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A Study of Causal Relationship Between S & P Bse Sensex, S & P BSE Small Cap and S & P BSE 100: A Multivariate Time Series Analysis

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ABSTRACT

Present study aims at analyzing the causal relationship between S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100. The study considers data for the time period from 2 July, 2012 to 31 October, 2013 to examine existence of any feed-back or lead-lag relation between these price indices which will facilitate understanding how any two price indices are affecting each other and up to what time period a particular price index have its effect on the other price index series. In this analysis, Vector Autoregressive Model (VAR model) and Vector Error Correction Model (VECM) are estimated for the given price indices. First, we checked for stationarity of all three price series and it is found that they are non-stationary, therefore, first-difference series or return series are considered for the analysis. Secondly, using Akaike Information Criteria, Bayesian Information Criteria and Hannan Quinn Information Criteria, a 3-variate VAR (1) model is chosen. Also, using Johansen and Juselius Test for Cointegration VECM (1,1) is selected.

KEYWORDS: S & P BSE Sensex, S & P BSE Small Cap, S & P BSE 100, Vector Autoregressive Model (VAR model) and Vector Error Correction Model (VECM).

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INTRODUCTION

In past two decades, there has been a significant improvement in information and communication technology sector. Accessibility to information and data on stock prices and indices has improved drastically as a result of widespread use of internet. This information gets incorporated into individuals' decisions and actions who are actively participating in stock market.As a result, we can expect existence of some sort of relationship (either lead-lag or feed-back relation) between any two stock price series.In this paper, we will try to find out existence of a causal relationship between the three prices (or equity) indices from *Bombay Stock Exchange* by determining an appropriate *Vector Autoregressive Model (VAR model)* that studies the short run dynamics of the model. Also, we will try to fit a*Vector Error Correction Model (VECM)* that focuses upon the long run dynamics of the model for three price index series that are considered for this study.

Price Indices

In this paper, we have considered three price index series from Bombay Stock Exchange[1]. The indices that are considered include S & P BSE Sensex, S & P BSE Small Cap and S& P BSE 100 for time period 2 July, 2012 to 31 October, 2013.

Bombay Stock Exchange

More than 5000 companies are listed on BSE making it world's number one exchange in terms of listed members. The companies listed on BSE Ltd. command a total market capitalization of 1.32 Trillion US dollar as of January 2013. It is also one of the world's leading exchangesforindex options trading. BSE also provides a host of other services to capital market participants including risk management, clearing, settlement, market data services and education. It has a global reach with customers around the world and a nationwide presence. BSE systems and processes are designed to safeguard market integrity, drive the growth of the Indian capital market and stimulate innovation and competition across all market segments.

BSE's popular equity index *S&P BSE Sensex*is India's most widely tracked stock market benchmark index. It is traded internationally on the EUREX as well as leading exchanges of the BRCS nations (Brazil, Russia, China and South Africa). Other popular equity indices of BSE are*S & P BSE Small Cap, S & P BSE 100 and S & P BSE 200.*

Data Summary

Data summary or statistics for the three price indices - *S & P BSE Small Cap, S & P BSE 100 and S & P BSE 200*is presented in following table:

Table 1: Summary Statistics

Price Index	**S & P BSESensex**	**S & P BSE Small Cap**	**S & P BSE 100**
Number of Observations	333	333	333
Mean	19044.07	6347.325	5750.229
Standard Deviation	925.0809	687.4241	278.3899
Variance	855774.8	472551.9	77500.92
Skewness	-.4202242	.0779639	-.4721317
Kurtosis	2.657272	1.837152	2.288105

From table 1, we can infer that all three price series are platikurtic since coefficient of kurtosis is less than 3 for all three of them. Also, S & P BSE Sensex and S & P BSE 100 series are negatively skewed while S & P BSE small cap series is positively skewed.

Plot For Price Index Series

1) Plot for S & P BSE Sensex:

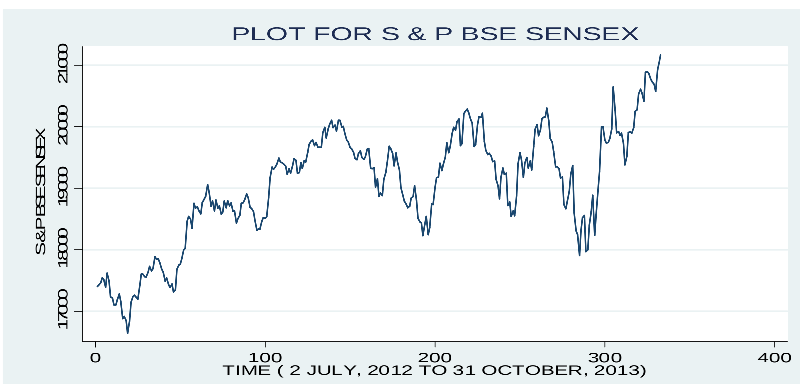

Figure 1: S & P BSE Sensex daily series during 2 July, 2012 and 31 October, 2013

Plot for S & P BSE SENSEX shows an upward trend for the selected time period despite occurrence of some fluctuations.

2) Plot forS & P BSE small cap:

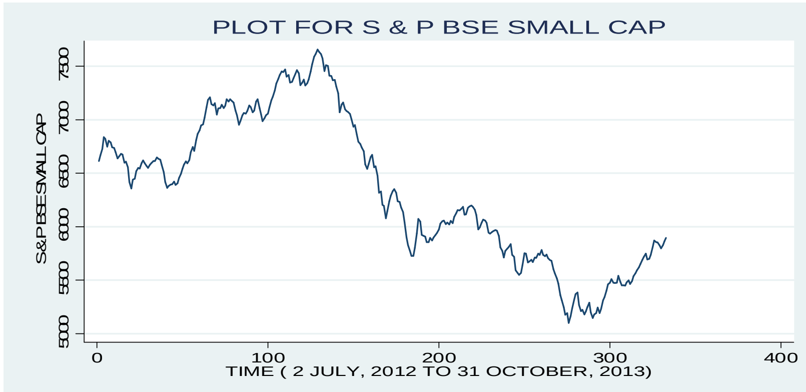

Figure 2: S& P BSE small cap daily series during 2 July, 2012 and 31 October, 2013

Plot for S & P BSE small cap shows initially an upward trend and then a downward trend for the selected time period despite occurrence of some fluctuations.

3) Plot for S & P BSE 100:

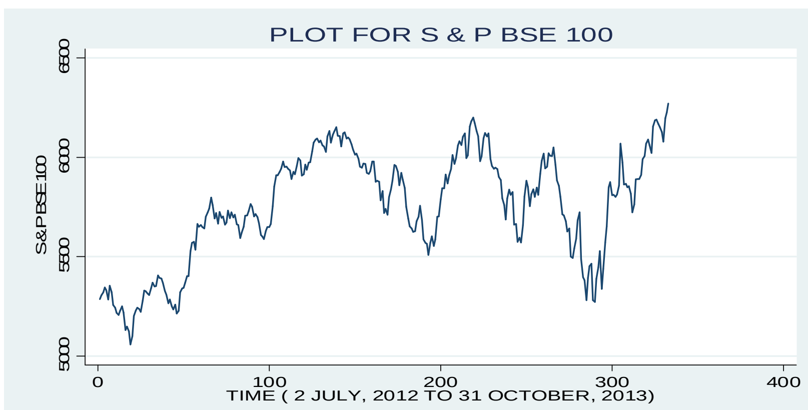

Figure 3: S & P BSE 100 daily series during 2 July, 2012 and 31 October, 2013

Plot for S & P BSE 100 shows initially an upward trend and then a random trend for the selected time period. This series has more frequent ups and downs as compared to previous series.

The plots for all three price indices depict presence of non-stationarity and this property is checked for using Augmented Dickey-Fuller unit-root test and Phillips-Perron unit-root test in next section.

METHODOLOGY

In this paper, we attempt to determine whether there is existence of any causal that is, lead-lag or feed-back relationshipbetween the three price indices discussed above. The study refers to the books by Anderson(1992)[2],Lutkepohl (2007)[3], Mills and Markellos (2008)[4] and Tsay(2005)[5] for conducting multivariate time series analysis.

Stationarity Test

The first step is to *check for stationarity* of each of the price series using *Augmented Dickey-Fuller unit-root test*and *Phillips-Perron unit-root test.*

Augmented Dickey-Fuller Test

The unit root test is then carried out under the null hypothesis γ = 0against the alternative hypothesis of γ > 0. The test statistic is given by following formula:

$$DF_{\tau} = \frac{\bar{\Upsilon}}{SE(\bar{\Upsilon})}$$

This test is computed and is compared to the relevant critical value for the Augmented Dickey-Fuller Test. If the test statistic is less (this test is non symmetrical so we do not consider an absolute value) than the (larger negative) critical value, then the null hypothesis of γ = 0 is rejected and we conclude that no unit root is present.

We also select appropriate order of integration for all the three price seriesandmake themstationary. And then we fit an appropriate *Vector-Autoregression Model (VAR model).* Now, we will discuss a *standard m-variate VAR(p) model*.

A 'm-variate'VAR(p) model

A standard m-variate VAR(p) model has following form:

$$X_t = C + \phi^1 X_{t-1} + \phi^2 X_{t-2} + \dots\dots\dots + \phi^P X_{t-p} + \varepsilon_t$$

where,$X_t$is *mx1* vector of m variables

$\phi^P$is coefficient matrix for X_{t-p}variable (p = 1,2,…p)

$C$is*mx1* vector of constants

$\varepsilon_t$is*mx1* vector of error terms

Selecting An Appropriate VAR Model

To select an appropriate VAR model following criterionis used. Appropriate model is chosen on the basis of the values of AIC and BIC. The model that has minimum value for AIC and BIC is chosen as appropriate VAR model.

Akaike Information Criteria (AIC)

This criterion uses the following formula for choosing appropriate value of i which minimizes the value of AIC. AIC(i) is given by following formula:

$$\mathrm{AIC(i)} = \ln(|\Sigma i|) + \frac{2m^2 i}{T}$$

Bayesian Information Criteria (BIC)

This criterion uses the following formula for choosing appropriate value of i which minimizes the value of BIC. Note BIC imposes a higher penalty than AIC and thus tends to choose a lower value of i. BIC(i) is given by following formula:

$$\mathrm{BIC(i)} = \ln(|\Sigma i|) + \frac{m^2\ i(lnT)}{T}$$

Hannan Quinn Information Criteria(HQIC)

This criterion uses the following formula for choosing appropriate value of i which minimizes the value of HQIC. HQIC(i) is given by following formula:

$$HQIC(i) = ln(|\Sigma i|) + \frac{2m^2\ i\ ln(lnT)}{T}$$

Where,i is the order of lags for the VAR model, m is the number of variables considered for generating the corresponding VAR model, T is the number of observation of each variable and $\Sigma_i$is the variance-covariance matrix for corresponding VAR(i) model.

To confirm whether the correct VAR(i) model is chosen by above mentioned criterion or not we do a diagnostic test i.e., we check for white noise of residual terms for the chosen VAR(i) model using Jarque-Bera test statistic or Portmanteau test.

Granger's Causality Test

To check for presence of any causal relationship, we conduct a Granger's Causality Test.Consider any two time series say, X_t and Y_t, where X_t is defined by following equation:

$$X_t = \rho_1 X_{t-1} + \cdots \ldots \ldots . + \rho_p X_{t-p} + \beta_1 Y_{t-1} \ldots \ldots \ldots + \beta_p Y_{t-p} + \varepsilon_t$$

The null hypothesis under granger's causality test states that$Y_t$does not granger cause X_t i.e. $\beta_1 = \beta_2 = \ldots\ldots\ldots. = \beta_p = 0$.The test follows a chi-square distribution with p degrees of freedom.Here, if test statistic is greater than the critical value then we reject the null hypothesis and conclude that $Y_t$granger causes X_t.Note, if Y_t does not granger cause X_t then we say that Y_t is exogenous to X_t.

Orthogonalized-Impulse Response Functions

The study analyzes*Orthogonalized-Impulse Response Functions (OIRFs)*to explain the behavior of the series with respect to a shockthat occurs in any of the series and see how long does it take for a shock to die away.

Finally, we fit an appropriate *Vector Error Correction Model (VECM)* to study long run behavior of the model and find cointergration rank for the corresponding non-stationary price series.

Cointegration Rank

*Johansen and Juselius test for cointegration*is performed to find an appropriate rank of cointergration for the three price index series.

Hypothesis stating that rank is r is not rejected if the value of *Trace Statistic*is less than the critical value at an appropriate level of significance.

$$Trace\ Statistic, \qquad Q_r = -2\ln\left({L_{Hr}}/{L_{Hr+1}} \right) = -T\ln(1 - \lambda_{r+1})$$

Where, L_H is likelihood function, λ is the ratio of likelihood functions and T is number of observations.

Vector Error Correction Model

A VEC model can be represented by following equation:

$$\Delta Xt = \pi + \alpha\beta' X(t-1) + \varphi^1 \Delta X(t-1) + \ldots \ldots . + \varphi^p \Delta X(t-p) + \varepsilon(t)$$

Where, α is speed of adjustment towards long run equilibrium, $\varepsilon(t)$ is white noise. Also, α and β are full rank matrices.

RESULTS

Augmented Dickey-Fuller Unit-Root Test And Phillips-Perron Unit-Root Test

The results of Augmented Dickey-Fuller unit-root test and Phillips-Perron unit-root test for the three price indices - S & P BSE Sensex, S & P BSE Small CAP and S& P BSE 100 are represented by following table:

Table 2: Results of Test for Stationarity for Price Series

Price Index	Test	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	MackinnonApproximate P-Value
S & PBSE Sensex Prices	ADF	-1.874	-3.455	-2.878	-2.570	0.3444
	PP	-6.404	-20.366	-14.000	-11.200	0.4528
S & P BSE Small Cap Prices	ADF	-1.210	-3.455	-2.878	-2.570	0.6695
	PP	-2.101	-20.366	-14.000	-11.200	0.7564
S & P BSE 100 Prices	ADF	-2.254	-3.455	-2.878	-2.570	0.1873
	PP	-8.300	-20.366	-14.000	-11.200	0.2881

Above table shows that all three price indices S & P BSE Sensex, S & P BSE Small Cap and S& P BSE 100 are*non-stationary at 5% significance level* i.e. the test statistic value for Augmented Dickey-Fuller unit-root test and Phillips-Perron unit-root test is lesser than the critical value, therefore, we do not reject the hypothesis of non-stationarity and infer that all the three price indices are non-stationary.

For fitting an appropriate VAR model we will have to make these price indices stationary i.e. we will difference it. The *first differnced series* has following formula:

$$r_t = \log\left({P_t}/{P_{t-1}} \right) * 100$$

where, r_t is the return series for corresponding price index series.

The results of Augmented Dickey-Fuller unit-root test and Phillips-Perron unit-root test for the return series of the corresponding price index are represented by following table:

Table 3: Results of Test for Stationarity for Return Series

Series	**Test**	**Test Statistic**	**1% Critical Value**	**5% Critical Value**	**10% Critical Value**	**Mackinnon Approximate P-Value**
S & P BSE Sensex Returns	ADF	-4.862	-3.455	-2.878	-2.570	0.0000
	PP	-264.928	-20.365	-14.000	-11.200	0.0000
S & P BSE Small Cap Returns	ADF	-3.009	-3.455	-2.878	-2.570	0.0002
	PP	-224.291	-20.365	-14.000	-11.200	0.0000
S & P BSE 100 Returns	ADF	-4.485	-3.455	-2.878	-2.570	0.0340
	PP	-276.319	-20.365	-14.000	-11.200	0.0000

Above table shows that return series for all three price indices S & P BSE Sensex, S & P BSE Small Cap and S& P BSE 100 are *stationary at 5% significance level* i.e. the test statistic value for Augmented Dickey-Fuller unit-root test and Phillips-Perron unit-root test is greater than the critical value, therefore, we reject the hypothesis of non-stationarity and infer that all the three return series or first differenced series for the price indices are stationary.

Plot for First Differenced Series for the Price Indices

1) Plot for First Difference Series of S & P BSE Sensex:

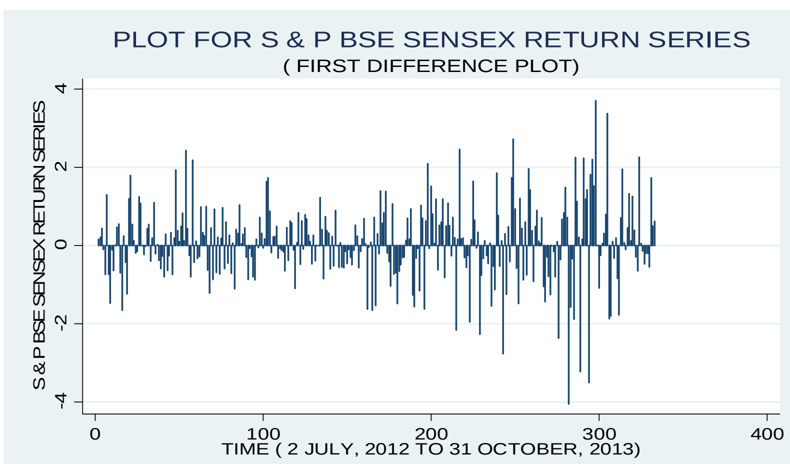

Figure 4: S & P BSE Sensex return series during 2 July, 2012 and 31 October, 2013

Plot for S & P BSE Sensex return series depicts stationarity.

2) Plot for First Difference Series of S & P BSE Small Cap:

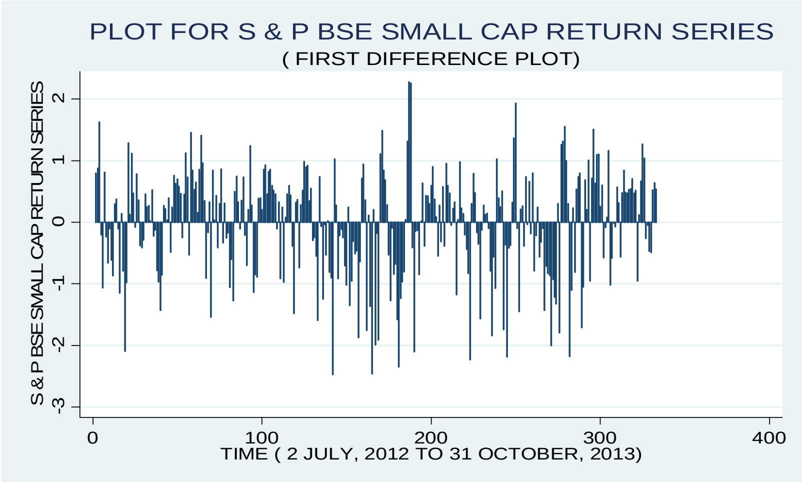

Figure 5: S & P BSE Small Cap return series during 2 July, 2012 and 31 October, 2013

Plot for S & P BSE Small Cap return series depicts stationarity property.

3) Plot for First Difference Series of S & P BSE 100:

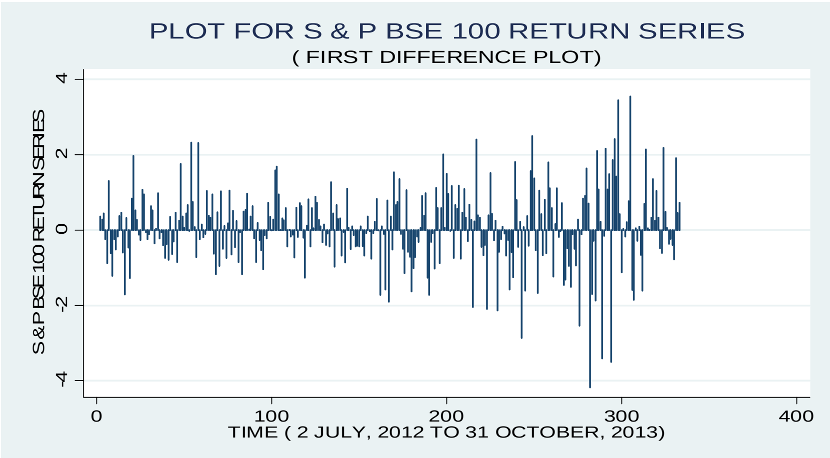

Figure 6: S & P BSE 100 return series during 2 July, 2012 and 31 October, 2013

Plot for S & P BSE 100 return series depicts stationarity property.

Data Summary for the Return Series

Table 4: Data Summary – Return Series

Return	**BSE Sensex**	**BSE Small Cap**	**BSE 100**
Number of Observations	332	332	332
Mean	.0590102	-.0346658	.0514047
Standard Deviation	.9970354	.8568699	1.012339
Variance	.9940796	.7342261	1.02483
Skewness	-.1111614	-.4730622	-.1902524
Kurtosis	4.962624	3.129842	4.842355

From above table, we can infer that all the three return series are laptokurtic since coefficient of kurtosis is greater than 3 for all three of them. Also, all the three return series for S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100 are negatively skewed.

Cross-Correlograms

Now we analyze the plot for cross-correlogramto see how the return series for all three indices relate to each other.

1) Plot for Cross-Correlogram between S & P BSE Sensex and S & P BSE 100 return series:

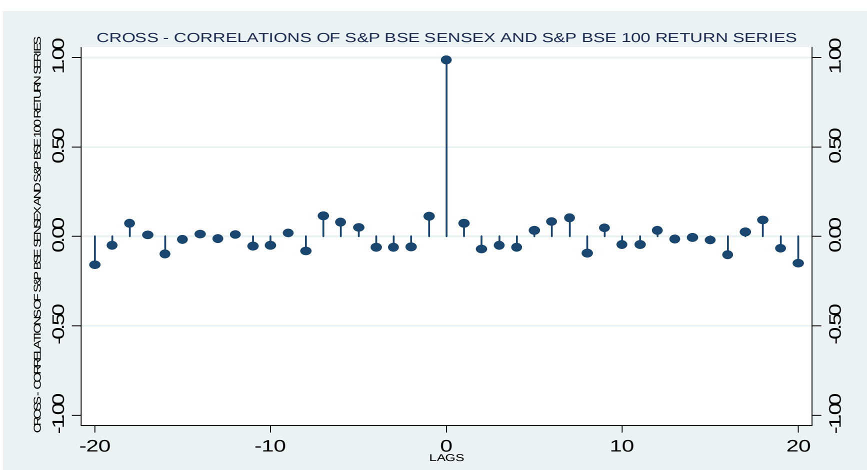

Figure 7: Cross-Correlogram - S & P BSE Sensex and S & P BSE 100 return series

Above plot depicts that the two return series are contemporaneously correlated and at all other lags these two series are correlated with a very low value of cross-correlations.

2) Plot For Cross-Correlogram between S & P BSE Sensex and S & P BSE Small Cap return series:

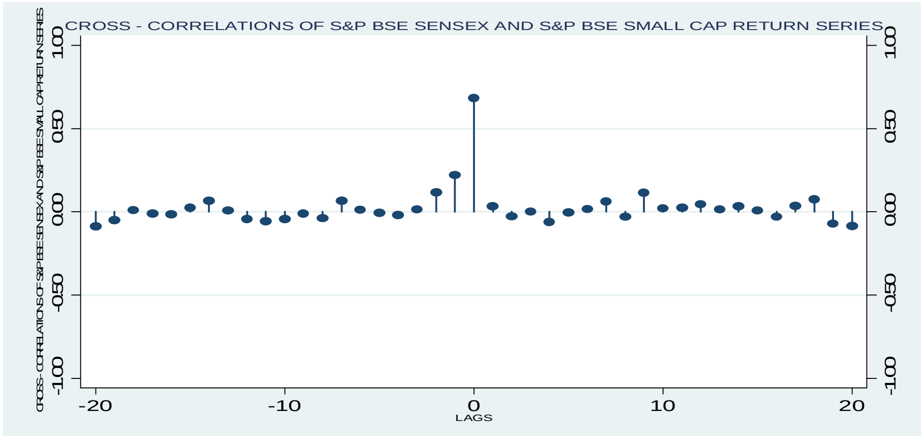

Figure 8: Cross-Correlogram - S & P BSE Sensex and S & P BSE Small Cap return series

Above plot depicts that the two return series are contemporaneously correlated and at lag 1 the two series are correlated and at all other lags these two series are correlated with a very low value of cross-correlations.

3) Plot for Cross-Correlogram between S & P BSE 100 And S & P BSE Small Cap return series:

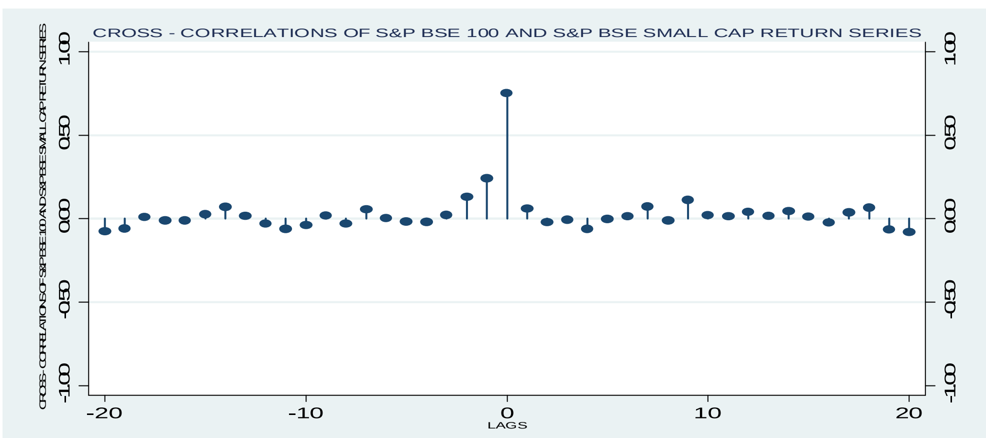

Figure 9: Cross-Correlogram - S & P BSE 100and S & P BSE Small Cap return series

Above plot depicts that the two return series are contemporaneously correlated and at lag 1 also the two series are correlated and at all other lags these two series are correlated with a very low value of cross-correlations.

Selection of an Appropriate VAR Model

Following table shows the coefficients of the lagged variables in our 3-variate VAR(p) model: (Note: Following table shows values of only significant coefficients upto 20 lags.)

Table 5: Coefficients of the Lagged Variables

Return Series	Lags	Coefficient	Standard Error	Z Value	P> |Z|
S & P BSE Sensex Return – S & P BSE Sensex Return	5	1.250997	.4139912	3.02	0.003
	9	-1.180324	.4252742	-2.78	0.006
	20	-1.310944	.4282488	-3.06	0.002
S & P BSE Sensex Return – S & P BSE Small Cap Return	14	.2566843	.1306602	1.96	0.049
S & P BSE Sensex Return – S & P BSE 100 Return	5	-1.292849	.4516627	-2.86	0.004
	9	1.152949	.4628697	2.49	0.013
	20	1.203777	.4686002	2.57	0.010
S & P BSE Small Cap Return – S & P BSE Sensex Return	9	-1.205898	.3545783	-3.40	0.001
	20	-.9893957	.3570583	-2.77	0.006
S & P BSE Small Cap Return – S &P Be Small Cap	1	.2185508	.1065337	2.05	0.040
	16	.2582591	.1099769	2.35	0.019
	18	-.2677268	.1098797	-2.44	0.015
S & P BSE Small Cap Return – S & P BSE 100 Return	9	1.190188	.385924	3.08	0.002
	20	.9717881	.390702	2.49	0.013
S & P BSE 100 Return – S & P BSE Sensex Return	5	1.22574	.4229738	2.90	0.004
	9	-1.290372	.4345017	-2.97	0.003
	18	-.9311807	.4405397	-2.11	0.035
	20	-1.381986	.4375408	-3.16	0.002
S & P BSE 100 Return – S & P BSE Small Cap Return	14	.2794528	.1334953	2.09	0.036
S & P BSE 100 Return – S & P BSE 100 Return	5	-1.265535	.4614627	-2.74	0.006
	9	1.278219	.4729129	2.70	0.007
	18	1.022168	.4844138	2.11	0.035
	20	1.281402	.4787678	2.68	0.007

Following table shows the value of **AIC**, **BIC** and **HQIC** tests for **3-variate VAR(p) model:**

Table 6: AIC, BIC and HQIC tests for 3-variate VAR(p) model

Lag	LL	LR	DOF	PValue	FPE	AIC	HQIC	SBIC
0	-535.99	.	.	.	.005369	3.28653	3.30037	3.32122
1	-493.209	85.562*	9	0.000	.00437*	3.08054*	3.13591*	3.21931*
2	-486.196	14.027	9	0.121	.004423	3.09266	3.18954	3.3355
3	-484.289	3.8125	9	0.923	.004619	3.13591	3.27432	3.48283
4	-480.101	8.3759	9	0.497	.004756	3.16525	3.34519	3.61625

Where LL – log likelihood, LR – likelihood ratio, DOF – degrees of freedom, FPE – final prediction error, AIC – Akaike information criteria, HQIC - Hannan Quinn information criteria, SBIC –Schwarz'sbayesian information criteria.

Above tests shows that the values of AIC, BIC and HQIC statistics get minimized at lag one. *Therefore, we conclude that VAR model is of lag one order i.e. we have a three-VARIATE VAR(1) MODEL for S & P BSE SENSEX, S & P BSE SMALL CAP and S & P BSE 100 return series.*

Diagnostic Test

Diagnostic test is conducted to confirm the accurateness of selection of order of lag for the VAR model. The jarque bera test for disturbance term, have all p values > 0.05 indicating that the disturbance term is white noise. Following table shows p values for each equation of the three-variate VAR(1) model:

Table 7: Diagnostic Test Results

Equation	**P Value**
S & P BSE Sensex Return	0.75812
S & P BSE Small Cap Return	0.56473
S & P BSE 100 Return	0.67595
All	0.62891

Above table shows that all the p values for all three equations of our 3-variate VAR(1) model are greater than 0.05 indicating that disturbance terms are white noise.

Stability Check for VAR Model

To check for stability of the VAR model, we check whether all eigenvalues lie inside the unit circle or not. The eigenvalues are .3199234, .06079747 + .1145976i and .06079747 - .1145976i. Since all the eigenvalues lie inside the unit circle, we conclude that the VAR model satisfies stability condition.

3-Variate VAR(1) Model for S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100 return series is described by following equations:

$$Sensex_t = .1642321 + .2456958\, Sensex_{t-1} + .0085958\, smlcp_{t-1} - .1680642\, bse100_{t-1} + \varepsilon_t$$

$$smlcp_t = .0641246 - .4803429\, Sensex_{t-1} + .2185508\, smlcp_{t-1} + .5024542\, bse100_{t-1} + \varepsilon_t$$

$$bse100_t = .1559477 + .1677478\, Sensex_{t-1} + .0157094 smlcp_{t-1} - .0781418\, bse100_{t-1} + \varepsilon_t$$

where, Sensex represents S & P BSE Sensex return,smlcp represents S & P BSE small cap return,bse100 represents S & P BSE 100 return and $\varepsilon_t$is the residual term.

Granger's Causality Test

Following table shows results for granger's causality test:

Table 8: Granger's Causality Test

Equation	**Excluded**	**Chi-Square**	**P > Chi-Square**
S & P BSE Sensex Return	S & P BSE Small Cap Return	23.844	0.249
S & P BSE Sensex Return	S & P BSE 100 Return	42.136	0.003
S & P BSE Sensex Return	All	75.089	0.001
S & P BSE Small Cap Return	S & P BSE Sensex Return	41.883	0.003
S & P BSE Small Cap Return	S & P BSE 100 Return	41.012	0.004
S & P BSE Small Cap Return	All	73.191	0.001
S & P BSE 100 Return	S & P BSE Sensex Return	47.151	0.001
S & P BSE 100 Return	S & P BSE Small Cap Return	21.619	0.362
S & P BSE 100 Return	All	75.52	0.001

Above test results show:

- S & P BSE Sensex granger causes S & P BSE Small Cap and S & P BSE 100 since both the p values are less than 0.05.
- S & P BSE Small Cap does not granger causesS & P BSE Sensex and S & P 100 since the p values are greater than 0.05.
- S & P BSE 100 granger causes S & P BSE Sensex and S & P BSE Small Cap since p values are less than 0.05.

Orthogonalized-Impulse Response Functions (OIRFs)

The orthogonalized-impulse response functions (OIRFs) show how a shock in a particular series affects the other series and how its affect die over time. The *orthogonalized-impulse response functions (OIRFs)*for the three-variate VAR(1) model are represented by following graphs:

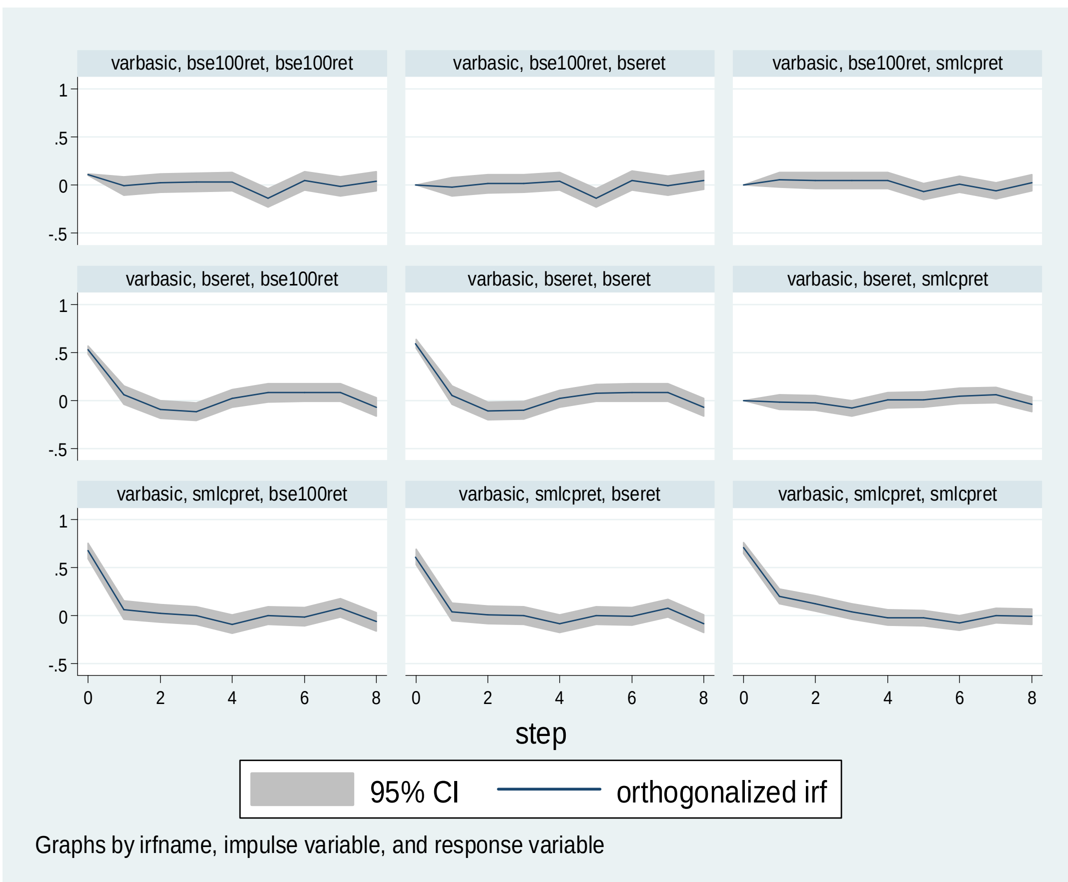

Figure 10: Orthogonalized-Impulse Response Functions

In graph: bse100ret is S & P BSE 100 Return Series, bseret is S & P BSE Sensex Return Series and smlcpret is S & P BSE Small Cap Return Series.

Above orthogonalized-impulse response functions show:

- A shock in S & P BSE 100 does not affect any of the series and it dies down rapidly.
- A shock in S & P BSE Sensex affects its own evolution and also affects S & P BSE 100 though the effect of the shock dies down completely after 3-4 steps or lags. This shock does not affect the evolution of S & P BSE Small Cap.
- A shock in S & P BSE Small Cap affects its own evolution as well as the evolution of S & P BSE Sensex and S & P BSE 100 and its effect die down eventually after 6-7 steps or lags.

FITTING A VECTOR ERROR CORRECTION MODEL (VECM) FOR S & P BSE SENSEX, S & P BSE SMALL CAP AND S & P BSE 100 PRICE SERIES

For fitting a *Vector Error Correction Model (VECM)*for S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100 price series,we first compute cointegrating rank so as to find the number of long run relationships that exists for the model.

Checking for Cointegrating Rank of Price Index Series of S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100

Following table shows the results of Johansen and Juselius test for cointegration:

Table 9: Johansen and Juselius Test for Cointegration

Rank	Trace Statistic	5 % Critical Value
0	39.8608	29.68
1	8.5691*	15.41
2	0.0228	3.76

In above table, the test chooses cointegration rank of order 1 as the value of trace statistic is less than the critical value at 5% significance level.

The Johansen and Juselius test for cointegration concludes that there exists one long run relationship between the variables S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100 price index.

Now we fit an appropriate *VEC model(p,r)* for the price indices where p is the order of lag of VAR model chosen by AIC, BIC and HQIC statistics and r is cointergration rank.

Therefore, S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100 price indices are defined by VECM(1,1).

Following are the equations of VECM(1,1):

$$\Delta Sensex_t = 1.681027 + .0165279\ Sensex_{t-1} + .5697371\,\Delta\, Sensex_{t-1} + .0869666\,\Delta smlcp_{t-1} - 1.637193\Delta\, bse100_{t-1} + \varepsilon_t$$

$$\Delta smlcp_t = -4.642492 + .0059458\, smlcp_{t-1} - .0492066\Delta\, Sensex_{t-1} + .283679\,\Delta smlcp_{t-1} + .192412\ \Delta\, bse100_{t-1} + \varepsilon_t$$

$$\Delta bse100_t = -.0358938 + .0050235\, bse100_{t-1} + .1574799\,\Delta\, Sensex_{t-1} + .0317138\,\Delta smlcp_{t-1} - .4228768\,\Delta\, bse100_{t-1} + \varepsilon_t$$

Where, Sensex represents S & P BSE Sensex price index,smlcp represents S & P BSE Small Cap price index,bse100 represents S & P BSE 100 price index and ε_t is the residual term.

CONCLUSION

The S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100 price index series are found to non-stationary by augmented dickey-fuller test and phillips-perron test. Therefore, we differenced them to get a stationary series and again tested for stationarity and concluded that the first order difference series are stationary for three price indices.

The appropriate vector autoregression model(VAR model) for the three first differenced series is found to be VAR(1) using AIC, BIC and HQIC. Diagnostic test also confirms the accurateness of our lag order selection.

Granger's causality test concludes the following results:

- S & P BSE Sensex granger causes S & P BSE Small Cap and S & P BSE 100.
- S & P BSE Small Cap does not granger causes S & P BSE Sensex and S & P 100.
- S & P BSE 100 granger causes S & P BSE Sensex and S & P BSE Small Cap.

Therefore, we conclude that there is existence of causal relationships among S & P BSE Sensex, S & P BSE Small Cap and S & P BSE 100 price index series.

The appropriate vector error correction model(VECM) for the three non-stationary price indices is VECM(1,1). This model is chosen using Johansen and Juselius test for cointegration.

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