$ : gross value of property, plant and equipment for *i* company during year *t* (Compustat #7)

$\varepsilon_{i,t}$ : residual for *i* company during year *t*

DD1 argued that standard deviation of residuals is one important measurement variable of earnings quality. Larger the value of standard deviation, poorer the predictability of earnings quality.

# 5 Empirical Study

## 5.1 Regression Estimation

According to the regression results in Table 2, explanatory power (Adj. $R^2$) of the measurement model is 79.9 %, which is higher than DD2 model with no doubt. It should be noted that mean of residuals is 0.00, which is in line with one of the most important assumptions of linear regression model. Standard deviation of residuals is 0.2144.

Table 2: Regression results and residual analysis

$$TCA_{i,t} = \alpha_0 + \beta_1 CFO_{i,t-1} + \beta_2 CFO_{i,t} + \beta_3 CFO_{i,t+1} + \beta_4 \Delta \mathrm{Re}v_{i,t} + \beta_5 PPE_{i,t} + \varepsilon_{i,t}$$

Panel A: Regression results

| variable | coefficient |
|---|---|
| intercept | |
| $CFO_{i,t-1}$ | 0.823 |
| $CFO_{i,t}$ | 0.486 |
| $CFO_{i,t+1}$ | -0.070 |
| $\Delta Rev_{i,t}$ | 0.008 |
| $PPE_{i,t}$ | 0.036 |
| number of samples | 53,689 |
| F-value | 42698.78 |
| DW | 1.994 |
| Adj. $R^2$ | 0.799 |

Panel B: Descriptive statistics of residual term

| | mean | median | minimum | maximum | S.D |
|---|---|---|---|---|---|
| $\varepsilon_t$ | 0.0000 | -0.0032 | -1.6161 | 1.5704 | 0.2144 |

Note: $TC_t$: total current accruals for *i* company during year *t* ; $CFO_{i,t-1}$ : cash flow from operation for *i* company during year *t-1* ; $CFO_{i,t}$ : cash flow from operation for *i* company during year *t* (Compustat #308) ; $CFO_{i,t+1}$ : cash flow from operation for *i* company during year *t+1* ; $\Delta REV_{i,t}$ : change in net sales for *i* company during year *t* (Compustat #12) ; $PPE_{i,t}$ : gross value of property, plant and equipment for *i* company during year *t* (Compustat #7) ; $\varepsilon_{i,t}$ : residual for *i* company during year *t*

## 5.2 Statistical Tests of $C_{MAQ}$

### 5.2.1 Homogeneity test of investment targets

Under the above premise that three investment targets are of interest, Fmax test is conducted to conclude the hypothesis of homogeneity among $C_{MAQ}$'s is rejected to further clarify different capability of earnings quality. Assumes that $C_{MAQ}$ of three investment targets is (1.002, n1=22, v1=22), (2.5833, n2=19, v2=19.22) and (1.482, n3=21, v3=21), respectively. With reference to Eq. (14), we conduct $C_{MAQ}$ homogeneity test and statistics shown in Table 3.

Table 3: Investment target $C_{MAQ}$ homogeneity test (α=0.05)

| $\bar{V}-1$ | $S^2_{P\max}$ | $S^2_{P\,mix}$ | $F_{max}$ statistic | $F_{max}$ critical value ($K$=3, $V$=20) | Test result |
|---|---|---|---|---|---|
| 19.74 | 0.04547 | 0.00685 | 6.638 | 2.950 | Reject $H_0$ |

Note: Hartley (1950) provided $F_{max}$ critical value table at significant level of 0.05 and 0.001, but without 0.1
critical value. Significant level of 0.05 is selected here and the closest degrees of freedom at 20 is used for the
decision of $F_{max}$ critical value.

As expected, null hypothesis of homogeneity is rejected based on *Fmax* test decision rule. It means that earnings quality of three investment targets are significantly not identical and pair-wise comparisons based on computing confidence intervals are next analysis to be focused.

### 5.2.2 Pairs Comparison of $C_{MAQ}$'s

To further identify differences between each pair of $C_{MAQ}$'s for investment targets, investment target 1 is matched with investment target 2 and 3, labeled as (1, 2) and (1, 3). Eqs. (18) And (19) are applied to compute $\hat{C}_{MAQi}/\hat{C}_{MAQj}$, $\sqrt{UCI}$ and $\sqrt{LCI}$, and comparison results shown in Table 4.

Table 4: Pair-wise comparison tests of $C_{MAQ}$'s for investment targets (α=0.05)

| *I* investment target | *J* investment target | $\hat{C}_{MAQi}/\hat{C}_{MAQj}$ | $\sqrt{UCI}$ | $\sqrt{LCI}$ | results |
|---|---|---|---|---|---|
| 1 | 2 | 0.3879 | 0.9613 | 0.2500 | Significant |
| 1 | 3 | 0.6761 | 1.6185 | 0.4389 | Not significant |
| 2 | 3 | 1.7431 | 4.2574 | 1.1040 | Significant |

Note: F(0.025,ν1, ν2) and F(0.975, ν1, ν2) are calculated using the combinations of ν1 and ν2

Test results apparently suggest that, since confidence interval of (1, 3) includes 1, null hypothesis cannot be rejected. Therefore, there is no significant difference on earnings quality capability between investment target 1 and 3. For the comparison of (2, 3), null hypothesis is rejected based on both confidence limits are greater than 1, and hence, investment target 2 is better than investment target 3 from the viewpoint of statistical confidence. At last, investment target 2 should be better than investment target 1 by test conclusion and the figures of confidence limits. To sum up, target 2 can be the best solution in one's investment portfolio due to its investment risk caused by the earnings quality is the smallest among three targets.

## 6 Conclusion

Whenever making investment decisions according to personal preferences and criteria, investor's judgment is primarily based on information from financial statements. Usually, investors would evaluate business performance and interpret hidden information to select the best investment targets. Earnings quality of financial statements is relatively important in this situation. A review of those related researches, it should be noticed that some scholars measure earnings quality based on estimation errors. However, previous studies only took dispersion degree of estimation errors into account, while overlooking centralized tendency of them, which may lead to misjudgments.

This study combines dispersion degree and centralized tendency of estimation errors to work on the measurement of earnings quality. With reference to the consideration of investor's tolerance on measurement error from Chang et al. (2012), this study proposes the index $C_{MAQ}$ and matches it with investment risk caused by the earnings quality factors. To test the applicability of $C_{MAQ}$, financial data of U.S. companies from Compustat are selected in regression model (Francis et al., 2005). From the results of Fmax test and pair-wise comparisons, we can tell that larger the $C_{MAQ}$ value, smaller risk of investment target, and vice versa. The upcoming challenge should be on providing accounting implications of $C_{MAQ}$.

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## Appendix A

$$F_{\max} = \frac{Max\left\{\left(\frac{C_{MAQ1}}{\hat{C}_{MAQ1}}\right)^2 、\left(\frac{C_{MAQ2}}{\hat{C}_{MAQ2}}\right)^2 、\left(\frac{C_{MAQ3}}{\hat{C}_{MAQ3}}\right)^2\right\}}{Min\left\{\left(\frac{C_{MAQ1}}{\hat{C}_{MAQ1}}\right)^2 、\left(\frac{C_{MAQ2}}{\hat{C}_{MAQ2}}\right)^2 、\left(\frac{C_{MAQ3}}{\hat{C}_{MAQ3}}\right)^2\right\}} \tag{A-1}$$

If null hypothesis $H_0 : C_{MAQ1} = C_{MAQ2} = C_{MAQ3}$ is true, then

As $\left(\frac{C_{MAQ1}}{\hat{C}_{MAQ1}}\right)^2 \sim \chi^2_{v_1} / v_1$ **(**Appendix A1), Eq. (A-1) can be changed into the following:

$$F_{\max} = \frac{Max\left\{\chi^2_{v_1}/v_1 、\chi^2_{v_2}/v_2 、\chi^2_{v_3}/v_3\right\}}{Min\left\{\chi^2_{v_1}/v_1 、\chi^2_{v_2}/v_2 、\chi^2_{v_3}/v_3\right\}} \tag{A-2}$$

However, Hartley (1950) used $F_{max}$ to test the differences of multiple variants and null hypothesis $H_0 : \sigma_1^2 = \sigma_2^2 = \sigma_3^2$; H1: at least one $\sigma_i^2$ is unequal, and its verification statistic is:

$$F_{\max[3,\bar{v}-1]} = \frac{s^2_{\max}}{s^2_{\min}} = \frac{Max\{s_1^2, s_2^2, s_3^2\}}{Min\{s_1^2, s_2^2, s_3^2\}} \tag{A-3}$$

If $H_0$ is true, then Eq. (A-3) can be changed into the following:

$$F_{\max[3,\bar{v}-1]} = \frac{Max\left\{\left(\frac{v_1 s_1^2}{\sigma_1^2}\right)\Big/ v_1, \left(\frac{v_2 s_2^2}{\sigma_2^2}\right)\Big/ v_2, \left(\frac{v_3 s_3^2}{\sigma_3^2}\right)\Big/ v_3\right\}}{Min\left\{\left(\frac{v_1 s_1^2}{\sigma_1^2}\right)\Big/ v_1, \left(\frac{v_2 s_2^2}{\sigma_2^2}\right)\Big/ v_2, \left(\frac{v_3 s_3^2}{\sigma_3^2}\right)\Big/ v_3\right\}}$$

$$=\frac{Max\left\{\chi^2_{v_1}/v_1,\ \chi^2_{v_2}/v_2,\ \chi^2_{v_3}/v_3\right\}}{Min\left\{\chi^2_{v_1}/v_1,\ \chi^2_{v_2}/v_2,\ \chi^2_{v_3}/v_3\right\}} \tag{A-4}$$

As (A-2) = (A-4); therefore $F_{\max} \sim F_{\max[3,\bar{v}-1]}$.

## Appendix A1

If *d=USL-LSL*

$$\left(\frac{C_{MAQ_i}}{\hat{C}_{MAQ_i}}\right)^2 = \frac{\left(\dfrac{d}{1.645\sqrt{\sigma^2+(\mu-T)^2}}\right)^2}{\left(\dfrac{d}{1.645\sqrt{\overset{\approx}{s}{}_p^2+(\bar{x}_p-T)^2}}\right)^2} = \frac{\overset{\approx}{s}{}^2+(\bar{x}_p-T)^2}{\sigma^2+(\mu-T)^2}$$

$$=\frac{\overset{\approx}{s}{}_p^2/\sigma^2+(\bar{x}_p-T)^2/\sigma^2}{1+(\mu-T)^2/\sigma^2} \tag{A1-1}$$

In this case, if $(\mu-T)^2/\sigma^2=\delta$, then Eq. (A1-1) can be changed into the following:

$$(1+\delta)\left(\frac{C_{MAQ_i}}{\hat{C}_{MAQ_i}}\right)^2 = \overset{\approx}{s}{}_p^2/\sigma^2+(\bar{x}_p-T)^2/\sigma^2$$

$$=[\overset{\approx}{s}{}_p^2+(\bar{x}_p-T)^2]/\sigma^2 \tag{A1-2}$$

$$(1+\delta)\left(\frac{C_{MAQ_i}}{\hat{C}_{MAQ_i}}\right)^2 = \overset{\approx}{\tau}{}^2/\sigma^2 \tag{A1-3}$$

As, $\overset{\approx}{\tau}{}^2=\frac{1}{n}\sum(x_p-T)^2$ Eq. (A1-3) can be changed into the following:

$$(1+\delta)\left(\frac{C_{MAQ_i}}{\hat{C}_{MAQ_i}}\right)^2 = [\frac{1}{n}\sum(x_p-T)^2]/\sigma^2 \tag{A1-4}$$

Patnaik (1949) pointed out that

$$\frac{\sum(x_p - T)^2}{\sigma^2} \sim \chi^2_{v_i} \quad (v_i = \frac{(n_i + \lambda_i)^2}{(n_i + 2\lambda_i)} \ , \ \lambda_i = \frac{n_i \times (\mu_i - T)^2}{\sigma_i^2} \text{); hence,}$$

$$\frac{\overset{\approx}{\tau}^2}{\sigma^2} \sim \chi^2_{v_i} / v_i \tag{A1-5}$$

Therefore,

$$\left( \frac{C_{MAQ_i}}{\hat{C}_{MAQ_i}} \right)^2 \sim \chi^2_{v_i} / v_i \tag{A1-6}$$