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A Vector Autoregressive Market Model for IT Sector Stocks in India

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Abstract

This study proposes a vector autoregressive form for the market model and tests its significance against the market model for information technology (IT) sector stocks in the Indian stock market. The analysis was performed for a sample of nineteen IT sector stocks listed on the National Stock Exchange of India, of which nine stocks were large-cap, six were mid-cap, and four were small-cap. The study period considered was Jan. 1, 2018 – Dec. 31, 2018.

The key contribution of the study was the finding that the vector autoregressive model is a better model of stock returns than the market model for IT sector stocks. Thus, IT sector stocks seem to react more to market movements from the previous day than on the day itself. The implication for asset pricing modelling is that systematic risk may be further decomposed into a component corresponding to sensitivity to market movements on the day and a component corresponding to sensitivity to market movements on the previous day. The asset pricing model would be extended to include market risk premia for both of these components of systemic risk.

Keywords: market model, vector autoregressive model, IT sector, asset pricing modelling, systematic risk.

Introduction

The market model (also called the single-index model) is a framework which represents the inter-relationship between all stocks through the market portfolio (Sharpe, 1963). It asserts that stock returns are linearly related with market returns, specifically,

$$r_t = \alpha + \beta r_{M,t}$$

where α is the expected return of the stock when market return is zero, and β is the sensitivity of stock returns to changes in market returns. The model also yields a decomposition of the total risk/volatility of stock returns into a systematic component (related with market risk) and an unsystematic component (risk that is specific to the stock). Subsequently, the parameter β plays a pivotal role in the Capital Asset Pricing Model (CAPM), which relates the expected returns of the stock with its systematic risk.

The market model is very widely used in financial research, for evaluating and comparing stock/portfolio performance, for estimating systematic risk and cost of capital in capital budgeting, for computing abnormal returns in event studies (e.g. Brown and Warner, 1980), and for testing asset pricing models (Fama and MacBeth, 1973; Gibbons, 1988).

Several studies have identified certain econometric limitations with the market model, particularly heteroskedasticity. McDonald and Lee (1988) proposed a generalised functional form for the market model using Box-Cox transformations in order to stabilise variance and reduce heteroskedasticity. Coutts et al (1997) found significant parameter instability in the market model, which they suggested was affected considerably by non-firm-specific events. Mills (1995) suggested that the market model should be estimated only after examining cointegration and/or short-run dynamics of the relationship between the stock price and the market index. Fama and Ross (1976) proposed the Arbitrage Pricing Theory, which generalised the CAPM to include multiple macro-economic factors in the market model. French (1996) extended the CAPM by including the size and book-to-market effects. Carhart (1997) suggested a further extension of the Fama-French three-factor model including the momentum factor.

Another direction along which the CAPM was extended was that of autocorrelation. Jegadeesh and Titman (1993) explained medium-term autocorrelation in stock returns using the momentum effect. Chan (1993) suggested that cross-autocorrelations in stock returns may be explained through nonsynchronous trading and that, further, cross-autocorrelation coefficients of stock returns are significantly higher under large market movements than under small market movements. Soufian (2001) suggested that, before analysing factor models, it is essential to identify the process that generating the stock returns and macro-economic series and that vector autoregressive models may be used for this purpose. Dash (2014, 2017) has used vector autoregressive models to test for Granger causality between stock returns and market returns.

The present study proposes a vector autoregressive form for the market model and tests its significance against the market model for information technology (IT) sector stocks in the Indian stock market.

Data & Methodology

The objective of the study is to examine vector autoregressive extensions of the market model for IT sector stocks in the Indian stock market.

The sample stocks considered for the study are listed in Table 1 below. The study period considered was Jan. 1, 2018 – Dec. 31, 2018. The data was collected from the National Stock Exchange of India (www.nseindia.com) . The NSE index Nifty 50 was considered as a proxy for the market portfolio. The risk-free rate was taken to be 6.33% p.a. based on average MIBOR for the study period.

Table 1. Sample stocks considered for the study

Large-cap	**Mid-cap**
Tata Consultancy Services	Persistent Systems
Infosys Technologies	Firstsource Solutions
Wipro Technologies	Cyient
HCL Technologies	Hexaware Technologies
Tech Mahindra	Sonata Software
Larsen & Tourbo Infotech	Zenstar Technologies
MindTree	
Mphasis	**Small-cap**
Oracle Financials Services Software	Eclerx Services
	NIIT Technologies
	Nucleus Software Exports
	Mastek

The daily returns of the sample stocks and of the Nifty 50 index were computed as the percentage change in daily closing prices, adjusting for dividends and stock splits/bonus share issues, if any. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test was used to test the stationarity of the series.

The market model was estimated for each of the sample stocks using the regression model:

$$r_t = \alpha + \beta r_{M,t} + \varepsilon_t$$

As an alternative, the study proposes a vector autoregressive market model of the form:

$$r_t = \alpha + \varphi_1 r_{t-1} + \cdots + \varphi_p r_{t-p} + \beta r_{M,t} + \beta_1 r_{M,t-1} + \cdots + \beta_q r_{M,t-q} + \varepsilon_t$$

where the lag structures p and q are determined by minimising the Akaike Information Criterion (AIC).

The significance of the vector autoregressive model over the market model is tested using the nested F-test.

Analysis & Findings

The descriptive statistics of the sample stock returns are presented in Tables 2a, 2b, and 2c below.

Table 2a. Descriptive statistics of daily returns – large cap stocks

	TCS	*Infosys Tech*	*Wipro Tech*	*HCL Tech*	*Tech Mahindra*	*L & T Infotech*	*MindTree*	*Mphasis*	*Oracle Fin Serv*
Mean	0.17%	0.14%	0.07%	0.08%	0.18%	0.19%	0.20%	0.13%	-0.02%
Std Dev	1.63%	1.48%	1.40%	1.77%	1.94%	2.50%	2.62%	2.33%	1.64%
Sharpe	**0.0898**	**0.0738**	0.0302	0.0317	**0.0795**	**0.0669**	**0.0673**	0.0465	-0.0288
Skewness	0.2911	-0.1829	-0.0830	-0.7078	0.0314	0.6378	-0.8777	0.3736	0.1638
Max.	6.41%	4.21%	5.24%	4.93%	8.23%	11.32%	9.18%	9.12%	5.42%
Min.	-5.57%	-4.66%	-4.15%	-7.77%	-7.26%	-7.68%	-18.36%	-6.17%	-5.25%

Table 2b. Descriptive statistics of daily returns – mid cap stocks

	Persistent Systems	*Firstsource*	*Cyient*	*Hexaware*	*Sonata Software*	*Zenstar Tech*
Mean	-0.03%	0.12%	0.02%	-0.02%	0.13%	0.13%
Std Dev	2.38%	2.87%	2.21%	2.76%	3.03%	2.66%
Sharpe	-0.0217	0.0316	-0.0008	-0.0149	0.0351	0.0394
Skewness	-1.5976	0.3610	0.5866	-1.0781	0.6683	0.5791
Max.	6.36%	11.42%	11.67%	12.89%	14.57%	12.74%
Min.	-16.64%	-7.98%	-6.70%	-15.65%	-10.90%	-8.99%

Table 2c. Descriptive statistics of daily returns – small cap stocks

	Eclerx	*NIIT Tech*	*Nucleus S/W Exp*	*Mastek*
Mean	-0.10%	0.23%	-0.14%	0.07%
Std Dev	1.87%	2.80%	2.61%	3.00%
Sharpe	-0.0677	**0.0721**	-0.0629	0.0162
Skewness	0.9943	-0.0943	0.7791	0.6979
Max.	9.85%	9.50%	13.12%	15.18%
Min.	-5.17%	-12.22%	-6.87%	-10.32%

The performance of the sample IT sector stocks varied considerably, with mean daily returns ranging between -0.14% and 0.23%, and the volatility of daily returns ranging between 1.40% and 3.03%. In terms of risk-adjusted excess returns (i.e. Sharpe ratio), several stocks outperformed the Nifty 50 index, which had a Sharpe ratio of 0.0626, particularly among the large-cap IT stocks. The best-performing stock was TCS, with a Sharpe ratio of 0.0898. Some of the sample stock returns were considerably negatively skewed, particularly HCL Technologies, Mindtree, Persistent Systems, and Hexaware, while Eclerx was considerably

positively skewed. Some very extreme negative daily returns and some very extreme positive daily returns were observed for several sample stocks: Mindtree (-18.36%), Persistent Systems (-16.64%), NIIT Technologies (-12.22%), Mastek (+15.18% and -10.32%), Sonata Software (+14.57% and -10.90%), Hexaware (+12.89% and -15.65%), Nucleus Software Exports (+13.12%), Zenstar Technologies (+12.74%), Cyient (+11.67%), Firstsource (+11.42%), and L&T Infotech (+11.32%).

The results of the KPSS tests for stationarity of the returns of the sample stocks are presented in Table 3 below.

Table 3. Results of the KPSS test for stationarity

	KPSS Stat	p-value
Nifty 50	0.0542	> 0.1000
TCS	0.1124	> 0.1000
Infosys Tech	0.0956	> 0.1000
Wipro Tech	0.1405	≈ 0.0630
HCL Tech	0.1322	≈ 0.0780
Tech Mahindra	0.1213	≈ 0.0970
L & T Tech	0.1027	> 0.1000
Mphasis	0.0667	> 0.1000
MindTree	0.0222	> 0.1000
Oracle Financials Services Software	0.1276	≈ 0.0860
Persistent Systems	0.1180	> 0.1000
Firstsource	0.0943	> 0.1000
Cyient	0.1175	> 0.1000
Hexaware	0.1245	≈ 0.0920
Sonata Software	0.0844	> 0.1000
Zenstar Tech	0.0590	> 0.1000
Eclerx	0.1441	≈ 0.0570
NIIT Tech	0.1100	> 0.1000
Nucleus Software Exports	0.1144	> 0.1000
Mastek	0.1322	≈ 0.0780

All of the sample stock daily returns and Nifty 50 daily returns were found to be stationary at 5% level of significance.

The results of the market model regressions are summarised in Table 4 below.

Table 4. Results of market model regressions

	alpha	beta	R^2	p-value
TCS	0.17%	0.2155	1.07%	0.1062
Infosys Tech	0.13%	0.1857	0.97%	0.1247
Wipro Tech	0.07%	0.0211	0.01%	0.8537
HCL Tech	0.08%	0.0387	0.03%	0.7889
Tech Mahindra	0.17%	0.2488	1.01%	0.1168
L & T Tech	0.19%	0.1620	0.26%	0.4284
Mphasis	0.13%	0.1855	0.39%	0.3316
MindTree	0.19%	0.3313	0.99%	0.1212
Oracle Financials Services Software	-0.02%	0.1109	0.28%	0.4073
Persistent Systems	-0.04%	0.3765	1.53%	0.0529
Firstsource	0.12%	-0.0919	0.06%	0.6956
Cyient	0.03%	-0.0995	0.12%	0.5827
Hexaware	-0.01%	-0.0783	0.05%	0.7292
Sonata Software	0.13%	0.2215	0.33%	0.3721
Zenstar Tech	0.12%	0.3525	1.08%	0.1044
Eclerx	-0.10%	-0.0331	0.02%	0.8290
NIIT Tech	0.24%	-0.3358	0.88%	0.1428
Nucleus Software Exports	-0.14%	0.1263	0.14%	0.5552
Mastek	0.07%	0.2339	0.37%	0.3415

It was found that none of the market model regressions were statistically significant at 5% level of significance, with the highest R^2 at 1.53%. Further, the beta estimates were found to be relatively low and statistically insignificant. Thus, the market model was not adequate in explaining stock returns for IT sector stocks.

The results of the vector autoregressive model regressions are summarised in Table 5 below.

Table 5. Results of vector autoregressive model regressions

	alpha	phi_1	$beta_M$	$beta_{M(-i)}$	R^2	p-value
TCS	0.16%	-0.0540	0.2066	0.4363**	5.52%	0.0034
Infosys Tech	0.12%	-0.0400	0.1664	0.6353**	8.83%	0.0001
Wipro Tech	0.06%	0.0414	0.0186	0.3111**	3.24%	0.0328
HCL Tech	0.06%	-0.0482	0.0165	0.5252**	5.62%	0.0030
Tech Mahindra	0.16%	-0.0331	0.2163	0.5852**	6.44%	0.0002
L & T Tech	0.16%	-0.0023	0.1387	0.9145**	8.47%	0.0001
Mphasis	0.12%	-0.0201	0.1711	0.3856**	2.06%	0.0448
MindTree	0.17%	0.0073	0.3050	0.8405**	7.35%	0.0004
Oracle Financials Services Software	-0.04%	-0.1288*	0.0898	0.5304**	7.96%	0.0002
Persistent Systems	-0.06%	-0.0180	0.3541*	0.6599**	6.15%	0.0016
Firstsource	0.08%	0.0718	-0.1252	1.1600**	10.47%	0.0000
Cyient	0.01%	-0.0077	-0.1271	0.6051**	4.73%	0.0086
Hexaware	-0.03%	-0.0371	-0.0913	0.7862**	5.16%	0.0052
Sonata Software	0.06%	0.1228*	0.1521	1.3842**	15.07%	0.0000
Zenstar Tech	0.08%	0.1038*	0.3265	0.7718**	7.82%	0.0002
Eclerx	-0.12%	-0.0072	-0.0596	0.5064**	4.52%	0.0111
NIIT Tech	0.19%	0.0593	-0.3556	1.1867**	11.80%	0.0000
Nucleus Software Exports	-0.17%	0.0708	0.0829	1.1300**	12.26%	0.0000
Mastek	0.05%	-0.0013	0.1891	1.1989**	10.08%	0.0000

The optimal lag structure minimising the AIC was found to be p = q = 1 for all of the vector autoregressive models. It was found that all of the vector autoregressive model regressions were statistically significant at 5% level of significance, with R^2 in the range of 2.06% to 15.07%. Further, the beta estimates for one-day lagged Nifty 50 returns were all found to be statistically significant at 1% level of significance. Thus, the vector autoregressive model was adequate in explaining stock returns for IT sector stocks.

The results of the nested F-tests are summarised in Table 6 below.

Table 6. Results of nested F-tests

	F Stat	p-value
TCS	5.6520	0.0040
Infosys Tech	10.3455	0.0000
Wipro Tech	4.0058	0.0194
HCL Tech	7.1074	0.0010
Tech Mahindra	6.9645	0.0011
L & T Tech	10.7637	0.0000
Mphasis	3.1396	0.0451
MindTree	8.2375	0.0003
Oracle Financials Services Software	10.0130	0.0001
Persistent Systems	5.9073	0.0031
Firstsource	13.9529	0.0000
Cyient	5.8067	0.0034
Hexaware	6.4656	0.0018
Sonata Software	20.8266	0.0000
Zenstar Tech	8.7741	0.0002
Eclerx	5.6556	0.0040
NIIT Tech	14.8571	0.0000
Nucleus Software Exports	16.5762	0.0000
Mastek	12.9582	0.0000

It was found that the vector autoregressive model was significant over the market model for all sample stocks at 5% level of significance.

Discussion

The results of the study suggest that the vector autoregressive model is a better model of stock returns than the market model. Specifically, as the one-day lagged Nifty 50 returns were found to be statistically significant at 1% level of significance, IT sector stocks seem to react more to market movements from the previous day than on the day itself. This could be due to the relative isolation of IT stocks from domestic economic shocks, as their customer base is primarily the American and European markets.

The implication for asset pricing modelling is that systematic risk may be further decomposed into a component corresponding to sensitivity to market movements on the day and a component corresponding to sensitivity to market movements on the previous day. The asset pricing model would be extended to include market risk premia for both of these components of systemic risk. This would need to be formalised theoretically and tested empirically in other sectors.

There are some limitations inherent in the study. The sample size for the study was relatively small, only nineteen stocks in the IT sector, and the research period was very short, only one year. Thus, the results of the study may not be generalisable. Additionally, the data of the sample stocks may contain many outliers, as there were several stocks with very extreme positive and negative daily returns, which may have affected the significance of the market model regressions. There is also the possibility of multicollinearity, as there may be significant autocorrelation in index returns, and heteroskedasticity. The latter may require a GARCH model approach. Also, the highest R^2 attained using the vector autoregressive model was a little above 15%, suggesting that there is scope to include other factors to improve the explanatory power. In particular, for the IT sector, exchange rates would be expected to play a major role. Further, other indices may be more appropriate than the Nifty 50 index; for example the Nifty-IT index or even the S&P 500 index. Other macroeconomic variables may also play an important role. These should be investigated in future studies.

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