The Ubiquitous *ln*-Transformation in Forecasting: It Is More Complicated Than Advertised!

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Abstract

Context As Forecasters, we are advised to use the log/*ln*-Transformation for Y-Variates when there is evidence of a generating process that creates panel-points that are multiplicative over the section of the panel that will be used in developing a Time Series Forecasting Model [TSFM]. This advice is usually given as a ***Rule***—implying that there are no-application-conditions that need to be considered—*to wit*: **If** the panel tests to be multiplicative, **Then**: (i) Apply the *ln*-Transformation to the Y-Variate-values of the panel, (ii) Select FMs, and (iii) Create the forecasting profiles. We have found in consulting-engagements and, also in academic instruction, that the *ln*-Transformation merits reflective consideration to arrive at forecasts that inform the decision-making process. ***Focus*** In this research report, we offer: *A **Four**-Staged Judgment-Based **D**ecision **A**nalytic Protocol* for identifying TSFMs that likely should be included in: {The TSFM Candidate Set} when the *ln*-Transformation is warranted. These ***DA-Screening Stages*** are: (i) Experiential-Based ***Judgmental*** Screening where: Decision-Makers evaluate the **R**elative **A**bsolute **E**rror [RAE] Profiles of the TSFMs as: *ln*-Transformed & as: Downloaded, (ii) ***Inferential*** Screening for the Mean[RAE]s using the Welch[ANOVA]] and their Pairwise Mean[RAE]-comparisons using the Tukey-Kramer HSD-Profiles, (iii) ***Vetting*** Screening related to the Median[RAE]s as profiled using the Wilcoxon and Kruskal-Wallis Test and also for their Pairwise Comparisons using the Wilcoxon Method, and (iv) ***Discovery*** Screening using a Relational DA:FM-Platform to identify other TSFM-options heretofore not tested that may merit consideration.

Keywords: forecasting TS-Model profile scoring, vetting screens

1. Introduction: Why Is the *ln*-Transformation, a Staple in Time Series Forecasting?

1.1 Overview Vignettes

Following are two vignettes that are the introduction to the technical aspects of this research report—The *focus* of which is: [*Time Series Forecasting & The Role of the ln-Transformation*]. *Pedagogic Note*: We have circulated the following vignettes to Master's Level Students as interesting aspects of: (i) Time Series Forecasting, as well as (ii) The use of the *ln*-Transformation in forecasting. They seemed to have provided a useful context as the introductory-background-setting to the focus of this research report which is:

> *In the usual time series forecasting-context, what role can the ln-Transformation be expected to play?*

Consider following, the background setting for developing information on the above question.

1.1.1 The "*Elephant*" in the Forecasting Room

We are referencing the ubiquitous *ln*-Transformation of the Y-Variate; it is routinely applied to Y-Variate Panels that will be inputted to Time Series Forecasting Models, hereafter: [FM]. However, rarely are the reasons for the use of *ln*-Transformations made explicit, justified by vetting tests, considered *ex-post* to determine if they were warranted, or were useful in the forecasting context. Like the "*Elephant*"—They exist as a phase in the preparation of the data but are usually never actively recognized. We endeavor to change these behaviors.

1.1.2 The Historical Context: Euler [1707-1783]: The Father of the Most Useful Base-Function—Ever!

The historical event that seems to have launched the *ln*-Transformation, as a staple in forecasting, is Euler's synthesis of a century of investigations on the nature of logarithms, where here and there, versions of the Base $[e]$ were aired in these *ln*-musings*. In about 1748, Euler was the first to form the Limiting-form of the Base[e]. The forecasting impact of the {*ln-Transformation* & Base$[e]$ partnership} is that ***when*** the Y-Variate to be forecasted has the following ***e***xponential-form: {Y-Variate ≡ $[e^{f[t]}]$} where the exponent of the Base $[e]$ is a function of time, the logarithmic transformation [*ln*-Transformation] of: $[e^{f[t]}]$, is *ln*$[[e^{f[t]}]$ or {*ln*[Y-Variate] = *ln*[1] + *f*[*t*]]}. The *ln*-transformed Y-Variate is *often* much easier to analyze than the exponential-form: {Y-Variate ≡ $[e^{f[t]}]$}. This is usually referred to as: "Unpacking or Linearizing" the *exponential structure* of the Y-Variate. It is usually the case that the unpacked-version is more amenable to fitting Linear FM-forms. Additionally, the function: [y =$e^{f[t]}$] has as its first derivative: $y' = [[\frac{\partial[f[t]}{\partial t}] \times e^{f[t]}]$—i.e., the function y'= [C[t] × $e^{f[t]}$] reproduces or replicates the function itself, with a multiplicative factor. Thus, the rate of growth of a Euler-Form is, by definition, a Modified Euler-Form! This makes Euler-modeling constructs *unique* in the Base-World-context and are useful where modeling Growth is at issue. *See: https://mathshistory.st-andrews.ac.uk/HistTopics/e/

2. Using the *ln*-Transformation: Arguments & Illustrations

2.1 Overview

This section introduces the details, the assemblage of which, are issues regarding the use of *ln-Transformations*. Collopy and Armstrong (1992) [C&A], who created the ***Rule*** Based Forecasting [**R**BF] Expert System, drew significantly from: (i) The Watershed-Forecasting Competition conducted by: Prof. Dr. Makridakis [The M-Study See Makridakis *et al.* (1982)], as well as (ii) from interviews with a number of forecasting researchers in developing their RBF Expert System. [See C&A [p.1395]]. Our interest is in C&A's Rule [No.2 :[p.1409]]:

> "***IF*** *the functional form is multiplicative,* ***THEN*** *use a log transformation of the original series*.

Interesting Issue This Rule's ***IF*** & ***THEN*** Nature, in an epistemological context, leaves no conditions on its application.

2.2 The Transform Gurus: Box & Cox

The definitive work on transformations was penned by Box & Cox (1964) [B-C]. It may as well have been "*Cast in Stone*" as it has never been modified to any extent. The B-C transformation-set follows the codex: Given a function $[f_x]$ that is either ***Convex*** or ***Concave*** to the Ordinate, the B-C Transform that is *suggested* is a Transform that "***bends"*** $[f_x]$ in the other direction and so "*straightens* $[f_x]$ *in the CC-Plot Space*". Effectively, they suggest that:

I. Functions: $f[x]$ that are ***Concave to the Ordinate*** are likely *linearized* with: The Transformation Set: {$\sqrt{f[x]}$ & *ln*$[f[x]]$}, while

II. Functions: $g[x]$ that are ***Convex to the Ordinate*** are likely *linearized* with the Power-Transform Set: λ^p where: p >1, typically 2 or 3.

For example, *given the above context*, the B-C transform codex for the [λ-*Power* Transform: [f_x^{λ}: $\boldsymbol{\lambda^{p=2}}$] is:

[λ > 0] Power Transform of: $[f_x]$ is: [($f_x^{\lambda=2}$ − 1) / (λ =2)]

Assume that for $f_{x=8}$, the 8th Panel-**V**alue is: 1.2447, the B-C Power Transform: [λ= 2] is:

$$\text{B-C: } \{V_{x=8} = 1.2447\text{: } \lambda= 2\} \text{ gives: } [(1.2447^2 - 1) / 2] = \boldsymbol{0.274639}$$

Alert There are a number of *Google*™ Search Links that indicate that for the above B-C: [x = 1.2447: λ= 2], the Power Transform is: 1.2447^2 = 1.549278; ***this is not correct***. For interesting literature that are classical applications on the *ln*-Transformation See: [Cooke (1998), Lütkepohl & Xu (2012), and Tukey (1977)].

2.3 An Illustration: The critical details of the ln-Transform

For example, a variable that exhibits ***t***ime related growth that accelerates at *The Euler-Rate* for a driver-variable during [time [***t***]] has what is called: "natural"-exponential-growth with respect to **t**. As this is our *wheelhouse*; let us ***suppose*** that there is such a growth process that is the generating-process [or driver] of the Y-Variate: [Y= *The Value of the Current Ratio of a Class of Blue-Chip S&P*$_{500}$ *Securities*]. In this case, assume that the Euler-Form measured is: [Y-Variate = [$e^{[9.2\% \times t]}$]]. See Figure 1:

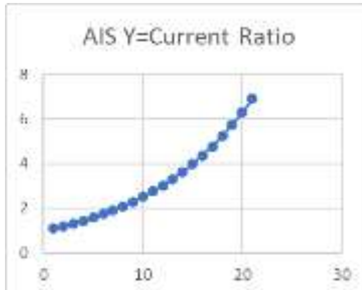

Figure 1. *Assumed* Y-Variate [*The Value of the Current Ratio of a Class of Blue-Chip Securities*]

Critical Note: Figure A presents a line that is *Concave to the Ordinate* [*The Y-Axis*] and so is also Convex to the *Abscissa* [*The X-axis*]. ***We will always use the orientation of a line only as it is relative to the Ordinate***.

The 21 observations for this Y-Variate are presented in Table 1 following:

Table 1. Y-Variate Panel = [*The Value of the Current Ratio of a Class of Blue-Chip Securities*]

1.**096365**; **t=1***	1.202016	1.317848	1.444842	1.584074	1.736723	1.904082
2.087569	2.288737	2.50929	2.751098	3.016207	3.306863	3.625528
3.974902	4.357942	4.777895	5.238316	5.743105	6.296538	6.903303; **t=21**

*where: The Current Ratio Profile at t=1, **is**: Y= [$e^{[9.2\% \times [t=1]]}$] or $e^{[9.2\%]}$ = ***1.096365.***

Discussion

A forecaster notices that:

I. as, this is a Euler-base function, it can be un-packed to its [f_t]-profile over [*t*], by taking *ln* of the Panel in Table 1, the generating function of which is [[9.2% × t]], and

II. thus, f_t= [9.2% × t]] would be ***much simpler*** to use to generate Y-[Current Ratio]-Variate *forecasts* ***rather than*** to fit a FM to the Y-Panel in Table 1.

For example, to check if, *in fact*, the growth rate is *Euler-calibrated* over the Panel in Table 1, she runs a ***vetting-screen*** on the data in Table 1. She knows that, *if and only if*, this is a Euler-form *then* the *ln* of the data in Table 1 should be a true ***straight-line***. To this end, she creates the following ***vetting***-intel:

$ln[Y: [Current\ Ratio]_t]$ gives: $ln[e^{[9.2\% \times t]}]$; this ***un-packed*** is:

ln[Y- Variate] = [*ln*(1) + $ln[e^{[9.2\% \times t]}]$, or = [0 + [9.2% × t] or

$ln[Y: [Current\ Ratio]_t]$ is: [f_t] = [9.2% × t]

which is a ***true straight-line*** in the *ln*-measure! See Figure 2:

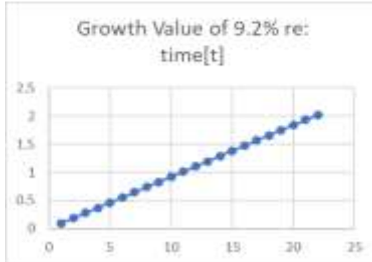

Figure 2. *ln*[Y-Variate: Table 1]

Assume she wants to project/forecast the Current Ratio for *t* =22. *She does not need a Forecasting Model****, as she has determined that the Y-Variate is a Euler-Form as Figure B is a straight-line,*** she just makes the following computation:

$$[f_{t=22}] = [9.2\% \times t] = [0.092 \times 22] = 2.024.$$

The *Excel*™[forecast] of the Y-Variate is: EXP[2.024]= ***7.568539***

This "forecast" is ***7.568539 and is*** in the AIS-calibration because ***the Y-Variate is a Euler-Form***, and thus is identically equal to: $e^{f[9.2\% \times 22]}$. This is, of course, a ***tautology*** as the Y-Variate ***is*** a Euler-form.

Discussion

When we find an ***exact*** Euler-Form Profile, as was presented ***in the above example***, there is NO need of a FM! One simply takes the *ln* of the Euler-Form and the forecast will be: The EXP[*ln*[$e^{f[t]}$]] or EXP[$f[t]$]] in the measure of the AIS Y-Variate. ***Caveat*** However, this is ***True*** only under the conditions indicated. In our experience, we have NEVER found an ***exact*** Euler-Form that *was stable* over the entire range of a longitudinal-Panel. And, *dare we say*, neither has anyone else who is doing trading market studies! The point of this introduction was to indicate that applying the *ln*-Transform is a very reasonable first step in the Forecasting Context when:

I. There is evidence of a *multiplicative generating process.* [*Note: The generating process does not need to be a Euler-Class function—only that the generating process of the Y-Variate creates a* **multiplicative** *Panel!*], and

II. The Y-Variate is ***Concave to the Ordinate***—actually, we just use a visual screen to make this determination,

The reason that C&A have offered Rule 2 is that the *ln*-Transform applied to the Y-variate Panel, under the above conditions "linearizes" the Y-Variate Panel thus, making it more amenable to forecasting with a The OLS Two-Parameter [Intercept & Slope] Linear TS Regression FM. However, *as there are important conditions to this assumed feature of a ln-Transform*, we feel that that C&A *Rule No.2* begs critical examination.

2.4 The Application of the ln-Transformation: When & How Is It Likely to Help in TS Forecasting

If one of the tests for the application of the *ln*-Transformation is: *panel-point multiplicity*, then the test for *multiplicity* is a possible "confounder" to the correct use of the *ln*-Transformation! For example, here is the Plot of [g(x)]:

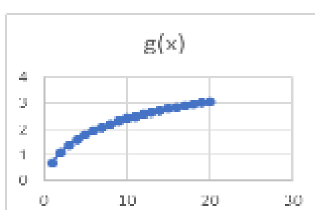

Figure 3. Example of [g(x)] that is *Convex* to the Ordinate

The generating process of g(x) is, by any measure, Multiplicative. Thus, if we follow C&A's *Rule 2* and take the *ln* of this Y-Variate Panel, we obtain the following:

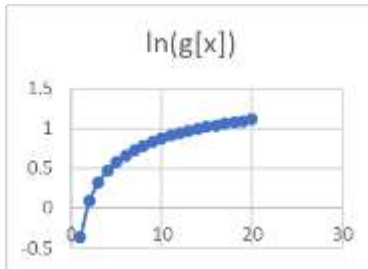

Figure 4. Projection of ln[g(x)]

This model, ln(g(x)), (i) still tests to be multiplicative, (ii) is even more Convex to the Ordinate, and (iii) is far from a linear-projection! Thus, the *multiplicity* of g(x), resulted in using the ln-Transformation as we were following the C&A's [Rule 2], and so the multiplicity of g(x) was a confounder as it leads us to "*Do the Wrong Thing*" if the goal of the application of the ln-Transform was to create a more linearized-panel.

2.4.1 Doing the Right Thing

As noted in Sections 2.2 & 2.3, the Box & Cox Transform Set, spans an interesting and very practical Y-Variate Space. For example, if we applied the B-C: [Power-Transform: $\lambda^{p=3}$] to the panel in Figure C, this results in the plot in Figure 5:

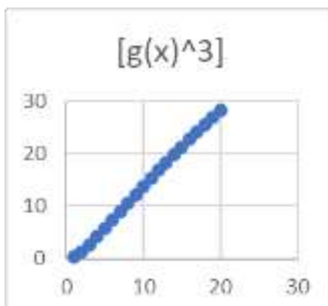

Figure 5. Power Transform $\lambda^{p=3}$ applied to: $g[x]$

The B-C λ-Power Transformed function: $g[x]^{p=3}$ produces a projection close to a linear function.

2.4.2 The Message Is Simple, "*Look Before You Leap*"

To follow C&A's Rule[2] and so elect to use the ln-Transformation so as to linearize your Y-Variate-Panel, which is the *manifest rationale* to take the ln-Transform so as to make the Y-Variate more amenable to fitting a OLSR-Class-FM to generate intel for Planning, is not as simple as it sounds. In fact, Lütkepohl & Xu (2012, p.619) indicate that:

"*Using logs can be damaging for the forecast precision if a stable variance is not achieved*."

Consider now our screening-measure for multiplicity, which is the starting point for considering the ln-Transform.

2.4.3 The Coefficient of Determination [CoD]: A Designer Multiplicity Screen

In electing to use a ln-Transform, the forecaster is advised to: ***First*** discern the nature of the multiplicity of the panel-points that will be used to create the forecasts that are to be used by the Planning Committee. In this case, we suggest using the following inferential test of the Coefficient of Determination [CoD[of the Y-Variate under consideration. The reason that we prefer the CoD, among the many others that are possible, is that the COD is the R^2 of the OLS Linear Regression and this, of course, "*dove-tails*" very well with the purpose of using the ln-Transform. The CoD is defined as:

CoD ≡ [**P**earson **P**roduct **M**oment **C**orrelation [$\hat{\rho}$]]^2

where: $\hat{\rho}$ is the sample estimate of the population PPMC[ρ].

We find: **IF** the ***F**alse **P**ositive **E**rror* [FPE] of $\hat{\rho}$ for the Null of H_o is < 15%, **THEN** the CoD likely indicates that the Y-Variate has a generating process that is *multiplicative* in nature.

3. The Four-Staged *J*udgment-*B*ased: *D*ecision *A*nalytical-*F*orecast *M*odel *S*creening: [*J-B:DA-FMS*] Protocol

3.1 Overview

Above we have presented graphical informative detailing the nature of the *ln*-Transformation. This was the motivation for the development of what is to follow in terms of using and benefiting from intel generated by the [J-B:DA-FMS] Protocol. The first set of conditionals that need to be addressed are: *The Pre-FM Analysis*: [*Data Preparation*]. ***Alert*** Our experiential-*spin* on these *Pre-Analysis* steps is that, in the practice of forecasting, they are very often either: (i) ignored or, (ii) poorly executed.

3.2 Pre-FM DA Y-Variate Screening

When the forecaster is considering a Y-Variate Dataset that is to be forecasted, there are the following ***two*** screening stages to be executed to ***qualify*** the Y-Variate as valid input to the [J-B:DA-FMS] Protocol:

Stage A

I. Is the Y-Variate dataset, as downloaded, likely "*reasonably*" linear based upon an *experientially informed visual-vetting*? **if Yes, then proceed to Stage B. If No, then**

II. Is the Y-Variate dataset, as downloaded, likely to be: Section [2.4.3]-CoD-inferentially vetted as a series that is multiplicative over the panel-set of data to be forecasted? **if Yes, then proceed to Stage B, If No, then**

III. The Director of Forecasting [DoF] must consider other Y-Variates to determine the Y-Variates that qualify for input to the [J-B:DA-FMS]} Protocol.

Stage B

If the forecaster's "*terminal*" answers to this query-screen are: ***Yes***, then there are the following ***eight*** data preparation steps that are *pre-conditions* to the use of the [J-B:DA-FMS] Protocol:

I. The Y-Variate under consideration is a variable, the forecast of which, usually portends intel **likely to inform** the decision-making of the **Planning Committee**,

II. The Graph of the Y-Variate as downloaded is judged to be: **Not be Convex to the Ordinate** over the panel that will be used in forecasting,

III. A section of this Y-Variate panel **can be held-back** to evaluate the acuity of the forecasts generated by the FMs selected to create the forecasting-projections,

IV. The measures of forecast acuity **were *a prior* specified and agreed upon** by all in the forecasting process to be useful in informing the members of the Planning Committee,

V. The *ln*-Transformation is **Possible**—i.e., all Panel Points are > 0,

VI. As ***D**ecision **A**nalytics* is the current and "correct *mode d'analyse*", usually there would be a **few FMs selected** from: {*The FM-Candidate Set*}: [*A Firm Archive where FMs that have proven to be useful in forecasting & planning are detailed*],

VII. **Robustness Consideration** The inputs to the selected FMs will be: **(i)** The downloaded AIS-data, ***as well as***, **(ii)** The related *ln*-Transformed panels,

VIII. ALL of the results from the *ln*-transformed panels **will be Re-Transformed**—i.e., The finals results for informing the planning process must be: EXP[*ln*-Forecasting Results] and so presented in the AIS-measures as downloaded from the firm's AIS, and

IX. SUMMARY Screening Decision—**IF** ALL eight of the Stage B Screens are likely true, **THEN** the **[*J-B:DA-FMS*] Protocol is likely to be a vetted protocol and will likely create useful intel foe the Planning Committee.**

Toggle Caveat The results of the *Pre-FM DA Y-Variate Screening* will very likely be that the set of FMs that ***qualify*** to create the forecasts for DA-screening will be in the FM-Range of: {Moving Average, Simple Exponential Smoothing, OLS Linear Regression, ***or*** ARIMA(0, 2, 2)/Holt FMs}. FMs, such as the following, that were used in the M-Study: [Box-Jenkins Transfer Functions, Bayesian Iterative, Adaptive Rate Exponential Smoothing, Two-Stage Adaptive Integrated Models, ***or*** The Weighted Average Combinations of FMs] will rarely have the underlying operational assumptions that would rationalize their selection for the Y-Variates that are screened by the set of conditionals presented in Section 3.2. **Note** All of the FMs cited above are detailed in: The M-Study [Makridakis et al. (1982):$_{\text{[Appendix 2]}}$.

4. The Operational Details of the [J-B:DA-FMS] Protocol

4.1 Overview

We have selected a derivative of the Y-Variate Panel [f[x]] presented in Figure A. This is an excellent transition from the introductory section. Specifically, for forecasting, we will ***re-form*** the Y: *Current Ratio* of Figure A & Table 1: To reflect three Euler-segments, n = 7 ***for each***. The Euler[segments] are: $e^{[r[i]\% \times t]}$ where: r[i]: = 2.3% then = 4.3%, and finally = 6.3%. These values are in Table 2.

Table 2. Re-Formed Table 1 to reflect Three Sections of a Euler-Form

r=[2.3%] × t	**1.02327**	1.047074	1.071436	1.096365	1.121873	1.147976	1.174685
r=[4.3%] × t	**1.41058**	1.472556	1.537258	1.604801	1.675313	1.748923	1.825767
r=[6.3%] × t	**2.57281**	2.740115	2.918296	3.108064	3.310171	3.525421	3.754669

The graph of this segmented-Euler-Panel of Table 2 is:

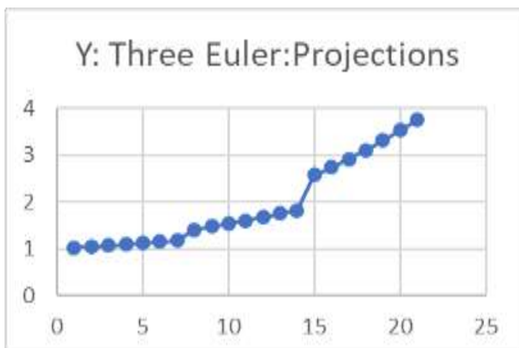

Figure 6. The Plot of the Y-Variate Composed of Three Euler-Forms

Pre-FM DA Y-Variate Screening In this case, we apply the ***Stage A*** screening tests for Table 2 as follows:

I. Is the Y-Variate dataset, as downloaded, likely "*reasonably*" linear based upon an *experientially informed visual-vetting*? ***We suggest that the above Plot of Table 2 does not seem to be linear. Thus, we consider the next Screening Phase***

II. Is the Y-Variate dataset, as downloaded, likely to be: *Section [2.4.3]-CoD-inferentially vetted* as a series that is multiplicative over the panel-set of data to be forecasted? ***To offer information on this question, we will address the inferential nature of the CoD of Table 2.***

The CoD of Table 2 is**:** 89.3%**; thus**, the PPMC is**: 94.5%** [$\sqrt{89.3\%}$]. The required inferential test of Section [2.4.3] is:

$$[t_{[Calc]}] = [\ [94.5\% \times \sqrt{19}]\ /\ [1 - (94.5\%)^2]\text{^}0.5] = \mathbf{12.6}$$

$$[t_{[df=[21-2]]}] = \mathbf{12.6}\ \textit{thus}, \text{ the FPE[p-value] is } <0.0001$$

This FPE[p-value] indicates that the Y-Variate in Table 2 has a set of panel points that are clearly multiplicative. This being the likely case, we move to the ***Stage B***, considerations. All the eight of the ***Stage B Screens*** seem to be ***True***—Including, of course, **Stage B[II]:** The Graph of the Y-Variate of Figure F[Table 2] as Downloaded is judged **Not be Convex to the Ordinate** over the Panel that will be used in forecasting.

4.2 Continued Probing of the Proposed Panel

To test to determine if Figure F is a Euler-Form *for the full-Panel, n=21*, we examine the *ln* of Table 2 to determine if the *ln*-Transform creates a straight-line over the full-panel; if this were to be the case, NO FM would be needed. See Section [3.1[Stage A]]. This gives:

Table 3. *ln*-Transformation of Table 2: Three Euler-Forms

0.023	0.046	0.069	0.092	0.115	0.138	0.161
0.344	0.387	0.43	0.473	0.516	0.559	0.602
0.945	1.008	1.071	1.134	1.197	1.26	1.323

Discussion

In this case, each Row is indexed for the changing *r*. For example, row [1] starts as: *ln*[$e^{[2.3\% \times t]}$for t: 1,- - -,7; Row [2] starts as: *ln*[$e^{[4.3\% \times t]}$for t: 8,- - -,14; and Row[3] starts as: *ln*[$e^{[6.3\% \times t]}$for t: 15,- - -,21.

Computational Vetting:

Table 3 Matrix[1,1] is [2.3% × 1] = ***0.023***,

Table 3 Matrix[2,1] is [4.3% × 8] = ***0.344***, *and*

Table 3 Matrix[3,1] is [6.3% × 15] = ***0.945***

The graph of the *ln*[Table 3] is:

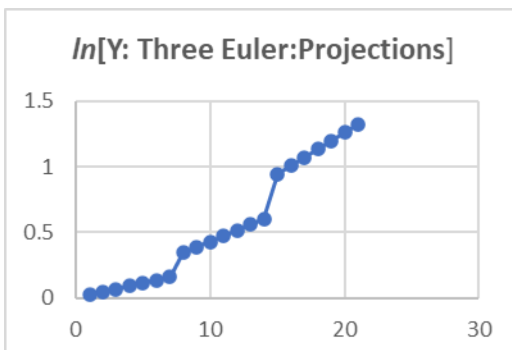

Figure 7. The Plot of the *ln*[Three Euler-Forms of Table 2]

Discussion

In this case, there is visual evidence that the *ln* of: {Y: Three Euler Panels [Figure F]} is *not a Straight-Line for the 21 Panel-Points*; ***thus***, as the [J-B:DA-FMS] *Protocol is a* ***D****ecision* ***A****nalytical Screening Platform*, we will select a ***set of FMs*** to create the forecasts from the Panels in Tables 2 **&** 3.

4.3 Summary: *Pre-FM Selection*

This intel indicates that as:

I. There is visual evidence that the plot of the downloaded Y-Variate [Table 2] was not *likely:* (i) *Linear nor* (ii) *Convex to the Ordinate*, ***and as***

II. The CoD of Table 2 suggests that the panel points in Table 2 are *likely multiplicative in Nature*, ***then***

the [J-B:DA-FMS] Protocol *may be used* to generate two-forecasts for each FM-selected: One for the Panel in **Table 2** as *Download* & One for The Box-Cox *ln-Transformed Panel* **[Table 3]**.

5. The Four-Staged Judgment-Based: Decision Analytical-Forecast Model Screening: [*J-B:DA-FMS*] Protocol

5.1 The DA-Analysis: The Measure of Forecasting Acuity

Given the above intel, the next step is to select the measure of ***Forecasting Acuity***. In this regard, we strongly prefer the **R**elative **A**bsolute **E**rror [RAE] as our measure of forecasting acuity. Also, See Armstrong & Collopy (1992).

Here following are the computations and the ***rationale*** for selecting the RAE:

The usual [or Standard Form] configuration for the RAE is:

RAE ≡ The Ratio of The Absolute Percentage Errors [APEs] of two FMs.

where: the ***Numerator*** is the FM to be **T**ested: FM_T; and, the ***Denominator*** is the **B**ench**m**arking FM_{Bm}**.** Thus, the value of the RAE, in this standard format, is:

RAE ≡ [APE[FM_T]] / [APE[FM_{Bm}]]

For a **particular panel** under evaluation, **IF** the RAE is >1.0, this indicates the ***fact*** that:

The APE[FM_T] was > the APE[FM_{Bm}].

Thus, this rationalizes that the FM_{Bm} out-performed the FM_T on their relative APE-measures. ***Alert*** Belhadjali & Lusk (2025) [B&L] indicate that for large panel inferential companions, the overall Mean [RAE]s of various blocks of panels can be difficult to de-code. However, in our FM-Triage context, we will be creating ***individual*** ratio benchmarks for ***each*** forecast. Thus, the Mean [RAE] of these individual-ratio-benchmarks is a meaningful indication of the relative forecasting activity. ***Note*** This Mean [RAE] is different conceptually than the aggerate ratios of: [Mean [APE [FM_T] / Mean [APE [FM_{Bm}]]. We will indicate this difference when we offer the illustrative computations.

5.2 The DA-Analysis: The Selection of the FMs

The last phase in the protocol is to select the FMs to be used. Usually, the DoF will examine the firm's {Archives of FM-Candidates} that have been successfully used in the past and, are so vetted. Then, the DoF's selections will be used in the [J-B:DA-FMS] Protocol. The authors selected the following FMs:

I. ***The Random Walk*** **[*RW*]** ***FM Model*** of the M-Study & C&A. The RW FM uses the Last panel point of the panel that will be used to parameterize the FMs-selected as the RW-FM forecasts for ***all*** the projections required. Thus, the RW FM is a ***Static*** FM and for this reason is very often used ***to benchmark the Data-Driven Dynamic FMs***,

II. ***The OLSR***-Two Parameter [Intercept &Slope] ***Linear*** Time Series Forecasting Model [*OLSR*] See: *SAS*™[*JMP*™[Bivariate[p.73]$_{[v.13]}$]2005], and

III. ***The ARIMA(0, 2, 2) Model***—also referred to as: The Two Parameter [Intercept &Slope] Linear ***Exponential Smoothing*** Time Series Model of ***Holt***. See: SAS[JMP[p.615]$_{[v.\mathbf{13}]}$].

5.3 Summary

These are the Standard FMs that have been in use for many decades and address: *linear* as well as *exponential* data profiles. For our measure of FM-Acuity, the RAE, the *dynamic* FMs will be benchmarked by the *static* RW FM. In the service of the DA-Profile Screening, we will create RAE-Forecasting Acuity Profiles using the data in: Table 2 & Table 3. This will produce the following four-profiles:

I. FM[OLSR: RAE[OLSR/**RW**]: Download[Table 2],

II. FM[OLSR: RAE[OLSR/**RW**]: *ln*[Download[Table 3]],

III. FM[Holt: RAE[Holt/**RW**]: Download[Table 2], and

IV. FM[Holt: RAE[Holt/**RW**]: *ln*[Download[Table 3]]

6. The DA Scenario Profiling: The Results

6.1 The Acuity Measure: Illustrative Computations

As noted above, the RAE is our preferred measure of forecasting acuity. In the interest of clarity, let us consider the RAE-Profile for the OLSR[DL[Table 2] as well as the Holt[*ln*[Table 3]].

6.2 Computations for: The APE[*OLSR*[*DL*[*Table 2*]]]

Initially, the DA-Analyst will compute the APE of the OLSR[DL]

Table 4. APE[OLSR[Download of Table 2] *OLSR***[***DL*]]

Forecasts[FC_t]	OLSR[DL]	Holdbacks[DL]	APE[ORSL[DL]]
[$FC_{t=22}$]	3.488149	3.998823	0.127706
[$FC_{t=23}$]	3.628252	4.258854	0.148068
[$FC_{t=24}$]	3.768354	4.535793	0.169196
[$FC_{t=25}$]	**3.908457**	**4.830742**	**0.19092**
[$FC_{t=26}$]	4.04856	5.144869	0.213088
[$FC_{t=27}$]	4.188662	5.479424	0.235565
Average[APE]	N/A	N/A	**0.180757**

Computational Illustration for [$FC_{t=25}$] The OLSR forecast at: [t = 25], was: **3.908457**. The Actual Value[Holdback] for the Y-Variate[Current Ratio] at: [t=25], was: **4.830742**. [EXP[25 ×6.3%] thus, the APE[OLSR[$FC_{t=25}$]] is:

APE[OLSR[$FC_{t=25}$]]: ABS[3.908457 − 4.830742] / 4.830742] **= 0.19092**

The Mean of the APE is: **0.180757**. This indicates that overall, for the six forecasts, that the non-directional error as a percentage of the actual value was 18.1%. C&A have noted that for their Rule Based Forecasting Expert System that 25% for an APE is a justifiable decision-making *Toggle-Point*. See C&A [p.1405]. In this case, as the APE[OLSR[DL]] is < than 25%, we note this a positive indication of acceptable forecasting acuity re: The APE measure.

6.3 Benchmarking of the Dynamic-FMs

The next measure for the [J-B:DA-FMS] Protocol is the benchmark of APE[OLSR[DL]] *relative to the Random Walk FM*. ***Recall*** We are using the RW FM as the Benchmark of the OLSR & Holt FMs. This concept is endemic to our de-coding the acuity of a FM's relative APE. For example, the Mean APE[OLSR[DL]] was 18.1% and using C%A's calibration, 18.1% seems like a positive indication of the performance of the OLSR FM. However, what if it were to be the case that the RW FM—*the simplest* ***static*** *forecasting projection possible*—had an APE profile, the Mean of which, was **7.2%**. In this case, the RW FM was outperforming the OLSR FM! This would be critical intel in the selection of the OLSR[DL] as a FM-candidate that merits inclusion in the {Set of FM-Candidates} to be considered by the Planning Committee. Following we suggest that the DA-Analyst create the APE of the RW FM as this is the benchmark that is often used to judge the forecasting acuity of a FM as measured as the RAE.

6.3.1 The APE of the RW FM

It is not uncommon to criticize the RW FM as "*Absurdly Simple*" because the RW forecast is the last observation that is used to fit data driven FMs such as: The OLSR & The Holt. *Point well taken*—in fact, Makridakis *et al.* (1982) labeled the RW FW as the *Naive 1 Model*. However, the **S**imple: [**αE**xponential **S**moothing FM]: [S**E**S[**α**]] after it reaches its last calibration, uses as its forecast the last Panel-value as the forecasts for *All* the horizons as does the RW FM. See: SAS[JMP[p.614]$_{[v.13]}$]. Thus, in addition to the fact that both the M-Study and C&A used the RW as a FM, there is this SAS-precedent of offering an extension of the SES as the RW FM. We offer this as a vetting indication for our selection of the RW FM as our benchmark.

6.3.2 The Gold Standard Forecasting Benchmark

Following is the Table for creating the APE[RW] that will be the benchmark for all four FM: {OLSR[DL] & Holt[DL] & OLSR[*ln*] & Holt[*ln*]}.

Table 5. APE of the RW FM

Forecasts[FC_t]	RW	Holdbacks	APE[RW]
[$FC_{t=22}$]	3.754669	3.998823	0.061057
[$FC_{t=23}$]	3.754669	4.258854	0.118385
[$FC_{t=24}$]	3.754669	4.535793	0.172213
[$FC_{t=25}$]	**3.754669**	**4.830742**	**0.222755**
[$FC_{t=26}$]	3.754669	5.144869	0.270211
[$FC_{t=27}$]	3.754669	5.479424	0.314769
Average	N/A	N/A	**0.193232**

Discussion The computation to be made for the RW[APE] for [t = 25] is as follows:

ABS[3.754669 – 4.830742] / 4.830742] = **0.222755**

6.3.3 The ***Individual*** RAE-Benchmarking

Finally, the Mean[RAE] is derived as:

Mean[RAE[OLSR[DL]/RW]] = Mean:[[APE_t^{OLSR} / APE_t^{RW}]] where: t= 1, - - -, 6

This computation is presented in Table 6:

Table 6. The OLSR[Table 2] Profile for the RAE

Forecasts[FC_t]	APE_t^{OLSR}	APE_t^{RW}	$RAE_{APE_t^{RW}}^{APE_t^{OLSR}}$
[$FC_{t=22}$]	0.127706	0.061057	2.091603
[$FC_{t=23}$]	0.148068	0.118385	1.250735
[$FC_{t=24}$]	0.169196	0.172213	0.982479
[$FC_{t=25}$]	**0.19092**	**0.222755**	**0.857084**
[$FC_{t=26}$]	0.213088	0.270211	0.788598
[$FC_{t=27}$]	0.235565	0.314769	0.748374
Average	N/A	N/A	**1.119812**

Computational Illustration:

$$RAE_{APE_{t=25}^{RW}}^{APE_{t=25}^{OLSR}} = [APE_{t=25}^{OLSR} \ / \ APE_{t=25}^{RW}]$$

$$RAE_{APE_{t=25}^{RW}}^{APE_{t=25}^{OLSR}} = [\mathbf{0.19092 \ / \ 0.222755}] = \mathbf{0.857084}$$

The Mean of: [$RAE_{APE_t^{RW}}^{APE_t^{OLSR}}$] was **1.119812**, thus indicating that the OLSR FM did not outperform the RW FM as the Mean Ratio was >1.0—to wit: The OLSR[DL] FM was greater in the APE-context than was that of the RW FM and so did ***not*** markedly outperform the RW FM as the RAE [Mean] was > 1.0. In most contexts, this would suggest that the OLSR[DL] **would not likely qualify** as a FM to be included in the FM-Candidate Set. ***Note*** This Mean of: $RAE_{APE_t^{RW}}^{APE_t^{OLSR}}$ is the correct relative measure for the evaluation of forecasting acuity as it was formed ***individually*** over the projections. The ***aggregate*** *of* the Ratio of the Mean [APEs] is misleading as B&L have suggested, Specifically, the Ratio: {[*Mean* [OLSR[APE]]} */ Mean* [RW[APE]] of: Table 4[0.180757] /Table 5[0.193232] = ***0.936*** compared to the individual measure of Table 6 of: ***1.119812***. As **0.936** is < than ***1.119812*** this *could be interpreted* as evidence that the OLSR FM outperformed the RW FM.

6.4 Computations for: *The Holt*[*ln*]

Next, the DA-Analyst will compute the APE of the Holt[*ln*]. In this case, we have applied the *ln*-Transformation to the dataset in Table 3. The Holt[*ln*] is found in Table 7,

Table 7. APE[Holt[Download of Table 3] *Holt*[*ln*]]

Forecasts[FC_t]	Holt[*ln*]	Holdbacks[*ln*]
[$FC_{t=22}$]	1.393382	1.386
[$FC_{t=23}$]	1.463722	1.449
[$FC_{t=24}$]	1.534062	1.512
[$FC_{t=25}$]	1.604402	1.575
[$FC_{t=26}$]	1.674741	1.638
[$FC_{t=27}$]	1.745081	1.701
Average	N/A	N/A

6.4.1 The Re-Transformation Imperative: Back to the AIS-Context

In this case, the *ln*-Measures should be transformed back to the AIS-Measures of the firm. The reason for this is a practical matter of facilitating the communication of the meaning of the FM-Profile. *Exclusively*, in our experience, the Planning Committee will **REFUSE** to work with the *ln*-Transformed-values. ***Rationale*** Here is a paraphrase of the Chair of the Planning Committee made during a presentation of the results of the Forecasting Planning Session.

> *"Before you go any further, we need to see the ACTUAL forecasts—I* [*and WE*] *have no idea what this Logarithm—# # # # is all about. So, lets re-schedule the forecasting briefing—and ASAP present us with AIS-numbers—NO Smoke & Mirrors."*

Following on this *admonition*, we always present the forecasting profiles in the measure of the AIS of the firm!

6.4.2 Holt[*ln*]: Computational Illustration

Given the *ln*-information in Table 7, we recommend that the DA-Analyst re-transform the *ln*-intel as follows:

Table 8. Re-Transformation of the Holt[*ln*[Table 7]]

Forecasts[FC_t]	Holt[*ln*]	Holdbacks[*ln*]	Holt[EXP[ln]]	Holdbacks[EXP[ln]]
[$FC_{t=22}$]	1.393382	1.386	4.028453	3.998823
[$FC_{t=23}$]	1.463722	1.449	4.322017	4.258854
[$FC_{t=24}$]	1.534062	1.512	4.636974	4.535793
[$FC_{t=25}$]	**1.604402**	**1.575**	**4.974882**	**4.830742**
[$FC_{t=26}$]	1.674741	1.638	5.337415	5.144869
[$FC_{t=27}$]	1.745081	1.701	5.726366	5.479424
Average	N/A	N/A	N/A	N/A

Computational Illustration For [$FC_{t=25}$], we have:

EXP[Holt[*ln*]] is EXP[**1.604402] = 4.974882, and**

EXP[Holt[*ln*]] is EXP[**1.575] = 4.830742**

Using these EXP:[Re-Transformed [ln]]-values that are now in the usual AIS-measures, the DA-Analyst will create the following Table 9 for the APE[Holt[EXP[ln]]]:

Table 9. For the Re-Transformed Holt [ln] of Table 8 giving the APE[AIS[Values]]

Forecasts[FC_t]	Holt[EXP[ln]]	Holdbacks[EXP[ln]]	APE[Holt[EXP[ln]]
[$FC_{t=22}$]	4.028453	3.998823	0.007410
[$FC_{t=23}$]	4.322017	4.258854	0.014831
[$FC_{t=24}$]	4.636974	4.535793	0.022307
[$FC_{t=25}$]	**4.974882**	**4.830742**	**0.029838**
[$FC_{t=26}$]	5.337415	5.144869	0.037425
[$FC_{t=27}$]	5.726366	5.479424	0.045067
Average [APE]	N/A	N/A	0.026146

Discussion

The computation to be made for the [APE[Holt[EXP[ln]]]] for [t = 25] is as follows:

ABS[4.974882 − 4.830742] / 4.830742] = **0.029838**

6.4.3 The RAE for the Holt[ln]

Finally, the $RAE_{APE_{t=25}^{RW}}^{APE_{t=25}^{Holt}}$= [$APE_{t=25}^{Holt}$ / $APE_{t=25}^{RW}$] gives the following Table 10.

Table 10. For the Holt Re-Transformed Data the RAE is Presented

Forecasts[FC_t]	APE_t^{Holt}	APE_t^{RW}	$RAE_{APE_t^{RW}}^{APE_t^{Holt}}$
[$FC_{t=22}$]	0.007410	0.061057	0.121359
[$FC_{t=23}$]	0.014831	0.118385	0.125278
[$FC_{t=24}$]	0.022307	0.172213	0.129532
[$FC_{t=25}$]	**0.029838**	**0.222755**	**0.133950**
[$FC_{t=26}$]	0.037425	0.270211	0.138502
[$FC_{t=27}$]	0.045067	0.314769	0.143175
Average[RAE]	N/A	N/A	**0.131966**

Discussion

The computation to be made for the [RAE[Holt[EXP[ln]]]] for [t = 25] is as follows:

$RAE_{APE_{t=25}^{RW}}^{APE_{t=25}^{Holy}}$ = [**0.029838 / 0.222755] = 0.133950**

The Mean of: [$RAE_{APE_t^{RW}}^{APE_t^{Holt}}$ ***individually* over [*t*]**] is: **0.131966**. This indicates that the Holt[Exp[ln[Re-Transformed]]] FM ***markedly*** outperformed RW FM. In most contexts, this would suggest that the Holt[Exp[ln[Re-Transformed]]] FM **likely qualifies** as a FM likely to inform the decision-making process of the Planning Committee and so would merit being included in the {FM-Candidate Set}.

These computations are used to create the comparative intel for the tests of the following Four FMs:

{OLSR[DL] & OLSR[ln] & Holt[DL] & Holt[ln]}

7. The [J-B:DA-FMS] Protocol: The Four Judgmental Stages

7.1 Overview

Recall the explicit focus of this research report:

> *We are interested in offering a forecasting protocol that is exclusively focused on:* ***D****ecision* ***A****nalytical Screening of various forecasting profiles for Time Series Forecasting Models where the ln-Transformation is Analytically warranted.*

In this context, we offer The J-B:DA-FMS Protocol that has the following four ***Judgmental*** vetting phases:

I. ***Experiential Vetting*** The discussion among the members of the Planning Committee to evaluate the ***RAE-Profiles*** of the *four* FMs under examination,

II. ***Inferential Vetting*** The discussion of the inferential *parametric* analyses of the ***Mean*[*RAE*]s** using: The Welch[ANOVA] & The Tukey-Kramer HSD FPE-$C_2^{n=4}$[pairwise comparisons],

III. ***Enhanced Confirmatory Vetting*** A discussion of *confirmatory* robustness vetting analyses of the ***Median*[*RAE*]*s*** using the Wilcoxon and Kruskal-Wallis Rank Sum test, where the pairwise comparisons are developed from the Wilcoxon Method, and

IV. ***Exploratory Discovery Vetting*** A forecast-profiling of: {The Downloaded AIS Y-Variates *as well as* The *ln*[Downloaded AIS Y-Variates} using one of the commercially available SQL-Platforms, where: These Y-Variate Panels are profiled by ALL the FMs in that firm's [SQL[Data Base]]. Usually, this will be conducted only by the members of the Division of Forecasting. This exploratory screening is used to determine if there are FMs that are not in the firm's {Archive of Active Forecasting Models}but seemed to have performed well for the FMs in the FM[SQL[Data Base]]. These FMs can then be evaluated to determine if they qualify to be included in the firm's {Archive of Active Forecasting Models}.

7.2 The Experiential Vetting Phase

This judgmental-intel will be used, in most cases, by the members of the Planning Committee based upon their collective experiential-intel to identify for reflective discussion: (i) Planning Intel gleaned from the Y-Variates tested, and (ii) The FMs in Table 11 that seem to constitute possible FM-Candidates for the Archives that will be used in future forecasting studies.

Table 11. Forecasting Results for the Models Tested

Test Values	OLSR[DL]	RW[DL]	**Indication**	Holt[DL]	RW	Indication
Mean[APE]	0.18076	0.19323	OLSR[DL]	0.04126	0.19323	Holt[DL]
RAE_{RW}^{FM}	**[Σ_{RW}^{OLSR} = 1.119812]**		[≈=] to The RW[DL]	**[Σ_{RW}^{Holt} = 0.193818]**		[>] The RW[DL]
	OLSR[*ln*]	RW	Indication	Holt[*ln*]	RW	Indication
Mean[APE]	0.01885	0.19323	OLSR[*ln*]	0.02615	0.19323	Holt[*ln*]
RAE_{RW}^{FM}	**[Σ_{RW}^{OLSR} = 0.18344]**		[>] The RW[DL]	**[Σ_{RW}^{Holt} = 0.131966]**		[>] The RW[DL]

7.2.1 Decoding the FM-Screen: The Experiential Vetting Phase

In our case, there are two FMs: OLSR & Holt and two Y-Variate Measures: AIS-GAAP SEC-Measures [Table 2] & The *ln*[AIS-GAAP SEC-Measures[Table 3]] to be considered relative to the question: For the DA-Profiles in Table 11,

> *which FMs seem to you, as a member of the Planning Committee, likely to provide: understandable, relevant & useful intel, the* ***nature of which*** *would inform* ***your*** *decision-making?*

Note: For each of the four segments of Table 11, there would be the following data and computational presentations.

We have Bolded & Shaded the four Key RAE Measures in Table 11. These are the ***Average*** of: {The FM-APE divided by the RW-APE ***individually for each of the six-forecasts***}. We offer these RAE-Measures as the key-evaluation intel as they indicate how the APE of the FM compares ***on Average*** to the APE of the Random Walk ***individually*** for the six-forecasts. Also, ***note*** that the shaded cells in Table 11 are also shaded where we detailed the computations. Consider as an illustration the Holt[DL].

7.2.2 The APE[Holt[DL]] & The RAE[Holt[APE[DL]] / APE[RW]]

Table 12. Illustration of the Holt RAE-Profile as Presented in Table 11

Forecasts[FC_t]	$APE_t^{Holt[DL]}$	$APE_t^{RW[DL]}$	$RAE^{APE_t^{Holt[DL]}}_{APE_t^{RW\{DL]}}$
[$FC_{t=22}$]	0.00790	0.061057	0.129381
[$FC_{t=23}$]	0.018334	0.118385	0.154865
[$FC_{t=24}$]	0.031192	0.172213	0.181126
[$FC_{t=25}$]	**0.04614**	**0.222755**	**0.207134**
[$FC_{t=26}$]	0.062874	0.270211	0.232686
[$FC_{t=27}$]	0.081121	0.314769	0.257715
Average	0.04126	0.1932318	**0.193818**

Computations Details

For: [$FC_{t=25}$]. The $APE_{t=25}^{Holt[DL]}$ = 0.04614 & $APE_{t=25}^{RW[DL]}$ = 0.222755. In this case, the $RAE^{APE_t^{Holt[DL]}}_{APE_t^{RW\{DL]}}$ = 0.04614 / 0.222755 = **0.207134**

Note The final or reported RAE in Table 11 is the Mean of: [$APE_{t=i}^{Holt[DL]}$ / $APE_{t=i}^{RW[DL]}$ for $_{t:\ 22,\ ---,\ 27}$] = **0.193818**. It is **NOT** the ratio of the Mean of: [The $APE_{t=25}^{Holt[DL]}$ / $APE_{t=25}^{RW[DL]}$] which is: 0.04126 / 0.1932318 = 0.213526.

7.2.3 The Authors' Assumed Summary Experiential Judgmental De-Coding

Considering **only** the Holt[DL[Table 2]] dataset, the Mean of $APE_t^{Holt[DL]}$ is[0.04126] ≈ **5%** which is ***very low*** compared to the C&A-Toggle Point of **25%**—suggesting that the Holt[DL] forecasts were almost equal to the actual holdbacks used to evaluate the Holt's forecasting acuity. Also, the Holt [DL]FM outperformed the Mean [RW-Benchmark] of APE [**0.1932318**] in a major manner—logically suggesting that the Holt was dynamically *in sync* with the generating process that was driving the Current Ratio: Y-Variate Panel. Finally, the $RAE^{APE_t^{Holt[DL}}_{APE_t^{RW\{DL]}}$ was **0.193818** also < **25%**. Overall, the Holt FM using the DLs of the Current Ratio performed very well and, to our minds, merits to be included in the FM-Candidate Set for possible use in the future.

7.3 The Inferential Vetting Phase

In this next, phase, the DA-Group will evaluate the RAE of the four FMs, there are two sub-inferential Phases:

7.3.1 The Welch ANOVA Parametric Analysis

In this inferential phase, we are interested in *Mean* differences of the four FMs for the RAE using the RW as the benchmark. This dataset is presented following:

Table 13. RAE: Profiles of the Four FM used for the Welch{ANOVA]

FMs	$RAE^{APE_t^{OLSR[DL]}}_{APE_t^{RW\{DL]}}$	$RAE^{APE_t^{OLSRln[DL]}}_{APE_t^{RW\{DL]}}$	$RAE^{APE_t^{Holt[DL]}}_{APE_t^{RW\{DL]}}$	$RAE^{APE_t^{Holtln[DL]}}_{APE_t^{RW\{DL]}}$
$[FC_{t=22}]$	2.091603	0.621206	0.129381	0.121359
$[FC_{t=23}]$	1.250735	0.25511	0.154865	0.125278
$[FC_{t=24}]$	0.982479	0.130139	0.181126	0.129532
$[FC_{t=25}]$	0.857084	0.065362	0.207134	0.13395
$[FC_{t=26}]$	0.788598	0.02459	0.232686	0.138502
$[FC_{t=27}]$	0.748374	0.004239	0.257715	0.143175
Average	**1.119812**	**0.183441**	**0.193818**	**0.131966**

Discussion In this case, the Welch[FPE[Null[p-value]]] which controls for intra-group-variance differences. is***: 0.0047*** and is highly significant in favor of Rejection of the H_o: that there are no RAE-Mean differences over the four test-groups. ***Thus, we shall probe them***.

7.3.2 De-Coding the Welch-Indications

Using the Tukey-Kramer HSD-Pairwise Test where the LSM are, in this context, also the Arithmetic Means, we find the following pairwise differences <0.0001:

Table 14. T-K[HSD]-Pairwise Intel for the Welch[ANOVA] inferential Results

Pairwise [p-values]	**RAE{FPE[T-K [HSD]]}**
The p-value for the	{OLSR[DL] v. **OLSR[*ln*]**}
Pairwise Tests of the	{OLSR[DL] v. **Holt[DL]**}
RAE{**< 0.0001**}	{OLSR[DL] v. **Holt[*ln*]**}

Discussion ***Clarification Note:*** The FMs that outperformed the APE of the RW **F**M re: **APE*-forecasting acuity*** are those that are **Bolded** in Table 14. **Simply 1.119812 is not inferentially aligned with: {0.183441 or 0.193818 or 0.131966}.** This inferential FPE:[RAE-profile] aligns with and, so confirms, the judgmental opinions expressed above as the: 7.2.3 The Authors' Assumed Summary Experiential Judgmental De-Coding**.** There is clear experiential judgmental as well as strong inferential evidence re: the T-K Pairwise profile in Table 14 that consideration should be given to selecting not only the *ln*-Transformed Panels but in addition the DL Panel for the Holt FM.

7.4 Enhanced Confirmatory Vetting: The Median Profiles

The Median-vetting screen is an ***extension*** of the Judgment & Inferential Phases. In this context, we examined the Median [RAE]s of the four RAE-profiles as this is very important confirmatory evidence. As this extension, we will conduct the following: Robustness-Test using the Kruskal-Wallis Rank-Sum Median difference tests. ***This is suggested only as an extended Vetting-Screen***. This would be a vetting-confirmation of the Welsh & T-K[HSD] tests presented in Table 14. In this case, we find that the Median Profiles are:

Table 15. Median Inferential Profiles & FPE[Wilcoxon and Kruskal-Wallis Tests]

Test-Sets	Median	**FPE[Wilcoxon and Kruskal-Wallis Tests]**
HoltDL	0.097750	Pairwise Tests {<=0.04}
Holtln	0.131741	{OLSR[DL] **v.** OLSR[*ln*]} **&**{OLSR[DL] **v.** Holt[DL]}
OLSRDL	***0.919782***	{OLSR[DL] **v.** Holt[*ln*]} **& {OLSR[*ln*] v. Holt[*ln*]}***
OLSRln	0.194130	

*The Pairing Bolded is the only one that differs from the Pairwise RAE[Mean] Profiles of Table 14. In this case, the Holt[*ln*] outperformed the OLSR[*ln*] re: Their RW[APE]-profile.in the Median-Measure

Discussion

The rationale for examining the Median Profile is that if their RAE [Median] inferential-profile is not radically different from that of the RAE [Mean] inferential-profile, then that is an inferential indication that the sampled-populations are reasonably *not A-Normal*—i.e., *highly* skewed or *dramatically* platykurtic or leptokurtic and so the FPEs are reflective of the Nature of the RAE-Populations. This in turn, indicates that the intel from the inferential tests is likely germane to informing the decision-making process.

7.5 Summary Results

It is clear that the similarity of the inferential profiles of the Means [Table 14] & Medians [Table 15] given the judgmental indications of Table 11. suggest that the J-B:DA-FMS Protocol has value in offering useful planning intel and enhancing the selection of FMs to be included in the: {FM-Candidate Set} for reflective consideration in the future.

7.6 Explorational Discovery Vetting

7.6.1 Overview

The last Phase of the [J-B:DA-FMS] Protocol is both begged and enabled by the unprecedented explosive growth of the Relational-Data Base Enterprises [R-DBE] that offer: (i) SQL-search-links to the AIS-database of their clients, (ii) Standard DA-modules that offer a multiplicity of views of various partitions of the firm's data as captured, (iii) Designer DA-platforms that provide analytic profiles of the AIS-Data, and finally, (iv) AI-programs that can be created using *python™-esque code*, that can further create AIS-profiles to inform the decision-making process(*es*). Many of these R-DBEs offer FM-Platforms that are richly endowed with most all of the FMs currently used in organizations for forecasting and planning. For example, *Alteryx*™ (https://www.alteryx.com/) *SparkED*™ has a forecasting platform with many of the currently used FMs including Neural-Net FMs. [***Transparency Indication*** *We have no financial links with Alteryx*]. We suggest for this Exploratory Discovery Phase that the DoF link-in the Y-Variate datasets under examination and run them using the FM-Platform offered by the R-DBE. ***Rationale*** The members of the Division of Forecasting can compare their Y-Variate datasets that have NOW been vetted by three relatively independent screens [as noted above] against the R-DBR FM-Profiles to identify FMs that can be examined for future vetting cycles. This ***Exploratory Discovery Phase*** is not uncommon in the R-DBE sector.

8. Summary and Outlook

8.1 Summary

We have suggested a *Four-Staged **J**udgment-**B**ased **D**ecision **A**nalytical-***F**orecast **M**odel *Screen**ing*** [J-B:DA-FMS] Protocol that offers conditional-tests and screens that rationalize the use of the Box-Cox ***ln*[λ]-*Transformation***. This is, we agree, a rather limited focus given the large number of Box & Cox Transforms that are possible. However, our [J-B:DA-FMS] Protocol is ***generic*** and so may be modified to deal with any of the usual Box-Cox Transforms. It would be of value, given the technical nature of this research report which has drifted into the *Tedious-Zone*, to offer the following *Simple Capsule of our Protocol.*

8.1.1 Essential Details of the [J-B:DA-FMS] Protocol

The recapitulation is:

I. We have addressed as focus: (i) The *ln*-Transformation of (ii) Y-Variates for (iii) Time Series Forecasting, where it is possible to use the (iv) RAE as benchmarked by (v) the RW FM, **for**

II. O*nly* Y-Variates that have: (i) Panel-Points that are 0 >, (ii) visual-profiles that are not *Convex* to the Ordinate, and (iii) Panel-Point association where the PPMC of the $CoD[FPE[H_o]]$ tests to be <0.15%, ***assuming that***

III. The four Judgment Phase: {***Experiential Vetting*** & ***Inferential Vetting*** & ***Enhanced Confirmatory Vetting,*** **and** ***Explorational Discovery Vetting***} are carefully executed, ***and that***

IV. The Results of these Judgment Phases are Profiled in Tabular Form—*Such as Table 11* [*Forecasting Results for the Models Tested*], ***and finally that the DoF***

V. Presents these Tabular Results to the Planning Committee and maintains the: {Archive of the Forecasting Model Candidates}.

8.1.2 The C&A[Rule 2] Suggested Revision

Our research report was motivated by the C&A's RBF Model—in particular C&A's $RBF_{[ln\text{-Rule}[2]]}$. As we have developed our protocol through the four stages, we have become aware of issues that offer suggestive modifications of C&A's $RBF_{[ln\text{-Rule}]}$. In fact, C&A have encouraged research to arrive at suggested modifications of the RBF Model. For example, C&A offer [p. 1408[***Bolding added by the authors.***]:

> *"The conditions analysis suggested that some extrapolation methods may dominate* ***in certain situations****. If these situations can be readily identified,* ***a selection procedure*** *may be used instead of combining. - - -.* ***Further research is needed on the basis of rule-based selection procedures.*** *- - -. The rule-based forecasting procedure offers promise.* ***We provide our rules as a starting point.*** *Hopefully, they will be* ***replaced*** *by simpler and fewer rules."*

Based upon our research, we suggest that the following modifications be considered and tested for their relevance and generalizability:

> *IF the functional form is: multiplicative, and not convex to the ordinate, THEN: (i) use a log/ln Transformation of the original series, and (ii) test both Panels for their forecasting acuity before making the decision as to how to combine these FMs in the execution of the RBF Model* [***Authors suggested modification of: C&A*****[*****The Rule Base*****[*****No.2 :*****[*****p.1409*****]]]**.

8.2 Outlook: Final Observations

8.2.1 The Archive Imperative

The Four-Staged Judgment-Based: Decision Analytical-Forecast Model Screening: Protocol requires that the selected-FMs be archived in the Firm's {FM-Candidate Set}. This is an ***Active Archive***—meaning that it is reviewed on a regular basis. For most organizations this is an on-going dynamic process—rather than once a year perfunctory-review. In this usual dynamic context, the FM-Candidate Set should offer access to the following intel:

I. The date that the FM was evaluated using the following: Y-Variate Panels [details given],

II. The nature of the CoD and if the *ln*-Transform was used [IF NOT, then details given],

III. The Results [detailed] of forecasting acuity for each of the FMs as presented, for example, in Table 11,

IV. Any analyst's comments that were made that may aid in the FM selection process, and

V. Finally, there needs to be a protocol for removing a FM from the Archives and transferring it to an: {Archive of Previous Forecasting Candidate Models no longer Active}.

8.2.2 The AI-Temptation

We have, in the past, integrated computational modules into our Master's Level forecasting courses, the intention of which were to facilitate the creation of relevant intel, that would ***lead to an amelioration of the quality of decision-making*** in the forecasting domain. Our DA-modules were: *Excel*™ IF[AND/OR]-platforms, Simple *VBA*™-Code-Based Modules, and sometimes *Python*™-Code-Based Modules to ***create*** Intel that can be used to ***create*** insights as to additional investigative insights. These computational modules were ONLY used to "*Do the Heavy-Lifting re: the Computations*". We stressed in these forecasting courses the following:

> *Never, create AI* [*Decision-Screens*] *in a DA Decision-making context that* ***eliminate*** *displaying INTEL-created by your DA-Modules under the assumption that AI Modules can be relied on to "Do the Right Thing"—i.e., the AI-Modules can screen YOUR DA-Profiles and display only the "****Best Choices****".*

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Authors' contributions

Drs. Belhadjali, Gaber and Lusk were responsible for study design and revising. Prof. Lusk was responsible for the data collection. Profs. Belhadjali and Lusk drafted the manuscript and Prof. Gaber revised it. All authors read and approved the final manuscript. Drs. Belhadjali, Gaber and Lusk contributed equally to the study.

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