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EXCEL'S BUILT-IN FORECASTING MODULE (FORECAST.ETS) FOR ANALYZING STATISTICAL TIME SERIES

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ABSTRACT: *In this article, we use the well-known Exponential Smoothing Methods (ESM) family of Time Series (TS) prediction methods discussed in Rahardja (2020) to quickly and easily include level (intercept), trend (slope), and seasonality components into Excel (version 2016 and higher) forecasts. We use the "FORECAST.ETS" built-in function in Excel (2019) to carry out such ESM-family forecasting. Forecasting with this Excel feature does not need prior knowledge of the Box-Jenkins methodology (1976). (version 2016 and above). A sales data series is used to demonstrate the Excel (2019) TS forecast function.*
Excel, Exponential Smoothing Techniques, Time Series, and Prediction.

I. INTRODUCTION

In today's enterprises, a large number of decision-makers must manage and anticipate their future needs (volume) of different goods or tasks. For instance, economics and business studies are often interested in predicting their consistent (daily, weekly, monthly, yearly) needs (volume), such as the weekly sales of bread, the monthly sales of beer at a micro market, the annual sales of vehicles, etc.

In today's fast-paced business environment, most practitioners and forecasters cannot afford to conduct rigorous research, dig deep into the available online software manuals, or reinvent the wheel, nor can they attempt to comprehend numerous papers [1–15] all the way to every single comprehensive paper as listed on Rahardja (2020) paper [16], just to determine which Time-Series (TS) forecasting methods are appropriate for their needs and requirements.

Thus, in this work, we describe and summarise the basic, fast, and easy TS-forecasting approaches using an Excel (FORECAST.ETS) function [17-21] in order to bridge the gaps between what is accessible and easily-and-quickly producible [by an ordinary non-statistician analyst] within short timeframe. Keep in mind that such an Excel "feature" is not an optional add-on that must be purchased. It is really a "built-in" feature of Excel versions 2016 and above.

The literature study was divided into three families of TS-forecasting techniques in the Rahardja (2020) research [16] (see Table 1 for a list of each TS-name method's and model equation). Remember that there are three families of TS models that fall into this category: the Unobserved Component Model (UCM) family, often known as the Structural Models in TS literature [7], and the Exponential Smoothing Model (ESM) family, which is a subset of the Box-Jenkins model. Beyond the capabilities of the ESM-family, the final two family models (ARIMA and UCM) can manage a variety of aspects that are much more complicated.

Remember that only level (intercept), trend (slope), and seasonality may be included into the ESM-family TS models [2-15]. The TS-forecasting techniques in the ESM-family are basic and straightforward enough to be applied in Microsoft Excel (version 2016 or above). The "FORECAST.ETS" function in Excel may be used to accomplish this kind of forecasting [17–21].

The portions of this essay are arranged as follows. We define the data format requirements for forecasting in Excel (2019) in Section 2 [22]. The ESM-family TS models are described in Section 3 along with instructions for utilising the "FORECAST.ETS" function in Microsoft Excel (2019) with sales time-series data.

data, as an example. We next use the Excel (2019) [22] function "FORECAST.ETS" [17-21] on the sales-data series [21] as an example (Section 4) to show the TS modelling. In the last section (Section 5), we summarise the main ideas and provide suggestions for the Excel (2019) software-based ESM-family TS-forecasting approaches [2-15].

II. DATA

The TS data format requirement in Excel is displayed in Figure 1. In Figure 1, we stack the TS data into two columns. Here, the first column is the ‘DATE’ (for example, monthly: Oct-2000, Nov-2000, Dec-2000, etc). The second column is the ‘VOLUME’ or counts of items or workload.

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	A	B
1	DATE	VOLUME
2	10/1/2000	6,962
3	11/1/2000	6,058
4	12/1/2000	4,477
5	1/1/2001	13,794
6	2/1/2001	14,745
7	3/1/2001	15,549
8	4/1/2001	11,174
9	5/1/2001	9,707
10	6/1/2001	6,436
11	7/1/2001	6,760
12	8/1/2001	6,971
13	9/1/2001	6,340
14	10/1/2001	5,154
15	11/1/2001	3,652
16	12/1/2001	2,762
17	1/1/2002	8,228
18	2/1/2002	10,656
19	3/1/2002	12,604
20	4/1/2002	9,928
21	5/1/2002	9,216
22	6/1/2002	6,586
23	7/1/2002	6,475

Figure 1: The "Input" Data Format Requirement for Excel.

Note that there is a distinction between forecasting versus last-observation-carry-forward (LOCF) method [23]. In LOCF method [23], the purpose is to use the past data to impute missing values. Imputation methods are intended for missing values; and not purposed to forecast. The purpose of forecasting is to project future values. The consequence for forcing such non-suitable LOCF method [23] in place of TS-forecasting methods is that the resulting estimates can suffer severe biased.

III. EXCEL (FORECAST.ETS) FUNCTION

In this section, after we stack the TS-data into an Excel-readable format, we utilize the Excel (2019) [22] function "FORECAST.ETS" to produce forecasts (series of future projections) using ESM-family algorithms. Such Excel function is simple and easy-to-use (user friendly) because it does not require any familiarity with the (1976) Box-Jenkins methods [1].

To recapitulate, the Table 1 (Column 2) of Rahardja (2020) paper [16] prescribed all the ESM-family models (with the specific TS-model name) which include/exclude any trend and/or seasonality components. Hence, users can do graphical assessment by just plotting the series. Then decide visually (as opposed to numerically) whether there is obvious trend (slope) and/or seasonality. Then obtain the TS-model name. Note that the following two [out of eight] ESM-family models: Multiplicative Seasonal ESM [9] and Winters Multiplicative ESM [11] listed on Table 1 of Rahardja (2020) paper [16] are not implementable by Excel function (due to the complexity of their hybrid models). The following remaining six ESM-family models are implementable by the Excel FORECAST.ETS function:

1) SIMPLE (Single) ESM [2]: use it when TS data has No Trend and No Seasonality.
2) DOUBLE (Brown) ESM [3]: use it when TS data has Trend but No Seasonality.
3) LINEAR (Holt) ESM [8]: use it when TS data has Trend (2 smoothing weights) but No Seasonality.
4) DAMPTREND ESM [6]: use it when TS data has Trend (2 smoothing weights & a damping parameter) but No Seasonality.
5) ADD-SEASONAL (Additive Seasonal) or TRIPLE (Holt-Winters) ESM [10]: use it when TS has No Trend but Seasonality.
6) ADDWINTERS (Winters Additive) ESM [11]: use it when the TS data has Trend and Seasonality.

The Excel "FORECAST.ETS" function is new in Excel 2016. According to the Microsoft Support (2021) website [17], the "FORECAST.ETS" function is available in Excel for Microsoft 365, Excel 2021, Excel 2019, and Excel 2016.

The FORECAST.ETS function [17–21] in Excel is used to forecast data using an Exponential Smoothing Method (ESM) [2–15]. ESM [2–15] in statistics is used for smoothing time series data by assigning weights exponentially to future values over time. This differs from a simple moving average where past observations are weighted equally. Such FORECAST.ETS function [17–21] calculates or predicts a future value based on existing (historical) data by using the AAA (additive error, additive trend and additive seasonality) version of the advanced machine learning Exponential Triple Smoothing (ETS) algorithm. The predicted value is a continuation of the historical values in the target date range, which should be a continuous timeline with an equal interval between dates. It can be used to predict future sales, inventory requirements or general consumer trends. This FORECAST.ETS function [17–21] requires the timeline to be organized with a constant step between the different points. For example, that could be a monthly timeline with values on the first of every month, a yearly timeline, or a timeline of numerical indices. The syntax of the FORECAST.ETS function is as follow.

```
=FORECAST.ETS(target_date, values, timeline, [seasonality], [data_completion], [aggregation])
```

The FORECAST.ETS function [17–21] syntax has the following arguments.

- **Target_date** (Required). The data point for which you want to predict a value. Target date can be date/time or numeric. If the target date is chronologically before the end of the historical timeline, FORECAST.ETS returns the #NUM! error.
- **Values** (Required). Values are the historical values, for which you want to forecast the next points.
- **Timeline** (Required). The independent array or range of numeric data. The dates in the timeline must have a consistent step between them and cannot be zero. The timeline is not required to be sorted, as FORECAST.ETS will sort it implicitly for calculations. If a constant step cannot be identified in the provided timeline, FORECAST.ETS will return the #NUM! error. If timeline contains duplicate values, FORECAST.ETS will return the #VALUE! error. If the ranges of the timeline and values aren't of same size, FORECAST.ETS will return the #N/A error.
- **Seasonality** (Optional). A numeric value. The default value of 1 means Excel detects seasonality automatically for the forecast and uses positive, whole numbers for the length of the seasonal pattern. 0 indicates no seasonality, meaning the prediction will be linear. Positive whole numbers will indicate to the algorithm to use patterns of this length as the seasonality. For any other value, FORECAST.ETS will return the #NUM! error. Maximum supported seasonality is 8,760 (number of hours in a year). Any seasonality above that number will result in the #NUM! error.
- **Data completion** (Optional). Although the timeline requires a constant step between data points, FORECAST.ETS supports up to 30% missing data, and will automatically adjust for it. 0 will indicate the algorithm to account for missing points as zeros. The default value of 1 will account for missing points by completing them to be the average of the neighboring points.
- **Aggregation** (Optional). Although the timeline requires a constant step between data points, FORECAST.ETS will aggregate multiple points which have the same time stamp. The aggregation parameter is a numeric value indicating which method will be used to aggregate several values with the same time stamp. The default value of 0 will use AVERAGE, while other options are SUM, COUNT, COUNTA, MIN, MAX, MEDIAN.

IV. EXAMPLE

Among numerous research examples [17–21] of forecast calculation via Excel built-in function, Exceljet [21] utilized the Excel FORECAST.ETS function beautifully to illustrate a sales-data example in very clear-and-concise way, as follows.

In the sales data-series example on Figure 2, we type the Excel function on the Cell D13 as "=FORECAST.ETS(B13,C5:C12,B5:B12,4)" and press enter. Note that we intentionally stack the forecast output into the third column, given the first two columns have already satisfied the data-format requirement as described in Figure 1, previously. Such intention is purposed so that the plotted graphs will be displayed in two distinctive colors, in order to differentiate between the observed (past) data and the forecasts (i.e., the future projected values). The fourth (last) argument in the above function is the seasonality. Since the data (visually) is quarterly, so seasonality is given as 4, since there are 4 quarters in a year, and the seasonal pattern is 1 year.

Alternatively, to find-out seasonality (numerically), we can use another built-in Excel function "FORECAST.ETS.SEASONALITY" [24] to return the length of the repetitive pattern Excel detects for a specified time series. Note that to apply such seasonality function, we need to re-stack the forecasted values which originally stacked in different column (purposed to differentiate past-versus-forecast sales graphical plots

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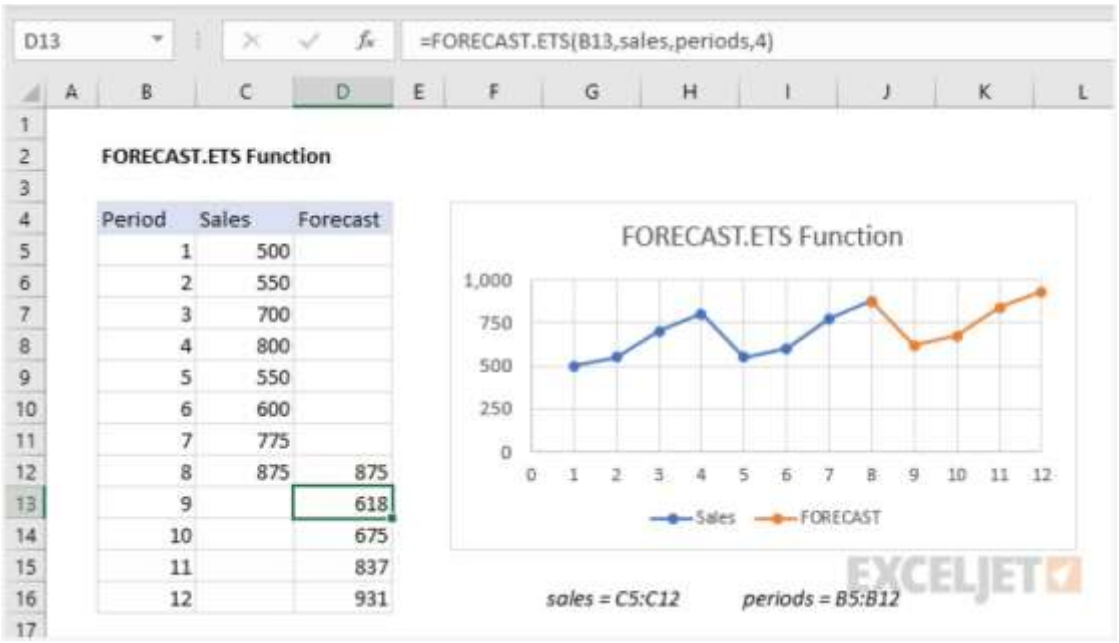

Figure 2: The Excel FORECAST.ETS Function.

in two distinctive colors), to be re-stacked in the same column as the (past) observed data. Hence, for the above sales-data example, the Excel FORECAST.ETS.SEASONALITY function [24] can be used to calculate the length of the seasonal pattern in sales between Period 1 and 12, as "=FORECAST.ETS.SEASONALITY(C5:C16,B5:B16)", after we re-stack the forecasted series into the same column as the observed (past) data series. In other words, the argument C5:C16 contains the sales values, and the argument B5:B16 contains a timeline. With these inputs, the FORECAST.ETS.SEASONALITY function [24] returns 4, as the seasonality numeric result because the interpreted values in C5:C16 represent quarterly sales data, and the length of the season is 1 year, which is 4 quarters.

V. CONCLUSION

In this article, we discussed a fast and straightforward method of TS-forecasting that may be done via the use of an Excel function called FORECAST.ETS [17–21]. We come to the conclusion that the built-in function FORECAST.ETS in Excel (version 2016 and above) is a very simple-and-quick, easy-to-use (user friendly) way to implement the well-known Exponential Smoothing Methods (ESM) family of Time Series (TS) methods [2–15] reviewed in Rahardja [16]. This was our main finding. This kind of Excel function is a simple and speedy method for forecasting that takes into consideration any level (intercept), trend (slope), and seasonality that may be included in the model. This Excel-based route of the TS-forecast option calls for a very little amount of CPU effort. It is not necessary to have experience with the Box-Jenkins methodology [1] in order to predict using such an Excel function (version 2016 and above). We have showed the use of the Excel (2019) [22] FORECAST.ETS function [17–21] to predict the future 4-period projections of sales volume by using a small (only 8-period) time-series sales-data example [21]. This example only has 8 periods of time-series data. In addition, we have shown a demonstration of the use of the FORECAST.ETS.SEASONALITY function [24] to compute the seasonality period. The numeric result of this function may be inputted into the fourth parameter (seasonality period) of the FORECAST.ETS function [17–21].

Due to its user-friendliness, economic viability (neither add-ons nor new software purchase are required), not requiring very long series of TS data, and very small computing resource required, the FORECAST.ETS built-in function [17–21] of Excel (version 2016 and above) is highly recommendable for many users who are not familiar with the Box-Jenkins methods [1].

DISCLAIMER STATEMENT

This research represents the author's own work and opinion. It does not reflect any policy nor represent the official position of the U.S. Department of Defense nor any other federal agency.

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