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MODIFIED HOLT 's LINEAR MODELS FOR INTRADAY DATA

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ABSTRACT:There are many types of time series models and some of them are univariate time series models, multivariate time series models, interval time series models and intraday time series models etc.. in this paper two intraday time series models are introduced and they are modified holt's model-I and modified holt's model-II are estimated using Root mean square error criteria by taking alpha rages from 0.1 to 0.9 ane0.99 for all three models i.e. holt's linear model, modified holt's linear model-I ,modified holt's linear model-II empirical investigation are calculated using intraday data of temperature of dalles

KEYWORDS: Holt's linear model, modified Holt's linear model-I, modified Holt's linear model-II, temperature

I.INTRODUCTION

There are so many models are developed and modified for intraday models. Intraday models possesses there won models, it can not take usual models which satisfies year wise data, monthly data and quarter data. General models for time series are single exponential smoothing model, Holt linear model, Holt winter model, Adoptive exponential smoothing model, Auto regressive model, moving average models, Auto regressive moving average models for different orders of Auto regressive and moving averages, Auto regressive integrated moving averages(p, q, r) for different values of p, q, r, different models of Auto regressive conditionally heteroscedasticity like generalized Auto regressive conditional heteroscedasticity(GARCH), IGARCH,EGARCH etc. These models are univariate models of time series.Multivariate models of time series are vector auto regression (VAR), vector auto regressive moving average (VARMA), vector auto regressive integrated moving average (VARIMA), multiple Regression, Discount weighted regression models etc.,

In this paper we explain Holt's linear model and introduced two modified Holt's models for intraday data. Modified Holt's model -1 is fitted by modification of Holt model i.e., in place of linear trend by substituting exponential curve. Modified Holt's model-2 is fitted by modification of Holt model i.e in place of linear trend by substituting power curve. Which model is best among Holt's linear model, Holt's modified model-1, Holt's modified model-2 using Root mean square error criteria.

Generally Holt's model is based on seasonality and trend. In Holt's model trend follows additive model. Holt's model is a two parameter model. Holt (1957) extended single exponential smoothing to linear exponential smoothing to allow forecasting of data with trends. Equations for trend, level and forecast are as follows

$$L_T = \alpha u_T + (1-\alpha)(L_{T-1} + \hat{b}_{T-1})$$

where L_T denotes level at time 't' and it obtains sum of two components, first component is product of constant 'α' with time series value Y_t and second component is sum of level L_{T-1} and estimated value of trend $\hat{b}_{T-1}$ and this sum is multiplied with $(1-\alpha)$

L_T is level at time 'T'

u_T is time series value at time 'T'

L_{T-1} is level at time point 'T-1'

$\hat{b}_{T-1}$ is trend at time point 'T-1'

α is a constant lies between '0' and '1', generally 'α' is substituted for different values like 0.1, 0.2, 0.3, 0.4,……,0.9 and upon using mean square error criterion we conclude which α is the best suit to data, by minimum value of MSE.

Equation for trend

$$b_t = \beta(L_T - L_{T-1}) + (1-\beta)b_{t-1}$$

Here b_t denotes trend at time point't' and it is sum of two components, first component is L_{T-1} is subtracted from L_t and that difference is multiplied with constant 'β' and second component is product of $(1-\beta)$ with b_{t-1}.

Where b_t is trend at time point't'

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L_T is level at time 't'

L_{T-1} is level at time point 't-1'

b_{t-1} is trend at time 't-1'

β is constant lies between 0 and 1.

$$F_{t+m} = L_t + b_t m$$

……………for forecast.

Holt model assumes linear form of forecast equation and calculation will be changed by adding one year data.

Thus $\hat{b}_T$ is an unbiased estimator of b.

Generally Holt's model is used when time series data is in the form of year wise or month wise where as data is in the form of day wise or hour wise it can not suit well. Therefore in this paper we are introduced two modified Holt's models.

Modified Holt's model – 1: Generally Holt's model follows linear trend. modified trend Holt's model follows exponential curve of form

$$Y_{t+m} = L_t b_t^m$$

The exponential curve used for forecast is

$$Y_{t+m} = L_t b_t^m$$

Modified Holt's model is converted in to General Holt's model by taking natural logarithms on both sides.

$$\log Y_{t+m} = \log L_T b_t^m$$

$$\log Y_{t+m} = \log L_T + m \log b_t$$

$$F_{t+m}^1 = A_t^1 + B_t^1 m$$

where F_{t+m}^1 is forecast for modified Holt's model.

A_t^1 is level for modified Holt's model.

B_t^1 is trend for modified Holt's model.

The three equations for modified Holt's model -1 are as follows

For level $A_t^1 = \alpha_1 Y_t + (1-\alpha_1)(A_{t-1}^1 + B_{t-1}^1)$

For trend $B_t^1 = \beta_1 (A_t^1 - A_{t-1}^1) + (1-\beta_1) B_{t-1}^1$

For Forecast $Y_t = A_t^1 + B_t^1 m$

where α_1 lies between 0 and 1, β_1 lies between 0 and 1.

Modified Holt's method -2: In this modified model, power curve is used in place of linear trend of Holt's model. In general power curve is

$$Y = ax^b$$

The modified Holt's method-II is

$$F_{t+m} = L_t m^{b_t}$$

By taking log on both sides, we get

$$\log F_{t+m} = \log L_t + b_t \log m$$

$$Y_t = A_t + B_t t$$

$$Y_t = \log F_{t+m}$$

$$A_t = \log L_t$$

$$B_t = b_t$$

$$t = \log m$$

The three equations for level, trend and forecast using modified Holt's model-2 are

For level $A_t = \alpha_2 Y_t + (1-\alpha_2)(A_{t-1} + b_{t-1})$

For trend $B_t = \beta_2 (A_t - A_{t-1}) + (1-\beta_2) B_{t-1}$

For forecast $F_t^1 = A_t + B_t t$

Here both α_2 and β_2 are lies between 0 and 1.

Generally linear model may fluctuate i.e., it may take positive or negative values. By taking log to any data it smoothes data and it decreases errors.

Root Mean Square Error: Positive square root of mean square error gives Root mean square error ($RMSE$).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (Y_t - F_t)^2}{n}}$$

Mean square error and Root mean square error criteria is especially used to choose which model possesses best fit to data compared with some other model. A model which takes small MSE or RMSE is the best model compared to other models.

Relative Errors: Relative or percentage errors are computed by taking difference of original value and forecast value which gives error, this error is divided with original value and multiplies 100.

$$PE_t = \left(\frac{Y_t - F_t}{Y_t} \right) \times 100$$

Mean Percentage Error (MPE): Sum of percentage errors divided by number of observations gives Mean Percentage Error (MPE).

Mean Absolute Percentage Error ($MAPE$): Absolute percentage error divided by total number of observations gives mean absolute percentage error ($MAPE$)

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} |PE_t|.$$

Generally all the above errors of accuracy are used to study about constants fitted to data and to choose best model to data. A model which possesses minimum error is good for data.

Empirical investigations:

Intraday data plays an vital role in many fields like atmospheric science for forecast of hour to hour temperature in summer, in rainy season moisture in air etc., in business markets forecast of trading hour to hour, loss or gain of

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trading etc. in telephone exchange department forecast of call demand of hour to hour basis, in call center to estimate about cell services etc. In this we are paperfitted three models of Holt's method to forecast temperature of Dallas data.

Holt's method: For forecast of Dallas data we are fitting Holt's method. Holt's method contains trend, level and forecast equations separately

$$L_T = \alpha u_T + (1-\alpha)(L_{T-1} + \hat{b}_{T-1})$$ ---------------level

$$b_T = \beta(L_T - L_{T-1}) + (1-\beta) b_{T-1}$$ ----------------trend

$$F_{T+m} = L_T + b_T m$$ -------------forecast

Where L_T is level at time 'T'

b_T is trend at time point 't'

L_{T-1} is level at time point 'T-1'

b_{T-1} is trend at time 't-1'

α , β are constants lies between 0 and 1.

By taking time series value as Dallas temperature (u_t), we fit Holt linear model for different values of α and β as follows

HOLT,s MODEL CALCULATION										
PERIODS	TEMPERATURE	alpha	beta	Lt	bt	1-alpha	1-beta	forecast when m=1	Error	Error square
1	52	0.9	0.1	52	0	0.1	0.9	52		
2	52			52	7.1E-16			52	0	0
3	51			51.1	-0.09			51.01	-0.01	1E-04
4	52			51.901	-0.0009			51.9001	0.0999	0.00998
5	51			51.09	-0.0819			51.0081	-0.0081	6.6E-05
6	51			51.0008	-0.0826			50.9182	0.08183	0.0067
7	50			50.0918	-0.1653			49.9265	0.07346	0.0054
8	50			49.9927	-0.1587			49.834	0.16601	0.02756
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33931	73			65.7	6.57			72.27	0.73	0.5329
33932	74			73.827	6.7257			80.5527	-6.5527	42.9379
33933	74			74.6553	6.13596			80.7912	-6.7912	46.1208
33934	72			72.8791	5.34475			78.2239	-6.2239	38.7365
33935	70			70.8224	4.6046			75.427	-5.427	29.4522
33936	67			67.8427	3.84617			71.6889	-4.6889	21.9855
33937	66			66.5689	3.33417			69.9031	-3.9031	15.2339
33938	65			65.4903	2.8929			68.3832	-3.3832	11.4461
33939	65			65.3383	2.58841			67.9267	-2.9267	8.56574
33940	65			65.2927	2.325			67.6177	-2.6177	6.85222
33941	64			64.3618	1.99941			66.3612	-2.3612	5.57517
33942	64			64.2361	1.78691			66.023	-2.023	4.09262
FORECAST FOR 24 HOURS										
33943	61.36363636			61.8296	1.36756			63.1971	-1.8335	3.36172
33944	60.3041958			60.5935	1.1072			61.7007	-1.3965	1.95018
33945	59.24475524			59.4903	0.88616			60.3765	-1.1318	1.28087
33946	58.18531469			58.4044	0.68895			59.0934	-0.9081	0.8246
33947	57.12587413			57.3226	0.51188			57.8345	-0.7086	0.50216
33948	56.06643357			56.2432	0.35275			56.596	-0.5296	0.28043
33949	55.00699301			55.1659	0.20974			55.3756	-0.3686	0.1359
33950	53.94755245			54.0904	0.08121			54.1716	-0.224	0.05019

33951	52.88811189			53.0165	-0.0343			52.9822	-0.094	0.00885
33952	51.82867133			51.944	-0.1381			51.8059	0.02276	0.00052
33953	50.76923077			50.8729	-0.2314			50.6415	0.12774	0.01632
33954	49.70979021			49.803	-0.3153			49.4877	0.2221	0.04933
33955	48.65034965			48.7341	-0.3906			48.3435	0.30689	0.09418
33956	47.59090909			47.6662	-0.4584			47.2078	0.3831	0.14677
33957	46.53146853			46.5991	-0.5192			46.0799	0.45159	0.20394
33958	45.47202797			45.5328	-0.5739			44.9589	0.51315	0.26332
33959	44.41258741			44.4672	-0.6231			43.8441	0.56847	0.32316
33960	43.35314685			43.4022	-0.6673			42.735	0.61819	0.38216
33961	42.29370629			42.3378	-0.707			41.6308	0.66287	0.4394
33962	41.23426573			41.2739	-0.7427			40.5312	0.70303	0.49426
33963	40.17482517			40.2105	-0.7748			39.4357	0.73913	0.54631
33964	39.11538462			39.1474	-0.8036			38.3438	0.77156	0.59531
33965	38.05594406			38.0847	-0.8295			37.2552	0.80072	0.64115
33966	36.9965035			37.0224	-0.8528			36.1696	0.82692	0.68379

Modified Holt's model-1: Year wise, quarter wise and month wise data can not satisfy univariate models of intraday and intra week datas. In this modified Holt's model we are taking curve of form exponential in place of trend in Holt's method. By takeing logarithms to exponential curve it covert to trend. Generally log smoothes data and it reduces the fluctuations.

$$Y_{t+m} = L_t b_t^m$$

Take log on both sides

$$\log Y_{t+m} = \log L_T b_t^m$$

$$\log Y_{t+m} = \log L_T + m \log b_t$$

$$F_{t+m}^1 = A_t^1 + B_t^1 m$$

The modified Holt's model-1 contains level, trend and forecast equations are

For level $A_t^1 = \alpha_1 Y_t + (1-\alpha_1)(A_{t-1}^1 + B_{t-1}^1)$

For trend $B_t^1 = \beta_1 (A_t^1 - A_{t-1}^1) + (1-\beta_1) B_{t-1}^1$

For Forecast $Y_t = A_t^1 + B_t^1 m$

where α_1 lies between 0 and 1, β_1 lies between 0 and 1.

Exponential curve calculation:

Periods	Temperature	alpha	beta	Log yt	Lt	Bt	bt	abs	1-alpha	1-beta	forecast	Error square
1	52	0.7	0.9	3.9512	3.9512	0.01	-4.6052	4.60517	0.3	0.1	8.5564	21.20759244
2	52			3.9512	5.3328	1.2444	0.21865	0.21865			5.5514	2.56064416
3	51			3.9318	4.4177	0.6991	-0.3579	0.35791			4.7756	0.711992803
4	52			3.9512	4.1986	0.1273	-2.061	2.06101			6.2596	5.328361629
5	51			3.9318	4.6301	0.4012	-0.9134	0.91338			5.5435	2.597597689
6	51			3.9318	4.4153	0.1532	-1.8759	1.87592			6.2913	5.566939421
7	50			3.912	4.6258	0.2047	-1.586	1.58605			6.2118	5.289179507
8	50			3.912	4.602	0.001	-6.9388	6.93885			11.541	58.19849382
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33931	73			4.2905	3.0033	2.703	0.99436	0.99436			3.9977	0.085719817
33932	74			4.3041	4.2121	1.3582	0.30619	0.30619			4.5183	0.045914729
33933	74			4.3041	4.3683	0.2764	-1.2859	1.28589			5.6542	1.822979608
33934	72			4.2767	4.6899	0.3171	-1.1486	1.14863			5.8386	2.43952891

33935	70			4.2485	4.7255	0.0637	-2.7532	2.75315			7.4787	10.43402135
33936	67			4.2047	5.1869	0.4216	-0.8637	0.86369			6.0506	3.407270548
33937	66			4.1897	4.7479	0.3529	-1.0416	1.04157			5.7895	2.559510689
33938	65			4.1744	4.6589	0.0448	-3.1052	3.10516			7.7641	12.88588233
33939	65			4.1744	5.2513	0.5376	-0.6206	0.62061			5.8719	2.881558601
33940	65			4.1744	4.6836	0.4571	-0.7828	0.7828			5.4664	1.669397091
33941	64			4.1589	4.5511	0.0735	-2.6101	2.61006			7.1612	9.013949884
33942	64			4.1589	5.0596	0.4649	-0.7658	0.76585			5.8254	2.777365797

Forecast for 24 hours:

33943	61.3636364			4.1168	4.6294	0.3407	-1.0768	1.07685			5.7062	2.526284346
33944	60.3041958			4.0994	4.5815	0.0091	-4.7013	4.70128			9.2827	26.86694988
33945	59.2447552			4.0817	5.642	0.9554	-0.0456	0.04563			5.6876	2.579071823
33946	58.1853147			4.0636	4.5508	0.8865	-0.1205	0.12047			4.6713	0.369254389
33947	57.1258741			4.0453	4.2331	0.1973	-1.6229	1.62285			5.8559	3.278502745
33948	56.0664336			4.0265	4.5754	0.3278	-1.1154	1.11539			5.6907	2.769565602
33949	55.006993			4.0075	4.5124	0.0238	-3.7364	3.73644			8.2489	17.98966377
33950	53.9475524			3.988	5.2663	0.6808	-0.3844	0.38444			5.6507	2.764580921
33951	52.8881119			3.9682	4.4729	0.6459	-0.4371	0.43708			4.91	0.887071274
33952	51.8286713			3.9479	4.2366	0.1481	-1.9096	1.90958			6.1461	4.832082125
33953	50.7692308			3.9273	4.5929	0.3356	-1.092	1.09197			5.6849	3.089242984
33954	49.7097902			3.9062	4.4398	0.1043	-2.2608	2.26085			6.7007	7.809020308
33955	48.6503497			3.8847	4.7295	0.2711	-1.3052	1.30524			6.0347	4.622693135
33956	47.5909091			3.8626	4.5143	0.1666	-1.7923	1.79234			6.3066	5.972946216
33957	46.5314685			3.8401	4.5801	0.0759	-2.5785	2.57852			7.1586	11.01216463
33958	45.472028			3.8171	4.8195	0.2231	-1.5001	1.50007			6.3196	6.262590979
33959	44.4125874			3.7935	4.5514	0.2191	-1.5184	1.5184			6.0697	5.181191153
33960	43.3531469			3.7694	4.4595	0.0608	-2.8007	2.80068			7.2602	12.18562431
33961	42.2937063			3.7446	4.7993	0.3119	-1.1651	1.16506			5.9644	4.92714479
33962	41.2342657			3.7193	4.3928	0.3347	-1.0946	1.09463			5.4874	3.126391117
33963	40.1748252			3.6932	4.2315	0.1117	-2.1919	2.19192			6.4234	7.453868281
33964	39.1153846			3.6665	4.4936	0.2471	-1.3982	1.39816			5.8917	4.951664665
33965	38.0559441			3.6391	4.3149	0.1361	-1.994	1.99404			6.3089	7.128084812
33966	36.9965035			3.6108	4.4202	0.1085	-2.2214	2.22138			6.6416	9.185794833

Modified Holt's model – 2: Holt's linear model forecast follows linear model. In this modified Holt's model-2 we are assuming that forecast follows power curve of form

$$Y = ax^b$$

The forecast equation of modified Holt's model – 2 is

$$F_{t+m} = L_t m^{b_t}$$

By taking log on both sides, we get

$$\log F_{t+m} = \log L_t + b_t \log m$$

$$Y_t = A_t + B_t t$$

Where $Y_t = \log F_{t+m}$, $A_t = \log L_t$, $B_t = b_t$, $t = \log m$

The three equations for level, trend and forecast are as follows

For level $A_t = \alpha_2 Y_t + (1-\alpha_2)(A_{t-1} + b_{t-1})$

For trend $B_t = \beta_2 (A_t - A_{t-1}) + (1-\beta_2) B_{t-1}$

For forecast $Y_t = A_t + B_t t$

α and β are constants lies between 0 and 1.

Power curve calculation

Period	alpha	beta	logYt	Lt	Bt	1-alpha	1-beta	forecast when m=1	ERROR	error square
1	0.9	0.9	0	0	0.69315	0.1	0.1			
2			0.69315	0.69315	0.69315			0.69315	0	0
3			1.09861	1.12738	0.46012			1.38629	-0.28768	0.08276
4			1.38629	1.40642	0.29714			1.58751	-0.20121	0.04049
5			1.60944	1.61885	0.22091			1.70356	-0.09412	0.00886
6			1.79176	1.79656	0.18203			1.83976	-0.048	0.0023
7			1.94591	1.94918	0.15556			1.97859	-0.03268	0.00107
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.			.						.	.
33931			10.4321	9.38888	8.44999			0	10.43208	108.828
33932			10.4321	11.1728	2.45052			17.8389	-7.40675	54.86
33933			10.4321	10.7513	-0.1343			13.6233	-3.19117	10.1835
33934			10.4322	10.4506	-0.284			10.6169	-0.18476	0.03414
33935			10.4322	10.4056	-0.0689			10.1667	0.265535	0.07051
33936			10.4322	10.4227	0.00844			10.3368	0.095482	0.00912
33937			10.4323	10.4321	0.00936			10.4311	0.001136	1.3E-06
33938			10.4323	10.4332	0.00189			10.4415	-0.00922	8.5E-05
33939			10.4323	10.4326	-0.0004			10.4351	-0.00279	7.8E-06
33940			10.4323	10.4323	-0.0003			10.4322	0.000114	1.3E-08
33941			10.4324	10.4323	-2E-05			10.4321	0.000312	9.7E-08
33942			10.4324	10.4324	4.6E-05			10.4323	7.9E-05	6.2E-09
forecast for 24 hours										
33943			10.4324	10.4324	3.9E-05			10.4324	-8.3E-06	6.8E-11
33944			10.4325	10.4325	3.1E-05			10.4325	-1E-05	1.1E-10
33945			10.4325	10.4325	2.9E-05			10.4325	-2.2E-06	4.7E-12
33946			10.4325	10.4325	2.9E-05			10.4325	4.02E-07	1.6E-13
33947			10.4326	10.4326	2.9E-05			10.4326	3.32E-07	1.1E-13

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33948			10.4326	10.4326	2.9E-05			10.4326	5.52E-08	3E-15
33949			10.4326	10.4326	2.9E-05			10.4326	-1.8E-08	3.3E-16
33950			10.4326	10.4326	2.9E-05			10.4326	-1.2E-08	1.4E-16
33951			10.4327	10.4327	2.9E-05			10.4327	-2.4E-09	5.9E-18
33952			10.4327	10.4327	2.9E-05			10.4327	-4.1E-10	1.7E-19
33953			10.4327	10.4327	2.9E-05			10.4327	-7.4E-10	5.5E-19
33954			10.4328	10.4328	2.9E-05			10.4328	-1E-09	1.1E-18
33955			10.4328	10.4328	2.9E-05			10.4328	-1.1E-09	1.2E-18
33956			10.4328	10.4328	2.9E-05			10.4328	-1.1E-09	1.2E-18
33957			10.4329	10.4329	2.9E-05			10.4329	-1.1E-09	1.1E-18
33958			10.4329	10.4329	2.9E-05			10.4329	-1.1E-09	1.1E-18
33959			10.4329	10.4329	2.9E-05			10.4329	-1.1E-09	1.1E-18
33960			10.4329	10.4329	2.9E-05			10.4329	-1.1E-09	1.1E-18
33961			10.433	10.433	2.9E-05			10.433	-1.1E-09	1.1E-18
33962			10.433	10.433	2.9E-05			10.433	-1.1E-09	1.1E-18
33963			10.433	10.433	2.9E-05			10.433	-1.1E-09	1.1E-18
33964			10.4331	10.4331	2.9E-05			10.4331	-1.1E-09	1.1E-18
33965			10.4331	10.4331	2.9E-05			10.4331	-1.1E-09	1.1E-18
33966			10.4331	10.4331	2.9E-05			10.4331	-1.1E-09	1.1E-18

SUMMARY AND CONCLUSIONS

In this paper we introduced two modified Holt's linear models for intraday data.

Modified Holt's model-1: Year wise, quarter wise and month wise data can not satisfy univariate models of intraday and intra week datas. In this modified Holt's model we are taking curve of form exponential in place of trend in Holt's method. By takeing logarithms to exponential curve it covert to trend. Generally log smoothes data and it reduces the fluctuations.

$$Y_{t+m} = L_t b_t^m$$

Take log on both sides

$$\log Y_{t+m} = \log L_T b_t^m$$

$$\log Y_{t+m} = \log L_T + m \log b_t$$

$$F_{t+m}^1 = A_t^1 + B_t^1 m$$

The modified Holt's model-1 contains level, trend and forecast equations are

For level $\quad A_t^1 = \alpha_1 Y_t + (1-\alpha_1)(A_{t-1}^1 + B_{t-1}^1)$

For trend $\quad B_t^1 = \beta_1 (A_t^1 - A_{t-1}^1) + (1-\beta_1) B_{t-1}^1$

For Forecast $\quad Y_t = A_t^1 + B_t^1 m$

where α_1 lies between 0 and 1, β_1 lies between 0 and 1.

Modified Holt's model – 2: Holt's linear model forecast follows linear model. In this modified Holt's model-2 we are assuming that forecast follows power curve of form

$$Y = ax^b$$

The forecast equation of modified Holt's model – 2 is

$$F_{t+m} = L_t m^{b_t}$$

By taking log on both sides, we get

$$\log F_{t+m} = \log L_t + b_t \log m$$

$$Y_t = A_t + B_t t$$

Where $Y_t = \log F_{t+m}$,

$A_t = \log L_t$, $B_t = b_t$, $t = \log m$

The three equations for level, trend and forecast are as follows

For level $\quad A_t = \alpha_2 Y_t + (1-\alpha_2)(A_{t-1} + b_{t-1})$

For trend $\quad B_t = \beta_2 (A_t - A_{t-1}) + (1-\beta_2) B_{t-1}$

For forecast α and β are constants lies between 0 and 1.

These models are empirically calculated using intraday data of Dallas and 24 hours forecast is given.

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