2015

TSAF Project – Dataset 4

Group 1:

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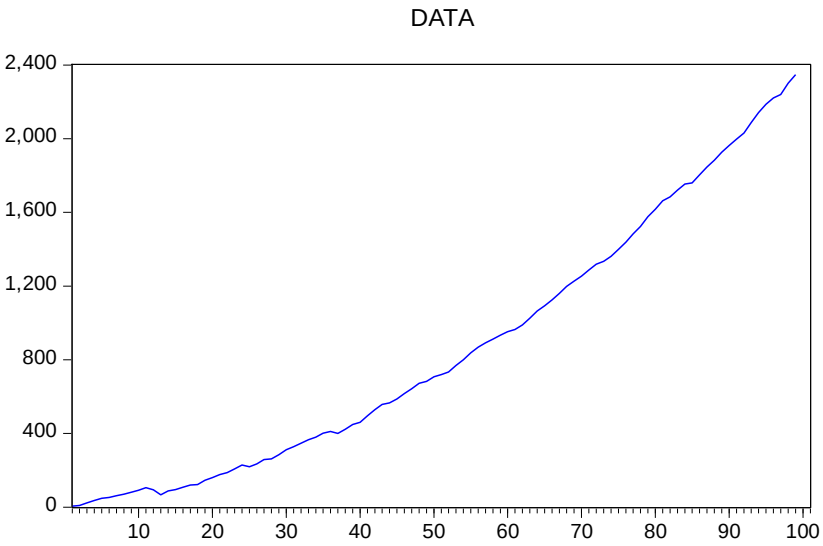
Exploratory analysis

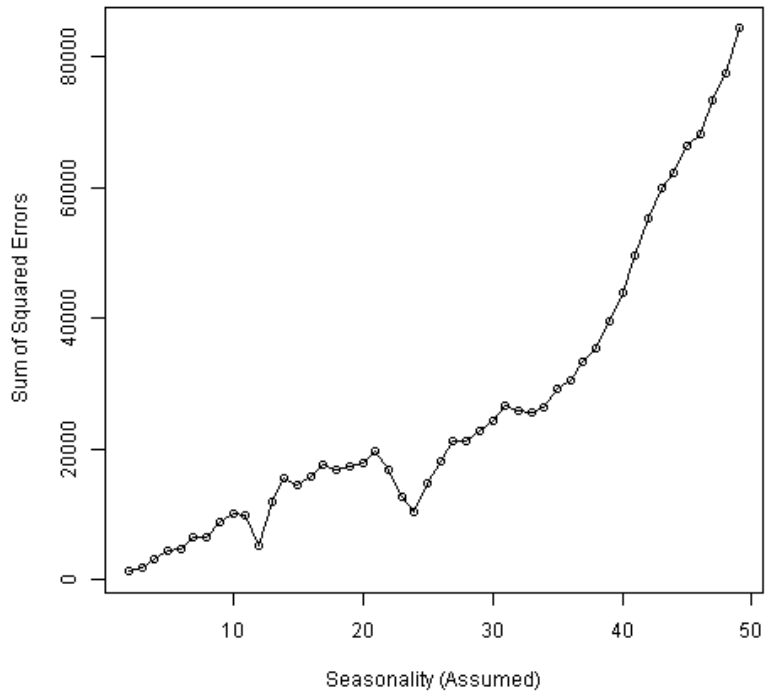
Trend



This graph shows that the trend is likely to be non-linear. Regressing the data against t and t^2 suggests that the trend is quadratic (higher order terms are insignificant)

Seasonality

Without assuming the period of seasonality, we used decompose function of R and generated a graph showing the trend, seasonality and residual series for different assumed seasonalities varying from 2 to floor(99/2)=49. In the absence of seasonality, the sum of squared residuals is expected to increase with seasonality.



This shows that the seasonality of the data is either 12 or 24. Period of seasonality will be confirmed in the steps that follow.

Modelling strategy

Estimation/Forecast 1: ARIMA (2,2,0) (12,0,0)

1. As suggested in the exploratory analysis, the trend is quadratic. This can be verified by finding order of integration (ADF test on level, 1st difference and 2nd difference). The series is I(2) in nature, which confirms the presence of quadratic trend

Table 1: ADF test on first differenced series

Null Hypothesis: D(DATA) has a unit root
Exogenous: Constant
Lag Length: 11 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.756046	0.8260
Test critical values:	1% level	-3.508326	
	5% level	-2.895512	
	10% level	-2.584952	

*MacKinnon (1996) one-sided p-values.

Table 2: ADF test on second differenced series

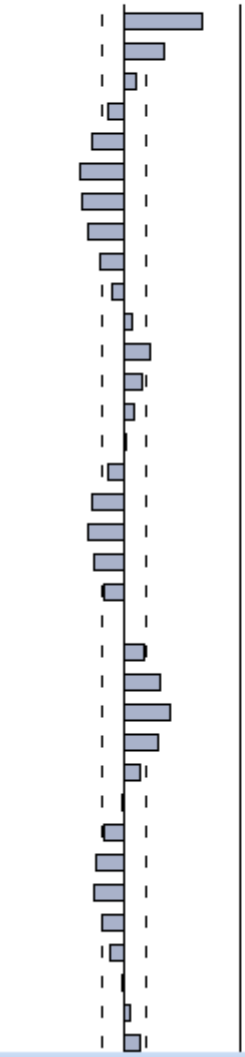
Null Hypothesis: D(DATA,2) has a unit root
Exogenous: Constant
Lag Length: 10 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.894673	0.0000
Test critical values:	1% level	-3.508326	
	5% level	-2.895512	
	10% level	-2.584952	

*MacKinnon (1996) one-sided p-values.

2. Correlogram of residue from regression (quadratic in t) shows presence of autoregressive effect in lags 1, 2 and seasonal (AR or MA) effect at lag 12

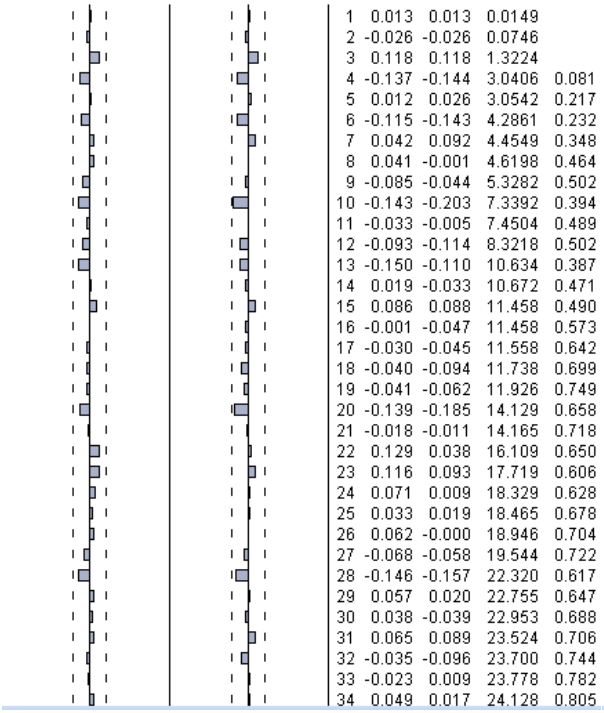
Date: 02/20/15 Time: 13:07
Sample: 1 101
Included observations: 99



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.702	0.702	50.252	0.000
		2	0.364	-0.254	63.883	0.000
		3	0.115	-0.057	65.249	0.000
		4	-0.140	-0.264	67.309	0.000
		5	-0.287	-0.036	76.092	0.000
		6	-0.395	-0.220	92.849	0.000
		7	-0.372	0.073	107.89	0.000
		8	-0.327	-0.200	119.64	0.000
		9	-0.220	0.103	125.04	0.000
		10	-0.100	-0.147	126.17	0.000
		11	0.073	0.276	126.78	0.000
		12	0.244	-0.076	133.61	0.000
		13	0.165	-0.242	136.79	0.000
		14	0.085	-0.022	137.64	0.000
		15	0.013	-0.056	137.66	0.000
		16	-0.150	-0.243	140.36	0.000
		17	-0.279	-0.117	149.88	0.000
		18	-0.326	-0.044	162.99	0.000
		19	-0.264	-0.024	171.71	0.000
		20	-0.173	-0.046	175.52	0.000
		21	-0.003	0.138	175.52	0.000
		22	0.173	0.006	179.38	0.000
		23	0.318	0.052	192.69	0.000
		24	0.411	-0.035	215.17	0.000
		25	0.299	-0.130	227.24	0.000
		26	0.145	-0.183	230.12	0.000
		27	-0.011	-0.119	230.14	0.000
		28	-0.183	-0.062	234.84	0.000
		29	-0.262	0.049	244.62	0.000
		30	-0.265	-0.025	254.77	0.000
		31	-0.189	0.118	260.01	0.000
		32	-0.121	-0.070	262.19	0.000
		33	-0.024	-0.024	262.27	0.000
		34	0.065	-0.195	262.93	0.000
		35	0.136	-0.037	265.81	0.000

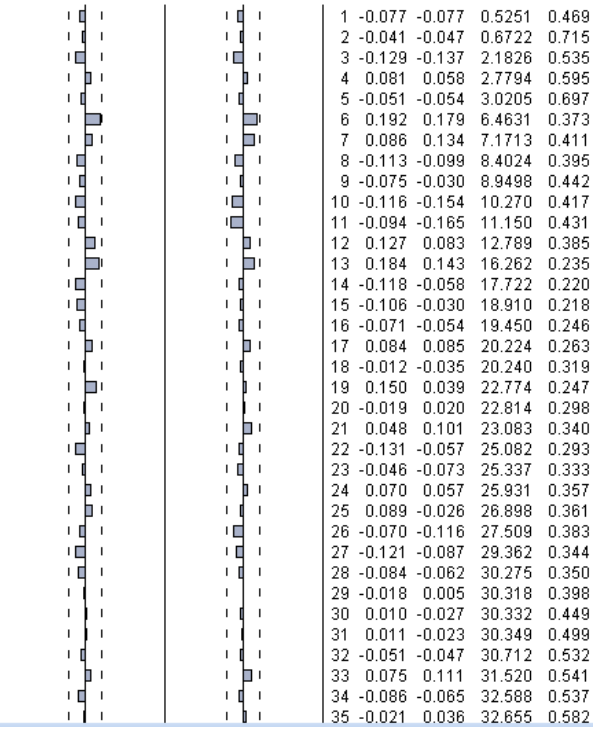
3. After regressing residual with AR(1), AR(2) and SAR(12), we observed that all the coefficients are significant and less than 1 and the reside has reached white noise (p-value(Q-stat)>.05). Correlogram of squared residue suggests that the errors are iid (p-value(Q-stat)>.05)

Date: 02/20/15 Time: 13:10
Sample: 1 101
Included observations: 85
Q-statistic probabilities adjusted for 3 ARMA terms



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.013	0.013	0.0149	
		2	-0.026	-0.026	0.0746	
		3	0.118	0.118	1.3224	
		4	-0.137	-0.144	3.0406	0.081
		5	0.012	0.026	3.0542	0.217
		6	-0.115	-0.143	4.2861	0.232
		7	0.042	0.092	4.4549	0.348
		8	0.041	-0.001	4.6198	0.464
		9	-0.085	-0.044	5.3282	0.502
		10	-0.143	-0.203	7.3392	0.394
		11	-0.033	-0.005	7.4504	0.489
		12	-0.093	-0.114	8.3218	0.502
		13	-0.150	-0.110	10.634	0.387
		14	0.019	-0.033	10.672	0.471
		15	0.086	0.088	11.458	0.490
		16	-0.001	-0.047	11.458	0.573
		17	-0.030	-0.045	11.558	0.642
		18	-0.040	-0.094	11.738	0.699
		19	-0.041	-0.062	11.926	0.749
		20	-0.139	-0.185	14.129	0.658
		21	-0.018	-0.011	14.165	0.718
		22	0.129	0.038	16.109	0.650
		23	0.116	0.093	17.719	0.606
		24	0.071	0.009	18.329	0.628
		25	0.033	0.019	18.465	0.678
		26	0.062	-0.000	18.946	0.704
		27	-0.068	-0.058	19.544	0.722
		28	-0.146	-0.157	22.320	0.617
		29	0.057	0.020	22.755	0.647
		30	0.038	-0.039	22.953	0.688
		31	0.065	0.089	23.524	0.706
		32	-0.035	-0.096	23.700	0.744
		33	-0.023	0.009	23.778	0.782
		34	0.049	0.017	24.128	0.805

Date: 02/20/15 Time: 13:10
Sample: 1 101
Included observations: 85



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.077	-0.077	0.5251	0.469
		2	-0.041	-0.047	0.6722	0.715
		3	-0.129	-0.137	2.1826	0.535
		4	0.081	0.058	2.7794	0.595
		5	-0.051	-0.054	3.0205	0.697
		6	0.192	0.179	6.4631	0.373
		7	0.086	0.134	7.1713	0.411
		8	-0.113	-0.099	8.4024	0.395
		9	-0.075	-0.030	8.9498	0.442
		10	-0.116	-0.154	10.270	0.417
		11	-0.094	-0.165	11.150	0.431
		12	0.127	0.083	12.789	0.385
		13	0.184	0.143	16.262	0.235
		14	-0.118	-0.058	17.722	0.220
		15	-0.106	-0.030	18.910	0.218
		16	-0.071	-0.054	19.450	0.246
		17	0.084	0.085	20.224	0.263
		18	-0.012	-0.035	20.240	0.319
		19	0.150	0.039	22.774	0.247
		20	-0.019	0.020	22.814	0.298
		21	0.048	0.101	23.083	0.340
		22	-0.131	-0.057	25.082	0.293
		23	-0.046	-0.073	25.337	0.333
		24	0.070	0.057	25.931	0.357
		25	0.089	-0.026	26.898	0.361
		26	-0.070	-0.116	27.509	0.383
		27	-0.121	-0.087	29.362	0.344
		28	-0.084	-0.062	30.275	0.350
		29	-0.018	0.005	30.318	0.398
		30	0.010	-0.027	30.332	0.449
		31	0.011	-0.023	30.349	0.499
		32	-0.051	-0.047	30.712	0.532
		33	0.075	0.111	31.520	0.541
		34	-0.086	-0.065	32.588	0.537
		35	-0.021	0.036	32.655	0.582

4. ARCH LM test suggests that there is no ARCH effect (null hypothesis cannot be rejected)

Table 3: ARCH test (12 lags)

Heteroskedasticity Test: ARCH

F-statistic	1.007144	Prob. F(12,60)	0.4539
Obs*R-squared	12.23901	Prob. Chi-Square(12)	0.4267

5. Dynamic forecast on the last 12 observations shows MAPE of 0.4732%
   Static forecast on the last 12 observations shows MAPE of 0.3376%

Estimation/Forecast 2: ARIMA (2,1,0) (12,1,0)

1. New series was generated by performing one difference and one seasonal difference simultaneously. The new series was found to be stationary
   Table 4: ADF test on detrended, deseasonalized series

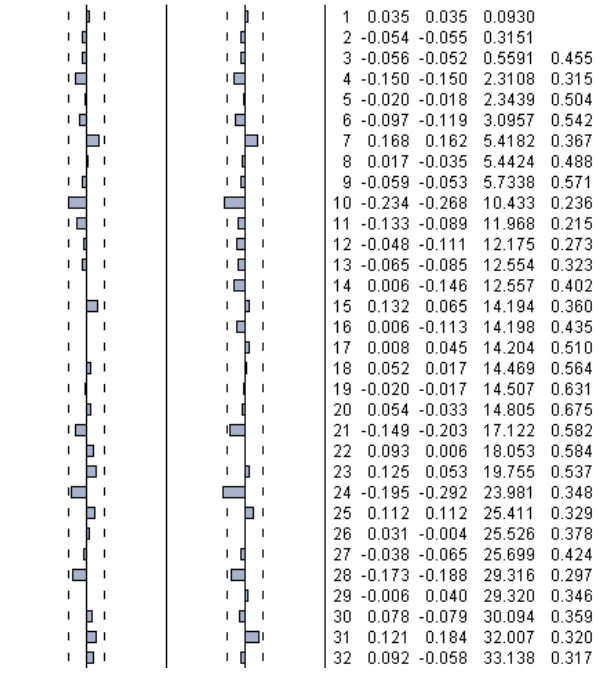
Null Hypothesis: DTDS has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.045251	0.0000
Test critical values:	1% level	-3.509281	
	5% level	-2.895924	
	10% level	-2.585172	

*MacKinnon (1996) one-sided p-values.

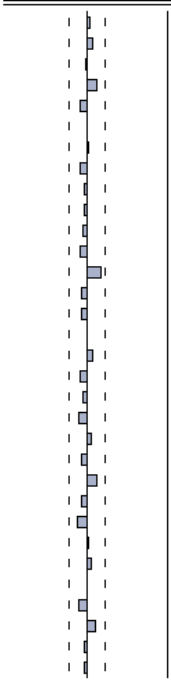
2. Correlogram of this series does not show clear AR, MA signs, but it shows presence of SAR at lag 12. After including SAR(12), AR(2) was also found to be significant, leading to increase in adj R^2. Residual correlogram showed white noise & squared residual correlogram showed iid

Date: 02/20/15 Time: 13:31
Sample: 1 101
Included observations: 72
Q-statistic probabilities adjusted for 2 ARMA terms



	Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
1			0.035	0.035	0.0930	
2			-0.054	-0.055	0.3151	
3			-0.056	-0.052	0.5591	0.455
4			-0.150	-0.150	2.3108	0.315
5			-0.020	-0.018	2.3439	0.504
6			-0.097	-0.119	3.0957	0.542
7			0.168	0.162	5.4182	0.367
8			0.017	-0.035	5.4424	0.488
9			-0.059	-0.053	5.7338	0.571
10			-0.234	-0.268	10.433	0.236
11			-0.133	-0.089	11.968	0.215
12			-0.048	-0.111	12.175	0.273
13			-0.065	-0.085	12.554	0.323
14			0.006	-0.146	12.557	0.402
15			0.132	0.065	14.194	0.360
16			0.006	-0.113	14.198	0.435
17			0.008	0.045	14.204	0.510
18			0.052	0.017	14.469	0.564
19			-0.020	-0.017	14.507	0.631
20			0.054	-0.033	14.805	0.675
21			-0.149	-0.203	17.122	0.582
22			0.093	0.006	18.053	0.584
23			0.125	0.053	19.755	0.537
24			-0.195	-0.292	23.981	0.348
25			0.112	0.112	25.411	0.329
26			0.031	-0.004	25.526	0.378
27			-0.038	-0.065	25.699	0.424
28			-0.173	-0.188	29.316	0.297
29			-0.006	0.040	29.320	0.346
30			0.078	-0.079	30.094	0.359
31			0.121	0.184	32.007	0.320
32			0.092	-0.058	33.138	0.317

Date: 02/20/15 Time: 13:32
Sample: 1 101
Included observations: 72



	Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
1			0.037	0.037	0.1018	0.750
2			0.080	0.078	0.5850	0.746
3			-0.021	-0.026	0.6177	0.892
4			0.130	0.127	1.9484	0.745
5			-0.095	-0.103	2.6601	0.752
6			0.002	-0.009	2.6604	0.850
7			0.018	0.040	2.6870	0.912
8			-0.098	-0.127	3.4917	0.900
9			-0.034	-0.001	3.5903	0.936
10			-0.049	-0.041	3.7973	0.956
11			-0.055	-0.066	4.0593	0.968
12			-0.082	-0.036	4.6587	0.968
13			0.186	0.190	7.7790	0.858
14			-0.068	-0.085	8.2080	0.878
15			-0.074	-0.088	8.7131	0.892
16			0.001	0.037	8.7133	0.925
17			0.082	0.021	9.3578	0.928
18			-0.092	-0.065	10.193	0.925
19			-0.049	-0.049	10.437	0.941
20			-0.115	-0.158	11.784	0.923
21			0.064	0.119	12.217	0.934
22			-0.071	-0.045	12.753	0.940
23			0.128	0.110	14.522	0.911
24			-0.079	-0.059	15.216	0.914
25			-0.126	-0.186	17.002	0.882
26			0.018	0.035	17.041	0.908
27			0.055	0.066	17.400	0.921
28			-0.002	0.006	17.401	0.940
29			-0.109	-0.131	18.868	0.925
30			0.112	0.038	20.465	0.904
31			-0.031	0.021	20.593	0.922
32			-0.032	-0.030	20.729	0.937

3. ARCH LM test suggests that there is no ARCH effect (null hypothesis cannot be rejected)
   Table 5: ARCH test

Heteroskedasticity Test: ARCH

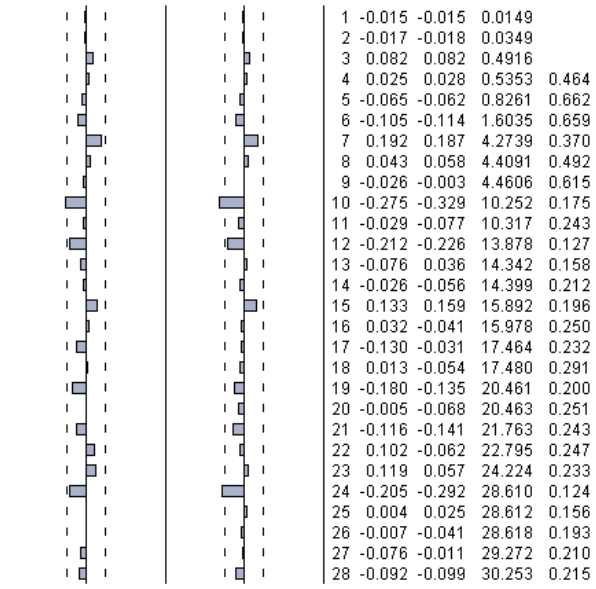
F-statistic	0.373076	Prob. F(12,47)	0.9668
Obs*R-squared	5.218160	Prob. Chi-Square(12)	0.9503

4. Dynamic forecast on the last 12 observations shows MAPE of 0.7352%
   Static forecast on the last 12 observations shows MAPE of 0.4243%

Estimation/Forecast 2: ARIMA (1,0,1) (12,2,0)

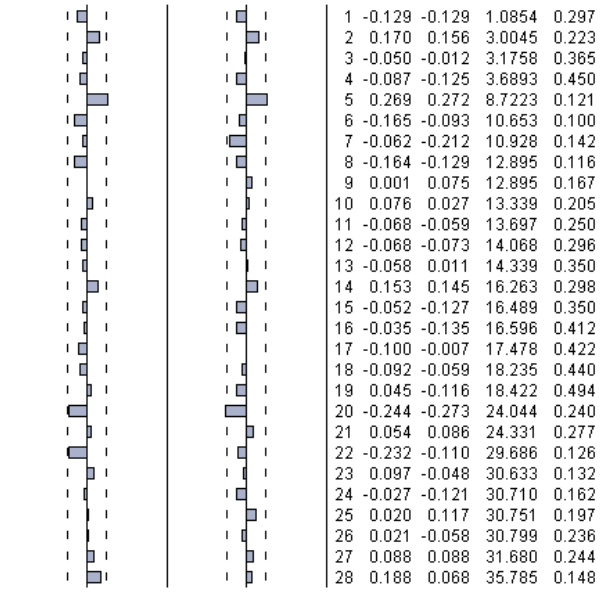
1. Deseasonalizing twice: Series is stationary, verified using ADF test
2. Correlogram suggests AR(1), MA(1), SAR(12). Correlogram of residual after estimation shows white noise and iid. ARCH tests showed that ARCH effect is absent

Date: 02/20/15 Time: 19:18
Sample: 1 101
Included observations: 62
Q-statistic probabilities adjusted for 3 ARMA terms



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.015	-0.015	0.0149	
		2	-0.017	-0.018	0.0349	
		3	0.082	0.082	0.4916	
		4	0.025	0.028	0.5353	0.464
		5	-0.065	-0.062	0.8261	0.662
		6	-0.105	-0.114	1.6035	0.659
		7	0.192	0.187	4.2739	0.370
		8	0.043	0.058	4.4091	0.492
		9	-0.026	-0.003	4.4606	0.615
		10	-0.275	-0.329	10.252	0.175
		11	-0.029	-0.077	10.317	0.243
		12	-0.212	-0.226	13.878	0.127
		13	-0.076	0.036	14.342	0.158
		14	-0.026	-0.056	14.399	0.212
		15	0.133	0.159	15.892	0.196
		16	0.032	-0.041	15.978	0.250
		17	-0.130	-0.031	17.464	0.232
		18	0.013	-0.054	17.480	0.291
		19	-0.180	-0.135	20.461	0.200
		20	-0.005	-0.068	20.463	0.251
		21	-0.116	-0.141	21.763	0.243
		22	0.102	-0.062	22.795	0.247
		23	0.119	0.057	24.224	0.233
		24	-0.205	-0.292	28.610	0.124
		25	0.004	0.025	28.612	0.156
		26	-0.007	-0.041	28.618	0.193
		27	-0.076	-0.011	29.272	0.210
		28	-0.092	-0.099	30.253	0.215

Date: 02/20/15 Time: 19:18
Sample: 1 101
Included observations: 62



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.129	-0.129	1.0854	0.297
		2	0.170	0.156	3.0045	0.223
		3	-0.050	-0.012	3.1758	0.365
		4	-0.087	-0.125	3.6893	0.450
		5	0.269	0.272	8.7223	0.121
		6	-0.165	-0.093	10.653	0.100
		7	-0.062	-0.212	10.928	0.142
		8	-0.164	-0.129	12.895	0.116
		9	0.001	0.075	12.895	0.167
		10	0.076	0.027	13.339	0.205
		11	-0.068	-0.059	13.697	0.250
		12	-0.068	-0.073	14.068	0.296
		13	-0.058	0.011	14.339	0.350
		14	0.153	0.145	16.263	0.298
		15	-0.052	-0.127	16.489	0.350
		16	-0.035	-0.135	16.596	0.412
		17	-0.100	-0.007	17.478	0.422
		18	-0.092	-0.059	18.235	0.440
		19	0.045	-0.116	18.422	0.494
		20	-0.244	-0.273	24.044	0.240
		21	0.054	0.086	24.331	0.277
		22	-0.232	-0.110	29.686	0.126
		23	0.097	-0.048	30.633	0.132
		24	-0.027	-0.121	30.710	0.162
		25	0.020	0.117	30.751	0.197
		26	0.021	-0.058	30.799	0.236
		27	0.088	0.088	31.680	0.244
		28	0.188	0.068	35.785	0.148

3. Dynamic forecast on the last 12 observations shows MAPE of 0.7963%
   Static forecast on the last 12 observations shows MAPE of 0.4755%

Choice of model and results

Since the first model showed lesser in-sample error, we proceed with the forecast results of first model. Point estimates and interval estimates (95% confidence) for 100 and 101 are:

Time period #	**Lower limit 95% CI**	**Point estimate**	**Upper limit 95% CI**
100	2370.076	2386.697	2403.318
101	2404	2429.459	2455