Modelling of capital asset pricing by considering the lagged effects

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Abstract. In this paper the problem of modelling the Capital Asset Pricing Model (CAPM) with the effect of the lagged is discussed. It is assumed that asset returns are influenced by the market return and the return of risk-free assets. To analyse the relationship between asset returns, the market return, and the return of risk-free assets, it is conducted by using a regression equation of CAPM, and regression equation of lagged distributed CAPM. Associated with the regression equation lagged distributed CAPM, this paper also developed a regression equation of Koyck transformation CAPM. Results of development show that the regression equation of Koyck transformation CAPM has advantages, namely simple as it only requires three parameters, compared with regression equation of lagged distributed CAPM.

1. Introduction

Referring Allen & Bujang [1] and Franses & Oest [5] standard form of Capital Asset Pricing Model (CAPM) was first developed separately by Sharpe in 1964, Lintner in 1965 and Mossin in 1969, therefore, the model is often called the CAPM form Sharpe-Lentner-Mossin. Most of the making of CAPM is based on a series of assumptions, namely: (i) An evaluation of the portfolio based on the expected return and standard deviation of the portfolio over a specified period of time; (ii) investor action based solely on considerations of expected return and standard deviation of the portfolio; (iii) The assets of the individual (individual assets) can completely broke up the smallest (fully divisible). Based on asset, it can buy assets on the desired amount; (iv) There is an interest rate and a risk-free savings (risk free lending and borrowing rate).This rate applies to all investors; (v) There are no transaction costs and income taxes; (vi) Information can be obtained directly (instantly) and free for all investors; (vii) individual investor action can not affect the price of the asset. In contrast, the actions of all investors (together and in the same direction) may affect the price of assets in the market; (viii) Each investor has the same hope (homogeneous expectations) against expectations of return, standard deviation and covariance of assets; and (ix) All assets can be traded (marketable) [6], [10].

According to Allen & Bujang [1] and Kuehn et al. [7], CAPM regression Equality is used to analyze the effect of the market index return on asset returns. The regression equation of CAPM is to link the level of expected returns on risk assets with a risk of the asset in a balanced condition [11]. In the equilibrium conditions of the capital markets, the difference between the market return with the return of risk-free assets referred to as the market risk premium, while the difference between the returns of assets with a risk-free asset return is referred to as the risk premium asset. In the CAPM, the
risk premium of assets was affected by the independent variable market risk premium in the same period [11]. We estimate that the risk premium assets are not only influenced by the market risk premium in the same period, but it can be influenced also by the market risk premium in the period - previous period or periods lagged. So that the CAPM model like this, known as the lagged distributed CAPM model. The weakness of distributed lagged CAPM is no sign that is efficient to determine the length lagged [3].

Associated with the lagged distributed, according Franses & Oest [5], Koyck transformation model assumes that the lagged effect on the explanatory variables are unlimited (infinite), but the coefficient parameter (for the variables lagged) down geometrically. Transformation model of Koyck has advantages, namely simple as it only requires three parameters. Therefore, in this paper intends to develop equation of Koyck transformation CAPM. The goal is to get an alternative model CAPM analysis. To clarify the application of this CAPM models, in this paper is given a numerical illustration.

2. Model of Capital Asset Pricing Model (CAPM)
In this section we explore the regression equation of CAPM, distribution lagged CAPM, and the development of the model of Koyck transformation CAPM.

2.1. Regression Equations of CAPM
The basic equation of the standard CAPM is known that the balance of the capital market will be indicated by the asset markets, where the line connecting the investment portfolio of a risk-free opportunity to opportunity-risk investment portfolio [2]. This relationship applies to all assets, either efficient or inefficient. To determine the position of the market portfolio, it needs to be combined between risky assets [6], [7]. If we let \( r_f \) returns risk-free assets at time \( t \), then the expectation of risk-free asset is \( E(r_f) \), and the variance of the risk free asset is \( Var(r_f) = 0 \). All investors are assumed to invest in the same portfolio, namely the market portfolio. This assumption is valid because the assumptions in the CAPM, which all investors using the same analysis, which uses Markowitz's method [9]. In a state of equilibrium, all risk assets should be on the market portfolio, because all investors would hold that portfolio [8].

If the portfolio is composed of all the assets in the market, and we let \( r_m \), market return at time \( t \), then the expected market return is \( E(r_m) \) and the variance of the market return is \( Var(r_m) \). The difference between the return expectations of the market with expectations of returns risk-free assets amounted to \( E(r_m) - \mu_f \) referred to as market risk premiums, and the ratio between the risk of a market premium to market risk \( \sigma_m \), i.e., \( [E(r_m) - \mu_f] / \sigma_m \) is the slope of the capital market line equation [9]. If we let \( r_p \) portfolio return of capital markets at the time \( T \), then the portfolio return expectations of the capital market is \( E(r_p) \), and the variance of portfolio return of capital markets is \( Var(r_p) \). Line equation of capital market portfolios can be expressed as:

\[
E(r_p) = E(r_f) + \frac{[E(r_m) - E(r_f)]}{\sigma_m} \sigma_p
\]

(1)

Slope \( [E(r_m) - \mu_f] / \sigma_m \) is the market price of the portfolio risk efficiency. The market price shows the additional return required by the market [11], [8].
Furthermore, suppose \( r_t \) assets return at time \( t \), with expectations of asset returns \( \mu_t = E(r_t) \) and variance \( \sigma_t^2 = \text{Var}(r_t) \). Based on the concept of capital market portfolios line mentioned above, the relationship between \( E(r_t) \), \( E(r_{mt}) \), and \( E(r_{ft}) \), can be expressed as:

\[
E(r_t) - E(r_{ft}) = \beta \{E(r_{mt}) - E(r_{ft})\}
\]

(2)

where \( \beta \) is the slope. The difference between the expected return of assets to the expected return of risk-free assets amounted to \( [E(r_t) - E(r_{ft})] \) known as the risk premium for assets [2].

Equation (2) empirically cannot be tested statistically, since the equation (2) is an equality expectation. Expectations equation is a value that has not been observed. Therefore, in order regression equation of CAPM empirically testable shall be amended as follows:

\[
r_t - r_{ft} = \beta_0 + \beta_1(r_{mt} - r_{ft}) + e_t
\]

(3)

Therefore the risk-free asset returns have flats constant, it can be written as \( \mu_f = E(r_{ft}) \). Because it is a risk-free assets, then the variance is \( \sigma_f^2 = \text{Var}(r_{ft}) = 0 \) [11]. So the equation (3) can be expressed as:

\[
r_t - \mu_f = \beta_0 + \beta_1(r_{mt} - \mu_f) + e_t
\]

(4)

Where \( \beta_0 \) is the constant term, \( \beta_1 \) is the slope, and \( e_t \) is the residual. Sequence of residual \( \{e_t\} \) are assumed white noise, which is normal distribution with the average 0 and variance \( \sigma_e^2 \) [5].

Estimation of equation (4) can be done with the least squares method.

2.2. Distributed Lagged CAPM

The assumptions in the making of the standard CAPM is still used in the making of a distributed lagged CAPM. An important difference that the distributed lagged CAPM can be accommodate a possible effect of the risk premium on some past period, while the standard CAPM cannot do it [2].

Let \( r_t \) be an asset returns in the period \( t \), and \( r_{mt} \) market index return in the period \( t \). It is known that the return of risk-free assets in the period \( t \), \( r_{ft} \) has the average \( \mu_f = E(r_{ft}) \) constant and \( \sigma_f^2 = \text{Var}(r_{ft}) = 0 \). The regression equation of distributed lagged CAPM as follows:

\[
r_t - \mu_f = \alpha_0 + \beta_0(r_{mt} - \mu_f) + \beta_1(r_{mt-1} - \mu_f) + \ldots + \beta_l(r_{mt-l} - \mu_f) + e_t
\]

(5)

Where \( \alpha_0 \) is constant term, \( \beta_i \) (\( i = 1,\ldots,l \)) is coefficient of market risk premium, with \( l \) is length lagged, and \( e_t \) is the residuals row of the regression equation of lagged distributed CAPM, which is assumed to be normally distributed white noise with the average 0 and variance \( \sigma_e^2 \). Constants \( \alpha_0 \) and coefficients \( \beta_i \) of parameters where \( i = 1,\ldots,l \) can be estimated using the least squares method (least square). A difficulty in the CAPM model with the lagged is to determine the length lagged influential.

Estimation of length lagged with Ad-Hoc method. To overcome the difficulties of determining the length of the lagged effect, it can be done by looking at signs of stability coefficient parameters. The way that is done by looking at the changes in positive sign (+) or negative (-) of the coefficient parameters. Length lagged is selected at the time showed stability (continued positive or continued negative) if lagged changed in length. If lagged extended, then the sign of the coefficient parameter inconsistent, it means that lagged cannot be selected. The weakness of this method is there are no clues about long lagged. Another weakness especially respect to economic data (time series) often have a high correlation (Gujarati, 1978).

2.3. Koyck Transformation CAPM
Based on the shape of CAPM with lagged, in this paper can be developed into a form of Koyck transformation CAPM, which equation can be written as follows:

\[ r_t - \mu_f = \alpha_0 + \beta_0(r_{mt} - \mu_f) + \beta_0 \lambda (r_{mt-1} - \mu_f) + \beta_0 \lambda^2 (r_{mt-2} - \mu_f) + \ldots + \varepsilon_t \quad (6) \]

or can be written into a simpler form as follows:

\[ r_t - \mu_f = \alpha_0 + \beta_0 \sum_{l=0}^{\infty} \lambda^l (r_{mt-l} - \mu_f) + \varepsilon_t \quad (7) \]

The first lagged from equation (7) as follows:

\[ r_{t-1} - \mu_f = \alpha_0 + \beta_0 \sum_{l=0}^{\infty} \lambda^l (r_{mt-l-1} - \mu_f) + \varepsilon_{t-1} \quad (8) \]

If equation (8) multiple by \( \lambda \), the obtained:

\[ \lambda (r_{t-1} - \mu_f) = \lambda \alpha_0 + \beta_0 \sum_{l=0}^{\infty} \lambda^{l+1} (r_{mt-l-1} - \mu_f) + \lambda \varepsilon_{t-1} \quad (9) \]

When the equation (7) is subtracted by equation (9) obtained:

\[ (r_t - \mu_f) - \lambda (r_{t-1} - \mu_f) = \alpha_0 - \lambda \alpha_0 + \beta_0 (r_{mt} - \mu_f) + \varepsilon_t - \lambda \varepsilon_{t-1} \quad (10) \]

or

\[ (r_t - \mu_f) = \alpha_0 (1 - \lambda) + \beta_0 (r_{mt} - \mu_f) + \lambda (r_{t-1} - \mu_f) + \varepsilon_t - \lambda \varepsilon_{t-1} \quad (11) \]

For example \( \nu_t = \varepsilon_t - \lambda \varepsilon_{t-1} \), equation (11) can be written as follows:

\[ r_t - \mu_f = \alpha_0 (1 - \lambda) + \phi_0 (r_{mt} - \mu_f) + \lambda (r_{t-1} - \mu_f) + \nu_t \quad (12) \]

Compared to CAPM by lagged form, Koyck transformation CAPM simpler form only requires three parameters, namely: \( \alpha_0, \lambda \) and \( \beta_0 \). In addition, there is no reason multicollinearity occurrence. Noteworthy is that the initial form (equation (6)) begins with lagged, but the final form (equation (12)) ends with autoregresi. Referring Franses & Oest [5], equation (11) is a ARMAX model. Coefficient parameter equation (11) can be estimated using the method of instrumental variables or conditional likelihood.

3. Illustration Numerical Results and Discussion

In this section we explore numerical illustration of estimation of CAPM regression, estimation of distributed lagged CAPM, and estimation of Koyck transformation CAPM.

3.1. Estimation of CAPM regression

Suppose that there are as many as 400 stocks return data \( S \) and the market return (ISHG). It is known that the risk-free asset returns are relatively constant, with an average of \( \hat{\mu}_f = 0.0026462 \) and variance

\[ \hat{\sigma}^2_f = 0 \]. Estimator CAPM regression such data is:

\[ r_t - 0.0026462 = 0.00412 + 0.256 (r_{mt} - 0.0026462) + \varepsilon_t \quad (40.53) \quad (33.04) \]

\[ R^2 = 73.30\% \quad F = 109.85 \quad P - Value = 0.000 \]

• The verification test of the parameter estimator
  To constants estimator \( \hat{\beta}_0 \), the hypothesis being tested is \( H_0 : \hat{\beta}_0 = 0 \) with alternative \( H_0 : \hat{\beta}_0 \neq 0 \). Statistical \( t_{ratio}(\hat{\beta}_1) = 33.04 \). While at significant level \( \alpha = 0.05 \); critical value \( t_{(0.05, 925)} = 1.645 \). Show that \( t_{ratio}(\hat{\beta}_1) > t_{(0.05, 925)} \), hypothesis \( H_0 \) is rejected, it is mean that \( \hat{\beta}_1 = 0.256 \) significant.

• The suitability test of the model
The suitability test generated value determination $R^2 = 73.30\%$. It means that the market risk premium is correlated quite strongly with the risk premium stocks. To test the significance of the model, the hypothesis is $H_0: \hat{\beta}_0 = \hat{\beta}_1 = 0$ with alternative $H_1: \exists \hat{\beta}_i \neq 0$ (i = 0, 1). The regression model generates statistics $F = 109.85$ with probability $P - Value = 0.000$; at the level of significance $\alpha = 0.05$. It is clear that $P - Value < \alpha$, hypothesis $H_0$ is rejected. It means regression model is significant. Residual normality test shows $\varepsilon_t \sim N(0, 0.00000376)$, it means that residual $\varepsilon_t$ white noise.

3.2. Estimation of distributed lagged CAPM

Suppose that there are as many as 400 stocks return data $S$ and the market return (JCI). It is known that the risk-free asset returns are constant, with an average of $\mu_f = 0.0026462$ and variance $\sigma_f^2 = 0$. Regression estimator of CAPM for such data is

$$\hat{\sigma}_f^2 = 0.$$ Regression estimator of CAPM for such data is

$$R^2 = 79.60\% \quad F = 381.99 \quad P - Value = 0.000$$

The length of the lag regression estimator is 3. The coefficient signs become inconsistent parameter if lag extended again. It means that positive sign turn negative sign.

- The verification test of the parameter estimator

To constants estimator $\hat{\alpha}_0$, the hypothesis being tested is $H_0: \hat{\alpha}_0 = 0$ with alternative $H_0: \hat{\alpha}_0 \neq 0$. Statistical $t_{rasio}(\hat{\alpha}_0) = 18.24$; while at significant level $\alpha = 0.05$; critical value $t(0.05, 925) = 1.645$. Because $t_{rasio}(\hat{\alpha}_0) > t(0.05, 925)$ so that hypothesis $H_0$ is rejected. It means that $\hat{\alpha}_0 = 0.00388$ is significant. For parameter estimator $\hat{\beta}_0$, the hypothesis being tested is $H_0: \hat{\beta}_0 = 0$ with alternative $H_0: \hat{\beta}_0 \neq 0$. Statistical $t_{rasio}(\hat{\beta}_0) = 27.32$; it shows $t_{rasio}(\hat{\beta}_0) > t(0.05, 925)$. So that hypothesis $H_0$ is rejected and $\hat{\beta}_0 = 0.436$ is significant. Parameter estimator $\hat{\beta}_1$, the hypothesis being tested is $H_0: \hat{\beta}_1 = 0$ with alternative $H_0: \hat{\beta}_1 \neq 0$. Statistical $t_{rasio}(\hat{\beta}_1) = 16.26$; it shows $t_{rasio}(\hat{\beta}_1) > t(0.05, 925)$. So that hypothesis $H_0$ is rejected and $\hat{\beta}_1 = 0.276$ is significant. Parameter estimator $\hat{\beta}_2$, the hypothesis being tested is $H_0: \hat{\beta}_2 = 0$ with alternative $H_0: \hat{\beta}_2 \neq 0$. Statistical $t_{rasio}(\hat{\beta}_2) = 17.20$; it shows $t_{rasio}(\hat{\beta}_2) > t(0.05, 925)$. So that hypothesis $H_0$ is rejected and $\hat{\beta}_2 = 0.261$ is significant. Parameter estimator $\hat{\beta}_3$, the hypothesis being tested is $H_0: \hat{\beta}_3 = 0$ with alternative $H_0: \hat{\beta}_3 \neq 0$. Statistical $t_{rasio}(\hat{\beta}_3) = 8.23$; it shows $t_{rasio}(\hat{\beta}_3) > t(0.05, 925)$. So that hypothesis $H_0$ is rejected and $\hat{\beta}_3 = 0.132$ is significant.

- The suitability test of the model

The suitability test generated value determination $R^2 = 79.60\%$. It means that the market risk premium is correlated quite strongly with the risk premium stocks. To test the significance of the model, the hypothesis is $H_0: \hat{\alpha}_0 = \hat{\beta}_1 = 0$ with alternative $H_1: \exists \hat{\alpha}_0 \neq 0$ and or $\hat{\beta}_i \neq 0$, (i = 0, 1, 2, 3). The regression model generates statistics $F = 381.99$ with probability $P - Value = 0.000$; at the level of significance $\alpha = 0.05$. It is clear that $P - Value < \alpha$, hypothesis $H_0$ is
rejected. It means regression model is significant. Residual normality test shows $e_t \sim N(0,0.00001668)$, it means that residual $e_t$ white noise.

3.3. Estimation of Koyck transformation CAPM
Koyck models assume that the lagged effect on the explanatory variables are unlimited (infinite), but the coefficient parameter (for the variables lagged) down geometrically. Transformation model of Koyck has advantages, namely simple as it only requires three parameters, namely: $\lambda_0$, $\lambda$ and $\beta_0$.

Furthermore, suppose that $Y_{it} = S_{it} - \mu_f$, in the risk premium return stock $i$ $(i = 1,\ldots,N$ and $N$ number of shares) at the time $t$ $(t = 1,\ldots,T$ and $T$ the number of data), and W market risk premium return on time. Transformation Koyck CAPM form refer ARMAX model of equation (12). Because regression Koyck $Y_{it}$ to $I_{mt}$ produces small coefficient of determination $R^2$. Variable $Y_{it}$ is transformed to $M_{it} = \ln{\{(1+Y_{it})/(1-Y_{it})\}}$. Koyck regression equation to be estimated subsequently in the form $M_{it} = c_i + \beta_i I_{mt} + \lambda M_{it-1} + u_{it} - \lambda u_{it-1}$. Constant estimation $c_i = \alpha_i (1-\lambda_i)$, parameter coefficient $\lambda_i$ and multiplier $\beta_i$ conducted using the method of instrumental variables referring to equation (12) or conditional likelihood estimator. For example, the data will be analyzed regression of stock returns based Koyck transformation CAPM. Based on the results of the regression analysis, obtained estimator constants $\hat{c}_1 = -0.0155$ has a statistical value $t_{\text{ratio}}(\hat{c}_1) = -5.40$ with probability $P = 0.000$. The hypothesis tested is $H_0$ : $\hat{c}_1 = 0$ (alternatively: $H_1$: $\hat{c}_1 \neq 0$). Using a significance level of $\alpha = 0.05$ was obtained critical value statistic $t_{(0.05;824)} = 1.962847$. Because $t_{\text{ratio}}(\hat{c}_1) > t_{(0.05;824)}$, the hypothesis $H_0$ is rejected, which means significant estimator constants $\hat{c}_1 = -0.0155$.

To test the hypothesis estimator coefficient $\hat{\lambda}_1$ and multiplier $\hat{\beta}_1$ conducted in the same manner as a test of hypothesis estimator constants. The test results concluded that coefficient $\hat{\beta}_1 = 0.713$ and $\hat{\lambda}_1 = 0.321$ is significant.

The above regression coefficient of deterministic $R^2 = 67.80\%$. Simultaneous test on statistical regression models $F = 862.50$ with probability $P = 0.000$. The hypothesis tested is $H_0$: $\hat{c}_1 = \hat{\beta}_1 = \hat{\lambda}_1 = 0$ (alternatively: $H_1$: $\exists \hat{c}_1 \neq 0$, $\hat{\beta}_1 \neq 0$ and $\hat{\lambda}_1 \neq 0$). For significant level $\alpha = 0.05$ was obtained critical value statistic $F_{(0.05;3;824)} = 2.615708$. Because $F > F_{(0.05;3;824)}$ and $P\text{-Value} < \alpha$, so that hypothesis $H_0$ is that means regression model $M_{it} = -0.0155 + 0.713 I_{mt} + 0.321 M_{it-1} + u_{it} - 0.321 u_{it-1}$ or $M_{it} = -0.0155 + 0.713 (r_{mt} - \mu_f) + 0.321 (S_{it-1} - \mu_f) + u_{it} - 0.321 u_{it-1}$ is significant. Testing the assumption of normality residual $u_t$, results show that $u_t$ normal distribution with an average $\bar{\mu}_u = -4.4479 \times 10^{-17}$ = 0 and standard deviation $\sigma_{ul} = 0.07880$ or variance $\sigma_{ul}^2 = 0.00621$. Thus the above regression model accordingly.

4. Conclusions
In this paper discussed about modelling of Capital Asset Pricing Model (CAPM) with considering the delay effects. In the discussion of the CAPM includes the standard CAPM regression, lagged distributed CAPM regression, and CAPM regression Koyck transformation. Sharpe-Lentner-Mossin has introduced a regression equation of the standard CAPM. Regression standard CAPM does have a simple shape, but regression standard CAPM is not able to capture the effects of market risk premium
in the past. Then the CAPM regression equation developed by lagged distributed, which is able to capture the effects of market risk premium in the past. The difficulty is not easy to determine the length lagged. In this paper developed CAPM regression Koyck transformation. Regression of CAPM Koyck transformation is a form ARMAX simple, and capable of capturing the effects of market risk premium in the past.

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