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EXPONENTIAL SMOOTHING FOR FINANCIAL TIME SERIES DATA FORECASTING

Abstract. *The article begins with the formulation for predictive learning called exponential smoothing forecasting. The exponential smoothing is commonly applied to financial markets such as stock or bond, foreign exchange, insurance, credit, primary and secondary markets. The exponential smoothing models are useful in providing the valuable decision information for investors. Simple and double exponential smoothing models are two basic types of exponential smoothing method. The simple exponential smoothing method is suitable for financial time series forecasting for the specified time period. The simple exponential smoothing weights past observations with exponentially decreasing weights to forecast future values. The double exponential smoothing is a refinement of the simple exponential smoothing model but adds another component which takes into account any trend in the data. The double exponential smoothing is designed to address this type of data series by taking into account any trend in the data. Measurement of the forecast accuracy is described in this article. Finally, the quantitative value of the price per common share forecast using simple exponential smoothing is calculated. The applied recommendations concerning determination of the price per common share forecast using double exponential smoothing are shown in the article.*

Keywords: simple exponential smoothing; double exponential smoothing; forecast; smoothing factor; forecast error.

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ПРОГНОЗУВАННЯ ФІНАНСОВИХ ДАНИХ НА ОСНОВІ ЕКСПОНЕНЦІЙНОГО ЗГЛАДЖУВАННЯ

Анотація. *В статті описано метод експоненційного згладжування для прогнозування фінансових даних. Методи експоненційного згладжування широко застосовують для прогнозування даних на фінансових ринках, таких як ринок акцій та облігацій, страховий, кредитний ринки. Моделі експоненційного згладжування є корисними* *для прийняття управлінських рішень інвесторами. Просте експоненційне згладжування та експоненційне згладжування з трендовим регулювання є основними типами моделей експоненційного згладжування. Просте експоненційне згладжування є корисним для прогнозування фінансових даних на певний період часу, оскільки кожен фінансовий показник згладжується за допомогою ваги, яка зменшується по мірі віддалення від кінця ряду за експонентою. Експоненційне згладжування з трендовим регулювання пристосоване до регулювання тренду. В статті застосовано теоретичний матеріал до прогнозування ціни звичайної акції. Здійснено перевірку точності отриманого прогнозу та розраховано прогноз ціни звичайної акції на наступний період на основі простого експоненційного згладжування. Показано прикладне застосування методу експоненційного згладжування з трендовим регулюванням для визначення ціни звичайної акції.*

***Ключові слова**: просте експоненційне згладжування, експоненційне згладжування з трендовим регулюванням, прогноз, константа згладжування, помилка прогнозу.*

Татьяна Кужда

ПРОГНОЗИРОВАНИЕ ФИНАНСОВЫХ ДАННЫХ НА ОСНОВАНИИ ЭКСПОНЕНЦИАЛЬНОГО СГЛАЖИВАНИЯ

***Аннотация**. В статье описано метод экспоненциального сглаживания для прогнозирования финансовых данных. Методы экспоненциального сглаживания широко применяют для прогнозирования данных на финансовых рынках, таких как рынок акций и облигаций, страховой, кредитный рынки. Модели экспоненциального сглаживания полезны для принятия управленческих решений инвесторами. Простое экспоненциальное сглаживание и экспоненциальное сглаживание с трендовым регулированием являются основными типами моделей экспоненциального сглаживания. Простое экспоненциальное сглаживание полезно для прогнозирования финансовых данных на определенный период времени, поскольку каждый финансовый показатель сглаживается с помощью веса, которая уменьшается по мере удаления от конца ряда по экспоненте. Экспоненциальное сглаживание с трендовым регулированием приспособлено к регулированию тренда. В статье применен теоретический материал к прогнозированию цены обыкновенной акции. Осуществлена проверка точности полученного прогноза и рассчитан прогноз цены обыкновенной акции на следующий период на основе простого экспоненциального сглаживания. Показано прикладное применение метода экспоненциального сглаживания с трендовым регулированием для определения цены обыкновенной акции.*

***Ключевые слова**: простое экспоненциальное сглаживание, экспоненциальное сглаживание с трендовым регулированием, прогноз, константа сглаживания, ошибка прогноза.*

Introduction. A challenging task in financial markets such as stock or bond, foreign exchange, insurance, credit, primary and secondary markets is to predict the movement direction of financial markets so as to provide valuable decision information for investors. Thus, many researches and business practitioners have developed various types of forecasting methods. Of the various forecasting models, the exponential smoothing model has been found to be an effective method for the financial time series data predicting by business forecasters [1].

Exponential smoothing is forecasting technique that can be applied to time series, either to produce smoothed data to make forecasts. The exponential smoothing is commonly applied to financial market and economic data, but it can be used with any discrete set of repeated measurements. The exponential smoothing assigns exponentially decreasing weights as the observation get older. The procedure gives heaviest weight to more recent information and smaller weights to observations in the more distant past. The reason for this is that the future is more dependent upon the recent past than on the distant past [1].

Simple and double exponential smoothing models are two basic types of exponential smoothing method. The simple exponential smoothing method is suitable for financial time series forecasting for the specified time period. The simple exponential smoothing weights past observations with exponentially decreasing weights to forecast future values. In the exponential smoothing the most recent observations have the greatest influence to forecast [5].

Forecast based on simple exponential smoothing is calculated by the formula (1):

$$\hat{y}_{ES} = \alpha \cdot y_{t-1} + (1-\alpha) \cdot \hat{y}_{t-1} \quad (1)$$

where $\hat{y}_{ES}$ – is the forecast based on exponential smoothing for the next period *t*;

α (alpha) – is the smoothing factor between 0 and 1 (0< $\alpha \leq$1).

The smoothing factor is the factor used to smooth or filter the data from the most recent period.

y_{t-1} – is the actual data for the period before current time period *t*;

$\hat{y}_{t-1}$ – is the forecast for the period before current time period *t*. How initial smoothed forecast we need to use the first value of time series.

The value of smoothing factor α determines the degree of smoothing and how responsive the model is to fluctuation in the time-series data. The smoothing factor close to 0 means small influence of past data (adaptability to most recent data). The smoothing factor close to 1 means large influence of past data (rigidity of forecast). Forecasters determine the forecast weights, controlling how fast or slow the model responds to demand changes in your actual.

Double exponential smoothing is a refinement of the simple exponential smoothing model but adds another component which takes into account any trend in the data. Simple exponential smoothing models work best with data where there are no trend or seasonality components to the data. When the data reflects either an increasing or decreasing trend over time, simple exponential smoothing forecasts tend to lag behind observations [1].

The double exponential smoothing is designed to address this type of data series by taking into account any trend in the data. As with simple exponential smoothing, in double exponential smoothing models past observations are given exponentially smaller weights as the observations get older. In other words, recent observations are given relatively more weight in forecasting than the older observations [1].

Computation of the forecast using double exponential smoothing includes the following steps:

I step: Find the forecast based on simple exponential smoothing method ($\hat{y}_{ES}$) by the formula (1) as described above.

II step: Calculate the best estimate (b_t) of the trend for the time period t by the formula (2).

$$b_t = (1-\beta) \cdot b_{t-1} + \beta \cdot (\hat{y}_t - \hat{y}_{t-1}) \text{ ,} \quad (2)$$

where b_t is the best estimate of the trend for the next period *t*;

β – is the trend smoothing factor, (0 < $\beta \leq$ 1), used to smooth the trend.

The trend smoothing factor β must be the values in the range between 0 and 1. But, what are the “best” values to use for the trend smoothing factors? This depends on the data series being modeled. In general, the speed at which the older responses are smoothed is a function of the value of the smoothing factor. When this trend smoothing factor is close to 1, smoothing is quick – more weight is given to recent observations; and when it is close to 0, smoothing is slow – and relatively less weight is given to recent observations.

$\hat{y}_t$ – is the forecast based on simple exponential smoothing for the period *t*;

$\hat{y}_{t-1}$ – is the smoothed forecast for previous period.

III step: Find the forecast based on double exponential smoothing method. The forecast based on double exponential smoothing is the sum of the forecast based on simple exponential smoothing and the best estimate of the trend for the time period t. The forecast based on double exponential smoothing is given by the formula (3):

$$\hat{y}_{DES} = \hat{y}_{ES} + b_t , \qquad (3)$$

where $\hat{y}_{DES}$ – is the forecast based on double exponential smoothing;

$\hat{y}_{ES}$ – is the forecast based on simple exponential smoothing for the period *t*;

b_t – is the best estimate of the trend for the period *t*.

Exponential smoothing models in practice. The application of above theoretical information is described in example below. Statistical data on price per common share for 10 months are given in the table 1. Compute the forecast of price per common share for February using simple exponential smoothing, if the smoothing factor α is 0,3.

Table 1

Statistics on price per common share

Months	Price per common share, dollars
April	28,7
May	28,9
June	29,1
July	29,5
August	29,3
September	28,9
October	29,7
November	29,9
December	28,8
January	27,6

To determine the forecast for February using simple exponential smoothing, we need to know the forecast for January. This, in turn, requires us to know the forecast for December. So we need to go all the way back to the beginning and compute the forecast for each month. For May, we can use the formula (1). But how do we get the forecast for April? How initial smoothed value for April we can use the first value of time series, i.e. 28,9. The forecast of price per common share for February using simple exponential smoothing is reported in the table 2.

Table 2

Calculation results

Months	Price per common share, dollars	Forecast for the period before current time period *t*, if the smoothed factor is 0,3
April	28,7	–
May	28,9	28,7
June	29,1	0,3*28,9+(1-0,3)*28,7=28,76
July	29,5	0,3*29,1+(1-0,3)*28,76=28,86
August	29,3	0,3*29,5+(1-0,3)*28,86=29,05
September	28,9	0,3*29,3+(1-0,3)*29,05=29,13
October	29,7	0,3*28,9+(1-0,3)*29,13=29,06
November	29,9	0,3*29,7+(1-0,3)*29,06=29,25

December	28,8	0,3*29,9+(1-0,3)*29,25=29,45
January	27,6	0,3*28,8+(1-0,3)*29,45=29,25
February	*Forecast*	0,3*27,6+(1-0,3)*29,25=28,76

Thus, the forecast of price per common share for February using simple exponential smoothing is 29,09 dollars.

To measure the forecast accuracy is used the following errors: the absolute forecast error and the mean forecast error [2]. The absolute forecast error (*AFM*) is the difference between the actual statistical data (y_t) and the forecast values ($\hat{y}_t$):

$$AFE = y_t - \hat{y}_t , \qquad (4)$$

Mean forecast error (*MFE*) is a quantity used to measure how close forecasts are to the eventual outcomes. The mean forecast error is the sum of absolute forecast errors that is divided by number of periods (n):

$$MFE = \frac{\sum (y_t - \hat{y}_t)}{n} = \frac{\sum AME}{n} , \qquad (5)$$

Low value of the forecast error means the forecast is more accurate. Ideal value = 0; if $MFE < 0$, the forecast based on exponential smoothing tends to undervaluation; if $MFE > 0$, the forecast based on exponential smoothing tends to overvaluation [3].

The absolute forecast errors are reported in the table 3.

Table 3

Calculation results

Months	Price per common share, dollars	Forecast for the period before current time period *t*, if the smoothed factor is 0,3	Absolute forecast error
April	28,7	–	–
May	28,9	28,7	28,9-28,7=0,2
June	29,1	28,76	29,1-28,76=0,34
July	29,5	28,86	29,5-28,86=0,64
August	29,3	29,05	29,3-29,05=0,25
September	28,9	29,13	28,9-29,13= -0,23
October	29,7	29,06	29,7-29,06=0,64
November	29,9	29,25	29,9-29,25=0,65
December	28,8	29,45	28,8-29,45= - 0,65
January	27,6	29,25	27,6-29,25= -1,65

The mean forecast error by the formula (5) equals:

$$MFM = \frac{0,2 + 0,34 + 0,64 + 0,25 - 0,23 + 0,64 + 0,65 - 0,65 - 1,65}{9} \approx 0,02 .$$

Thus, the forecast of price per common share for February using simple exponential smoothing is quite accurate, but tends to little overestimation, because the mean forecast error is more than 0.

Microsoft Excel provides a lot of possibilities to forecasting based on exponential smoothing. Statistical data on price per common share for 10 months should be typed in Excel Spreadsheet. On the Tools menu, click "Data" / "Data Analysis" / "Exponential smoothing". The "Exponential smoothing" dialog box opens. We need to fill three cells: input range, output range and damping factor (Fig. 1). To fill "Input Range" click here and enter the cell reference for the range of data we want to analyze. To fill "Damping factor" enter the damping factor you want to use as the exponential smoothing factor. If smoothing factor is α =0,3; then damping factor is (1-α)=1-0,3=0,7. To fill "Output range" enter the reference for the upper-right cell of the output table. Finally, click Ok.

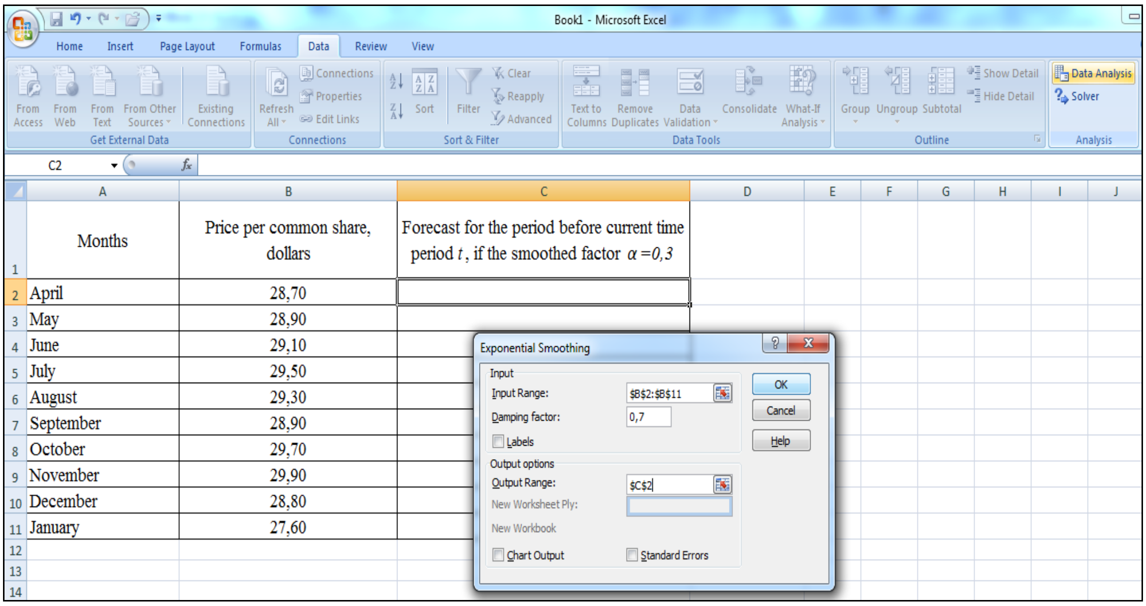
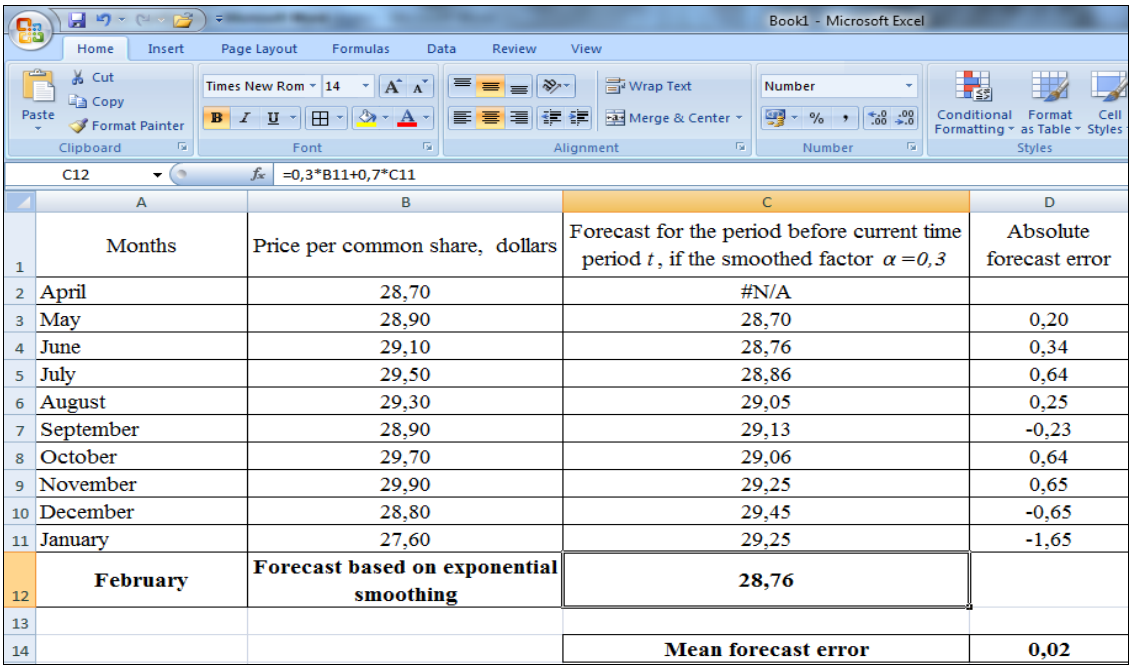


Fig. 1. "Exponential smoothing" dialog box

Computation results are shown on Fig. 2. To compute the forecast of price per common share for February highlight the last smoothed forecast value (cell C11) and copy it into the cell C12 (Fig. 2). The absolute forecast errors and mean forecast error are reported on fig. 2.



	A	B	C	D
1	Months	Price per common share, dollars	Forecast for the period before current time period t, if the smoothed factor α =0,3	Absolute forecast error
2	April	28,70	#N/A	
3	May	28,90	28,70	0,20
4	June	29,10	28,76	0,34
5	July	29,50	28,86	0,64
6	August	29,30	29,05	0,25
7	September	28,90	29,13	-0,23
8	October	29,70	29,06	0,64
9	November	29,90	29,25	0,65
10	December	28,80	29,45	-0,65
11	January	27,60	29,25	-1,65
12	**February**	**Forecast based on exponential smoothing**	**28,76**	
13				
14			**Mean forecast error**	**0,02**

Fig. 2. Forecast output

The application of double exponential smoothing on practice is described in example below. Using above example we need to compute the forecast of price per common share for February using double exponential smoothing, if the trend smoothing factor is β=0,2.

The best estimate of the trend for April doesn't calculate due to lack of previously reported data. The best estimate of the trend for May is zero. The best estimates (b_t) of the trend for the other time periods *t* are reported in the *table 4*.

Table 4

Calculation results

Months	Price per common share, dollars	Forecast for the period before current time period *t*, if the smoothed factor is 0,3	Best estimate of the trend for the time period *t*, if the trend smoothing factor is 0,2
April	28,7	–	–
May	28,9	28,7	0
June	29,1	28,76	(1-0,2)*0+0,2*(28,76-28,7)= 0,01
July	29,5	28,86	(1-0,2)* 0,01+0,2*(28,86-28,76)=0,03
August	29,3	29,05	(1-0,2)*0,03+0,2*(29,05-28,86)=0,06
September	28,9	29,13	(1-0,2)*0,06+0,2*(29,13-29,05)=0,06
October	29,7	29,06	(1-0,2)*0,06+0,2*(29,06-29,13)=0,04
November	29,9	29,25	(1-0,2)*0,04+0,2*(29,25-29,06)=0,07
December	28,8	29,45	(1-0,2)*0,07+0,2*(29,45-29,25)=0,09
January	27,6	29,25	(1-0,2)*0,09+0,2*(29,25-29,45)= 0,04
February	Forecast	28,76	(1-0,2)*(0,04)+0,2*(28,76-29,25)= - 0,07

Thus, the best estimate of the price per common share for February is – 0,07 dollars. The forecast of price per common share for February using double exponential smoothing is the sum of the price per common share forecast for February based on simple exponential smoothing and the best estimate of the price per common share for February.

$$\hat{y}_{DES} = 28{,}76 - 0{,}07 = 28{,}69 \ \ dollars.$$

The forecast of price per common share for February using double exponential smoothing equals 28,69 dollars.

Computations of the best estimate of the price per common share for February and the forecast of price per common share for February using double exponential smoothing are reported on fig. 3.

	A	B	C	D	E
1	Months	Price per common share, dollars	Forecast for the period before current time period t, if the smoothed factor $\alpha = 0,3$	Absolute forecast error	Best estimate of the trend for the time period t, if the trend smoothing factor $\beta = 0,2$
2	April	28,70	#N/A		
3	May	28,90	28,70	0,20	0
4	June	29,10	28,76	0,34	0,01
5	July	29,50	28,86	0,64	0,03
6	August	29,30	29,05	0,25	0,06
7	September	28,90	29,13	-0,23	0,06
8	October	29,70	29,06	0,64	0,04
9	November	29,90	29,25	0,65	0,07
10	December	28,80	29,45	-0,65	0,09
11	January	27,60	29,25	-1,65	0,04
12	**February**	**Forecast based on exponential smoothing**	**28,76**		-0,07
13					
14			**Mean forecast error**	**0,02**	
15					
16	**January**	**Forecast based on double exponential smoothing**	**28,69**		

Fig. 3. Forecast output

Conclusion. The data example I used previously is a very good example of a situation where we really need to predict financial data in financial markets such as stock or bond, foreign exchange, insurance, credit, primary and secondary markets. The exponential smoothing models provides the following advantages: it is easy to apply, it can produce accurate forecasts, it can produce forecasts quickly, it gives greater weight to more recent observations and it can alter the value of the smoothing constant to fit the model properly in any different circumstances. Thus, the exponential smoothing models are effective in providing the valuable decision information for managers and investors.

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