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Investigating and Comparing the Relationship between Macro-Economic Variables and Stock Returns Using APT and D-APT Models in Tehran Stock Exchange

[1]Moslem Moradzadeh, [2]Mohammad Nabi Shahiki Tash and [3]Mohammad Esmael Ezazi
[1]Department of Financial Management, [2]Department of Economics, [3]Department of Management, University of Sistan and Baluchestan, Zahedan, Iran

Abstract: The purpose of the study is presenting on improved version of arbitrage pricing theory as downside arbitrage pricing theory by the use of deviation standard concepts and it's comparsion with Arbitrage Pricing Theory. This research by including 84 stocks traded in the Tehran Stock Exchange and by using four macro-economic variables as dependent and independent variables deals with the evaluation of relationship between adjusted returns and downside beta and conventional beta in two model APT and D-APT throughout 2005-2014. The research deals with representing a new version of Arbitrage Pricing Theory as Downside Arbitrage Pricing Theory (D-APT) by more efficient measures of downside beta and semi-deviation standard beside conventional measures. The research indicate in APT, macro-economic factors except oil price are capable of pricing stock returns as exchange rate has negative correlation and inflation rate and stock index has positive correlation with return and explain 59.60% of returns changes in total. Besides, D-APT test results indicates a significant relationship of exchange rate, stock index, inflation rate with stock return as exchange rate has negative correlation and stock index and inflation rate has positive correlation with stock return and explains 29.7% of returns changes in total. The results of determination coefficient indicate higher efficiency of APT compared with D-APT.

Key words: Arbitrage Pricing Theory, Downside Arbitrage Pricing Theory, downside beta, semivariance, Iran

INTRODUCTION

Arbitrage Pricing Theory is based on the assumption of the absence of arbitrage opportunities in financial markets. This theory predicts a relationship between the returns of a portfolio and the returns of a single asset through a linear combination of many independent macro-economic variables. Expected returns are linear functions of weights of common factors (Harding, 2008). Not only does this model not deny numerous factors that influence the daily price of an individual asset and bonds but also it focuses on main factors that move total assets in a large portfolio. The identification of these factors can lead to an initial understanding of these influences on portfolio returns. In other words, pricing factors can be different from the real number of effective factors. Therefore, similar factors are not essential in all samples (Roll and Ross, 1984). This theory does not explain the factors. These factors may be price, interest rate, etc. Market portfolio return can be one of these factors. Some factors can experience higher sensitivity to changes (Brealey *et al*., 2011). In recent studies, researchers have tested this model using beta and variance coefficient (Baghdadabad and Glabadanidis, 2014). Multiple studies, however, indicate the inefficiency of these two scales to reflect the level of risks for an asset. It means that these two scales do not well play their role in single-factor models (Markowitz, 1959; Estrada, 2002). In order to identify such inefficiency, a number of studies offered a new version of variance known as semi variance and downside beta in developed single-factor CAPM (Capital Asset Pricing Model) Model (Estrada, 2002, 2004). All studies in the Iranian capital market used downside risk measures within single-factor CAPM Model; however, these criteria have not yet been studied in multi-factor models including APT. For the first time, this study aims to use semi variance and downside beta in order to identify the variance inefficiency (standard deviation) in developed APT Model known as D-APT (Downside-APT).

Research background: For many years, researchers have conducted multiple studies to examine APT and find the relationship between the macro-economic variables and

Corresponding Author: Moslem Moradzadeh, Department of Financial Management, University of Sistan and Baluchestan, Zahedan, Iran

stock returns. During the last few years, multiple studies have been conducted concerning the returns and its relationship with risk. Many models indicate various risk factors to explain the returns. The first model was introduced by Ross (1976) known as Arbitrage Pricing Theory (APT) to examine the relationship between the returns and risk factors followed by other researchers to test this model. A number of these studies evaluated APT model using financial and macroeconomic variables and their impact on expected returns. Most of these studies evaluated the beta for returns sensitivity to asset factors within mean-variance model. Baghdadabad and Glabadanidis (2014) used for the first time, downside beta as the risk criteria in APT. None of the researchers, however, have found a definitive conclusion about this model because the results differ concerning time and place. Cho (1984) examined APT in two industrial securities groups using factor analysis. The results showed that five or six inter-group factors are involved in the process of the production process of daily returns in two securities groups so that these common factors do not depend on the size of groups. Elton and Gruber (1988) studied the relationship between the structure of risk and macro-economic variables in the Japanese stock market. The results indicated four important factors to explain the returns production process. Hamao (1988) examined the APT using macroe-conomic factors in the Japanese stock market. The results showed that expected inflation changes, unforeseen changes in the risk premium and the slope of the time structure have an important effect on the stock market in Japan. Priestley (1996) studied the relationship of financial and macro-economic factors and the Arbitrage Pricing Theory and the production process of unexpected parts of factors. The results indicate that all five factors were significant: unexpected inflation, money supply, exchange rates, default risk and market portfolio returns. In addition to market factor, Faff and Chan (1998) believe that multiple variables are important to explain the gold stock returns. Antoniou *et al*. (1998) evaluated the empirical validity of Arbitrage Pricing Theory for securities traded in London Stock Exchange. They initially concluded that there are five common factors which can be used for pricing securities. Three factors (unexpected inflation, money supply and surplus returns of the market portfolio), however, provide similar pricing in both samples. Two other factors have not provided similar pricing. Gay Jr. (2008) studied the relationship between the stock returns and macro economic variables in four emerging economies including Brazil, Russia, India and China. The results indicate the relationship of related exchange rate and oil price with the prices of stock market index. No significant relationship was found between stock market returns in the past and now. Yang *et al*. (2010) examined the APT in China's Stock Market. The results showed no effect of three factors on stock returns. It means that APT is not applicable in Chinese Stock Exchange. Basu and Chawla (2014) examined the APT in stock market in India. The results indicate the suitable explanation of asset prices by this model. Factor analysis results showed the presence of two factors in pricing procedure including inflation and market. Baghdad Abad and Glabadanidis (2014) evaluated APT using downside risk approach. The results indicate that all defined variables are able to price the stock returns in D-APT Model, meaning that eight different factors are importantly effective in expected returns. These factors are industrial production, inflation rate, oil prices, exchange rates, the time structure of interest rates, savings rates and market returns.

MATERIALS AND METHODS

APT Model: Ross (1976) proposes a K-factor linear pricing model, namely, the APT as a more general model than the conventional Sharpe-Linter CAPM Model. This model indicates that all portfolios with zero-factor loadings have an expected return equal to the risk-free rate. It prescribes asset returns are generated by a (K+1) factor model with respect to a set of risk premia for each of the K factors and the risk-free rate. The initial APT model is both ex ante and ex post in specification of its returns and assumes that returns on the ith asset are driven by K factor as follows:

$$R_{it} = E(R_{it}) + b_{i1}\delta_{1t} + b_{i2}\delta_{2t} + \ldots + b_{ik}\delta_{kt} + u_{it}, i = 1, \ldots, N$$

where, R_{it}, $E(R_{it})$, b_{ik}, δ_{kt} and u_{it} are respectively the return of ith asset over the time t, the ex ante expected return of ith asset, the sensitivity of asset i-kth factor (factor's beta), the return of kth factor with $E(\delta_{kt}) = 0$ and an error term which represents idiosyncratic returns with $E(u_{it}) = 0$, $E(\delta_{kt}, u_{it}) = 0$ and $E(u_{it}, u_{jt}) = 0$ when i# j or s^2 when i = j. Ross (1976) shows that the equilibrium expected return of security i is linearly related to the b factor loadings in Eq. 2:

$$E(R_{it}) = \lambda_0 + \lambda_1 b_{i1} + \lambda_2 b_{i2} + \ldots + \lambda_k b_{ik} \quad (2)$$

where, λ_0 and λ_k are the returns on the riskless asset (R_f) and the market price sensitivity to the kth fundamental variable, respectively. Equation 2 is frequently referred to as the APT and implied that the expected return of an asset is a linear function of the risk premia on systematic factors. If k = 1, this would be similar to the CAPM so that the expected returns are proportional to a security's beta. Finally, if there is a riskless asset with a return of R_f, then by assuming $R_f = \lambda_0$, Eq. 2 is converted to Eq. 3:

$$E(R_{it})-R_f = \lambda_1 b_{i1} + \lambda_2 b_{i2} + ... + \lambda_k b_{ik} \quad (3)$$

To rewrite the APT as a multi-factor regression model allow R_f varies over the time and substitutes Eq. 2 into Eq. 1 to get a sum of non-linear regressions over the T time period as:

$$R_{it} - \lambda_{0t} = \sum_{j=1}^{k} b_{ij}(\lambda_j + \delta_{jt}) + u_{it} \quad (4)$$

For case of exposition, we consider an arbitrage pricing relationship which has a single stochastic factor or (k = 1). Then all assets must fall on the arbitrage pricing line under equilibrium pricing condition. A better interpretation for λ_1 is that it represents the risk premium under the equilibrium condition as:

$$E(R_i) = R_f + \left[\bar{\delta}_1 - R_f\right] b_{i1} \quad (5)$$

where, $\bar{\delta}_1$ is the expected return on a portfolio with unit sensitivity to the first factor and zero sensitivity, there are no other factors when k = 1, hence the risk premium, λ_1, will be different between Eq. 1 the expectation of a portfolio that has unit response to the first factor and Eq. 2 the risk-free rate:

$$\lambda_1 = \bar{\delta}_1 - R_f \quad (6)$$

In general, the APT can be again rewritten as:

$$E(R_{it}) - R_f = \left[\bar{\delta}_1 - R_f\right] b_{i1} + ... + \left[\bar{\delta}_k - R_f\right] b_{ik} \quad (7)$$

If Eq. 7 interprets as a linear regression equation (assuming that the vector of returns has a joint normal distribution and that the factors are linearly transformed), the coefficients, b_{ik}, will be defined as well as beta in the CAPM Model:

$$b_{ik} = \frac{COV(R_i, \delta_k)}{VAR(\delta_K)} = \frac{\sigma_{ik}}{\sigma_k^2} \quad (8)$$

where, COV (R_i, δ_k) or σ_{ik} and VAR $(\delta_k)^2$ σ_k^2 are, respectively the covariance between the ith asset return and the linear transformation of the kth factor and the variance of the linear transformation of the kth factor.

The constituent of b_{ik} is a fraction of the standard deviation of ith asset and kth factor and variance of the kth factor. However, there are numerous indications that the risk measure explained by variance (standard deviation) has drawbacks and limitations (Markowitz, 1959; Baghdadabad *et al.*, 2011).

D-APT Model: D-APT Model for the first time by Bghdadabad and Glabadanydys (2014) was presented. This model uses the semi-variance (semi-standard deviation) in place of the variance (standard deviation). they extend the same concept to factors' betas and the factors' downside betas in place of factors' betas. they refer to this model as the D-APT and state it more formally as follows:

$$R_{it} = E(R_{it}) + (\overline{\delta_{i1}} - R_f) b_{i1}^d + ... + (\overline{\delta_{k1}} - R_f) b_{ik}^d + u_{it}, \; i = 1, ..., N \quad (9)$$

where, E (R_{it}), R_{it}, $\overline{\delta_k}$, R_f and b^i_{kd} are, respectively, the ex ante expected return of ith asset, the return on asset i in time t, the expected return on a portfolio with unit sensitivity to the kth factor and zero sensitivity to all other factors or the kth factor with E (u_{it}) = 0, E (δ_{kt}, u_{it}) and E (u_{it}, u_{jt}) = 0 when i#j or σ^2 when i = j, the risk-free rate and the sensitivity of lower returns than average on the ith security to the kth factor (downside risk).

If Eq. 10 is interpreted as a linear regression equation, then the coefficients, b^i_{kd} are defined more formally as follows:

$$b_{ik}^d = \frac{SEICOV(R_i, \delta_k)}{SEMIVAR(\delta_k)} = \frac{E\{\min[(R_i - \mu_i), 0] * \min[(R_k - \mu_k), 0]\}}{E\{\min[(R_k - \mu_k), 0]^2\}} \quad (10)$$

where, b^i_{kd}, SEMICOV(R_i, δ_k), SEMIVAR (δ_k, R_i, R_k, μ_i), R_i, R_k and μ_k are the downside risk, the semi-covariance between the ith asset returns and linear transformation of the kth factor, the semi-variance of linear transformation of the kth factor, return of ith asset, return of kth factor, return average of ith asset during the estimation period and return average of kth factor during the estimation period, respectively.

Equation 11 posits that the forecast errors of stock returns are composed of K factors which are common to all securities $\bar{\delta}_k - R_f$ as well as an idiosyncratic term (u) which is specific to security i. Thus, according to the approach in Ross (1976), the equilibrium expected return on security i is linearly related to the factor loadings b^d as follows:

$$E(R_{it}) = \lambda_0 + [\lambda_1 - \lambda_0] b_{i1}^d + ... + [\lambda_k - \lambda_0] b_{ik}^d \quad (11)$$

where, λ_0 and $\lambda_1$are, respectively, the return on riskless asset (R_f) and sensitivity of the market price to the kth variable. Equation 11 is the D-APT Model and it describes the expected return of an asset as a linear function of the downside risk premia on systematic factors in the economy. If k = 1, this would be similar to the D-CAPM specification of expected returns as linear functions of securities' downside betas (Estrada, 2002). Finally, if there is a riskless asset with a rate of return R_f, then by assuming $R_F = \lambda_0$, Eq. 11 can be rephrased in term of excess returns as follows:

$$E\,(R_{it})\text{-}R_f = \lambda_1 b^d_{i1}+...+\lambda_k b^d_{ik} \tag{12}$$

In order to test the D-APT empirically, we allow R_f to change over time. Thus a non-linear regression over the T time period gets by substituting Eq. 12 into Eq. 11, they get a non-linear regression model:

$$R_{it}\text{-}\lambda_{0t} = \sum_{j=1}^{k} b^d_{ij}(\lambda_j+\delta_{jt})+u_{it} \tag{13}$$

Equation 13 can be tested using T observations on N portfolio returns, in which NK parameters in b^d_{ij} and K parameters in λ_j need to be estimated. The empirical specification is as follows:

$$R_{it}\text{-}\lambda_{0t} = \alpha_i+\sum_{j=1}^{k} b^d_{ij} f_{jt}+e_{it} \tag{14}$$

where, α_i is a constant vector equal to Eq. 15:

$$\sum_{j=1}^{k} b^d_{ij}\lambda_j \tag{15}$$

It is clear that the D-APT has three distinct advantages, namely, testable, it incorporates cross-equation non-linear restrictions of the linear factor pricing model and it incorporates the pricing restrictions of Eq. 15, namely, the price of risk of the jth factor must be the same for all assets. These pricing restrictions provide a necessary condition for the empirical test of the validity of the D-APT. First, Eq. 14 can be estimated. Second, it can be estimated using the APT restriction, Eq. 15. Imposing the pricing restriction in Eq. 15 and comparing the results with the unconstrained version in Eq. 13 allows us to test whether imposing the D-APT pricing restrictions in a multi-factor model framework leads to a statistically significant decrease in explanatory power. The constraint in Eq. 13 can be estimated using ITNLSUR. In terms of obtaining the estimations of sensitivities and risk premia, rewrite Eq. 13 as:

$$\rho_i = R_i\text{-}\lambda_0 = \sum_{j=1}^{k}\left(\lambda_j 1_T+\delta_j\right)b_{ij}+u_i \tag{16}$$

where, 1_T as a T vector is one and the T*1 vectors are defined by Eq. 17:

$$\begin{aligned} R_i &= [R_i(1),...,R_i(T)]',\ i=1,...,N,\\ \lambda_0 &= [\lambda_0(1),...,\lambda_0(T)]',\\ \delta_i &= \left[\delta_j(1),...,\delta_j(T)\right]',\ j=1,...,N\\ u_i &= [u_i(1),...,u_i(T)]',\ i=1,...,N \end{aligned} \tag{17}$$

The dependent variable in Eq. 16 is the excess return, $\rho_i = R_i\text{-}\lambda_0$ which requires an observable λ_0. Rewrite Eq. 16 as:

$$\begin{aligned} \rho_i &= \left[(\lambda'\otimes 1_T)+\delta\right]b^d_i+u_i\\ &= X(\lambda)b^d_i+u_i,\ i=1,...,N \end{aligned} \tag{18}$$

where, $\otimes$ denotes a Kronecker product and $X(\lambda)_{T*K} = (\lambda'\otimes 1_T)+\boldsymbol{\delta}$. Stacking the N equations yields:

$$\begin{pmatrix}\rho_1\\ \rho_2\\ .\\ .\\ \rho_N\end{pmatrix} = \begin{bmatrix} X(\lambda) & 0 & 0... & 0\\ 0 & X(\lambda) & 0... & 0\\ . & . & . & .\\ . & . & . & .\\ 0 & 0 & 0... & X(\lambda)\end{bmatrix} * \begin{pmatrix} b^d_1\\ b^d_2\\ .\\ .\\ b^d_N\end{pmatrix} + \begin{pmatrix}u_1\\ u_2\\ .\\ .\\ u_N\end{pmatrix} \tag{19}$$

Re-writing Eq. 19 more compactly leads to:

$$\rho = [I_N \otimes X(\lambda)]b^d+u \tag{20}$$

as the stacked system by replacing $X(\lambda) = (\lambda'\otimes 1_T)\boldsymbol{\delta}$: where p is a NT*1 vector of excess security returns, λ is a K*1 vector of downside prices of risk, $\boldsymbol{\delta}$ is a T*K matrix of observations on the K factors, b^d is a NT*1 vector of sensitivities and I_N is a N*N matrix.

Research method: Since, the real data were employed from 2005-2014, the study is considered causal-comparative one. It is also considered an applied study since it focuses on scientific application of the knowledge. The study covers the variables from 2005-2014. This research by including 84 Stocks Traded of banking, insurance and automobile companies in the Tehran Stock Exchange. Returns is considered the dependent variable, while exchange rate, inflation rate, global oil price and stock index are independent variables calculated in the form of $[\min(r^i_f\text{-}R_F, 0)]$ in D-APT model. Annual stock returns is the dependent variable in D-APT model calculated by $[\min(r^i_f\text{-}R_F, 0)]$.

Table 1: Result of fixed effects test

Redundant fixed effects test	Statistic	df	Prob.
APT			
Cross-section F	0.982462	96.771	0.5301
D-APT			
Cross-section F	1.686231	985.235	0.0040

Table 2: Results of APT Model estimation-pooling data

Variables	Coefficient	SD	t-statistic	p-values
Constant	15.165360	8.026956	1.889304	0.0592
Exchange rate	-0.003695	0.000414	-8.918136	0.0000
Index	0.002710	0.000150	18.090060	0.0000
Inflation rate	0.287332	0.041410	6.938773	0.0000
Oil price	0.198720	0.129309	0.536786	0.1247

R^2 = 0.598371; Adjusted R^2 = 0.596055; Durbin-Watson statistic = -2.098443; F-statistic = 258.3417; p-value (F-statistic) = 0.0000

The analysis of findings: Eviews 9 was employed to analyze the data. Stability testing is not required due to short period of time. First, Chow test is employed to determine the type of model. If the model is verified, panel Hausman test is studied to determine the fixed effects or random effects. Then, the final model is estimated.

The results of chow test estimation: Fixed-effect model is first estimated. Then the model is judged concerning pool or panel data according to the F Limer stat. In F Limer test, the assumption of equal intercepts (pooling or hybrid method) is compared against unequal intercepts (panel method).

- H_0: lack of fixed effect (pool model)
- H_1: fixed effects (panel model)

The results of table show that H_0 is rejected in APT Model, meaning that the model needs to be estimated without the consideration of fixed and random effects. The results of D-APT Model approve H_0 hypothesis, meaning that model needs to be estimated based on panel data (Table 1).

Final estimation of APT Model by pool data: According to the results of Chow test, the model needs to be estimated by pool model. After estimation, the results are tabulated (Table 2).

The results show that all variables except oil price are significant at 95% confidence level because all probability values are <0.05 except for oil price. Therefore, the significance of more than one factor means the APT Model verification. This means that more than one factor explain the changes of stock returns. The results also indicate a negative relationship between exchange rate and stock returns in companies. The results also showed a positive relationship of stock index, inflation rate and oil price with returns. Significance coefficients also indicate that one percent change in each of significant variables including exchange rate, stock index and inflation rate leads to -0.003695, 0.0027 and 0.287332% change in returns, respectively. On the other hand, adjusted coefficient of determination is reported 0.596055, meaning that 59.6% of dependent variable change (returns rate) is determined by independent variables. Durbin-Watson stat. is reported 2.098443. Since, it is between 1.5 and 2.5, close to 2, it indicates the presence of autocorrelation among the residuals in the regression. F-stat. is 258.3417. Since, F-stat. probability value is less than 0.05, it shows the correct model fitting. At 95% confidence level, the final model has intercept as follows:

$$R_i = 15.16536-0.003695\ EX+0.002710\ IND+0.287332\ IHF$$

Table 3: Result of random effects test

Test	Statistic	df	Prob.
Cross-section random	0.0000	8	1.000

Table 4: Results of D-APT Model estimation-fixed effects

Variables	Coefficient	Standard deviation	t-statistic	p-values
Constant	-15.44168	1.155660	-1.864000	0.30000
Exchange rate	-0.55546	0.148660	-8.875356	0.00000
Index	0.42960	0.098600	4.654890	0.00000
Inflation rate	1.21564	0.364880	5.478620	0.00000
Oil price	0.54630	0.047896	1.654850	0.09545

R^2 = 0.3622; Adjusted R^2 = 0.29712; Durbin-Watson statistic = 1.96548; F-statistic = 4.75425; p-value (F-statistic) = 0.0000

Final estimation of D-APT Model by panel data: Hausman test is employed to determine the model used in panel data. The model is first estimated by random effects. Then Hausman test is performed (Table 3).

- H_0: lack of relationship between independent variables and estimation error
- H_1: the relationship between independent variables and the estimation error

The results of above test indicate that H_0 is not rejected. In other words, random-effect model is not required and fixed-effect model needs to be employed. According to the results of Hausman test, the model needs to be estimated by fixed-effect model. The results are as follows (Table 4).

The above results show that all variables except for oil price are significant at 95% confidence level because all probability values are <0.05 except for oil price probability. Therefore, the significance of more than one factor means the D-APT Model verification. This means that more than one factor explain the changes of stock returns. The results also indicate a negative relationship between exchange rate and return stock companies. The results also showed a positive relationship of stock index, inflation rate and oil price with returns. Significance coefficients also indicate that one percent change in each of significant variables including exchange rate, stock index and inflation rate leads to -0.55546, 0.4296 and 1.21564% change in returns, respectively. On the other hand, adjusted coefficient of determination is reported 0.29712, meaning that 29.712% of dependent variable change (returns rate) is determined by independent variables. Durbin-Watson stat. is reported 1.96548. Since, it is between 1.5 and 2.5, close to 2, it indicates the lack of autocorrelation among the residuals in the regression. F-stat. is 4.75425. Since, F-stat. probability value is less than 0.05, it shows the correct model fitting. At 95% confidence level, the final model is as follows at 95% confidence level:

$$R_i = -15.44168-0.55546\ EX+0.4296\ IND+1.21564\ INF$$

CONCLUSION

In this study, along with APT Model, another model known as D-APT was introduced in Tehran Stock Exchange. The results indicate that all factors except oil price are able to price the stock in both APT and D-APT models at 95% confidence level so that exchange rate has a significant and negative relationship with stock returns, while consumer inflation rate and stock index have a significant and positive relationship with stock returns. On the other hand, the significance of more than one factor means the APT and D-APT Model verification. This means that more than one factor explain the changes of stock returns. These factors determine total stock returns changes by 59.6% in APT Model and 29.7% in D-APT Model. However, 41.4 and 71.3% of stock returns in APT model and D-APT can indicate the non-systematic risk which is the volatility of stock returns for companies in portfolio in the form of certain variance for each company which is associated with non-systematic factors. Therefore, it is concluded that a high share of returns variance has an unclear reason in each of companies in portfolio. The market does not pay any investment bonus for such as risk. The results of determination coefficient indicate higher efficiency of APT compared with D-APT.

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