**Supplementary Material S1**

**Development of an equation to predict the net protein requirements for growth of Zebu beef cattle**

L. F. Costa e Silva1,2, S. de Campos Valadares Filho1, P. Del Bianco Benedeti1,3,\*, E. Detmann1, A. C. Baião Menezes1, T. Eder Silva1,4, F. A. de Sales Silva1

***Animal journal***

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**Output of retained energy model validation**

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Regular Least-Squares Regression

REGRESSION ANALYSIS: Y = a + b\*X (Neter et al., 1996)

=====================================================

!! .Pearson's r is a parametric coefficient of correlation that measures the association of two continuous !!

!! random variables!!

!! .Goodness-of-fit is believable if Q(Chi≤) > 0.1!!

Estimate a ± SD: -0.16174 ± 0.09608

Estimate b ± SD: 0.96157 ± 0.02006

MSE: 0.71183 Root MSE: 0.84370

N: 486 r: 0.90888

r≤: 0.82607 Adj. r≤: 0.82571

Resistant r≤: 0.89798 Adj. Resistant r≤: 0.89756

Chi≤: 344.52423 Q(Chi≤): 1.00000

PARAMETER PROBABILITIES (Neter et al., 1996)

============================================

H0: r = 0 T-value (P-value): 47.94516 (0.00001)

H0: a = 0 T-value (P-value): -1.68335 (0.09295)

H0: b = 0 T-value (P-value): 47.94516 (0.00001)

H0: b = 1 T-value (P-value): -1.91593 (0.05596)

H0: a = 0 & b = 1 F-value (P-value): 38.98295 (0.00001) (Dent and Blackie, 1979)

H0: a = 0 & b = 1 F-value (P-value): 39.14404 (0.00001) (Mayer et al., 1994)

DISTRIBUTION ANALYSES (Shapiro and Wilk, 1965)

==============================================

!! .SW is the Shapiro-Wilk's W-value (0 to 1) that measures normal distribution in which small values lead !!

!! to the rejection of the null hypothesis of normality !!

SW's W-value for normality for X (P-value < W) : 0.98239 ( 0.00001)

SW's W-value for normality for Y (P-value < W) : 0.96914 ( 0.00001)

Empirical Distribution Function for Normality

=============================================

Predicted values (X):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.05541

Kuiper's V statistic: 0.09576

CramÈr-von Mises's W2 statistic: 0.33438 (P = 0.0001)

Watson's U2 statistic: 0.31153 (P = 0.0001)

Anderson-Darling's A2 statistic: 2.12372 (P = 0.0001)

Shapiro-Wilk's W statistic: 0.98239 (P = 0.0001)

-----

!! These calculations were not adjusted for Normal distribution!!

Observed values (Y):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.07450

Kuiper's V statistic: 0.11678

CramÈr-von Mises's W2 statistic: 0.61660 (P = 0.0001)

Watson's U2 statistic: 0.54123 (P = 0.0001)

Anderson-Darling's A2 statistic: 4.02737 (P = 0.0001)

Shapiro-Wilk's W statistic: 0.96914 (P = 0.0001)

-----

!! These calculations were not adjusted for Normal distribution!!

MOMENT ANALYSES (Neter et al., 1996)

====================================

X Abs Mean: 1.59087 Y Abs Mean: 1.69495

X Min: 0.53070 Y Min: 0.44180

X Max: 9.36570 Y Max: 9.78660

X Mean: 4.39426 Y Mean: 4.06367

X Median: 4.25585 Y Median: 3.83550

X Variance: 3.64885 Y Variance: 4.08418

X Std. Dev.: 1.91020 Y Std. Dev.: 2.02094

X Skewness: 0.19934 Y Skewness: 0.41115

X Kurtosis: 2.24398 Y Kurtosis : 2.36571

X - Y Mean: 0.33059 X - Y Var : 0.71575

Covariance: 3.50142

DIVERSE MEASURE ANALYSES

========================

!! .MEF is modeling efficiency; closer to one better it is !!

!! .CD is the coefficient of model determination; closer to one better it is!!

Mean Bias (Y - X) (MB): -0.33059 !! Model overprediction!! (Cochran and Cox, 1954)

Mean Bias, % of X (Predicted): -7.52321

Mean Bias, % of Y (Observed): -8.13525

H0: VarY = VarX, F-value: 1.11931 (P = 0.10747)

H0: MB = 0, T-value (same var.): -2.62079 (P = 0.00891)

H0: MB = 0, T-value (diff. var.): -2.62079 (P = 0.00891)

H0: MB = 0, T-value (paired w/cov.): -8.61444 (P = 0.00001)

H0: MB = 0, T-value (paired diff.): -8.61444 (P = 0.00001)

Mean Absolute Error |Y - X| (MAE): 0.73340

MAE, % of X (Predicted): 16.69007

MAE, % of Y (Observed): 18.04785

MA%E, |Y - X|/Y: 23.61529

MEF: 0.79794 (Loague and Green, 1991; Zacharias et al., 1996)

CD: 1.08669 (Loague and Green, 1991; Zacharias et al., 1996)

Maximum error = Max|Y - X|: 3.08400

CONCORDANCE CORRELATION COEFFICIENT (Lin, 1989; Deyo et al., 1991; Nickerson, 1997; Liao, 2003)

===============================================================================================

Lin (1998)

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Scale shift (v): 1.05797

Location shift (u): -0.16826!! Model overprediction!!

Bias correction (Cb): 0.98450

rc ± SE rc: 0.89480 ± 0.00886

Z-value (P-Value): 100.99960 (0.00001)

Lower - Upper 95% CI: [0.87743, 0.91216]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed rc ± SE rc: 1.44549 ± 0.04444

Transformed Z-value (P-Value): 32.52373 (0.00001)

Transformed Lower - Upper 95% CI: [1.35838, 1.53260]

Un-transformed Lower - Upper 95% CI: [0.87602, 0.91087]

Intraclass Correlation Coefficient (ICC)

----------------------------------------

rc: 0.89497

Liao (2003)

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Ar (~ Cb): 0.98434

Gr ± SE Gr (~ rc): 0.89465 ± 0.07307

Z-value (P-Value): 12.24340 (0.00001)

Lower - Upper 95% CI: [0.75144, 1.03787]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed Gr ± SE Gr: 1.44477 ± 0.36611

Transformed Z-value (P-Value): 3.94633 (0.00008)

Transformed Lower - Upper 95% CI: [0.72722, 2.16233]

Un-transformed Lower - Upper 95% CI: [0.62136, 0.97387]

RANK ANALYSIS - NONPARAMETRICS (Agresti, 1996, 2002)

====================================================

!! .Spearman's r is a nonparametric coefficient of correlation that measures the rank of the data values !!

!! .D is the sum squared difference of ranks !!

!! .Kendall's Tau is a nonparametric coefficient of correlation that measures the association based on !!

!! the number of concordances and discordances in paired observations!!

!! .KS is the Kolmogorov-Smirnov test that measures if X and Y have the same distribution !!

Spearman's r: 0.91989 H0: r = 0, T-value (P-value): 51.60367 (0.00001)

D: 1532626.0 H0: D = 0, Z-value (P-value): -20.25850 (0.00001)

Tau: 0.75023 H0: Tau = 0, Z-value (P-value): 24.71970 (0.00001)

KS: 0.12346 H0: dX = dY, N-value (P-value): 243.00000 (0.00107)

Mann-Whitney: n/a H0: WD = 0, Z-value (1-sided P-value) : 2.89894 (0.00187)

MEAN SQUARE ERROR OF PREDICTION (Bibby and Toutenburg, 1977)

============================================================

Mean Square Error of Prediction: 0.82356

Variance of MSEP: 1.32151

Standard deviation of MSEP: 1.14957

Coefficient of variation of MSEP, %: 139.58460

Square root of MSEP (RMSEP): 0.90750

RMSEP, % of mean X: 20.65205

RMSEP, % of mean Y: 22.33214

MSEP Decomposition I:

Mean bias ==> Mean X <> Mean Y: 0.10929 (13.270 %)

Unequal variances ==> Sx <> Sy: 0.01224 (1.486 %)

Incomplete (co)variation ==> r <> 1: 0.70204 (85.244 %)

MSEP Decomposition II:

Mean bias ==> Mean X <> Mean Y: 0.10929 (13.270 %)

Systematic bias ==> b <> 1: 0.00538 (0.653 %)

Random errors ==> r2 <> 1: 0.70890 (86.077 %)

**Output of ARC model validation**

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Regular Least-Squares Regression

REGRESSION ANALYSIS: Y = a + b\*X (Neter et al., 1996)

=====================================================

!! Pearson's r is a parametric coefficient of correlation that measures the association of two continuous !!

!! random variables!!

!! Goodness-of-fit is believable if Q(Chi≤) > 0.1!!

Estimate a ± SD: 7.14602 ± 9.88497

Estimate b ± SD: 1.06334 ± 0.06304

MSE: 868.68966 Root MSE: 29.47354

N: 177 r: 0.78686

r≤: 0.61914 Adj. r≤: 0.61697

Resistant r≤: 0.63221 Adj. Resistant r≤: 0.62798

Chi≤: n/a, Q(Chi≤): 1.00000

PARAMETER PROBABILITIES (Neter et al., 1996)

============================================

H0: r = 0, T-value (P-value): 16.86679 (0.00001)

H0: a = 0, T-value (P-value): 0.72292 (0.47070)

H0: b = 0, T-value (P-value): 16.86679 (0.00001)

H0: b = 1, T-value (P-value): 1.00470 (0.31643)

H0: a = 0 & b = 1, F-value (P-value): 29.01223 (0.00001) (Dent and Blackie, 1979)

H0: a = 0 & b = 1, F-value (P-value): 29.34380 (0.00001) (Mayer et al., 1994)

DISTRIBUTION ANALYSES (Shapiro and Wilk, 1965)

==============================================

!!.SW is the Shapiro-Wilk's W-value (0 to 1) that measures normal distribution in which small values lead !!

!! to the rejection of the null hypothesis of normality!!

SW's W-value for normality for X (P-value < W): 0.93338 (0.00001)

SW's W-value for normality for Y (P-value < W): 0.98155 (0.01911)

Empirical Distribution Function for Normality

=============================================

Predicted values (X):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

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Kolmogorov-Smirnov's D statistic: 0.11033

Kuiper's V statistic: 0.17217

CramÈr-von Mises's W2 statistic: 0.55067 (P = 0.0001)

Watson's U2 statistic: 0.46543 (P = 0.0001)

Anderson-Darling's A2 statistic: 3.10983 (P = 0.0001)

Shapiro-Wilk's W statistic: 0.93338 (P = 0.0001)

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!! These calculations were not adjusted for Normal distribution!!

Observed values (Y):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.05614

Kuiper's V statistic: 0.10875

CramÈr-von Mises's W2 statistic: 0.13593 (P = 0.0366)

Watson's U2 statistic: 0.13536 (P = 0.0262)

Anderson-Darling's A2 statistic: 0.86393 (P = 0.0267)

Shapiro-Wilk's W statistic: 0.98155 (P = 0.0191)

-----

!! These calculations were not adjusted for Normal distribution!!

MOMENT ANALYSES (Neter et al., 1996)

====================================

X Abs Mean: 25.68336 Y Abs Mean: 35.63069

X Min: 14.00000 Y Min 16.00000

X Max: 252.00000 Y Max:291.00000

X Mean: 152.80791 Y Mean:169.63277

X Median: 159.00000 Y Median: 169.00000

X Variance: 1241.86062 Y Variance: 2267.91551

X Std. Dev.: 35.24004 Y Std. Dev.: 47.62264

X Skewness: -1.06581 Y Skewness: -0.23223

X Kurtosis: 5.52220 Y Kurtosis: 3.82415

X - Y Mean: -16.82486 X - Y Var: 868.73620

Covariance: 1313.05940

DIVERSE MEASURE ANALYSES

========================

!! MEF is modeling efficiency; closer to one better it is!!

!! CD is the coefficient of model determination; closer to one better it is!!

Mean Bias (Y - X) (MB): 16.82486!! Model underprediction!! (Cochran and Cox, 1954)

Mean Bias, % of X (Predicted): 11.01046

Mean Bias, % of Y (Observed): 9.91840

H0: VarY = VarX, F-value: 1.82622 (P = 0.00004)

H0: MB = 0, T-value (same var.): 3.77832 (P = 0.00019)

H0: MB = 0, T-value (diff. var.): 3.77832 (P = 0.00019)

H0: MB = 0, T-value (paired w/cov.): 7.59441 (P = 0.00001)

H0: MB = 0, T-value (paired diff.): 7.59441 (P = 0.00001)

Mean Absolute Error |Y - X| (MAE): 25.09605

MAE, % of X (Predicted): 16.42326

MAE, % of Y (Observed): 14.79434

MA%E, |Y - X|/Y: 14.61151

MEF: 0.49142 (Loague and Green, 1991; Zacharias et al., 1996)

CD: 1.48565 (Loague and Green, 1991; Zacharias et al., 1996)

Maximum error = Max|Y - X|: 121.00000

CONCORDANCE CORRELATION COEFFICIENT (Lin, 1989; Deyo et al., 1991; Nickerson, 1997; Liao, 2003)

===============================================================================================

Lin (1998)

----------

Scale shift (v): 1.35138

Location shift (u): 0.41070! Model underprediction!!

Bias correction (Cb): 0.88494

rc ± SE rc: 0.69632 ± 0.03314

Z-value (P-Value): 21.01126 (0.00001)

Lower - Upper 95% CI: [0.63137, 0.76127]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed rc ± SE rc: 0.86012 ± 0.06433

Transformed Z-value (P-Value): 13.36985 (0.00001)

Transformed Lower - Upper 95% CI: [0.73403, 0.98621]

Un-transformed Lower - Upper 95% CI: [0.62553, 0.75574]

Intraclass Correlation Coefficient (ICC)

----------------------------------------

rc: 0.69722

Liao (2003):

Ar (~ Cb): 0.87013

Gr ± SE Gr (~ rc): 0.68467 ± 0.03294

Z-value (P-Value): 20.78825 (0.00001)

Lower - Upper 95% CI: [0.62011, 0.74922]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed Gr ± SE Gr: 0.83785 ± 0.06200

Transformed Z-value (P-Value): 13.51410 (0.00001)

Transformed Lower - Upper 95% CI: [0.71633, 0.95936]

Un-transformed Lower - Upper 95% CI: [0.61463, 0.74399]

RANK ANALYSIS - NONPARAMETRICS (Agresti, 1996, 2002)

====================================================

!! .Spearman's r is a nonparametric coefficient of correlation that measures the rank of the data values !!

!! .D is the sum squared difference of ranks !!

!! .Kendall's Tau is a nonparametric coefficient of correlation that measures the association based on !!

!! the number of concordances and discordances in paired observations!!

!! .KS is the Kolmogorov-Smirnov test that measures if X and Y have the same distribution !!

Spearman's r: 0.74200 H0: r = 0, T-value (P-value): 14.64162 (0.00001)

D: 238395.0 H0: D = 0, Z-value (P-value): -9.84374 (0.00001)

Tau: 0.56569 H0: Tau = 0, Z-value (P-value): 11.17843 (0.00001)

KS: 0.22034 H0: dX = dY, N-value (P-value): 88.50000 (0.00029)

Mann-Whitney: 3424.00000 H0: WD = 0, Z-value (1-sided P-value): 3.55683 (0.00019)

MEAN SQUARE ERROR OF PREDICTION (Bibby and Toutenburg, 1977)

============================================================

Mean Square Error of Prediction: 1146.90395

Variance of MSEP: n/a

Standard deviation of MSEP: 2192.90358

Coefficient of variation of MSEP, %: 191.20202

Square root of MSEP (RMSEP): 33.86597

RMSEP, % of mean X: 22.16245

RMSEP, % of mean Y: 19.96429

MSEP Decomposition I:

Mean bias ==> Mean X <> Mean Y: 283.07587 (24.682 %)

Unequal variances ==> Sx <> Sy: 152.46236 (13.293 %)

Incomplete (co)variation ==> r <> 1: 711.36572 (62.025 %)

MSEP Decomposition II:

Mean bias ==> Mean X <> Mean Y: 283.07587 (24.682 %)

Systematic bias ==> b <> 1: 4.95413 (0.432 %)

Random errors ==> r2 <> 1: 858.87395 (74.886 %)

**Output of BR-CORTE model validation**

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Regular Least-Squares Regression

REGRESSION ANALYSIS: Y = a + b\*X (Neter et al., 1996)

=====================================================

!! .Pearson's r is a parametric coefficient of correlation that measures the association of two continuous !!

!! random variables!!

!! .Goodness-of-fit is believable if Q(Chi≤) > 0.1 !!

Estimate a ± SD: 44.08737 ± 10.56667

Estimate b ± SD: 0.68530 ± 0.05586

MSE: 1226.26557 Root MSE: 35.01807

N: 177 r: 0.67998

r≤: 0.46237 Adj. r≤: 0.45930

Resistant r≤: 0.56003 Adj. Resistant r≤: 0.55497

Chi≤: n/a Q(Chi≤): 1.00000

PARAMETER PROBABILITIES (Neter et al., 1996)

============================================

H0: r = 0 T-value (P-value): 12.26797 (0.00001)

H0: a = 0 T-value (P-value): 4.17230 (0.00005)

H0: b = 0 T-value (P-value): 12.26797 (0.00001)

H0: b = 1 T-value (P-value): -5.63364 (0.00001)

H0: a = 0 & b = 1 F-value (P-value): 28.81951 (0.00001) (Dent and Blackie, 1979)

H0: a = 0 & b = 1 F-value (P-value): 29.14888 (0.00001) (Mayer et al., 1994)

DISTRIBUTION ANALYSES (Shapiro and Wilk, 1965)

==============================================

!! .SW is the Shapiro-Wilk's W-value (0 to 1) that measures normal distribution in which small values lead !!

!! to the rejection of the null hypothesis of normality !!

SW's W-value for normality for X (P-value < W): 0.95998 (0.00006)

SW's W-value for normality for Y (P-value < W): 0.98155 (0.01911)

Empirical Distribution Function for Normality

=============================================

Predicted values (X):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.09919

Kuiper's V statistic: 0.16605

CramÈr-von Mises's W2 statistic: 0.40333 (P = 0.0001)

Watson's U2 statistic: 0.35484 (P = 0.0001)

Anderson-Darling's A2 statistic: 2.23956 (P = 0.0001)

Shapiro-Wilk's W statistic: 0.95998 (P = 0.0002)

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!! These calculations were not adjusted for Normal distribution!!

Observed values (Y):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.05614

Kuiper's V statistic: 0.10875

CramÈr-von Mises's W2 statistic: 0.13593 (P = 0.0366)

Watson's U2 statistic: 0.13536 (P = 0.0262)

Anderson-Darling's A2 statistic: 0.86393 (P = 0.0267)

Shapiro-Wilk's W statistic: 0.98155 (P = 0.0191)

-----

!! These calculations were not adjusted for Normal distribution!

MOMENT ANALYSES (Neter et al., 1996)

====================================

X Abs Mean: 34.78668 Y Abs Mean: 35.63069

X Min: 18.00000 Y Min: 16.00000

X Max: 314.00000 Y Max: 291.00000

X Mean: 183.19774 Y Mean: 169.63277

X Median: 189.00000 Y Median: 169.00000

X Variance: 2232.82999 Y Variance: 2267.91551

X Std. Dev.: 47.25283 Y Std. Dev.: 47.62264

X Skewness: -0.70135 Y Skewness: -0.23223

X Kurtosis: 4.42945 Y Kurtosis: 3.82415

X - Y Mean: 13.56497 X - Y Var: 1440.42899

Covariance: 1521.51329

DIVERSE MEASURE ANALYSES

========================

!! .MEF is modeling efficiency; closer to one better it is !!

!! .CD is the coefficient of model determination; closer to one better it is!!

Mean Bias (Y - X) (MB): -13.56497!! Model overprediction!! (Cochran and Cox, 1954)

Mean Bias, % of X (Predicted): -7.40455

Mean Bias, % of Y (Observed): -7.99667

H0: VarY = VarX, F-value: 1.01571 (P = 0.45887)

H0: MB = 0, T-value (same var.): -2.69007 (P = 0.00748)

H0: MB = 0, T-value (diff. var.): -2.69007 (P = 0.00748)

H0: MB = 0, T-value (paired w/cov.): -4.75510 (P = 0.00001)

H0: MB = 0, T-value (paired diff.): -4.75510 (P = 0.00001)

Mean Absolute Error |Y - X| (MAE): 32.20904

MAE, % of X (Predicted): 17.58157

MAE, % of Y (Observed): 18.98751

MA%E, |Y - X|/Y: 20.04368

MEF: 0.28327 (Loague and Green, 1991; Zacharias et al., 1996)

CD: 0.93798 (Loague and Green, 1991; Zacharias et al., 1996)

Maximum error = Max|Y - X|: 121.00000

CONCORDANCE CORRELATION COEFFICIENT (Lin, 1989; Deyo et al., 1991; Nickerson, 1997; Liao, 2003)

===============================================================================================

Lin (1998)

----------

Scale shift (v): 1.00783

Location shift (u): -0.28596!! Model overprediction!!

Bias correction (Cb): 0.96069

rc ± SE rc: 0.65325 ± 0.04184

Z-value (P-Value): 15.61231 (0.00001)

Lower - Upper 95% CI: [0.57124, 0.73526]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed rc ± SE rc: 0.78095 ± 0.07299

Transformed Z-value (P-Value): 10.69952 (0.00001)

Transformed Lower - Upper 95% CI: [0.63789, 0.92400]

Un-transformed Lower - Upper 95% CI: [0.56346, 0.72779]

Intraclass Correlation Coefficient (ICC)

----------------------------------------

rc : 0.65439

Liao (2003)

-----------

Ar (~ Cb): 0.96991

Gr ± SE Gr (~ rc): 0.65952 ± 0.03328

Z-value (P-Value): 19.81950 (0.00001)

Lower - Upper 95% CI: [0.59430, 0.72474]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed Gr ± SE Gr: 0.79196 ± 0.05889

Transformed Z-value (P-Value): 13.44757 (0.00001)

Transformed Lower - Upper 95% CI: [0.67654, 0.90739]

Un-transformed Lower - Upper 95% CI: [0.58926, 0.71988]

RANK ANALYSIS - NONPARAMETRICS (Agresti, 1996, 2002)

====================================================

!! .Spearman's r is a nonparametric coefficient of correlation that measures the rank of the data values !!

!! .D is the sum squared difference of ranks !!

!! .Kendall's Tau is a nonparametric coefficient of correlation that measures the association based on !!

!! the number of concordances and discordances in paired observations !!

!! .KS is the Kolmogorov-Smirnov test that measures if X and Y have the same distribution !!

Spearman's r: 0.62021 H0: r = 0, T-value (P-value): 10.45917 (0.00001)

D: 350940.0 H0: D = 0, Z-value (P-value): -8.22798 (0.00001)

Tau: 0.45876 H0: Tau = 0, Z-value (P-value): 9.06550 (0.00001)

KS: 0.22599 H0: dX = dY, N-value (P-value): 88.50000 (0.00018)

Mann-Whitney: n/a H0: WD = 0, Z-value (1-sided P-value): 3.49707 (0.00024)

MEAN SQUARE ERROR OF PREDICTION (Bibby and Toutenburg, 1977)

============================================================

Mean Square Error of Prediction: 1616.29944

Variance of MSEP: n/a

Standard deviation of MSEP: 2252.26299

Coefficient of variation of MSEP, %: 139.34689

Square root of MSEP (RMSEP): 40.20323

RMSEP, % of mean X: 21.94526

RMSEP, % of mean Y: 23.70015

MSEP Decomposition I:

Mean bias ==> Mean X <> Mean Y: 184.00846 (11.385 %)

Unequal variances ==> Sx <> Sy: 0.13598 (0.008 %)

Incomplete (co)variation ==> r <> 1: 1432.15499 (88.607 %)

MSEP Decomposition II:

Mean bias ==> Mean X <> Mean Y: 184.00846 (11.385 %)

Systematic bias ==> b <> 1: 219.88151 (13.604 %)

Random errors ==> r2 <> 1: 1212.40946 (75.011 %)

**Output of NASEM model validation**

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Regular Least-Squares Regression

REGRESSION ANALYSIS: Y = a + b\*X (Neter et al., 1996)

=====================================================

!! .Pearson's r is a parametric coefficient of correlation that measures the association of two continuous !!

!! random variables!!

!! .Goodness-of-fit is believable if Q(Chi≤) > 0.1 !!

Estimate a ± SD: 59.43331 ± 9.67340

Estimate b ± SD: 0.61806 ± 0.05214

MSE: 1265.10325 Root MSE: 35.56829

N: 177 r: 0.66734

r≤: 0.44534 Adj. r≤: 0.44217

Resistant r≤: 0.43985 Adj. Resistant r≤: 0.43341

Chi≤: n/a Q(Chi≤): 1.00000

PARAMETER PROBABILITIES (Neter et al., 1996)

============================================

H0: r = 0 T-value (P-value): 11.85370 (0.00001)

H0: a = 0 T-value (P-value): 6.14399 (0.00001)

H0: b = 0 T-value (P-value): 11.85370 (0.00001)

H0: b = 1 T-value (P-value): -7.32524 (0.00001)

H0: a = 0 & b = 1 F-value (P-value): 31.72139 (0.00001) (Dent and Blackie, 1979)

H0: a = 0 & b = 1 F-value (P-value): 32.08392 (0.00001) (Mayer et al., 1994)

DISTRIBUTION ANALYSES (Shapiro and Wilk, 1965)

==============================================

!! .SW is the Shapiro-Wilk's W-value (0 to 1) that measures normal distribution in which small values lead !!

!! to the rejection of the null hypothesis of normality!!

SW's W-value for normality for X (P-value < W): 0.98366 (0.03628)

SW's W-value for normality for Y (P-value < W): 0.98155 (0.01911)

Empirical Distribution Function for Normality

=============================================

Predicted values (X):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.05990

Kuiper's V statistic: 0.10110

CramÈr-von Mises's W2 statistic: 0.13461 (P = 0.0382)

Watson's U2 statistic: 0.11544 (P = 0.0524)

Anderson-Darling's A2 statistic: 0.77095 (P = 0.0452)

Shapiro-Wilk's W statistic: 0.98366 (P = 0.0363)

-----

!! These calculations were not adjusted for Normal distribution!!

Observed values (Y):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.05614

Kuiper's V statistic: 0.10875

CramÈr-von Mises's W2 statistic: 0.13593 (P = 0.0366)

Watson's U2 statistic: 0.13536 (P = 0.0262)

Anderson-Darling's A2 statistic: 0.86393 (P = 0.0267)

Shapiro-Wilk's W statistic: 0.98155 (P = 0.0191)

-----

!! These calculations were not adjusted for Normal distribution!!

MOMENT ANALYSES (Neter et al., 1996)

====================================

X Abs Mean: 39.72830 Y Abs Mean: 35.63069

X Min:16.00000 Y Min: 16.00000

X Max: 326.00000 Y Max: 291.00000

X Mean: 178.29944 Y Mean:169.63277

X Median: 182.00000 Y Median: 169.00000

X Variance: 2644.00642 Y Variance: 2267.91551

X Std. Dev.: 51.41990 Y Std. Dev.: 47.62264

X Skewness: -0.42985 Y Skewness: -0.23223

X Kurtosis: 3.66082 Y Kurtosis: 3.82415

X - Y Mean: 8.66667 X - Y Var: 1643.62121

Covariance: 1624.91787

DIVERSE MEASURE ANALYSES

========================

!! .MEF is modeling efficiency; closer to one better it is !!

!! .CD is the coefficient of model determination; closer to one better it is!!

Mean Bias (Y - X) (MB): -8.66667 !! Model overprediction !! (Cochran and Cox, 1954)

Mean Bias, % of X (Predicted): -4.86074

Mean Bias, % of Y (Observed): -5.10908

H0: VarY = VarX, F-value: 1.16583 (P = 0.15525)

H0: MB = 0, T-value (same var.): -1.64518 (P = 0.10083)

H0: MB = 0, T-value (diff. var.): -1.64518 (P = 0.10083)

H0: MB = 0, T-value (paired w/cov.): -2.84405 (P = 0.00498)

H0: MB = 0, T-value (paired diff.): -2.84405 (P = 0.00498)

Mean Absolute Error |Y - X| (MAE): 31.72881

MAE, % of X (Predicted): 17.79524

MAE, % of Y (Observed): 18.70441

MA%E, |Y - X|/Y: 19.89545

MEF: 0.24197 (Loague and Green, 1991; Zacharias et al., 1996)

CD: 0.83393 (Loague and Green, 1991; Zacharias et al., 1996)

Maximum error = Max|Y - X|: 160.00000

CONCORDANCE CORRELATION COEFFICIENT (Lin, 1989; Deyo et al., 1991; Nickerson, 1997; Liao, 2003)

======================================================================

Lin (1998)

----------

Scale shift (v): 0.92615

Location shift (u): -0.17514!! Model overprediction!!

Bias correction (Cb): 0.98205

rc ± SE rc: 0.65536 ± 0.04235

Z-value (P-Value): 15.47410 (0.00001)

Lower - Upper 95% CI: [0.57235, 0.73837]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed rc ± SE rc: 0.78464 ± 0.07424

Transformed Z-value (P-Value): 10.56945 (0.00001)

Transformed Lower - Upper 95% CI: [0.63914, 0.93014]

Un-transformed Lower - Upper 95% CI: [0.56431, 0.73066]

Intraclass Correlation Coefficient (ICC)

----------------------------------------

rc : 0.65658

Liao (2003)

-----------

Ar (~ Cb): 0.98430

Gr ± SE Gr (~ rc): 0.65686 ± 0.03492

Z-value (P-Value: 18.81165 (0.00001)

Lower - Upper 95% CI: [0.58843, 0.72530]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed Gr ± SE Gr: 0.78728 ± 0.06142

Transformed Z-value (P-Value): 12.81838 (0.00001)

Transformed Lower - Upper 95% CI: [0.66690, 0.90765]

Un-transformed Lower - Upper 95% CI: [0.58294, 0.72000]

RANK ANALYSIS - NONPARAMETRICS (Agresti, 1996, 2002)

====================================================

!! .Spearman's r is a nonparametric coefficient of correlation that measures the rank of the data values !!

!! .D is the sum squared difference of ranks !!

!! .Kendall's Tau is a nonparametric coefficient of correlation that measures the association based on !!

!! the number of concordances and discordances in paired observations !!

!! .KS is the Kolmogorov-Smirnov test that measures if X and Y have the same distribution !!

Spearman's r: 0.63024 H0: r = 0, T-value (P-value): 10.73829 (0.00001)

D: 341683.5 H0: D = 0, Z-value (P-value): -8.36103 (0.00001)

Tau: 0.46502 H0: Tau = 0, Z-value (P-value): 9.18912 (0.00001)

KS: 0.17514 H0: dX = dY, N-value (P-value): 88.50000 (0.00753)

Mann-Whitney: n/a H0: WD = 0, Z-value (1-sided P-value): 2.13780 (0.01627)

MEAN SQUARE ERROR OF PREDICTION (Bibby and Toutenburg, 1977)

============================================================

Mean Square Error of Prediction: 1709.44633

Variance of MSEP: n/a

Standard deviation of MSEP: 2924.68933

Coefficient of variation of MSEP, %: 171.08986

Square root of MSEP (RMSEP): 41.34545

RMSEP, % of mean X: 23.18877

RMSEP, % of mean Y: 24.37350

MSEP Decomposition I:

Mean bias ==> Mean X <> Mean Y: 75.11111 (4.394 %)

Unequal variances ==> Sx <> Sy: 14.33777 (0.839 %)

Incomplete (co)variation ==> r <> 1: 1619.99745 (94.767 %)

MSEP Decomposition II:

Mean bias ==> Mean X <> Mean Y: 75.11111 (4.394 %)

Systematic bias ==> b <> 1: 383.52692 (22.436 %)

Random errors ==> r2 <> 1: 1250.80830 (73.170 %)

**Output of New Approach model validation**

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...................................................................................................................

Regular Least-Squares Regression

REGRESSION ANALYSIS: Y = a + b◊X (Neter et al., 1996)

=====================================================

!! .Pearson's r is a parametric coefficient of correlation that measures the association of two continuous !!

!! random variables!!

!! .Goodness-of-fit is believable if Q(Chi≤) > 0.1!!

Estimate a ± SD: 10.39188 ± 9.23761

Estimate b ± SD: 1.00829 ± 0.05689

MSE: 816.04466 Root MSE: 28.56650

N: 177 r: 0.80139

r≤: 0.64222 Adj. r≤: 0.64018

Resistant r≤: 0.64350 Adj. Resistant r≤: 0.63940

Chi≤: n/a Q(Chi≤): 1.00000

PARAMETER PROBABILITIES (Neter et al., 1996)

============================================

H0: r = 0 T-value (P-value): 17.72375 (0.00001)

H0: a = 0 T-value (P-value): 1.12495 (0.26215)

H0: b = 0 T-value (P-value): 17.72375 (0.00001)

H0: b = 1 T-value (P-value): 0.14566 (0.88436)

H0: a = 0 & b = 1 F-value (P-value): 14.68987 (0.00001) (Dent and Blackie, 1979)

H0: a = 0 & b = 1 F-value (P-value): 14.85776 (0.00001) (Mayer et al., 1994)

DISTRIBUTION ANALYSES (Shapiro and Wilk, 1965)

==============================================

!! .SW is the Shapiro-Wilk's W-value (0 to 1) that measures normal distribution in which small values lead !!

!! to the rejection of the null hypothesis of normality!!

SW's W-value for normality for X (P-value < W): 0.94322 (0.00001)

SW's W-value for normality for Y (P-value < W): 0.98155 (0.01911)

Empirical Distribution Function for Normality

=============================================

Predicted values (X):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.11262

Kuiper's V statistic: 0.17242

CramÈr-von Mises's W2 statistic: 0.51934 (P = 0.0001)

Watson's U2 statistic: 0.45902 (P = 0.0001)

Anderson-Darling's A2 statistic: 2.91275 (P = 0.0001)

Shapiro-Wilk's W statistic: 0.94322 (P = 0.0001)

-----

!! These calculations were not adjusted for Normal distribution!!

Observed values (Y):

Goodness-of-Fit Analyses (Davis and Stephens, 1989)

---------------------------------------------------

Kolmogorov-Smirnov's D statistic: 0.05614

Kuiper's V statistic: 0.10875

CramÈr-von Mises's W2 statistic: 0.13593 (P = 0.0366)

Watson's U2 statistic: 0.13536 (P = 0.0262)

Anderson-Darling's A2 statistic: 0.86393 (P = 0.0267)

Shapiro-Wilk's W statistic: 0.98155 (P = 0.0191)

-----

!! These calculations were not adjusted for Normal distribution!!

MOMENT ANALYSES (Neter et al., 1996)

====================================

X Abs Mean: 27.34138 Y Abs Mean: 35.63069

X Min: 15.00000 Y Min: 16.00000

X Max: 285.00000 Y Max: 291.00000

X Mean: 157.93220 Y Mean: 169.63277

X Median: 164.00000 Y Median: 169.00000

X Variance: 1432.66583 Y Variance: 2267.91551

X Std. Dev.: 37.85057 Y Std. Dev.: 47.62264

X Skewness: -0.81699 Y Skewness: -0.23223

X Kurtosis: 5.33096 Y Kurtosis: 3.82415

X - Y Mean: -11.70056 X - Y Var: 811.50642

Covariance: 1436.37623

DIVERSE MEASURE ANALYSES

========================

!! .MEF is modeling efficiency; closer to one better it is !!

!! .CD is the coefficient of model determination; closer to one better it is!!

Mean Bias (Y - X) (MB): 11.70056 !! Model underprediction!! (Cochran and Cox, 1954)

Mean Bias, % of X (Predicted): 7.40860

Mean Bias, % of Y (Observed): 6.89759

H0: VarY = VarX, F-value: 1.58300 (P = 0.00123)

H0: MB = 0, T-value (same var.): 2.55893 (P = 0.01094)

H0: MB = 0, T-value (diff. var.): 2.55893 (P = 0.01092)

H0: MB = 0, T-value (paired w/cov.): 5.46446 (P = 0.00001)

H0: MB = 0, T-value (paired diff.): 5.46446 (P = 0.00001)

Mean Absolute Error |Y - X| (MAE): 22.76271

MAE, % of X (Predicted): 14.41296

MAE, % of Y (Observed): 13.41882

MA%E, |Y - X|/Y: 13.27740

MEF: 0.58147 (Loague and Green, 1991; Zacharias et al., 1996)

CD: 1.44421 (Loague and Green, 1991; Zacharias et al., 1996)

Maximum error = Max|Y - XI: 113.00000

CONCORDANCE CORRELATION COEFFICIENT (Lin, 1989; Deyo et al., 1991; Nickerson, 1997; Liao, 2003)

======================================================================

Lin (1998)

----------

Scale shift (v): 1.25817

Location shift (u): 0.27559 !! Model underprediction!!

Bias correction (Cb): 0.93944

rc ± SE rc: 0.75286 ± 0.02979

Z-value (P-Value): 25.26955 (0.00001)

Lower - Upper 95% CI: [0.69446, 0.81125]

!! Inverse hyperbolic tangent transformation to improve normal approximation!!

Transformed rc ± SE rc: 0.97952 ± 0.06877

Transformed Z-value (P-Value): 14.24271 ( 0.00001 )

Transformed Lower - Upper 95% CI: [0.84472, 1.11431]

Un-transformed Lower - Upper 95% CI: [0.68830, 0.80558]

Intraclass Correlation Coefficient (ICC)

----------------------------------------

rc : 0.75376

Liao (2003)

-----------

Ar (~ Cb): 0.92829

Gr ± SE Gr (~ rc): 0.74392 ± 0.04594

Z-value (P-Value): 16.19459 (0.00001)

Lower - Upper 95% CI: [0.65389, 0.83395]

!! Inverse hyperbolic tangent transformation to improve normal approximation !!

Transformed Gr ± SE Gr: 0.95920 ± 0.10286

Transformed Z-value (P-Value): 9.32512 (0.00001)

Transformed Lower - Upper 95% CI: [0.75760, 1.16081]

Un-transformed Lower - Upper 95% CI: [0.63966, 0.82130]

RANK ANALYSIS - NONPARAMETRICS (Agresti, 1996, 2002)

====================================================

!! .Spearman's r is a nonparametric coefficient of correlation that measures the rank of the data values !!

!! .D is the sum squared difference of ranks !!

!! .Kendall's Tau is a nonparametric coefficient of correlation that measures the association based on !!

!! the number of concordances and discordances in paired observations !!

!! .KS is the Kolmogorov-Smirnov test that measures if X and Y have the same distribution !!

Spearman's r: 0.75698 H0: r = 0, T-value (P-value): 15.32490 (0.00001)

D: 224539.0 H0: D = 0, Z-value (P-value): -10.04246 (0.00001)

Tau: 0.58202 H0: Tau = 0, Z-value (P-value): 11.50113 (0.00001)

KS: 0.16384 H0: dX = dY, N-value (P-value): 88.50000 (0.01511)

Mann-Whitney: 2210.50000 H0: WD = 0, Z-value (1-sided P-value): 2.29628 (0.01083)

MEAN SQUARE ERROR OF PREDICTION (Bibby and Toutenburg, 1977)

============================================================

Mean Square Error of Prediction: 943.82486

Variance of MSEP: n/a

Standard deviation of MSEP: 1836.01907

Coefficient of variation of MSEP, %: 194.52964

Square root of MSEP (RMSEP): 30.72173

RMSEP, % of mean X: 19.45248

RMSEP, % of mean Y: 18.11073

MSEP Decomposition I:

Mean bias ==> Mean X <> Mean Y: 136.90322 (14.505 %)

Unequal variances ==> Sx <> Sy: 94.95373 (10.061 %)

Incomplete (co)variation ==> r <> 1: 711.96791 (75.434 %)

MSEP Decomposition II:

Mean bias ==> Mean X <> Mean Y: 136.90322 (14.505 %)

Systematic bias ==> b <> 1: 0.09782 (0.010 %)

Random errors ==> r2 <> 1: 806.82382 (85.484 %).