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# Beta Estimation in Indian Stock Markets - Some Issues

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**Abstract**

This study examines the reliability of the OLS beta estimates in Indian stock markets by considering the residual characteristics of the market model regressions. The statistics used include the coefficient of determination ($R^2$), the F-test for significance of the regression coefficient, the Durbin-Watson test for serial autocorrelation, the residual autocorrelation function, the Kolmogorov-Smirnov and Shapiro-Wilk tests for normality of the residuals, the presence of outliers, and White's test for heteroskedasticity.

The results of the study indicate some serious issues afflicting beta estimation in Indian stock markets, including: non-normality of stock returns and of residuals, extreme standardized residual values, heteroskedasticity, residual autocorrelation, and low $R^2$. Thus, the simple market model is likely to result in biased estimates for beta in Indian stock markets.

**Keywords:** beta, Indian stock markets, non-normality, extreme values, heteroskedasticity, residual autocorrelation.

## Introduction

The concept of beta is at the heart of the Capital Asset Pricing Model (CAPM) of Treynor (1961), Sharpe (1964), Lintner (1965) and Mossin (1966). Beta is a measure of an asset's systematic risk, representing the component of the asset's total risk that is undiversifiable through portfolio formation. Thus, beta is the portion of the asset's total risk that is associated with overall movements in the market or economy in general. In other words, beta measures the sensitivity of the asset's returns to movements in the market. Beta plays an important role in many financial applications such as estimating the cost of capital, applying various valuation models, and determining portfolio strategies. It is also used extensively in financial research, for applications such as determining relative risk, testing asset pricing models, testing trading strategies, and conducting event studies.

The CAPM assigns beta a central role in asset pricing. It is based on the principle that the relevant risk measure in holding a given security is the systematic risk, or beta, because all other sources of risk can be diversified away. This yields a linear relationship in equilibrium between the expected return of the asset and its beta.

A common approach to estimating beta is to apply the standard market model estimated under the ordinary least squares (OLS) technique. This was strongly advocated by Fama and MacBeth (1973), who interpreted the CAPM as implying a basic linear relationship between stock returns and market betas which should completely explain the cross-section of returns at a specific point in time. They proposed a two-pass methodology for empirically testing the CAPM. In the first pass, betas are estimated from a time-series regression of stock or portfolio returns on market returns, using a stock market index as a proxy for the market portfolio. In the second pass, the relationship between mean returns and betas is tested cross-sectionally across stocks or portfolios.

This study examines some issues in beta estimation in Indian stock markets, specifically those that arise from the time series nature of the market model regressions.

## Literature Review

The Fama-MacBeth (1973) methodology has been accepted as a standard procedure for testing the CAPM, and other factor models are often tested through a similar procedure: a regression model is proposed for the stock returns, and the theoretical implications are tested as hypotheses on the parameters of the regression model. However, the Fama-MacBeth methodology has been the subject of much criticism that has led to many attempts at improvement. Roll (1977) argued that that CAPM was logically equivalent to the assertion that the market portfolio was mean-variance efficient (i.e. that the CAPM was just a tautology), and, more seriously, that the market portfolio was in fact unobservable (i.e. the stock market index is not an appropriate model for the market portfolio).

Another major setback to the Fama-MacBeth methodology came from a series of papers by Fama and French (e.g. Fama and French, 1992) which asserted that beta by itself is not sufficient for explaining expected return - in particular, the empirical anomalies of the size effect, wherein small stocks outperform large stocks (Fama and French, 1992), and the

book-to-market effect, wherein stocks with high book-to-market equity ratios outperform stocks with low book-to-market ratios (Fama and French, 1992). Further, Fama and French (1992) demonstrated that the cross-sectional relationship between systematic risk and return was not significant once firm size and book-to-market ratio were included as explanatory variables. On the other hand, using alternative econometric techniques, Amihud et al (1992) reclaimed beta as the valid measure of risk in asset pricing, overturning Fama and French's results.

Another source of difficulty in the estimation of beta is the problem of time-varying betas and the stability of betas. The CAPM assumes that the beta coefficient is constant through time. Blume (1971) found that portfolio betas tend to regress toward the mean over time, and found low correlations of OLS betas through time, concluding that the estimate of an individual firm's beta has low predictive power for decision making in the current period. Vasicek (1973) argued that OLS beta estimates were biased in the sense that the more the sample estimate deviates from an unconditional expectation, the greater the chance that the estimate results from sampling error. Using Bayesian techniques, he proposed an unbiased beta estimate. Gray et al (2009) argued that OLS beta estimates with $R^2$ less than 10% were unreliable, were likely to be significantly lower than the true beta, and were expected to vary considerably over time. They recommended the use of the Vasicek correction technique especially for low $R^2$/beta estimates.

A basic principle of the CAPM involves the separation of estimating beta risk from its pricing. The CAPM assumes that one can define and measure systematic risk irrespective of risk aversion, which affects only the equilibrium pricing of individual assets. However, this separation is valid only under the restrictive assumption of two-factor separating distributions or alternatively, if the utility function is quadratic. An additional issue that complicates the problem of estimating beta is that one cannot separate the issue of risk aversion from the statistical loss function used in the estimation. Risk aversion signifies the asymmetric treatment of deviations from the regression of stock returns on market returns; on the other hand, statistical theory implies the equal treatment of observations. The clash between financial and statistical theories complicates the estimation procedure. Shalit and Yitzaki (2002) found that OLS estimators of beta coefficients of stocks and portfolios were highly sensitive to observations of extremes in market index returns, and that this sensitivity was rooted in the inconsistency of the quadratic loss function in financial theory. They proposed to introduce considerations of risk aversion into the estimation procedure using alternative estimators derived from Gini measures of variability to improve the reliability of beta estimators.

Another difficulty in the Fama-MacBeth methodology is the assumption of constant variance/volatility. There is a vast literature incorporating ARCH and GARCH models in the market model in order to improve the beta estimates (e.g. Armitage and Brzeszczynski, 2011). This methodology tends to result in lower beta estimates than OLS, and is significantly so for large-cap stocks.

## Methodology

The objective of the study is to examine some issues in beta estimation in Indian capital markets. The data for the study consisted of daily closing prices of all the stocks comprising the CNX Nifty in India's National Stock Exchange (NSE) as on 01/04/2014. The study period selected was April 1, 2013 - March 31, 2014. The rates of return of each of the stocks and the index have been calculated using the log-returns formula $r_{i,t} = \ln(S_{i,t}/S_{i,t-1})$, where $S_{i,t}$ and $S_{i,t-1}$ represent the closing prices of the stock/index at time t and t-1, respectively, correcting suitably for dividends, stock-splits/bonus share issues, and share buy-backs. The beta coefficients βi were then calculated using the market model as follows: $r_{i,t} = \alpha_i + \beta_i r_{M,t} + \epsilon_{i,t}$, where $r_{M,t}$ denotes the rate of return on the CNX Nifty, and $\alpha_i$ and $\beta_i$ are the regression parameters to be estimated.

The study examines the reliability of the OLS beta estimates by considering the residual characteristics of the market model regressions. The statistics used include the coefficient of determination ($R^2$), the F-test for significance of the regression coefficient, the Durbin-Watson test for serial autocorrelation, the residual autocorrelation function, the Kolmogorov-Smirnov and Shapiro-Wilk tests for normality of the residuals, the presence of outliers, and White's test for heteroskedasticity.

## Findings

The descriptive statistics and normality tests for each of the stocks and the index are presented in Table 1 below. The scatterplot of mean returns against standard deviation of returns is presented in Figure 1.

Table 1. Descriptive Statistics and normality tests

| | Min. | Max. | Mean | Std. Dev. | K.-S. test | p-value | S.-W. test | p-value |
|---|---|---|---|---|---|---|---|---|
| NIFTY | -4.17% | 3.74% | 0.07% | 1.14% | 0.0647 | 0.0128 | 0.9797 | 0.0012 |
| ACC | -6.61% | 6.07% | 0.08% | 1.74% | 0.0572 | 0.0457 | 0.9836 | 0.0054 |
| AMBUJA CEMENT | -11.17% | 7.73% | 0.06% | 2.06% | 0.0500 | 0.2000 | 0.9638 | 0.0000 |
| ASIAN PAINTS | -7.79% | 7.27% | 0.04% | 1.80% | 0.0801 | 0.0006 | 0.9619 | 0.0000 |
| AXIS BANK | -9.90% | 14.60% | 0.05% | 2.71% | 0.0578 | 0.0412 | 0.9605 | 0.0000 |
| BAJAJ AUTO | -4.72% | 5.40% | 0.06% | 1.57% | 0.0445 | 0.2000 | 0.9913 | 0.1437 |
| BANK OF BARODA | -8.93% | 10.08% | 0.03% | 2.82% | 0.0668 | 0.0086 | 0.9811 | 0.0020 |
| BHARATI AIRTEL | -6.39% | 7.55% | 0.03% | 2.21% | 0.0727 | 0.0027 | 0.9865 | 0.0181 |
| BHEL | -21.38% | 8.64% | 0.04% | 3.11% | 0.0831 | 0.0002 | 0.9005 | 0.0000 |
| BPCL | -8.94% | 7.22% | 0.08% | 2.45% | 0.0602 | 0.0282 | 0.9774 | 0.0005 |
| CAIRN | -4.95% | 5.21% | 0.08% | 1.50% | 0.0912 | 0.0000 | 0.9666 | 0.0000 |
| CIPLA | -8.19% | 4.76% | 0.00% | 1.47% | 0.0467 | 0.2000 | 0.9566 | 0.0000 |
| COAL INDIA | -10.68% | 6.73% | -0.03% | 2.00% | 0.0555 | 0.0591 | 0.9698 | 0.0000 |
| DLF | -12.34% | 9.25% | -0.11% | 3.27% | 0.0696 | 0.0051 | 0.9824 | 0.0034 |
| DR REDDY'S | -4.40% | 4.67% | 0.15% | 1.51% | 0.0511 | 0.2000 | 0.9923 | 0.2168 |
| GAIL | -6.77% | 4.81% | 0.07% | 1.68% | 0.0546 | 0.0670 | 0.9903 | 0.0933 |
| GRASIM | -4.89% | 6.17% | 0.01% | 1.59% | 0.0772 | 0.0010 | 0.9723 | 0.0001 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **HCL TECH** | -6.96% | 4.76% | 0.22% | 1.87% | 0.0547 | 0.0662 | 0.9796 | 0.0011 |
| **HDFC BANK** | -8.43% | 7.75% | 0.07% | 1.88% | 0.0770 | 0.0011 | 0.9643 | 0.0000 |
| **HDFC** | -8.12% | 6.34% | 0.03% | 2.00% | 0.0667 | 0.0088 | 0.9784 | 0.0007 |
| **HERO MOTO CO** | -6.51% | 7.14% | 0.15% | 1.71% | 0.0668 | 0.0086 | 0.9841 | 0.0068 |
| **HINDALCO** | -7.89% | 10.86% | 0.17% | 2.61% | 0.0588 | 0.0352 | 0.9841 | 0.0068 |
| **HINDUNILVR** | -4.46% | 16.03% | 0.10% | 1.85% | 0.1430 | 0.0000 | 0.7726 | 0.0000 |
| **ICICI BANK** | -5.58% | 8.88% | 0.07% | 2.29% | 0.0694 | 0.0053 | 0.9819 | 0.0028 |
| **IDFC** | -18.05% | 7.54% | -0.06% | 2.86% | 0.0649 | 0.0124 | 0.9387 | 0.0000 |
| **INDUSIND BANK** | -8.96% | 8.01% | 0.09% | 2.80% | 0.0568 | 0.0482 | 0.9814 | 0.0023 |
| **INFY** | -23.90% | 10.36% | 0.05% | 2.17% | 0.1631 | 0.0000 | 0.6242 | 0.0000 |
| **ITC** | -6.35% | 5.98% | 0.05% | 1.65% | 0.0646 | 0.0130 | 0.9778 | 0.0006 |
| **JINDAL STEEL** | -16.70% | 8.85% | -0.07% | 2.77% | 0.0850 | 0.0002 | 0.9231 | 0.0000 |
| **KOTAK BANK** | -6.07% | 8.43% | 0.07% | 2.06% | 0.0613 | 0.0234 | 0.9741 | 0.0002 |
| **L&T** | -7.74% | 6.80% | 0.12% | 2.19% | 0.0491 | 0.2000 | 0.9897 | 0.0760 |
| **LUPIN** | -6.91% | 5.01% | 0.16% | 1.66% | 0.0482 | 0.2000 | 0.9870 | 0.0229 |
| **M&M** | -4.89% | 5.50% | 0.05% | 1.82% | 0.0378 | 0.2000 | 0.9966 | 0.8719 |
| **MARUTI** | -8.35% | 7.75% | 0.17% | 2.00% | 0.0979 | 0.0000 | 0.9417 | 0.0000 |
| **MC DOWELL'S** | -7.68% | 12.53% | 0.13% | 2.36% | 0.0784 | 0.0007 | 0.9610 | 0.0000 |
| **NMDC** | -5.39% | 6.72% | 0.01% | 2.08% | 0.0595 | 0.0313 | 0.9877 | 0.0302 |
| **NTPC** | -12.49% | 4.08% | -0.07% | 2.01% | 0.0872 | 0.0001 | 0.8831 | 0.0000 |
| **ONGC** | -6.20% | 7.29% | 0.01% | 2.15% | 0.0357 | 0.2000 | 0.9942 | 0.4436 |
| **PNB** | -7.70% | 8.95% | 0.01% | 2.70% | 0.0561 | 0.0542 | 0.9860 | 0.0147 |
| **POWERGRID** | -11.86% | 4.36% | 0.00% | 1.62% | 0.0796 | 0.0006 | 0.9090 | 0.0000 |
| **RELIANCE** | -6.49% | 5.55% | 0.07% | 1.73% | 0.0572 | 0.0451 | 0.9866 | 0.0187 |
| **SBI** | -8.17% | 9.20% | -0.03% | 2.01% | 0.0475 | 0.2000 | 0.9701 | 0.0000 |
| **SSLT** | -9.43% | 15.16% | 0.08% | 2.85% | 0.0892 | 0.0001 | 0.9153 | 0.0000 |
| **SUN PHARMA** | -5.33% | 6.88% | 0.13% | 1.88% | 0.0498 | 0.2000 | 0.9876 | 0.0304 |
| **TATA MOTORS** | -6.17% | 9.54% | 0.16% | 2.17% | 0.0744 | 0.0019 | 0.9731 | 0.0001 |
| **TATA POWER** | -16.25% | 7.55% | -0.05% | 2.38% | 0.0752 | 0.0016 | 0.9266 | 0.0000 |
| **TATA STEEL** | -6.58% | 9.95% | 0.09% | 2.55% | 0.0324 | 0.2000 | 0.9920 | 0.1895 |
| **TCS** | -6.02% | 5.50% | 0.12% | 1.74% | 0.0682 | 0.0067 | 0.9835 | 0.0052 |
| **TECH MAHINDRA** | -5.00% | 7.23% | 0.21% | 1.89% | 0.0779 | 0.0008 | 0.9854 | 0.0115 |
| **ULTRATECH CEM** | -6.03% | 6.44% | 0.06% | 1.87% | 0.0677 | 0.0073 | 0.9705 | 0.0000 |
| **WIPRO** | -13.10% | 6.61% | 0.09% | 1.92% | 0.0728 | 0.0026 | 0.9016 | 0.0000 |

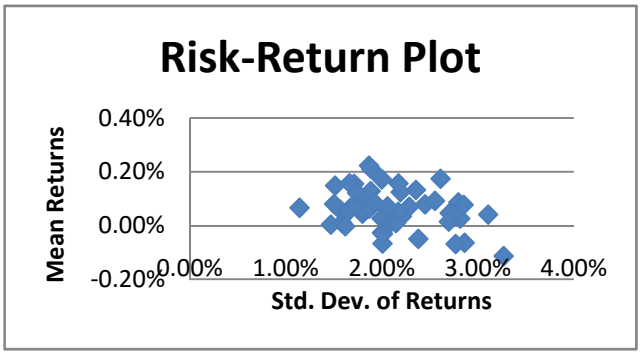


Figure 1. Scatterplot of Mean Returns against Std. Dev. of Returns

It was found that for 86% of the stocks there was evidence of non-normality of stock returns. Several of the stocks were found to have extreme high or low values: 22% of the stocks had extreme low values, less than –10%, while 14% had extreme high values, greater than 10%; only one stock had both.

The alpha and beta coefficients and the $R^2$ and F-tests for each of the stocks are presented in Table 2 below. The scatterplot of $R^2$ against beta is presented in Figure 2.

Table 2. Alpha, Beta, and $R^2$ estimates

| | alpha | beta | $R^2$ | F-test | p-value |
|---|---|---|---|---|---|
| ACC | 0.01% | 0.9312 | 37.59% | 149.9877 | 0.0000 |
| AMBUJA CEMENT | 0.00% | 0.9570 | 28.29% | 98.2113 | 0.0000 |
| ASIAN PAINTS | -0.99% | 1.8202 | 2.01% | 5.1175 | 0.0245 |
| AXIS BANK | -0.07% | 1.7198 | 52.73% | 277.7967 | 0.0000 |
| BAJAJ AUTO | 0.01% | 0.7786 | 32.28% | 118.7110 | 0.0000 |
| BANK OF BARODA | -0.08% | 1.6126 | 42.80% | 186.2975 | 0.0000 |
| BHARATI AIRTEL | -0.04% | 1.1414 | 34.89% | 133.4347 | 0.0000 |
| BHEL | -0.05% | 1.4068 | 26.76% | 90.9917 | 0.0000 |
| BPCL | 0.00% | 1.1923 | 30.91% | 111.4191 | 0.0000 |
| CAIRN | 0.05% | 0.4034 | 9.41% | 25.8499 | 0.0000 |
| CIPLA | -0.03% | 0.4662 | 13.16% | 37.721 | 0.0000 |
| COAL INDIA | -0.07% | 0.6777 | 14.98% | 43.8562 | 0.0000 |
| DLF | -0.23% | 1.8358 | 41.18% | 174.3381 | 0.0000 |
| DR REDDY'S | 0.12% | 0.4706 | 12.63% | 36.0039 | 0.0000 |
| GAIL | 0.02% | 0.6881 | 22.01% | 70.2795 | 0.0000 |
| GRASIM | -0.05% | 0.8500 | 37.52% | 149.5210 | 0.0000 |
| HCL TECH | 0.20% | 0.3311 | 4.11% | 10.6774 | 0.0012 |
| HDFC BANK | -0.01% | 1.2835 | 61.15% | 391.8962 | 0.0000 |
| HDFC | -0.06% | 1.2895 | 54.49% | 298.1168 | 0.0000 |
| HERO MOTO CO | 0.11% | 0.7151 | 22.79% | 73.5100 | 0.0000 |
| HINDALCO | 0.10% | 1.1976 | 27.46% | 94.2824 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| HINDUNILVR | 0.06% | 0.6034 | 13.85% | 40.0187 | 0.0000 |
| ICICI BANK | -0.03% | 1.5551 | 60.47% | 380.8840 | 0.0000 |
| IDFC | -0.18% | 1.6917 | 45.62% | 208.8486 | 0.0000 |
| INDUSIND BANK | -0.03% | 1.7564 | 51.49% | 264.3086 | 0.0000 |
| INFY | 0.02% | 0.4808 | 6.41% | 17.0474 | 0.0000 |
| ITC | -0.01% | 0.9037 | 39.07% | 159.6459 | 0.0000 |
| JINDAL STEEL | -0.14% | 1.0821 | 19.95% | 62.046 | 0.0000 |
| KOTAK BANK | -0.01% | 1.3026 | 52.25% | 272.4680 | 0.0000 |
| L&T | -0.11% | 1.2135 | 18.06% | 54.8935 | 0.0000 |
| LUPIN | 0.13% | 0.3816 | 6.87% | 18.3633 | 0.0000 |
| M&M | 0.00% | 0.8377 | 27.82% | 95.9851 | 0.0000 |
| MARUTI | 0.11% | 0.8736 | 24.92% | 82.6438 | 0.0000 |
| MC DOWELL'S | 0.08% | 0.7311 | 12.59% | 35.8573 | 0.0000 |
| NMDC | -0.05% | 0.9214 | 25.65% | 85.9156 | 0.0000 |
| NTPC | -0.12% | 0.7368 | 17.59% | 53.1617 | 0.0000 |
| ONGC | -0.07% | 1.2108 | 41.53% | 176.8890 | 0.0000 |
| PNB | -0.09% | 1.6546 | 49.13% | 240.4387 | 0.0000 |
| POWERGRID | -0.04% | 0.5981 | 17.83% | 54.0205 | 0.0000 |
| RELIANCE | 0.00% | 1.0776 | 50.96% | 258.7953 | 0.0000 |
| SBI | -0.11% | 1.1460 | 42.39% | 183.1974 | 0.0000 |
| SSLT | 0.00% | 1.1260 | 20.35% | 63.6088 | 0.0000 |
| SUN PHARMA | -0.19% | 0.8164 | 4.01% | 10.3980 | 0.0014 |
| TATA MOTORS | 0.09% | 1.0154 | 28.50% | 99.2331 | 0.0000 |
| TATA POWER | -0.12% | 0.9904 | 22.61% | 72.7396 | 0.0000 |
| TATA STEEL | 0.01% | 1.2605 | 31.83% | 116.2524 | 0.0000 |
| TCS | 0.09% | 0.5046 | 10.95% | 30.6227 | 0.0000 |
| TECH MAHINDRA | 0.19% | 0.2729 | 2.72% | 6.9742 | 0.0088 |
| ULTRATECH CEM | 0.00% | 0.9221 | 31.74% | 115.7820 | 0.0000 |
| WIPRO | 0.07% | 0.2601 | 2.40% | 6.1218 | 0.0140 |

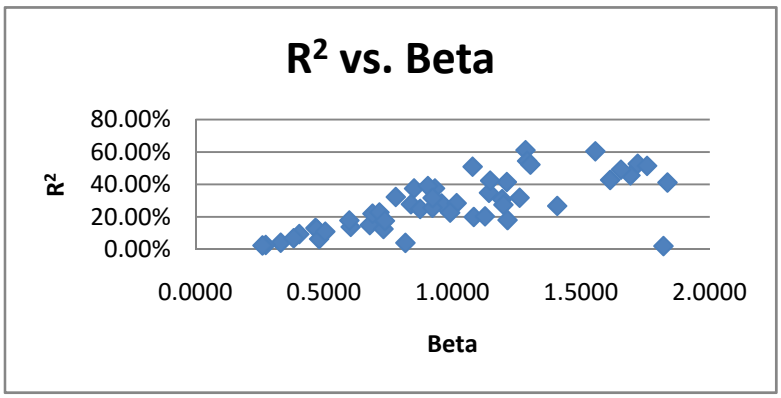


Figure 2. Scatterplot of $R^2$ against Beta

It was found that 16% of the stocks had low $R^2$ (lower than 10%). There was found to be significant positive correlation between beta and $R^2$ (r = 0.7071, $t_{cal}$ = 6.9283, p-value = 0.0000**). Two of the stocks (Sun Pharma and Asian Paints) had exceptionally low $R^2$ though their betas were relatively high (0.8164 and 1.8202, respectively). However, the OLS regressions were found to be significant for all stocks.

The residual autocorrelations of the market model regressions for each of the stocks are presented in Table 3 below.

Table 3. Residual Autocorrelations of the market model regressions

| | D.-W. | $\rho_1$ | $\rho_2$ | $\rho_3$ | $\rho_4$ | $\rho_5$ | $\rho_6$ | $\rho_7$ | $\rho_8$ | $\rho_9$ | $\rho_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **ACC** | 1.8538 | 0.0661 | 0.1023 | -0.0409 | 0.0465 | 0.0361 | 0.0645 | 0.1258 | 0.0435 | -0.0050 | -0.0108 |
| **AMBUJA CEMENT** | 2.0297 | -0.0158 | 0.0565 | 0.0225 | -0.0406 | -0.1110 | -0.0175 | 0.0014 | -0.0449 | -0.0616 | -0.0624 |
| **ASIAN PAINTS** | 2.0262 | -0.0131 | -0.0028 | -0.0312 | 0.0011 | 0.0248 | 0.0182 | -0.0034 | -0.0149 | -0.0089 | -0.0077 |
| **AXIS BANK** | 2.0378 | -0.0191 | 0.0429 | 0.1473 | -0.0465 | 0.0887 | -0.0468 | -0.0086 | -0.1095 | -0.0388 | -0.1077 |
| **BAJAJ AUTO** | 1.9470 | 0.0228 | -0.0498 | -0.0751 | -0.1476 | -0.0386 | 0.0739 | -0.0090 | 0.0425 | 0.0027 | -0.0890 |
| **BANK OF BARODA** | 1.9594 | 0.0189 | -0.1243 | -0.0529 | -0.1246 | 0.0267 | 0.0598 | -0.0906 | -0.0416 | 0.0975 | 0.0332 |
| **BHARATI AIRTEL** | 2.3003 | -0.1502 | 0.0684 | -0.1340 | 0.1009 | -0.0018 | 0.0355 | -0.0236 | 0.0362 | -0.0291 | -0.0137 |
| **BHEL** | 1.8147 | 0.0895 | 0.0090 | -0.0740 | -0.0792 | 0.0009 | -0.0185 | 0.1315 | -0.0061 | 0.0607 | -0.0629 |
| **BPCL** | 2.0247 | -0.0126 | -0.0264 | -0.0086 | -0.0620 | 0.1362 | -0.1300 | -0.0889 | -0.0204 | -0.0431 | -0.0375 |
| **CAIRN** | 2.3249 | -0.1840 | 0.0083 | -0.0699 | -0.1055 | 0.0841 | -0.0086 | 0.0985 | -0.0620 | -0.0467 | -0.0371 |
| **CIPLA** | 2.0410 | -0.0231 | 0.0095 | 0.0476 | 0.0323 | 0.0269 | -0.0747 | -0.0918 | -0.0468 | -0.0528 | -0.1310 |
| **COAL INDIA** | 1.9484 | 0.0241 | -0.0220 | -0.0057 | -0.0358 | 0.0038 | -0.0033 | -0.0748 | -0.0042 | -0.0757 | -0.0540 |
| **DLF** | 1.6875 | 0.1401 | -0.0211 | 0.0921 | -0.0914 | -0.0290 | -0.1271 | -0.1740 | -0.0816 | -0.0663 | -0.1281 |
| **DR REDDY'S** | 1.9176 | 0.0256 | -0.0956 | 0.0328 | 0.0006 | 0.0041 | -0.1258 | -0.1511 | 0.0083 | -0.0538 | -0.0715 |
| **GAIL** | 2.0480 | -0.0264 | 0.0068 | -0.0189 | -0.1431 | -0.0510 | 0.0423 | -0.0628 | -0.0117 | -0.0816 | -0.0494 |
| **GRASIM** | 2.0328 | -0.0177 | -0.0149 | -0.0343 | -0.1033 | 0.0394 | 0.0409 | -0.0079 | 0.1523 | -0.0552 | 0.0223 |
| **HCL TECH** | 2.0062 | -0.0049 | -0.0898 | -0.0098 | 0.0634 | -0.0244 | -0.0998 | 0.0798 | 0.1268 | -0.0410 | -0.1608 |
| **HDFC BANK** | 2.4162 | -0.2091 | -0.0072 | 0.0438 | -0.1031 | -0.0006 | -0.1230 | 0.0227 | -0.0782 | -0.0176 | 0.0759 |
| **HDFC** | 2.2038 | -0.1030 | -0.0284 | -0.0549 | -0.0145 | 0.0007 | -0.0069 | -0.0700 | 0.0149 | -0.0869 | -0.0969 |
| **HERO MOTO CO** | 2.1282 | -0.0654 | -0.1253 | 0.0059 | -0.0481 | -0.1558 | 0.0421 | 0.1107 | -0.0544 | 0.0707 | 0.1126 |
| **HINDALCO** | 2.0324 | -0.0404 | 0.0459 | -0.0035 | -0.0340 | 0.0105 | -0.1502 | 0.0890 | 0.0443 | 0.0896 | -0.0397 |
| **HINDUNILVR** | 1.7971 | 0.1007 | -0.0747 | -0.0246 | -0.0135 | -0.0115 | -0.0313 | -0.0233 | -0.0439 | -0.0357 | 0.0271 |
| **ICICI BANK** | 2.0706 | -0.0369 | -0.0152 | 0.0127 | -0.0239 | -0.0164 | 0.0229 | -0.0156 | 0.0586 | -0.1086 | -0.0254 |
| **IDFC** | 1.8602 | 0.0657 | -0.0714 | 0.1598 | -0.0904 | -0.0387 | 0.0779 | -0.1229 | -0.0584 | 0.1083 | -0.1211 |
| **INDUSIND BANK** | 2.1508 | -0.0776 | -0.0835 | 0.0197 | -0.0978 | 0.0802 | -0.1453 | -0.1067 | 0.1272 | 0.0745 | -0.0573 |
| **INFY** | 2.1383 | -0.0706 | -0.0017 | 0.0700 | 0.0591 | 0.1080 | 0.0656 | 0.0285 | -0.0026 | -0.0272 | 0.0098 |
| **ITC** | 2.0920 | -0.0508 | -0.0007 | -0.0276 | -0.0817 | 0.0448 | 0.0175 | -0.0105 | -0.0866 | 0.1014 | -0.0275 |
| **JINDAL STEEL** | 2.1122 | -0.0627 | -0.0030 | -0.0396 | 0.0543 | -0.0394 | -0.1143 | 0.1090 | 0.1888 | -0.0256 | -0.0502 |
| **KOTAK BANK** | 2.1393 | -0.0701 | -0.0342 | -0.0247 | -0.1532 | 0.0946 | -0.0604 | 0.0206 | -0.0442 | 0.0222 | -0.0112 |
| **L&T** | 2.0037 | -0.0032 | -0.0490 | 0.0289 | 0.0286 | 0.0078 | 0.0136 | 0.1607 | -0.0062 | 0.0228 | 0.0317 |
| **LUPIN** | 1.8738 | 0.0609 | -0.1382 | -0.1091 | 0.0150 | -0.0405 | 0.0316 | 0.0391 | -0.0046 | -0.0827 | -0.0155 |
| **M&M** | 2.1978 | -0.1006 | -0.1129 | -0.0799 | 0.1170 | -0.0625 | -0.0070 | 0.0435 | -0.0507 | 0.1439 | -0.0727 |
| **MARUTI** | 1.9736 | 0.0109 | -0.0012 | 0.0007 | -0.0642 | -0.0117 | 0.0799 | 0.0020 | -0.0364 | -0.0388 | 0.1286 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MC DOWELL'S | 2.1554 | -0.0782 | 0.0345 | 0.0323 | -0.0695 | -0.0723 | -0.0548 | -0.0072 | -0.0266 | 0.0146 | 0.0158 |
| NMDC | 2.0818 | -0.0429 | 0.0954 | -0.1067 | -0.0032 | 0.0266 | 0.0137 | 0.1475 | 0.0163 | 0.1084 | -0.1030 |
| NTPC | 2.2317 | -0.1168 | -0.0443 | 0.0914 | -0.0363 | -0.0729 | 0.0004 | 0.0310 | -0.0040 | 0.0289 | -0.1007 |
| ONGC | 2.2388 | -0.1290 | 0.0231 | -0.0040 | -0.2021 | 0.0178 | -0.0543 | -0.0106 | 0.0301 | 0.0163 | 0.0045 |
| PNB | 1.8764 | 0.0612 | -0.0054 | 0.0446 | 0.0137 | 0.0107 | -0.0631 | -0.0229 | 0.0496 | 0.0326 | 0.0185 |
| POWERGRID | 2.5453 | -0.2779 | 0.0490 | 0.0161 | -0.1289 | 0.0659 | 0.0195 | -0.0782 | -0.0345 | 0.0773 | -0.0553 |
| RELIANCE | 1.9676 | 0.0132 | -0.1284 | -0.0856 | -0.1189 | 0.0202 | 0.0648 | 0.0914 | -0.0471 | -0.0902 | 0.0013 |
| SBI | 1.9260 | 0.0362 | -0.0596 | 0.0475 | -0.0204 | -0.0268 | -0.0338 | -0.0235 | 0.0634 | -0.0126 | -0.0034 |
| SSLT | 2.3609 | -0.1860 | 0.1698 | 0.0285 | 0.0078 | 0.1317 | -0.1389 | 0.1545 | -0.0913 | 0.0548 | -0.0504 |
| SUN PHARMA | 2.1546 | -0.0778 | 0.0500 | -0.0668 | 0.0340 | -0.0199 | 0.0421 | 0.0440 | 0.0542 | -0.1011 | -0.0136 |
| TATA MOTORS | 2.0597 | -0.0319 | -0.0982 | -0.1257 | 0.0305 | -0.0142 | -0.0685 | 0.0221 | -0.0167 | 0.1033 | -0.0724 |
| TATA POWER | 2.2050 | -0.1041 | -0.0259 | -0.0759 | 0.0285 | 0.0064 | 0.0614 | -0.0965 | -0.0362 | 0.0151 | 0.1249 |
| TATA STEEL | 1.7729 | 0.1094 | 0.0755 | 0.0647 | 0.0537 | 0.0688 | 0.1213 | 0.0343 | 0.1092 | 0.1392 | 0.0269 |
| TCS | 2.0692 | -0.0375 | 0.0746 | 0.0290 | -0.0119 | 0.0933 | 0.0030 | -0.0613 | 0.0143 | -0.0585 | -0.1063 |
| TECH MAHINDRA | 1.9124 | 0.0402 | 0.0539 | -0.0815 | -0.0489 | 0.0357 | -0.0137 | -0.0120 | 0.0199 | -0.1038 | -0.0225 |
| ULTRATECH CEM | 1.9731 | 0.0107 | -0.0670 | 0.0671 | -0.0439 | -0.0360 | -0.0435 | -0.0415 | 0.1136 | -0.0847 | -0.0354 |
| WIPRO | 1.9055 | 0.0442 | -0.0711 | 0.1201 | 0.0469 | 0.0521 | -0.0312 | -0.0210 | 0.1069 | -0.0399 | 0.0653 |

It was found that 6% of the stocks showed evidence of significant negative autocorrelation based on the Durbin-Watson test, while none of the stocks showed evidence of significant positive autocorrelation. In fact, 24% of the stocks had some significant autocorrelations among the first ten lags.

The residual statistics and normality and heteroskedasticity tests for each of the stocks are presented in Table 4 below.

Table 4. Residual Statistics and normality and heteroskedasticity tests

| | Std. Dev. | Skew | Kurt | zMin | zMax | K.-S. test | p-value | S.-W. test | p-value | White's test | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ACC | 0.0137 | 0.0733 | 0.6925 | -3.5672 | 3.3295 | 0.0578 | 0.0412 | 0.9912 | 0.1394 | 2.8087 | 0.0938 |
| AMBUJA CEMENT | 0.0174 | -0.3420 | 3.8595 | -5.6311 | 2.7980 | 0.0875 | 0.0001 | 0.9525 | 0.0000 | 6.2680 | 0.0123 |
| ASIAN PAINTS | 0.0180 | -0.1340 | 2.8259 | -2.7821 | 2.8656 | 0.0454 | 0.2000 | 0.9927 | 0.2615 | 1.5405 | 0.2145 |
| AXIS BANK | 0.0186 | 0.4829 | 3.2154 | -2.7019 | 5.4459 | 0.0540 | 0.0737 | 0.9687 | 0.0000 | 6.3525 | 0.0117 |
| BAJAJ AUTO | 0.0129 | 0.2032 | 0.5036 | -3.0958 | 3.4795 | 0.0416 | 0.2000 | 0.9947 | 0.5306 | 0.4093 | 0.5223 |
| BANK OF BARODA | 0.0213 | 0.0078 | 2.4312 | -3.8648 | 4.1879 | 0.0605 | 0.0269 | 0.9716 | 0.0001 | 6.1512 | 0.0131 |
| BHARATI AIRTEL | 0.0178 | 0.5887 | 1.6106 | -3.1853 | 4.1073 | 0.0854 | 0.0001 | 0.9681 | 0.0000 | 0.0698 | 0.7917 |
| BHEL | 0.0266 | -2.0146 | 17.2109 | -8.0731 | 3.4284 | 0.0957 | 0.0000 | 0.8613 | 0.0000 | 0.2108 | 0.6461 |
| BPCL | 0.0204 | -0.0738 | 2.5380 | -4.0472 | 3.7492 | 0.0651 | 0.0119 | 0.9666 | 0.0000 | 1.3646 | 0.2428 |
| CAIRN | 0.0143 | 0.3527 | 1.1739 | -2.9680 | 3.6065 | 0.0678 | 0.0072 | 0.9817 | 0.0025 | 2.2525 | 0.1334 |
| CIPLA | 0.0137 | -0.4019 | 3.8679 | -5.4832 | 3.2084 | 0.0447 | 0.2000 | 0.9592 | 0.0000 | 0.0008 | 0.9778 |
| COAL INDIA | 0.0185 | -0.6363 | 3.1164 | -5.4014 | 2.7174 | 0.0556 | 0.0578 | 0.9692 | 0.0000 | 1.0774 | 0.2993 |
| DLF | 0.0251 | -0.0529 | 1.3639 | -3.5720 | 3.1972 | 0.0966 | 0.0000 | 0.9730 | 0.0001 | 0.3541 | 0.5518 |
| DR REDDY'S | 0.0141 | 0.0819 | 0.7655 | -3.3126 | 3.2833 | 0.0576 | 0.0430 | 0.9905 | 0.1022 | 2.0088 | 0.1564 |
| GAIL | 0.0148 | 0.1611 | 0.3509 | -2.6455 | 3.1686 | 0.0525 | 0.0901 | 0.9938 | 0.3954 | 9.1273 | 0.0025 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **GRASIM** | 0.0125 | 0.2512 | 0.2720 | -2.4014 | 3.4937 | 0.0477 | 0.2000 | 0.9924 | 0.2265 | 10.2249 | 0.0014 |
| **HCL TECH** | 0.0183 | -0.2811 | 0.8096 | -3.7830 | 2.3185 | 0.0460 | 0.2000 | 0.9845 | 0.0079 | 0.1611 | 0.6882 |
| **HDFC BANK** | 0.0117 | 0.2686 | 1.9268 | -3.3323 | 3.7504 | 0.0679 | 0.0070 | 0.9710 | 0.0001 | 7.5996 | 0.0058 |
| **HDFC** | 0.0135 | -0.0141 | 1.2632 | -3.5938 | 3.9206 | 0.0461 | 0.2000 | 0.9885 | 0.0424 | 5.5521 | 0.0185 |
| **HERO MOTO CO** | 0.0150 | 0.5555 | 1.1088 | -2.5683 | 3.5778 | 0.0682 | 0.0067 | 0.9788 | 0.0008 | 27.1377 | 0.0000 |
| **HINDALCO** | 0.0222 | 0.5057 | 1.3897 | -3.3866 | 3.7658 | 0.0580 | 0.0399 | 0.9778 | 0.0006 | 0.7008 | 0.4025 |
| **HINDUNILVR** | 0.0172 | 3.8272 | 30.4120 | -1.9923 | 9.1053 | 0.1303 | 0.0000 | 0.7490 | 0.0000 | 0.3505 | 0.5538 |
| **ICICI BANK** | 0.0144 | 0.2283 | 0.6945 | -3.2072 | 3.3567 | 0.0395 | 0.2000 | 0.9926 | 0.2447 | 22.5816 | 0.0000 |
| **IDFC** | 0.0211 | -0.7620 | 5.1630 | -5.6417 | 3.0945 | 0.0690 | 0.0057 | 0.9403 | 0.0000 | 18.8409 | 0.0000 |
| **INDUSIND BANK** | 0.0195 | 0.1365 | 2.9888 | -3.7831 | 4.8500 | 0.0729 | 0.0025 | 0.9666 | 0.0000 | 10.9973 | 0.0009 |
| **INFY** | 0.0210 | -5.3840 | 63.3411 | -11.0983 | 4.6292 | 0.1584 | 0.0000 | 0.6154 | 0.0000 | 0.7048 | 0.4012 |
| **ITC** | 0.0129 | -0.0827 | 0.2374 | -2.6438 | 2.8625 | 0.0442 | 0.2000 | 0.9930 | 0.2920 | 6.2811 | 0.0122 |
| **JINDAL STEEL** | 0.0248 | -1.1293 | 7.0689 | -6.0035 | 3.2584 | 0.0907 | 0.0000 | 0.9050 | 0.0000 | 0.9768 | 0.3230 |
| **KOTAK BANK** | 0.0142 | -0.0724 | 3.2281 | -4.8525 | 3.7761 | 0.0806 | 0.0005 | 0.9558 | 0.0000 | 2.6623 | 0.1028 |
| **L&T** | 0.0219 | -0.2022 | 0.9498 | -5.3665 | 3.8292 | 0.0450 | 0.2000 | 0.9575 | 0.0000 | 4.3677 | 0.0366 |
| **LUPIN** | 0.0161 | -0.0139 | 1.2075 | -4.276 | 3.011 | 0.0673 | 0.0079 | 0.9832 | 0.0046 | 3.9682 | 0.0464 |
| **M&M** | 0.0154 | -0.0376 | 0.1367 | -2.9639 | 2.7087 | 0.0221 | 0.2000 | 0.9975 | 0.9633 | 0.2614 | 0.6092 |
| **MARUTI** | 0.0173 | 0.4893 | 5.1001 | -4.7925 | 4.1648 | 0.0893 | 0.0000 | 0.9111 | 0.0000 | 1.4322 | 0.2314 |
| **MC DOWELL'S** | 0.0220 | 0.6869 | 3.3617 | -2.9982 | 5.3226 | 0.0587 | 0.0357 | 0.9633 | 0.0000 | 0.6679 | 0.4138 |
| **NMDC** | 0.0179 | 0.1312 | 0.6324 | -3.0472 | 3.2230 | 0.0337 | 0.2000 | 0.9918 | 0.1742 | 5.5012 | 0.0190 |
| **NTPC** | 0.0182 | -2.3650 | 14.8010 | -6.9757 | 2.2636 | 0.0829 | 0.0003 | 0.8475 | 0.0000 | 0.5660 | 0.4518 |
| **ONGC** | 0.0164 | -0.0110 | 0.8519 | -3.6946 | 3.0168 | 0.0353 | 0.2000 | 0.9918 | 0.1786 | 2.0447 | 0.1527 |
| **PNB** | 0.0192 | 0.4303 | 1.4268 | -3.0087 | 3.8328 | 0.0562 | 0.0530 | 0.9793 | 0.0010 | 1.1350 | 0.2867 |
| **POWERGRID** | 0.0147 | -1.6908 | 13.3918 | -7.6778 | 2.5746 | 0.0712 | 0.0037 | 0.8947 | 0.0000 | 1.1051 | 0.2931 |
| **RELIANCE** | 0.0121 | -0.0360 | 0.7018 | -3.2697 | 3.3981 | 0.0430 | 0.2000 | 0.9916 | 0.1625 | 0.8659 | 0.3521 |
| **SBI** | 0.0153 | 0.2533 | 2.1688 | -3.6875 | 4.1153 | 0.0748 | 0.0017 | 0.9701 | 0.0000 | 15.8772 | 0.0001 |
| **SSLT** | 0.0255 | 1.5525 | 7.1099 | -2.8971 | 6.0481 | 0.1055 | 0.0000 | 0.8972 | 0.0000 | 3.2542 | 0.0712 |
| **SUN PHARMA** | 0.0188 | 0.1792 | 0.9728 | -2.8899 | 3.8340 | 0.0358 | 0.2000 | 0.9907 | 0.1166 | 0.8332 | 0.3613 |
| **TATA MOTORS** | 0.0184 | 0.4410 | 1.3365 | -2.4453 | 4.5692 | 0.0606 | 0.0262 | 0.9818 | 0.0026 | 3.0262 | 0.0819 |
| **TATA POWER** | 0.0209 | -0.7095 | 7.3327 | -6.4863 | 3.8506 | 0.0755 | 0.0015 | 0.9310 | 0.0000 | 6.9100 | 0.0086 |
| **TATA STEEL** | 0.0211 | 0.6447 | 0.7982 | -2.5012 | 3.5238 | 0.0729 | 0.0026 | 0.9746 | 0.0002 | 0.0793 | 0.7782 |
| **TCS** | 0.0164 | 0.0900 | 1.0986 | -3.4261 | 3.0793 | 0.0545 | 0.0681 | 0.9820 | 0.0028 | 1.5097 | 0.2192 |
| **TECH MAHINDRA** | 0.0186 | 0.3555 | 0.6084 | -2.8716 | 3.5994 | 0.0778 | 0.0009 | 0.9828 | 0.0040 | 1.2722 | 0.2594 |
| **ULTRATECH CEM** | 0.0155 | -0.0924 | 1.9602 | -3.7019 | 4.1448 | 0.0469 | 0.2000 | 0.9763 | 0.0003 | 4.1578 | 0.0414 |
| **WIPRO** | 0.0190 | -1.4881 | 10.0602 | -6.8139 | 3.5709 | 0.0781 | 0.0008 | 0.8982 | 0.0000 | 0.4415 | 0.5064 |

It was found that for 78% of the stocks there was evidence of non-normality of residuals. For 12% of the stocks the residual distribution was negatively skewed with skewness less than –1, while for 4% of the stocks the residual distribution was positively skewed, with skewness greater than +1. All of the stocks showed leptokurtic residual distributions, with 68% of stocks having residual kurtosis greater than +1. Further, 70% of the stocks showed extreme low standardized residual values, less than –3, of which 50% were less than –3.5, and 84% of the stocks showed extreme high standardized residual values, greater than +3, of which 52%

were greater than +3.5. Also, for 36% of the stocks there was evidence of heteroskedasticity in residual variance.

**Discussion**

The results of the study highlight some of the serious issues afflicting beta estimation in Indian stock markets. Non-normality of stock returns was highly prevalent, as was non-normality of the market model regression residuals, the latter particularly tending to be highly leptokurtic, with extreme high and low standardized values. This implies that the standard errors of the OLS estimates are biased. Thus, OLS beta estimation may not be efficient; weighted least squares (WLS) beta estimation may be more suitable. Also, the extreme values should be investigated further to identify any market events/forces that can systematically explain them.

The results of the study provide some evidence of heteroskedasticity in the market model regression residual variance, again implying biasedness of the standard errors of the OLS estimates. WLS beta estimation may again provide a remedy. Also, ARCH or GARCH modeling may give better beta estimates (e.g. Armitage and Brzeszczynski, 2011).

The results of the study also indicate some prevalence of residual autocorrelation. This would suggest that an auto-regressive model may be more appropriate in place of the simple regression model. This may further be combined with generalized least squares (GLS) estimation.

The results of the study further indicate some prevalence of low explanatory power (e.g. Gray et al, 2009). This would imply that OLS beta estimates with $R^2$ less than 10% are unreliable, for which the Vasicek correction technique may provide better estimates. However, a possible cause for the low explanatory power of the market model could be as suggested by Fama and French (1992) that other determinants may need to be included in the model. Alternatively, more advanced econometric techniques such as filters may need to be employed to improve explanatory power.

There are several limitations inherent in the study. The sample stocks used for the analysis were the constituents of CNX Nifty, and were thus all highly traded large-cap stocks. Thus, the sample was small and unrepresentative. The mid-cap and small-cap stocks may exhibit quite different results. Similarly, thinly-traded stocks may be expected to exhibit quite different behavior. Further studies would need to examine these issues in beta estimation for a wider sample of stocks, and would need to compare the results of OLS beta estimation with other approaches such as WLS, auto-regressive GLS, ARCH/GARCH, and so on.

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