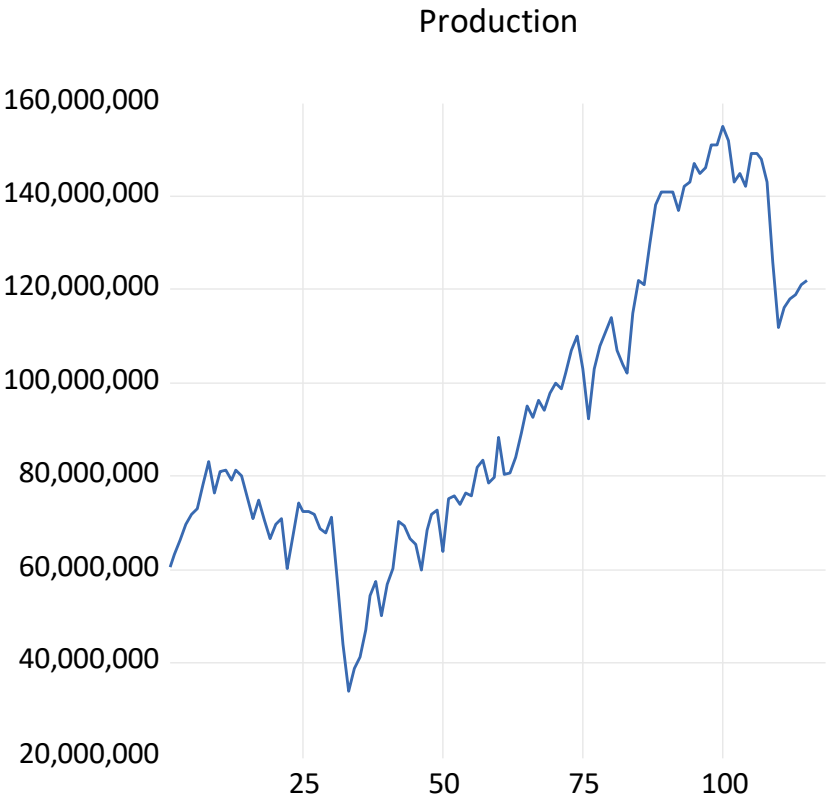
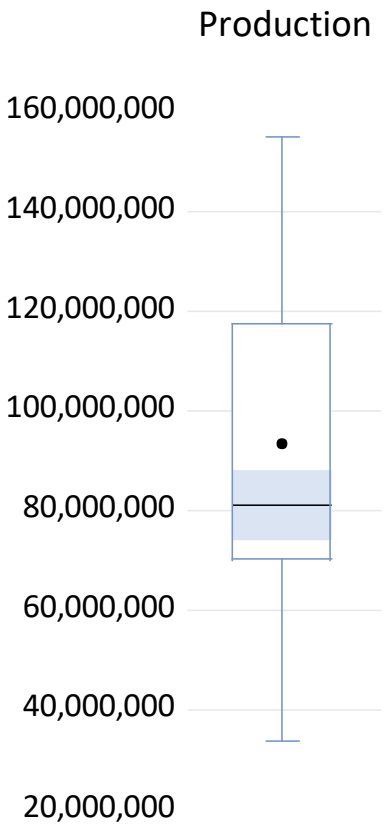
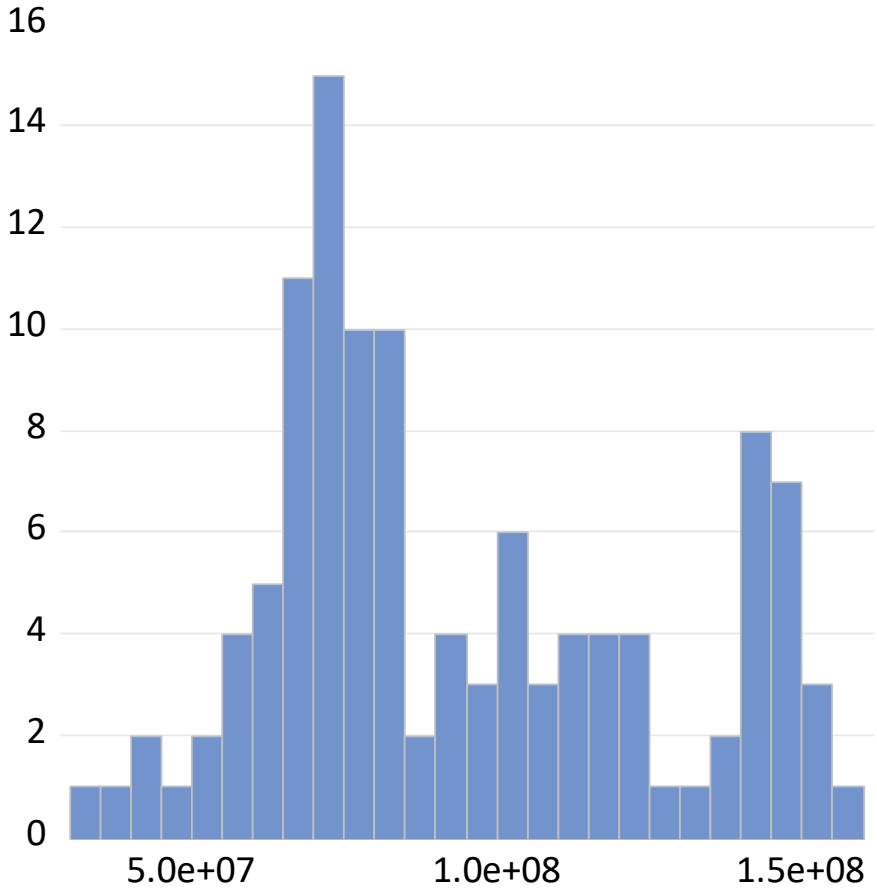
Data

TOTAL FORESTRY STATISTICS, U.S. GEOLOGICAL SURVEY. [All values in metric tons], annual from 1900 to 2014





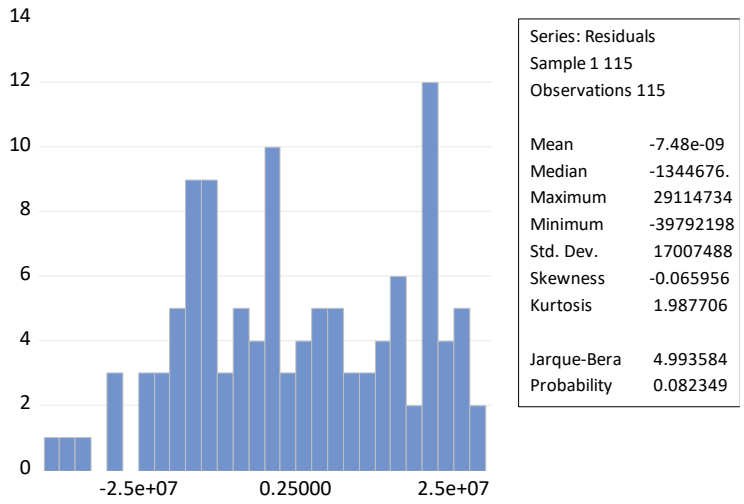


Series: PRODUCTION	
Sample 1 118	
Observations 115	
Mean	93499130
Median	81400000
Maximum	1.55e+08
Minimum	33900000
Std. Dev.	31417376
Skewness	0.457300
Kurtosis	2.097688
Jarque-Bera	7.909415
Probability	0.019164

Dependent Variable: PRODUCTION
Method: Least Squares
Date: 03/01/23 Time: 13:02
Sample (adjusted): 1 115
Included observations: 115 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	48339325	3165251.	15.27188	0.0000
@TREND	792277.3	47985.90	16.51063	0.0000

R-squared	0.706951	Mean dependent var	93499130
Adjusted R-squared	0.704357	S.D. dependent var	31417376
S.E. of regression	17082577	Akaike info criterion	36.16225
Sum squared resid	3.30E+16	Schwarz criterion	36.20999
Log likelihood	-2077.330	Hannan-Quinn criter.	36.18163
F-statistic	272.6008	Durbin-Watson stat	0.107119
Prob(F-statistic)	0.000000		



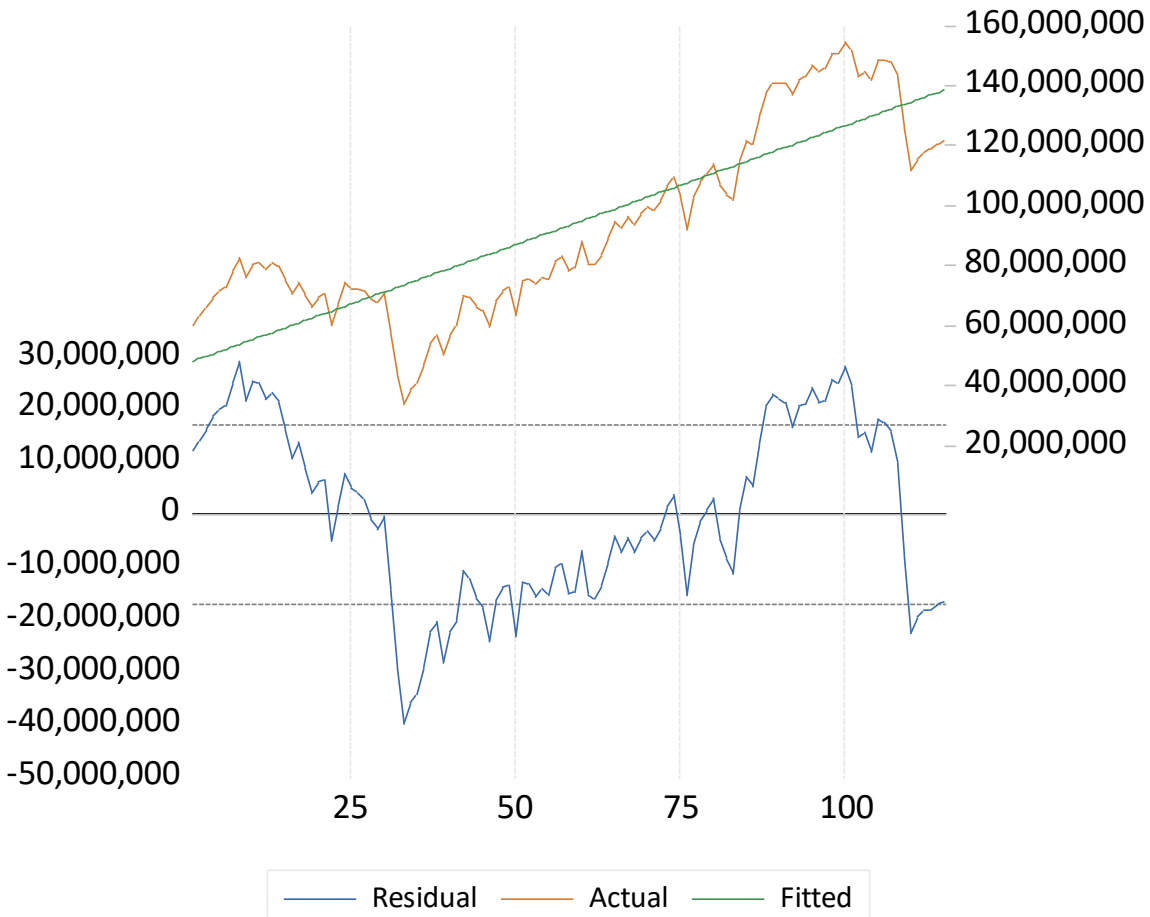
Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 10 lags

F-statistic	93.09727	Prob. F(10,103)	0.0000
Obs*R-squared	103.5442	Prob. Chi-Square(10)	0.0000

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/01/23 Time: 13:10
Sample: 1 115
Included observations: 115
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	178635.3	1050519.	0.170045	0.8653
@TREND	-4814.162	16046.79	-0.300008	0.7648
RESID(-1)	1.115993	0.098617	11.31642	0.0000
RESID(-2)	-0.242851	0.147357	-1.648048	0.1024
RESID(-3)	0.095898	0.146754	0.653459	0.5149
RESID(-4)	-0.038736	0.146778	-0.263906	0.7924
RESID(-5)	0.034905	0.146970	0.237500	0.8127
RESID(-6)	0.057546	0.149739	0.384309	0.7015
RESID(-7)	0.085544	0.149959	0.570446	0.5696
RESID(-8)	-0.287926	0.150711	-1.910455	0.0589
RESID(-9)	0.114149	0.152424	0.748890	0.4556
RESID(-10)	-0.007647	0.106861	-0.071564	0.9431

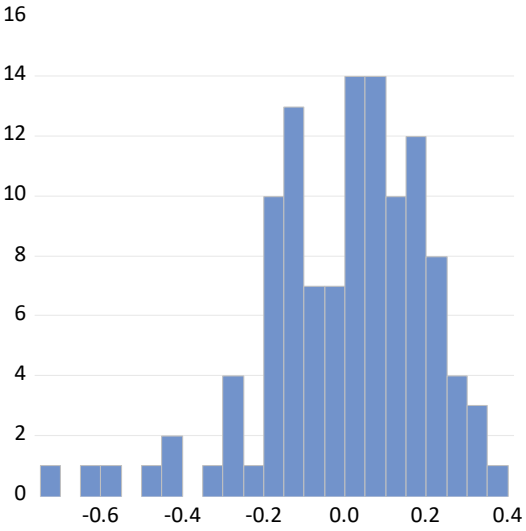
R-squared	0.900384	Mean dependent var	-7.48E-09
Adjusted R-squared	0.889746	S.D. dependent var	17007488
S.E. of regression	5647264.	Akaike info criterion	34.02973
Sum squared resid	3.28E+15	Schwarz criterion	34.31616
Log likelihood	-1944.710	Hannan-Quinn criter.	34.14599
F-statistic	84.63388	Durbin-Watson stat	1.953568
Prob(F-statistic)	0.000000		



Dependent Variable: PRODUCTION
Method: Least Squares
Date: 03/01/23 Time: 13:04
Sample (adjusted): 1 115
Included observations: 115 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	67581937	4025147.	16.78993	0.0000
@TREND	-229454.3	163172.4	-1.406208	0.1624
@TREND^2	8962.558	1385.137	6.470521	0.0000

R-squared	0.786690	Mean dependent var	93499130
Adjusted R-squared	0.782881	S.D. dependent var	31417376
S.E. of regression	14639255	Akaike info criterion	35.86205
Sum squared resid	2.40E+16	Schwarz criterion	35.93366
Log likelihood	-2059.068	Hannan-Quinn criter.	35.89112
F-statistic	206.5287	Durbin-Watson stat	0.149193
Prob(F-statistic)	0.000000		



Series: Residuals
Sample 1 115
Observations 115

Mean	4.62e-15
Median	0.018874
Maximum	0.353234
Minimum	-0.749991
Std. Dev.	0.200449
Skewness	-1.023169
Kurtosis	4.630822
Jarque-Bera	32.80895
Probability	0.000000

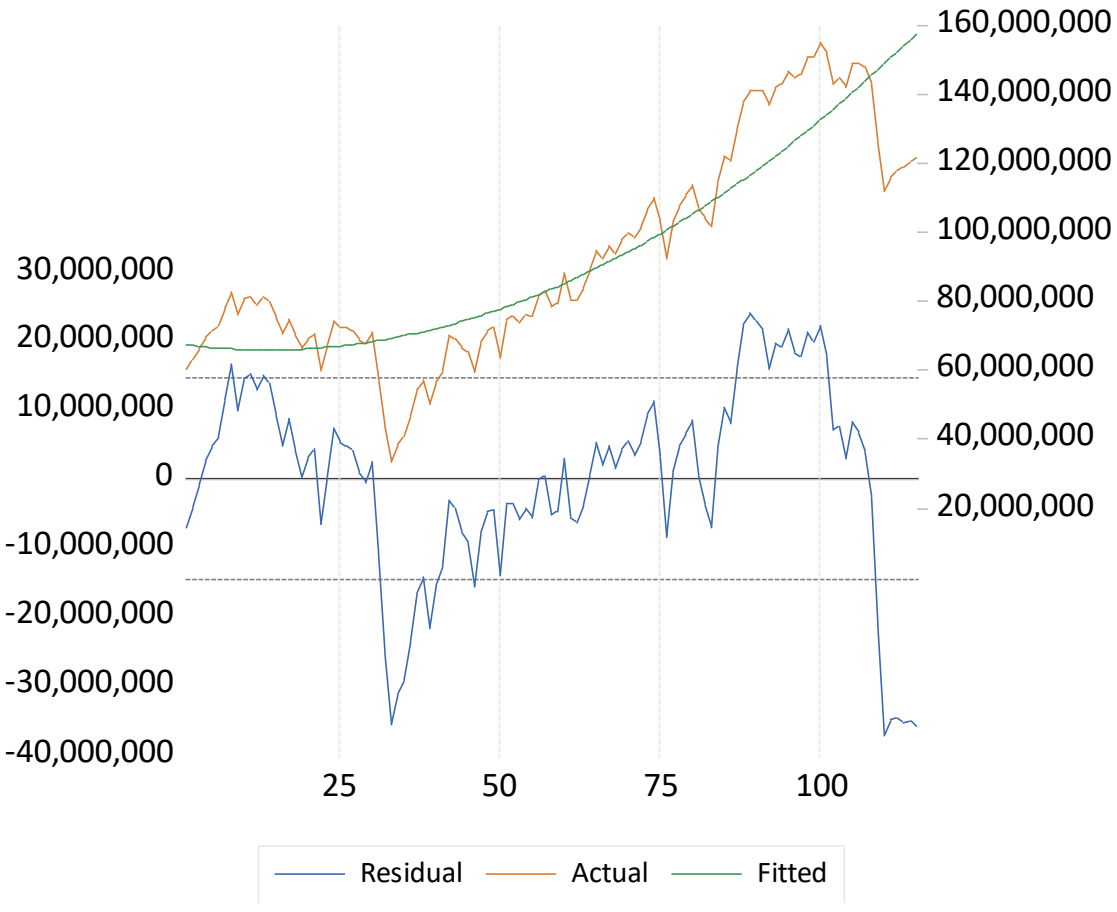
Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 10 lags

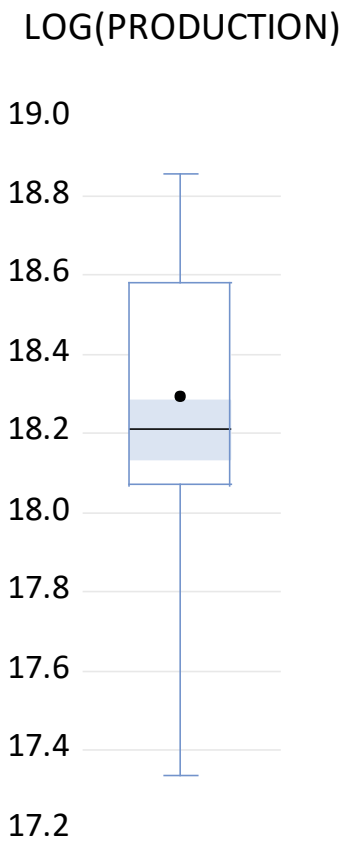
F-statistic	64.99266	Prob. F(10,102)	0.0000
Obs*R-squared	99.40007	Prob. Chi-Square(10)	0.0000

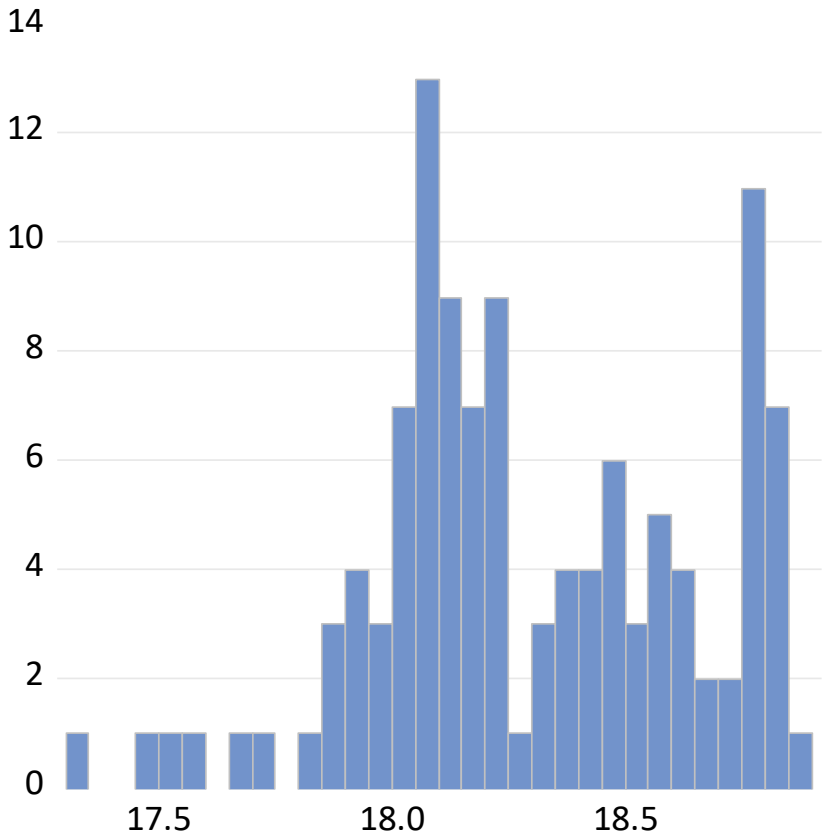
Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/01/23 Time: 13:12
Sample: 1 115
Included observations: 115
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-583462.9	1647215.	-0.354212	0.7239
@TREND	41892.37	73274.61	0.571717	0.5688
@TREND^2	-463.5714	665.0100	-0.697089	0.4873
RESID(-1)	1.105811	0.098924	11.17837	0.0000
RESID(-2)	-0.241159	0.147557	-1.634345	0.1053
RESID(-3)	0.094575	0.148207	0.638127	0.5248
RESID(-4)	-0.037059	0.148247	-0.249980	0.8031
RESID(-5)	0.038824	0.148499	0.261446	0.7943
RESID(-6)	0.032648	0.151573	0.215398	0.8299
RESID(-7)	0.074283	0.151855	0.489171	0.6258
RESID(-8)	-0.213286	0.152416	-1.399364	0.1647
RESID(-9)	0.021547	0.152750	0.141060	0.8881
RESID(-10)	0.050256	0.111072	0.452463	0.6519

R-squared	0.864348	Mean dependent var	-1.81E-09
Adjusted R-squared	0.848389	S.D. dependent var	14510272
S.E. of regression	5649894.	Akaike info criterion	34.03830
Sum squared resid	3.26E+15	Schwarz criterion	34.34860
Log likelihood	-1944.202	Hannan-Quinn criter.	34.16425
F-statistic	54.16055	Durbin-Watson stat	1.979798
Prob(F-statistic)	0.000000		





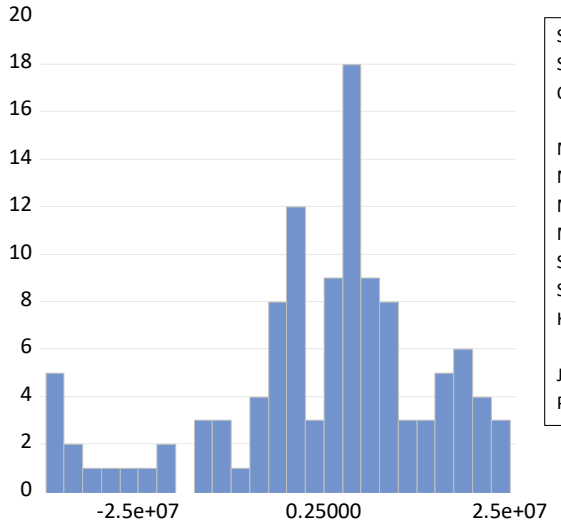


Series: LOG(PRODUCTION)	
Sample 1 118	
Observations 115	
Mean	18.29672
Median	18.21489
Maximum	18.85894
Minimum	17.33893
Std. Dev.	0.342029
Skewness	-0.144876
Kurtosis	2.541114
Jarque-Bera	1.411302
Probability	0.493787

Dependent Variable: LOG(PRODUCTION)
Method: Least Squares
Date: 03/01/23 Time: 13:14
Sample (adjusted): 1 115
Included observations: 115 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	17.82293	0.037305	477.7564	0.0000
@TREND	0.008312	0.000566	14.69691	0.0000

R-squared	0.656534	Mean dependent var	18.29672
Adjusted R-squared	0.653494	S.D. dependent var	0.342029
S.E. of regression	0.201334	Akaike info criterion	-0.350461
Sum squared resid	4.580514	Schwarz criterion	-0.302723
Log likelihood	22.15152	Hannan-Quinn criter.	-0.331085
F-statistic	215.9991	Durbin-Watson stat	0.139894
Prob(F-statistic)	0.000000		



Series: Residuals
Sample 1 115
Observations 115

Mean	-1.81e-09
Median	2725763.
Maximum	24203994
Minimum	-37055567
Std. Dev.	14510272
Skewness	-0.812321
Kurtosis	3.445996
Jarque-Bera	13.60053
Probability	0.001113

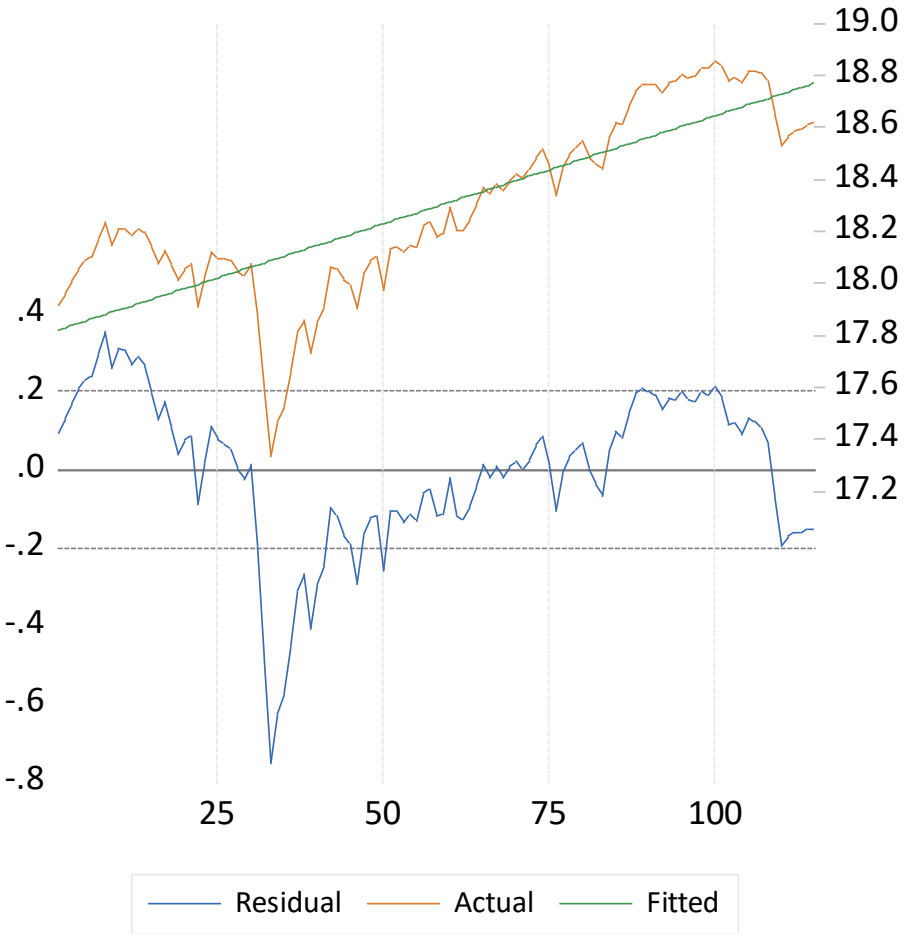
Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 10 lags

F-statistic	74.27011	Prob. F(10,103)	0.0000
Obs*R-squared	100.9939	Prob. Chi-Square(10)	0.0000

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/01/23 Time: 13:13
Sample: 1 115
Included observations: 115
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001633	0.013659	0.119547	0.9051
@TREND	-4.30E-05	0.000208	-0.206982	0.8364
RESID(-1)	1.120479	0.098340	11.39391	0.0000
RESID(-2)	-0.208247	0.147487	-1.411963	0.1610
RESID(-3)	-0.009531	0.146249	-0.065172	0.9482
RESID(-4)	0.060101	0.146253	0.410941	0.6820
RESID(-5)	-0.109439	0.145209	-0.753666	0.4528
RESID(-6)	0.200573	0.146335	1.370644	0.1735
RESID(-7)	-0.015133	0.147515	-0.102584	0.9185
RESID(-8)	-0.288828	0.147818	-1.953941	0.0534
RESID(-9)	0.109781	0.149374	0.734943	0.4640
RESID(-10)	0.064136	0.100941	0.635385	0.5266

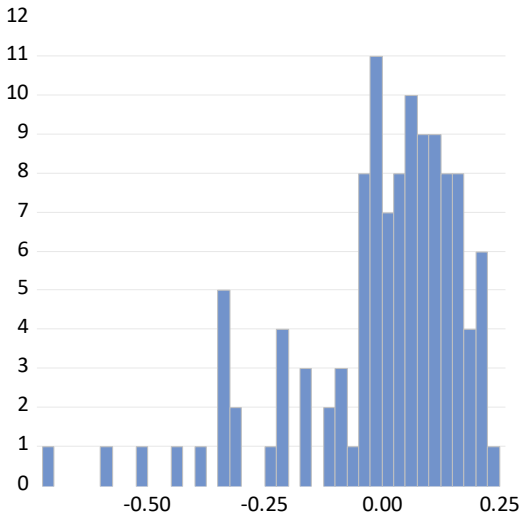
R-squared	0.878208	Mean dependent var	4.62E-15
Adjusted R-squared	0.865201	S.D. dependent var	0.200449
S.E. of regression	0.073595	Akaike info criterion	-2.281985
Sum squared resid	0.557872	Schwarz criterion	-1.995557
Log likelihood	143.2141	Hannan-Quinn criter.	-2.165726
F-statistic	67.51828	Durbin-Watson stat	1.981908
Prob(F-statistic)	0.000000		



Dependent Variable: LOG(PRODUCTION)
Method: Least Squares
Date: 03/01/23 Time: 13:15
Sample (adjusted): 1 115
Included observations: 115 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	18.01583	0.049832	361.5284	0.0000
@TREND	-0.001930	0.002020	-0.955496	0.3414
@TREND^2	8.98E-05	1.71E-05	5.239201	0.0000

R-squared	0.724142	Mean dependent var	18.29672
Adjusted R-squared	0.719216	S.D. dependent var	0.342029
S.E. of regression	0.181238	Akaike info criterion	-0.552272
Sum squared resid	3.678884	Schwarz criterion	-0.480665
Log likelihood	34.75562	Hannan-Quinn criter.	-0.523207
F-statistic	147.0030	Durbin-Watson stat	0.175567
Prob(F-statistic)	0.000000		



Series: Residuals
Sample 1 115
Observations 115

Mean	-3.09e-15
Median	0.046687
Maximum	0.227632
Minimum	-0.707136
Std. Dev.	0.179641
Skewness	-1.509789
Kurtosis	5.343114
Jarque-Bera	69.99683
Probability	0.000000

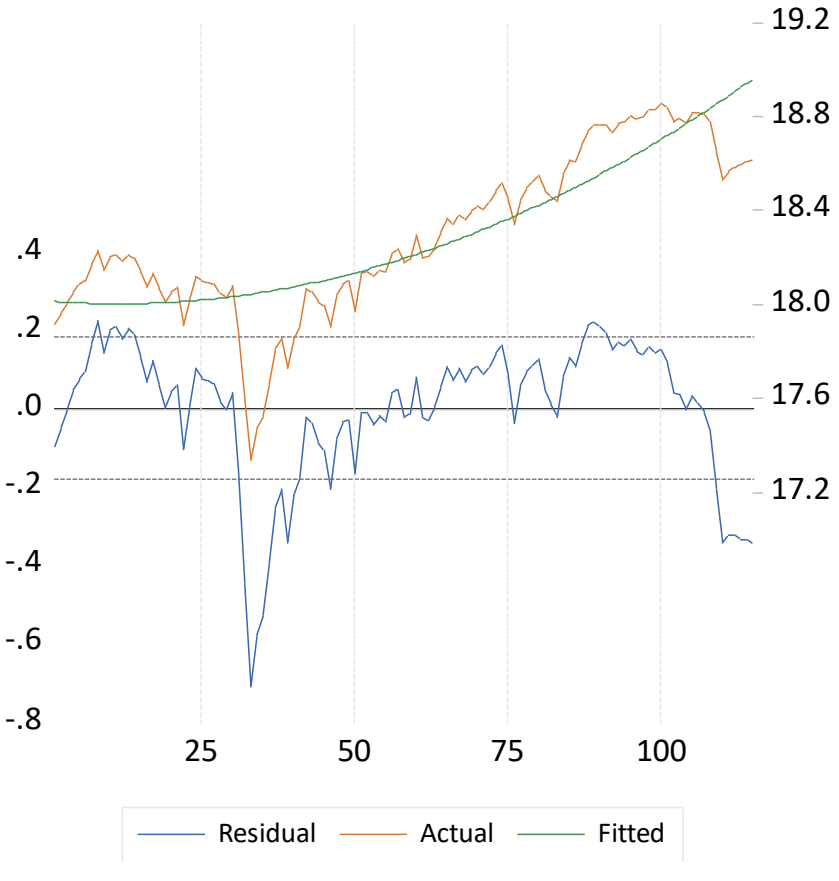
Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 10 lags

F-statistic	56.14266	Prob. F(10,102)	0.0000
Obs*R-squared	97.31907	Prob. Chi-Square(10)	0.0000

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/01/23 Time: 13:15
Sample: 1 115
Included observations: 115
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.007857	0.020936	-0.375291	0.7082
@TREND	0.000551	0.000882	0.624783	0.5335
@TREND^2	-5.97E-06	7.72E-06	-0.773065	0.4413
RESID(-1)	1.099922	0.098461	11.17110	0.0000
RESID(-2)	-0.202623	0.146797	-1.380294	0.1705
RESID(-3)	-0.003032	0.146480	-0.020697	0.9835
RESID(-4)	0.051468	0.146481	0.351360	0.7260
RESID(-5)	-0.096264	0.145693	-0.660731	0.5103
RESID(-6)	0.174071	0.146895	1.184997	0.2388
RESID(-7)	-0.015813	0.147832	-0.106966	0.9150
RESID(-8)	-0.227884	0.148058	-1.539156	0.1269
RESID(-9)	0.034992	0.148626	0.235434	0.8143
RESID(-10)	0.112218	0.103324	1.086075	0.2800

R-squared	0.846253	Mean dependent var	-3.09E-15
Adjusted R-squared	0.828165	S.D. dependent var	0.179641
S.E. of regression	0.074467	Akaike info criterion	-2.250804
Sum squared resid	0.565618	Schwarz criterion	-1.940507
Log likelihood	142.4212	Hannan-Quinn criter.	-2.124856
F-statistic	46.78555	Durbin-Watson stat	1.984513
Prob(F-statistic)	0.000000		



Estimation

As autocorrelation was present in all the models, the HAC standard errors need to be considered for inference

Dependent Variable: PRODUCTION
Method: Least Squares
Date: 03/01/23 Time: 13:11
Sample (adjusted): 1 115
Included observations: 115 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	48339325	7433188.	6.503175	0.0000
@TREND	792277.3	109352.0	7.245203	0.0000

R-squared	0.706951	Mean dependent var	93499130
Adjusted R-squared	0.704357	S.D. dependent var	31417376
S.E. of regression	17082577	Akaike info criterion	36.16225
Sum squared resid	3.30E+16	Schwarz criterion	36.20999
Log likelihood	-2077.330	Hannan-Quinn criter.	36.18163
F-statistic	272.6008	Durbin-Watson stat	0.107119
Prob(F-statistic)	0.000000	Wald F-statistic	52.49297
Prob(Wald F-statistic)	0.000000		

Dependent Variable: LOG(PRODUCTION)
Method: Least Squares
Date: 03/01/23 Time: 13:13
Sample (adjusted): 1 115
Included observations: 115 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	17.82293	0.093700	190.2128	0.0000
@TREND	0.008312	0.001198	6.938777	0.0000

R-squared	0.656534	Mean dependent var	18.29672
Adjusted R-squared	0.653494	S.D. dependent var	0.342029
S.E. of regression	0.201334	Akaike info criterion	-0.350461
Sum squared resid	4.580514	Schwarz criterion	-0.302723
Log likelihood	22.15152	Hannan-Quinn criter.	-0.331085
F-statistic	215.9991	Durbin-Watson stat	0.139894
Prob(F-statistic)	0.000000	Wald F-statistic	48.14662
Prob(Wald F-statistic)	0.000000		

Estimating the four given models and evaluating their performance led us to conclude that the quadratic trend is significant in both specifications. Graphs of the residuals as well as the goodness of fit and information criteria noticeably improved by its addition.

Dependent Variable: PRODUCTION
Method: Least Squares
Date: 03/01/23 Time: 13:12
Sample (adjusted): 1 115
Included observations: 115 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	67581937	6199084.	10.90192	0.0000
@TREND	-229454.3	315225.5	-0.727905	0.4682
@TREND^2	8962.558	3313.599	2.704781	0.0079

R-squared	0.786690	Mean dependent var	93499130
Adjusted R-squared	0.782881	S.D. dependent var	31417376
S.E. of regression	14639255	Akaike info criterion	35.86205
Sum squared resid	2.40E+16	Schwarz criterion	35.93366
Log likelihood	-2059.068	Hannan-Quinn criter.	35.89112
F-statistic	206.5287	Durbin-Watson stat	0.149193
Prob(F-statistic)	0.000000	Wald F-statistic	37.30606
Prob(Wald F-statistic)	0.000000		

Dependent Variable: LOG(PRODUCTION)
Method: Least Squares
Date: 03/01/23 Time: 13:16
Sample (adjusted): 1 115
Included observations: 115 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	18.01583	0.080462	223.9057	0.0000
@TREND	-0.001930	0.003534	-0.546112	0.5861
@TREND^2	8.98E-05	3.52E-05	2.555074	0.0120

R-squared	0.724142	Mean dependent var	18.29672
Adjusted R-squared	0.719216	S.D. dependent var	0.342029
S.E. of regression	0.181238	Akaike info criterion	-0.552272
Sum squared resid	3.678884	Schwarz criterion	-0.480665
Log likelihood	34.75562	Hannan-Quinn criter.	-0.523207
F-statistic	147.0030	Durbin-Watson stat	0.175567
Prob(F-statistic)	0.000000	Wald F-statistic	30.61205
Prob(Wald F-statistic)	0.000000		

Since the dependent variable is different among the two transformations, we cannot directly compare the level and log quadratic models. It is therefore not clear which one is better. Visualizing the production series and its log transformation, the latter exhibits distribution closer to the Gaussian, therefore we favor the log model.

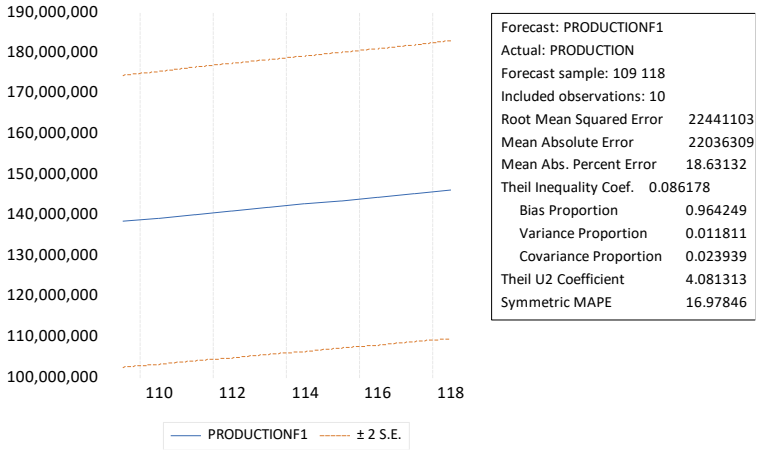
Forecast

When comparing the RMSEs on the last 10 forecasts, we can see that the quadratic models performed better as expected by their in-sample superiority. However, our preferred log model did not do as well in the out of sample forecast as the linear one. It is worth noting that the graph of our series shows that there was a drop in forestry production during the last 10 recorded years. Perhaps the log model would otherwise do better.

Dependent Variable: PRODUCTION
Method: Least Squares
Date: 03/01/23 Time: 14:09
Sample: 1 108
Included observations: 108
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	45927404	8078966.	5.684812	0.0000
@TREND	858124.0	117865.5	7.280534	0.0000

R-squared	0.719016	Mean dependent var	91837037
Adjusted R-squared	0.716365	S.D. dependent var	31696790
S.E. of regression	16880879	Akaike info criterion	36.13961
Sum squared resid	3.02E+16	Schwarz criterion	36.18928
Log likelihood	-1949.539	Hannan-Quinn criter.	36.15975
F-statistic	271.2456	Durbin-Watson stat	0.098800
Prob(F-statistic)	0.000000	Wald F-statistic	53.00618
Prob(Wald F-statistic)	0.000000		



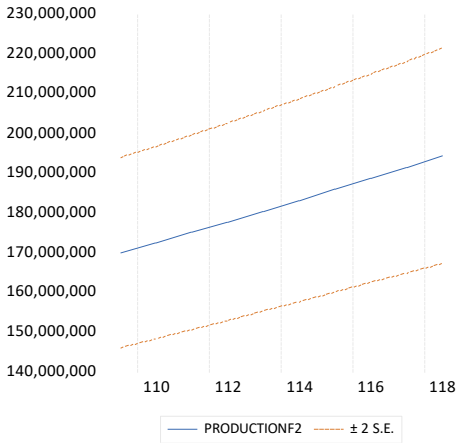
Forecast: PRODUCTIONF1
Actual: PRODUCTION
Forecast sample: 109 118
Included observations: 10

Root Mean Squared Error	22441103
Mean Absolute Error	22036309
Mean Abs. Percent Error	18.63132
Theil Inequality Coef.	0.086178
Bias Proportion	0.964249
Variance Proportion	0.011811
Covariance Proportion	0.023939
Theil U2 Coefficient	4.081313
Symmetric MAPE	16.97846

Dependent Variable: PRODUCTION
Method: Least Squares
Date: 03/01/23 Time: 14:07
Sample: 1 108
Included observations: 108
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	75653799	4920373.	15.37562	0.0000
@TREND	-824502.2	214843.6	-3.837686	0.0002
@TREND^2	15725.48	2160.143	7.279831	0.0000

R-squared	0.906711	Mean dependent var	91837037
Adjusted R-squared	0.904934	S.D. dependent var	31696790
S.E. of regression	9772981.	Akaike info criterion	35.05553
Sum squared resid	1.00E+16	Schwarz criterion	35.13003
Log likelihood	-1889.998	Hannan-Quinn criter.	35.08573
F-statistic	510.2691	Durbin-Watson stat	0.300904
Prob(F-statistic)	0.000000	Wald F-statistic	96.77499
Prob(Wald F-statistic)	0.000000		



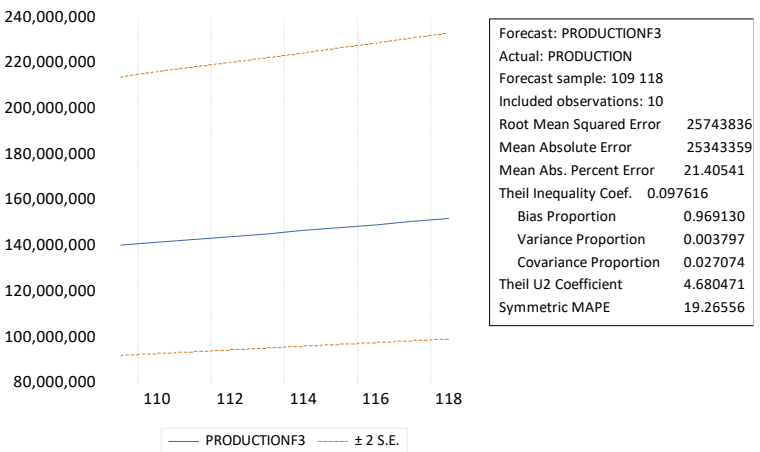
Forecast: PRODUCTIONF2
Actual: PRODUCTION
Forecast sample: 109 118
Included observations: 10

Root Mean Squared Error	59134746
Mean Absolute Error	58807718
Mean Abs. Percent Error	49.51165
Theil Inequality Coef.	0.198942
Bias Proportion	0.988970
Variance Proportion	0.000397
Covariance Proportion	0.010633
Theil U2 Coefficient	10.57554
Symmetric MAPE	39.58839

Dependent Variable: LOG(PRODUCTION)
Method: Least Squares
Date: 03/01/23 Time: 14:15
Sample: 1 108
Included observations: 108
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	17.80176	0.099888	178.2181	0.0000
@TREND	0.008890	0.001297	6.852790	0.0000

R-squared	0.655079	Mean dependent var	18.27737
Adjusted R-squared	0.651825	S.D. dependent var	0.344020
S.E. of regression	0.202994	Akaike info criterion	-0.332939
Sum squared resid	4.367880	Schwarz criterion	-0.283270
Log likelihood	19.97873	Hannan-Quinn criter.	-0.312800
F-statistic	201.3166	Durbin-Watson stat	0.138718
Prob(F-statistic)	0.000000	Wald F-statistic	46.96073
Prob(Wald F-statistic)	0.000000		



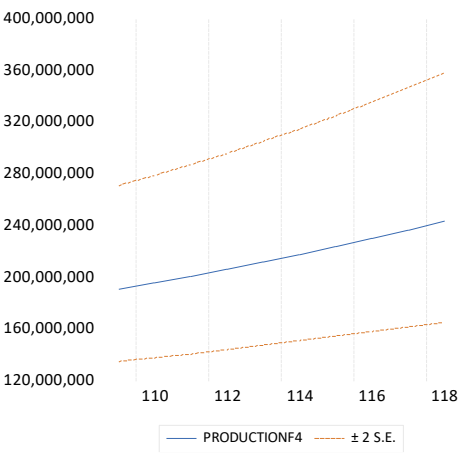
Forecast: PRODUCTIONF3
Actual: PRODUCTION
Forecast sample: 109 118
Included observations: 10

Root Mean Squared Error	25743836
Mean Absolute Error	25343359
Mean Abs. Percent Error	21.40541
Theil Inequality Coef.	0.097616
Bias Proportion	0.969130
Variance Proportion	0.003797
Covariance Proportion	0.027074
Theil U2 Coefficient	4.680471
Symmetric MAPE	19.26556

Dependent Variable: LOG(PRODUCTION)
Method: Least Squares
Date: 03/01/23 Time: 14:12
Sample: 1 108
Included observations: 108
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 5.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	18.09165	0.068579	263.8083	0.0000
@TREND	-0.007519	0.003041	-2.472956	0.0150
@TREND^2	0.000153	3.04E-05	5.050595	0.0000

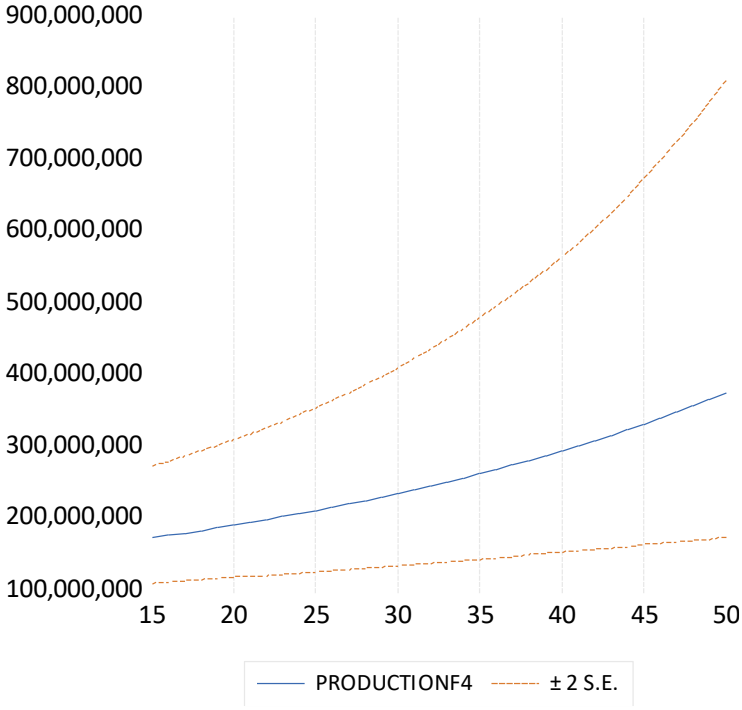
R-squared	0.806613	Mean dependent var	18.27737
Adjusted R-squared	0.802930	S.D. dependent var	0.344020
S.E. of regression	0.152719	Akaike info criterion	-0.893046
Sum squared resid	2.448935	Schwarz criterion	-0.818542
Log likelihood	51.22446	Hannan-Quinn criter.	-0.862837
F-statistic	218.9769	Durbin-Watson stat	0.249396
Prob(F-statistic)	0.000000	Wald F-statistic	55.41371
Prob(Wald F-statistic)	0.000000		

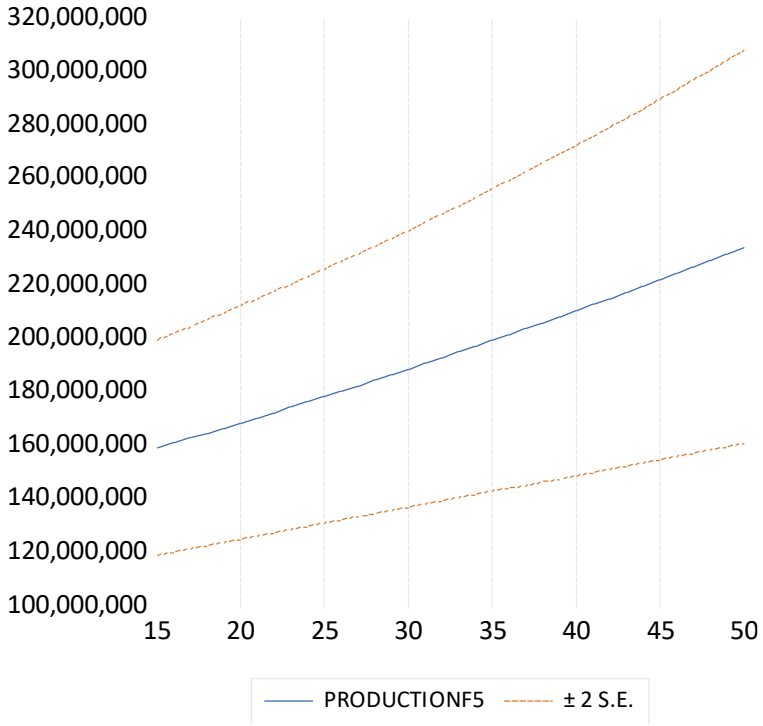


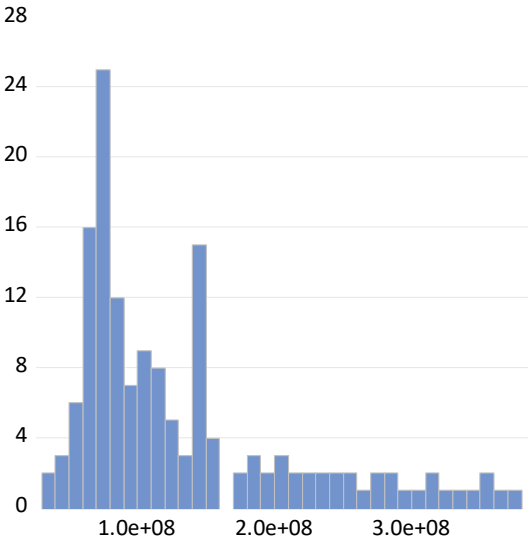
Forecast: PRODUCTIONF4
Actual: PRODUCTION
Forecast sample: 109 118
Included observations: 10

Root Mean Squared Error	88613391
Mean Absolute Error	87921884
Mean Abs. Percent Error	73.94171
Theil Inequality Coef.	0.271345
Bias Proportion	0.984454
Variance Proportion	0.005949
Covariance Proportion	0.009598
Theil U2 Coefficient	15.86557
Symmetric MAPE	53.79132

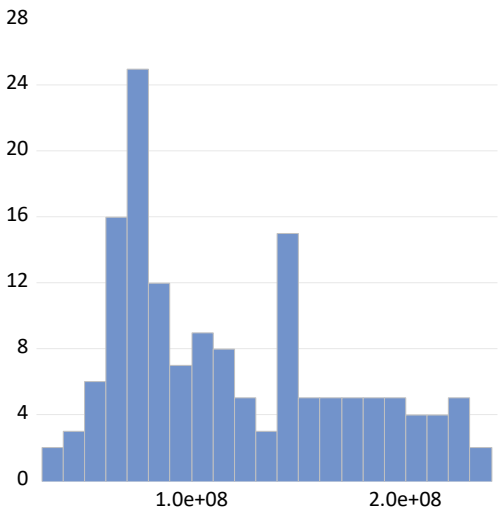
The 2050 forecasts are presented for both quadratic trend model. Productionf4, productionf5 represents the log and the level model, respectively. both forecasts are for the forestry series in levels. It is visible that the production is forecasted to be higher by the log specification.







Series: PRODUCTIONF4	
Sample 1900 2050	
Observations 151	
Mean	1.33e+08
Median	1.03e+08
Maximum	3.77e+08
Minimum	33900000
Std. Dev.	81313483
Skewness	1.297302
Kurtosis	3.811389
Jarque-Bera	46.49743
Probability	0.000000



Series: PRODUCTIONF5	
Sample 1900 2050	
Observations 151	
Mean	1.18e+08
Median	1.03e+08
Maximum	2.35e+08
Minimum	33900000
Std. Dev.	52641160
Skewness	0.588622
Kurtosis	2.186711
Jarque-Bera	12.88121
Probability	0.001595