Forecasting performance of capital asset pricing models in case of Pakistani market

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FORECASTING PERFORMANCE OF CAPITAL ASSET PRICING MODELS IN CASE OF PAKISTANI MARKET

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ABSTRACT

This study empirically tests the conditional CAPM, conditional consumption CAPM and conditional multifactor CAPM model with individual stocks traded at Karachi Stock Exchange (KSE), the main equity market in Pakistan for the period 1993-2004. The ability of conditional CAPM models in forecasting asset returns is assessed through predictability of excess return for the period 2005-2006. The results show that the macroeconomic variables that capture business cycle fluctuations are better in explaining the cross-section variation in expected returns, they are found to have better forecasting ability for out-of-sample stock returns in case of Pakistani Market. The evaluation of forecasting ability of the conditional asset pricing models shows that the forecasting power of conditional multifactor CAPM is relatively better compared to conditional CAPM model and conditional consumption CAPM models. It follows, therefore, that the business cycle variables provide useful information for predicting the future direction of stock prices. These variables include market return, call money rate, term structure, industrial production growth, inflation rate, foreign exchange rate and growth in oil prices.

1 INTRODUCTION

It is well documented that the major determinants of price movements of stocks are business cycle variables [Campbell (1987), Ferson and Harvey (1993) Cooper, Glen and Visalia (2001)]. Therefore, the CAPM model using the lagged standard business cycle variables tend to perform well in the empirical literature and studies also confirm this tendency for the Pakistani Market [Iqbal *et al* (2008) and Javid (2008)]. For investor, macroeconomists and policy makers this finding raises the question as to whether the macroeconomic variables that captures business-cycle fluctuations help in forecasting stock returns. Therefore, an attempt is made to determine whether the models that explain the assts prices well within the sample are also good predictors of prices outside the sample. This study follows the spirit of Ferson and Harvey (1993) that if the macroeconomic risk factors are representative of fundamental economic risks faced by all firms, then conditional form of this model can be used to predict future assets returns. It is interesting to examine the performance of conditional CAPM, conditional consumption CAPM and conditional multifactor CAPM because it allows investigating whether the additional factors reveal any more information about the future excess returns.

The ability of CAPM model in forecasting asset returns is assessed through predictability of excess returns. Based on empirical results of conditional CAPM, conditional consumption CAPM and conditional multifactor CAPM for the firm level data of Karachi Stock Exchange for the period 1993 to 2004, the forecasting power of CAPM models is assessed ahead for short period six months and long period twenty-four months to predict excess returns. We use statistical criteria (mean squared error, mean absolute error, bias proportion, variance proportion and covariance proportion) to evaluate return forecasts. These criteria have been widely used in academic research and can be easily applied by practitioners as well.

The study is organized as follows. Section 2 outlines the empirical methodology. The results are presented in section 3, followed by concluding section.

2. EMPIRICAL METHODOLOGY

We start with the basic idea that the realized stock returns are decomposed into expected return and unexpected returns, that is:

$$r_{it} = E_{t-1}(r_{it}) + \varepsilon_{it} \quad (1)$$

Where r_{it} and $E_{t-1}(r_{it})$ are the realized and expected returns on asset i at the end of period t conditional on the information available by the end of period t-1, while ε_{it} is the unexpected return on asset i due to unsystematic factors or unique firm specific events. The expected return can be written as:

$$E_{t-1}(r_{it} \mid Z_{t-1}) = E_{t-1}(\sum_{j=1}^{J} \beta_{jt} f_{jt} \mid Z_{t-1}) \quad (2)$$

Where f_{jt} is the risk factor, which is the market return in case of the conditional standard CAPM, growth in consumption in case of conditional consumption CAPM and the factor j in conditional multifactor model include a set of economic variables: market return, call money rate, term structure, growth in industrial production, unanticipated inflation, unanticipated change in exchange rate, growth in consumption and growth in oil prices. The coefficient vectors are the conditional betas of the stock returns and Z_{t-1} is the vector of mean zero information variables at time t. The previous empirical literature suggests that business cycle variables drive the business conditions and are more responsible for stock prices movements [Angas (1936)]. Therefore to model the conditional information, a set of lagged macroeconomic variables that derive the business condition in Pakistan and have long been used in the conditional asset pricing literature are used. The purpose is to examine time varying betas and risk premiums in Pakistan and their deriving forces from the perspective of macroeconomic environment in the country. The estimation technique is a refined version of the standard Fama and Macbeth (1973) time series and cross section approach. The information set includes lagged predetermined macroeconomic variables (market return, call money rate, term structure, industrial production growth, inflation rate, exchange rate and the growth rate of oil prices) and a constant. In conditional CAPM models, in the first step the relevant conditional betas are estimated as inverse of conditional variance-covariance matrix, multiplied by matrix of conditional covariances of an asset's returns with the economic variables and the details of this method are given in Appendix B. In estimating conditional betas, first of all conditional variances are estimated by Dravidian-Carroll (1987) method, which form the diagonal of variance-covariance matrix. Next, covariance terms are estimated to complete the variance-covariance matrix. Then for each month the vectors of conditional betas are computed by inverting the conditional variance-covariance matrix of the economic variables and post-multiplying the result by matrix of conditional covariance of economic variables with an asset's returns. This process is repeated for each of the chosen assets. By using these vectors of conditional betas, the cross section equation (3) is estimated month by month and slope coefficients measure risk premiums for each month. The average of economic risk premiums is then tested for the significance of its difference from zero. In addition, alternate t-ratios are computed using corrections for errors in betas suggested by Shaken (1992).

$$r_{it} = \lambda_{0t} + \sum_{j=1}^{J} \lambda_{jt} \beta_{ijt} + \varepsilon_{it} \tag{3}$$

Where λ_{0t} is the intercept and λ_{jt} is the slope coefficient of the risk factor associated with the economic variable j.

To examine the performance of a model, the forecast error of the predictability of excess returns are investigated so as to assess the forecast ability of a particular asset-pricing model. For forecasting the excess expected returns, recursive procedure is used. In the first step ARMA model is applied to forecast risk premiums for the next out of sample six months (January 2005 to June 2005). For this purpose in-sample estimated time varying risk premiums of the risk factors are used for the period 1993-2004 in conditional CAPM, conditional consumption CAPM and conditional multifactor model respectively. The same procedure is adopted for twelve months (January 2005 to December 2005); and twenty-four months (January 2005 to December 2006). Thereafter the coefficients estimated for risk premiums by equation (3) are used to predict out of sample risk factor premiums as follows:

$$\lambda_{t+1} = \alpha + \sum_{j=1}^{p} \phi_j \hat{\lambda}_{t+1-j} + \sum_{k=0}^{q} \theta_k \eta_{t+1-j} , \tag{4}$$

where λ_{t+1} is one period forward predicted risk premium, λ_k are estimated risk premium and η_t is residual term. For future periods η_t is set equal to its mean value that is zero.

In the second step factor sensitivities are estimated using the business cycle variables. These betas are estimated month by month using Dividian-Carroll (1987) method with the data from January 2005 to December 2006. The estimates of betas (factor loadings) are multiplied with their corresponding predicted factor premiums to calculate the expected excess returns of the stocks. Then these expected excess returns are compared with the realized excess returns and forecast errors are calculated.

In financial literature, commonly used measure to evaluate the predictability of asset return out of sample period is the root mean square error and means absolute error, which are used to compare forecasts of the same series across different models. Further, mean square forecast error is decomposed into three components: bias proportion, variance proportion and covariance proportion to analyze the nature of forecasting errors. The bias proportion measures how far away the forecasted mean return lies from the actual mean return. The variance proportion indicates the discrepancy between the extent of variation in the forecasted and actual returns. Finally, the covariance proportion measures the remaining unsystematic forecasting errors. Specifically, it indicates the lack of positive correlation between actual and the forecasted returns.

Data and Sample

The test of adequacy of conditional CAPM models is performed on the data of 50 firms (which contributed 90% to the total turnover of KSE in the year 2000) listed on the Karachi Stock Market (KSE), the main equity market in the Pakistan for the period January 1993 to December 2004.. In selecting the firms three criteria are used: (1) continuous listing on exchange for the entire period of analysis; (2) representative of all the important sectors and (3) have high average turnover over the period of analysis.

From 1993 to 2000, the daily data on closing price turnover and KSE 100 index are collected from the Ready Board Quotations issued by KSE at the end of each trading day, which are also available in the files of Security and Exchange Commission of Pakistan (SECP). For the period 2000 to 2004 the data are taken from KSE website. Information on dividends, right issues and bonus share book value of stocks are obtained from the annual report of companies, which are submitted on regular basis to SECP. Using this information daily stock returns for each stock are calculated as log first difference of closing prices after adjusting for dividends, bonus shares and right issues. The six months treasury-bill rate is used as risk free rate and KSE 100 Index as the rate on market portfolio. The economic variables such as treasury-bill rate, call rate, long-term government bond rate, wholesale price index, crude oil prices index, index of manufacturing output and foreign exchange rate are available on monthly frequencies and are obtained from Monthly Statistical Bullion of State Bank of Pakistan.

3. EMPIRICAL RESULTS

For in-sample estimation of the conditional CAPM, conditional consumption CAPM and conditional multifactor CAPM the sample period is set at January 1993 to December 2004, while for the forecasting horizon is set alternatively at January 2005 to June 2005, January 2005 to December 2006 and January 2005 to December 2006. The empirical tests of these models are carried out in excess return form and the risk factor is excess market return above the treasury-bill rate. For further insight the sample period is divided into sub-period of three year: 1993-1995, 1996-1998, 1999-2001 and 2002-2004; two large sub periods: 1993-1998 and 1999-2004; and for the whole sample period 1993-2004.

To test appropriateness of conditional CAPM models, in the first step conditional betas are estimated by Davidian-Carroll (1987) method following Schwert (1989), Ferson and Harvey (1993). In the second step a cross section regression of actual returns on betas is estimated for each month in the test period. The mean risk premiums so obtained are used to test, applying t-statistics, the null hypothesis that the risk premiums are equal to zero The results of average risk premium for market risk in conditional CAPM are presented in Table 1 The results indicate that the investors get positive compensation for market risk in sub-periods 1993-1995, 1993-1998, 1999-2004, 2002-2004 and the overall sample period 1993-2004. The intercept term is significantly different from zero for most of the sub-periods and overall period. To investigate that consumption risk can explain the variation in cross-section of expected returns in meaningful way, the per capita growth in real consumption is included in the standard CAPM model. The results for testing conditional consumption CAPM are reported in Table 2. The premium for consumption beta is positive and significant for most of the sub-periods and overall period. These findings suggest the conditional consumption CAPM is more supported with the data than is the standard CAPM for Pakistani market. These results are consistent with the findings of Ferson (1990). In conditional multifactor model, the set of macroeconomic variables is included in the test of conditional CAPM with the perspective to see whether these factors have pricing significance as against the market index following Chen *et al*. (1986). Table 3 reports the average of the conditional risk premiums estimates over sub-periods and the overall sample period. The intercept term is significantly different from zero for all the sub-periods except for the overall period. The results show that average premium for market risk is positive and significant for the sub-period 1999-2004, 2002-2004 and overall period 1993-2004 and inconclusive and insignificant otherwise. The premium for consumption growth is positive and significant in the period 1999-2001, 2002-2004, 1999-2004 and overall period 1993-2004. The foreign exchange rate risk is positively compensated in the market for the period 1993-1995, 1996-1998, 1993-1998 and overall period 1993-2004. The inflation risk is significantly negatively rewarded in the periods 1993-1995, 1996-1998, 2002-2004 and 1993-1998. The average premium for term structure is negative and significant for the period 1993-1995, 1996-1998, 1993-1998 and overall period 1993-2004. The call money rate risk has negative and significant compensation in the market for the period 1993-1995, 1999-2001 and 1993-1998. The industrial production risks have mixed but insignificant premium showing that the risk associated with industrial production is not priced during the period under study. The oil price risk is significantly and negatively compensated for the periods 1993-1995 and 1996-1998. These results are consistent with the findings of Ferson and Harvey (1991, 1993 and 1999). They emphasize the importance of identified predetermined lagged business-cycle variables as information set and suggest that these variables have significant explanatory power for time varying asset returns.

Table 1: Average Time-Varying Risk Premium Associated with Conditional CAPM

Year	λ_{0t}	λ_{1i}	R^2
1993-1995	-0.02***	0.02*	0.21
	(-1.70)	(2.66)	
	[-1.69]	[2.46]	
1996-1998	-0.02***	0.01	0.30
	(-1.57)	(0.48)	
	[-1.54]	[0.44]	
1999-2001	0.002	0.01	0.30
	(0.23)	(1.08)	
	[0.22]	[1.06]	
2002-2004	0.02*	0.02***	0.26
	(3.64)	(1.43)	
	[3.63]	[1.43]	
1993-1998	-0.02*	0.02**	0.22
	(-2.30)	(1.86)	
	[-2.29]	[1.72]	
1999-2004	0.01*	0.02**	0.28
	(2.59)	(1.79)	
	[2.57]	[1.78]	
1993-2004	-0.001*	0.02*	0.37
	(-2.80	(2.57)	
	[-0.28]	[2.50]	

. Note: The two set of t-values are reported, Fama-McBeth t-values in round bracket and error adjusted Shanken t-values in square bracket. The * indicates significant at 1%, ** indicates significant at 5% and *** indicates 10% significant level.

Table 2: Average Risk Premium of Conditional Consumption CAPM

Years	λ_{0t}	λ_{rm}	λ_{cg}	R^2
1998-2000	0.67*	-0.01*	0.02*	0.32
	(3.27)	(-3.82)	(3.08)	
	[0.481]	[-3.82]	[2.94]	
1999-2001	1.00*	-0.036*	0.03*	0.25
	(3.89)	(-10.20)	(3.62)	
	[2.38]	[-9.81]	[3.34]	
2000-2002	0.725*	-0.002	0.03*	0.20
	(3.08)	(-0.76)	(3.19)	
	[2.417]	[-0.76]	[3.00]	
2001-2003	0.65*	0.032*	0.03*	0.24
	(2.61)	(9.43)	(3.12)	
	[2.39]	[8.76]	[2.93}	
2002-2004	0.85*	-0.03*	0.03*	0.39
	(5.48)	(-11.60)	(5.15)	
	[4.64]	[-11.44]	[4.83]	
1993-2004	0.69*	0.02*	0.02*	0.28
	(3.92)	(6.17)	(4.35)	
	[2.56]	[6.01]	[4.10]	
1993-2004	0.77*	-0.004*	0.02	0.71
	(10.18)	(-3.93)	(10.37)	
	[1.31]	[-3.93]	[9.74]	

Note: The two set of t-values are reported, Fama-McBeth t-values in round bracket and error adjusted Shanken t-values in square bracket. The * indicates significant at 1%, ** indicates significant at 5% and *** indicates 10% significant level.

Table 3: Average Time-varying Risk Premiums in Conditional Multifactor CAPM

	λ_{0t}	λ_{RM}	λ_{CR}	λ_{TS}	λ_{IP}	λ_{UI}	λ_{EU}	λ_{CG}	λ_{OG}	R^2
1993-95	-0.01***	0.03	-1.75**	-16.92***	-0.03	-0.77***	1.37***	-0.26	-0.08***	0.26
	(-0.71)	(1.03)	(-1.72)	(-1.64)	(-0.72)	(-1.60)	(1.67)	(-0.10)	(-1.68)	
	[-0.71]	[.98]	[-1.06]	[-0.01]	[-0.70]	[-0.21]	[1.12]	[-0.04]	[1-.29]	
1996-98	-0.02*	-0.01	0.33	-8.50***	-0.06	-0.70*	1.79*	1.10	-0.12***	0.26
	(-3.48)	(-0.46)	(0.24)	(-1.61)	(-1.15)	(-2.80)	(2.45)	(0.43)	(-1.29)	
	[-3.46]	[-0.46]	[0.07]	[-0.02]	[-1.03]	[-2.40]	[2.14]	[0.04]	[-0.85]	
1999-01	0.01***	-0.01	-2.04***	-5.59	-0.05	-0.06	0.74	7.97*	-0.02	0.26
	(1.53)	(-0.36)	(-1.56)	(-0.35)	(-0.73)	(-0.10)	(0.77)	(1.69)	(-0.18)	
	[1.50]	[-0.36]	[-1.03]	[-0.01]	[-0.67]	[-0.09]	[0.10]	[1.62]	[-0.18]	
2002-04	0.02*	0.03***	3.23	0.19	0.04	-0.96***	0.20	9.71**	-0.12	0.33
	(2.86)	(1.65)	(0.66)	(0.02)	(1.00)	(-1.44)	(0.34)	(1.86)	(-1.00)	
	[2.72]	[1.57]	[0.02]	[0.01]	[0.89]	[-1.15]	[0.14]	[1.72]	[-0.67]	
1993-98	-0.01**	0.01	-0.61***	-12.33**	-0.04	-0.73*	1.60**	0.49	-0.03	0.26
	(-1.95)	(0.44)	(-1.39)	(-1.74)	(-0.83)	(-2.21)	(1.96)	(0.17)	(-0.33)	
	[-1.95]	[0.44]	[-1.06]	[-1.01]	[-0.78]	[-1.30]	[1.22]	[0.03]	[-0.32]	
1999-04	0.02*	0.01**	0.60	-2.70	0.00	0.45	0.47	8.84*	-0.07	0.31
	(3.08)	(1.80)	(0.20)	(-0.28)	(-0.11)	(0.99)	(0.84)	(2.53)	(-0.86)	
	[2.97]	[1.79]	[0.03]	[-0.01]	[-0.11]	[0.21]	[0.17]	[2.03]	[-0.73]	
1993-04	0.002	0.01**	0.02	-7.30**	-0.02	-0.12	1.01*	4.85*	-0.05	0.28
	(0.78)	(1.88)	(0.01)	(-1.62)	(-0.70)	(-0.40)	(2.06)	(2.12)	(-0.82)	
	[0.78]	[1.86]	[0.01]	[-1.23]	[-0.69]	[-0.27]	[1.20]	[2.04]	[-0.75]	

Note: The two set of t-values are reported, Fama-McBeth t-values in round bracket and error adjusted Shanken t-values in square bracket. The * indicates significant at 1%, ** indicates significant at 5% and *** indicates 10% significant level.

The results show that average time varying premium associated with market risk is positive and significant for some sub-periods. This finding suggests that if market is not efficient other macroeconomic risk factors improve the pricing significance of market risk. The negative risk premium for unanticipated inflation risk and term structure risk seem plausible. The expected return are higher in bad times, since investors are less willing to hold risky assets, and lower in good times. Inflation is lower in bad times and higher in good times, so this explains why investors get negative compensation for facing inflation risk. The unanticipated changes in inflation have the general effect of redistributing wealth among investors. The negative sign of these variables means that stock market assets are hedged against the adverse influence on other assets that are relatively more fixed in nominal terms. The term structure risk is negatively compensated, which shows that stocks whose returns are inversely related to increase in long-term over short-term rates are more valuable. The results show that production risks have no significant premium indicating that the instability in real sector of the economy does not have much role in explaining the variation in the expected returns of stocks at KSE. The reason may be that in Pakistani market the information about production changes is not assessable to investor. As regards the foreign exchange risk and oil price risks, these have weak effects, that is, negative premium for a few sub-periods. This indicatets that instability of foreign exchange rate or in oil prices affects the stock returns adversely in a limited way.

To determine whether the conditional models that explain the assets prices well within the sample are also good predictors of prices outside the sample, the forecasting performance of these models are evaluated. For forecasting the excess expected returns, in the first step ARMA model is applied to forecast risk premiums for the next out of sample six months (January 2005 to June 2005) based on the in-sample estimated time varying risk premiums for the period 1993-2004. The same procedure is adopted for twelve months (January 2005 to December 2005); and twenty-four months (January 2005 to December 2006). In the second step, the risk factors sensitivities are estimated using the business cycle variables. These betas are estimated month by month with the data from January 2005 to December 2006. The estimates of betas (factor loadings) are multiplied with their corresponding predicted factor premiums to calculate the expected excess returns of the stocks. Then these expected excess returns are compared with the realized excess returns and forecast errors are calculated.

The forecasts of the 50 returns for firms are pooled together to compute various indicators of forecasting performance. The results are documented in Table 4, which shows that the root mean square error and mean absolute error are relatively smaller for the conditional multifactor CAPM as compared to conditional CAPM or conditional consumption CAPM for all the three forecasting horizons (six months, one year and two years). This suggests that according to these two criteria the forecasting ability of conditional multifactor CAPM is relatively superior to conditional CAPM model and conditional consumption CAPM models. The statistics further show that the forecasting performance of conditional consumption CAPM is better than that of conditional CAPM. It is further observed that the bias proportion of mean square error is lower than the variance and covariance proportions. In particular, the bias proportion for the one-year and two-year planning horizons are almost negligible, indicating on average very little systematic error in forecasts.

Another interesting observation is that the root mean square forecasting error is generally smaller for the longer forecasting horizons, while the mean absolute forecasting error is larger. Thus, as found in most of the literature, the mean error increases with the increase in forecasting horizon. But the magnitudes of errors become less volatile, as indicated by mean square error, when the length of forecasting horizon is increased. This might be due to the reason that in case of KSE there is market crash in the month of March 2005. The KSE 100 has reached a record level of 10,303 on 15th March 2005 and this increase is on top of the cumulative 388 percent rise in KSE-100 in the preceding three years. The stock market turn bearish since March 16, 2005 and the KSE 100 index drop to as low as 6939 as on April 12, 2005 from its peak of 10,303 on 15th March 2005 showing a decline of 32.7 percent. Such a sharp rise in index and a subsequent steep decline represents abnormal and unhealthy movements in the equity market. This market crash and bearish trend in the six months of forecasting expected returns cause poor performance of all three models in that period. Therefore we can conclude that expected returns variation could be explained by macroeconomic variations that are real risks facing investors in Pakistani market. The expected returns vary over time and this variability has some business cycle correlations. This is the reason that expected returns are high in bad economic times because investors are less willing to hold risky assets and lower in good times. These economic variables also provide useful information for predicting the future direction of stock prices.

Table 4 Performance of Return Forecasts under Alternative CAPM Specifications

Period	Jan 2005-Jun 2005	Jan 2005-Dec 2005	Jan 2005-Dec 2006
Conditional CAPM			
Root mean Square Error	4.34	3.66	3.67
Mean Absolute Error	0.99	1.48	3.02
Bias Proportion	0.12	0.002	0.03
Variance Proportion	0.41	0.44	0.12
Covariance Proportion	0.64	0.65	0.90
Conditional Consumption CAPM			
Root mean Square Error	4.27	3.58	3.54
Mean Absolute Error	0.98	1.43	2.76
Bias Proportion	0.11	0.002	0.03
Variance Proportion	0.44	0.53	0.31
Covariance	0.63	0.56	0.70
Conditional Multifactor CAPM			
Root mean Square Error	3.67	3.34	3.67
Mean Absolute Error	0.87	1.42	2.78
Bias Proportion	0.12	0.002	0.002
Variance Proportion	0.83	0.59	0.32
Covariance	0.22	0.50	0.68

4. SUMMARY AND CONCLUSION

The macroeconomic variables that capture business cycle fluctuations are better in explaining the cross-section variation in expected return and are found to have better forecasting ability for out-of-sample stock returns in case of Pakistani market. The evaluation of forecasting ability of the conditional asset pricing models show that the forecasting power of conditional multifactor CAPM is relatively better compared to conditional CAPM model and conditional consumption CAPM models. It follows; therefore, economic fundamentals provide useful information for predicting the future direction of stock prices. These fundamental includes market return, call money rate, term structure, industrial production growth, inflation rate, foreign rate and growth in oil prices.

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Appendix A

Table A1. Set of Economic Variables

Definition	Data Source
Market Return defined as KSE 100 Index (RM)	Ready Board Quotations of KSE and KSE website
Manufacturing Output Index (IP)	Monthly Statistical Bullion, SBP
Per Capita Real Consumption (C)	Economic Survey
Call Money Rate (CR)	Monthly Statistical Bullion, SBP
Term Structure: Difference b/w 10-year government bond yield and 6-month treasury bills rate (TR)	Monthly Statistical Bullion, SBP
Whole Sale Price Index (WPI)	Monthly Statistical Bullion, SBP
Oil Price Index (O)	OPEC Website
Foreign Exchange rate (E)	Monthly Statistical Bullion, SBP

Appendix B: Estimation of Conditional Betas

To estimate conditional betas, first of all conditional variances are estimated. Suppose r_{it} is actual return and let $E\langle r_{it} | Z_{t-1} \rangle$ denotes its conditional return on available information set at time t-1. Let σ_{it} be the unconditional standard deviation of return on asset i and let $E\langle r_{it} | Z_{t-1} \rangle$, denotes its conditional form. The conditional standard deviation of r_{it} conditional on a vector of lagged predetermined macro variables (marker return, growth in consumption per capita,, growth in industrial production, call money rate, term structure, inflation rate, exchange rate and oil price growth rate) and a constant. These variables are likely to be correlated with asset returns and form a publicly available information set. The assumption is that the conditional mean of r_{it} is linear in Z_{t-1}. Then the following steps are estimated to transform residuals for estimation of conditional variance function:

$$r_{it} = Z_{t-i}\delta + \varepsilon_{it} \tag{B1}$$

$$\widehat{\varepsilon}_{it} = r_{it} - Z_{t-i}\widehat{\delta}_{t} \tag{B2}$$

where $\widehat{\delta}_{i}$ is the parameter estimate under OLS. The absolute values of residuals are used in the estimation of conditional standard deviation because it is a more robust choice [Davidian and Carroll (1987)]. Therefore a linear function for absolute residuals is estimated by OLS and $\widehat{\theta}$ is obtained from the regression equation:

$$|\widehat{\varepsilon}_{it}| = \sigma(\theta, Z_{t-1}) + v_{it} \tag{B3}$$

In next step the fitted $\sigma(\widehat{\theta}, Z_{t-1})$ are used to estimate GLS estimates of δ^{*} given in the following equation:

$$r_{it} / \sigma(\widehat{\theta}, Z_{t-1}) = \left[Z_{t-1} / \sigma(\widehat{\theta}, Z_{t-1}) \right] \delta^{*} + \varepsilon_{it}^{*} \tag{B4}$$

Then δ^{*} is used for Weighted Least Square to generate the final residuals, which are used to estimate θ^{*}, that is:

$$\varepsilon_{it}^{*} = r_{it} - Z_{t-1}\delta^{*} \tag{B5}$$

$$|\varepsilon_{it}^{*}| = \sigma(\theta^{*}, Z_{t-1}) + v_{it}^{*} \tag{B6}$$

The function $\sigma(\theta^{*}, Z_{t-1})$ is the fitted conditional standard deviation, the conditional standard deviation becomes:

$$\sigma^{*} = \sigma(\theta^{*}, Z_{t-1})\sqrt{\pi/2} \tag{B7}$$

The term $\sqrt{\pi/2}$ is a bias adjustment factor, which corrects for the fact that mean absolute deviation differs from standard deviation. The square of conditional standard deviations estimated by above method gives the conditional variance of asset return. To estimate conditional covariance of asset return with the market return need some more manipulation. To estimate conditional covariance between two variables $i \neq j$, the residual from equation (B5) are taken for estimation of the following equation:

$$(\sqrt{\varepsilon_{it}^{*}})(\sqrt{\varepsilon_{jt}^{*}})s_{ijt} = Z_{t-1}\psi + \varepsilon_{ijt} \tag{B8}$$

In this equation s_{ijt} is term that preserves the sign of the product of two residuals at each date. The fitted conditional covariances are:

$$sign(Z_{t-1}\widehat{\psi})(Z_{t-1}\widehat{\psi})^{2}(\pi/2), \quad \text{where } \operatorname{sgn}(x) = x/|x|. \tag{B9}$$

In this way the above procedure forms fitted value to estimate conditional covariance of asset returns with the market return. The conditional betas are then estimated as inverse of conditional variance vector multiplied by estimate vector of conditional covariance of asset returns with the market return.