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WHICH CAME FIRST? EGGS AND CHICKEN IN BRAZIL: A NEW STUDY[1]

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Abstract: Almost 42 years ago, Thurman e Fisher (1988), in a funny paper, using the Granger causality test, concluded, with American data that eggs Granger-cause chicken.In 2011, Shikida, Araujo Jr and Figueiredo (2011) replicated the test to Brazilian quarterly data (1987.I-2011.I) and found bi-causality. This article uses Brazilian monthly data (1987.1-2020.9) under three alternative versions of the Granger test: the classical Granger-causality test, the Toda-Yamamoto version of the same test and the nonlinear Granger-causality proposed by Vinod (2020a). We found evidence that, for Brazil, the bi-causality still prevails for eggs and chicken.

Keywords: Granger Test; Bi-causality; Time Series.

1. INTRODUCTION

In 1988, Thurman and Fisher ran the funniest Granger causality test of all time. Their motivation? The secular question: *which came first, the chicken or the egg?* Using data from the United States of America what did they find? For their sample, eggs came first. Their paper was an instant classic and have been used in time series econometric lectures by several scholars through the years. The interesting feature is that the authors do not seem to have tested for unit roots in egg and chicken time series[5].

Interested in the external validity of their result in a so-old interdisciplinary debate, Shikida, Araujo Jr and Figueiredo (2011) replicated their exercise with quarterly Brazilian data for chicken and egg (1987.I-2011.I) and found that, at least for Brazil, chickens cause eggs and eggs cause chickens. The difference between the findings for

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[1] The authors think that applied econometrics should not be only a necessary nightmare in the student's life. We sincerely hope that our (not so) funny use of econometrics can be a stimulus to undergraduate and graduate students. We thank William Summerhill (UCLA) for his commentaries.

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[5] Lesmeister (2013) using the same data, and considering that each series should not be used in levels, but in difference, shows that eggs still cause chickens with the same data of Thurman and Fisher (1988).

two big former European colonies did not spur any debate among economic historians or even among political scientists or philosophers.

Why was the academic world so quiet? Maybe they thought the evidence was based on a small sample[6]. That motivated us to go to a second round. So, almost 10 years later, in this short note, we go back to this secular question. Does the Brazilian 'egg and chicken' bi-causality still stand?

Our sample has monthly observations of eggs and chicken in the period Jan, 1987 to Sep, 2020 (instead of the quarterly frequency used in our previous study). From 2011 up to now, the R community grew significantly. So we decided to use R packages in this paper. Additionally, we check the robustness of our result with two alternative versions of Granger causality test: the Toda-Yamamoto and the nonlinear version of Vinod[7].

We explore the Granger causality between eggs and chicken in the next section. The third section complements the analysis using two alternative "robustness checks": the Toda-Yamamoto (1995) approach to Granger causality test and the Vinod (2020a) nonlinear version of the same test. The fourth section concludes.

2. EGGS AND CHICKEN IN BRAZIL: WHICH CAME FIRST?

We will follow Shikida, Araujo Jr and Figueiredo (2011) in working with the logarithms of eggs and chickens. The estimations of this paper were performed in R, using the package *forecast* and *lmtest*[8].

Both series were downloaded from the website of the Brazilian Institute of Geography and Statistics (IBGE). The units of measurement are, respectively, thousands of dozens for eggs and number of laying hens (which we will call here "chicken").

We chose to work on both series in logarithm scale. First of all, we check for the classical components of time series using an addictive decomposition. The plots are presented in Figure 1.

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[6] Or maybe the use of Portuguese limited our audience.

[7] Toda and Yamamoto (1995), Vinod (2020 a, b).

[8] Hyndman et al (2020) and Zeileis and Hothom (2002)..

Figure 1a - Ln(egg)

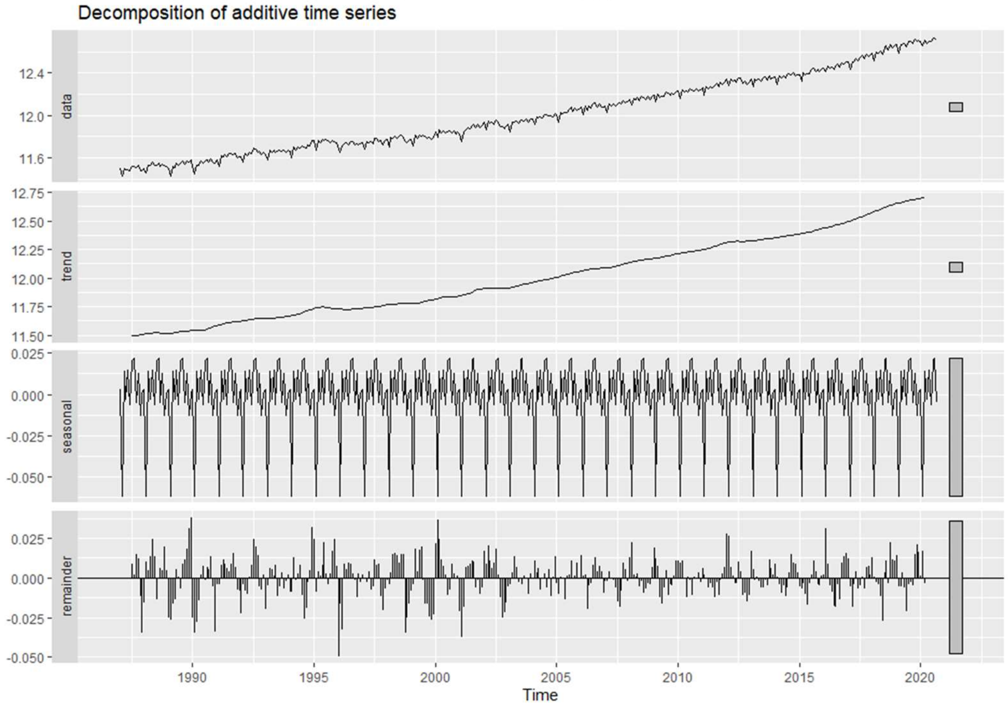
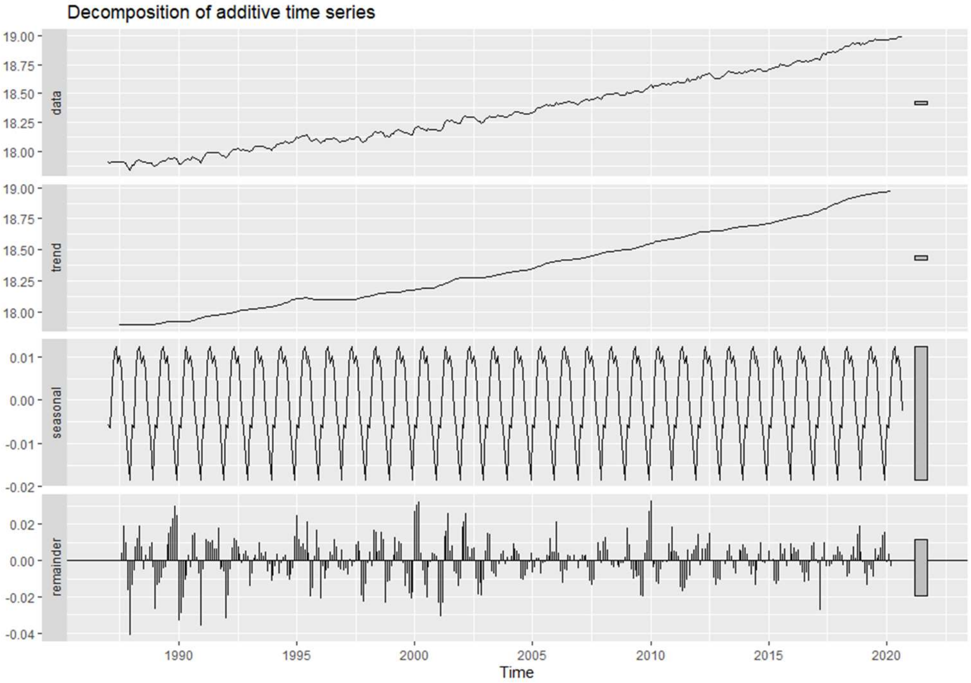


Figure 1b - ln(chicken)



Both series seem to have a positive trend[9] and a seasonal component. We estimated ARIMA models to filter the series[10]. After some attempts, we found that the

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[9] Landsburg once said that “For the past three decades, only one economic variable has exhibited strong steady growth year in and year out. I refer, of course, to the size of shopping carts”. See Landsburg (2000). Maybe we could add the Brazilian production of chickens and eggs to this select club of variables with strong steady growth through years....

[10] Both series were found to be I(1).

best fit for ln(egg) is an ARIMA (4,1,1)(2,1,2) and an ARIMA (1,1,2)(0,1,2) for ln(chicken)[11]. Figure 2 shows the residuals and the autocorrelation functions for each model.

Figure 2a- ln(egg)

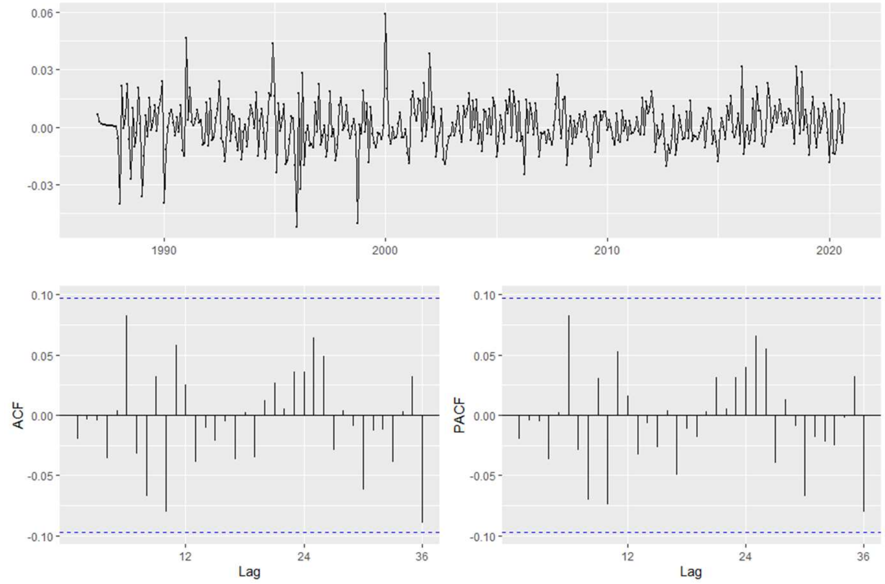
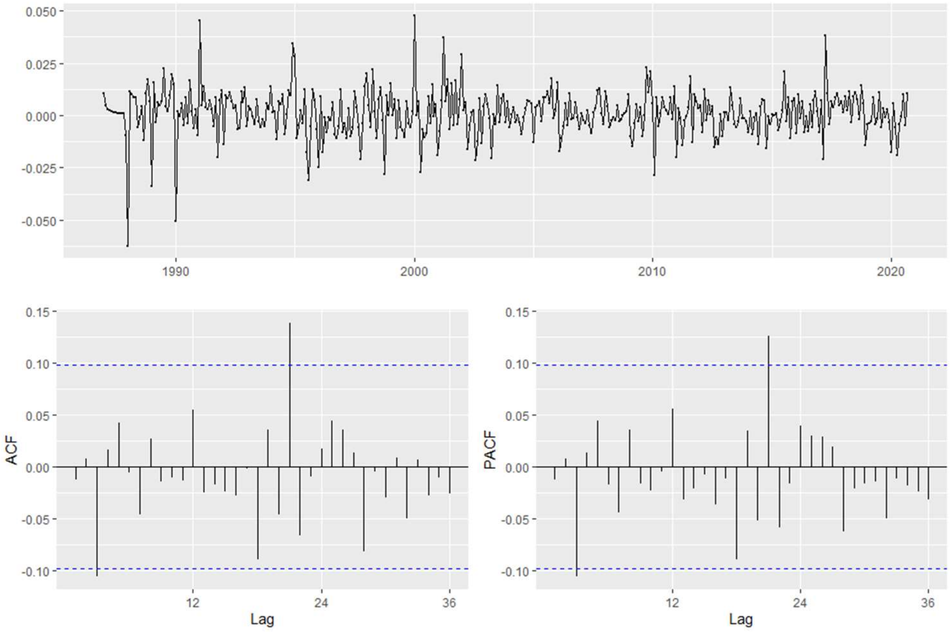


Figure 2b - ln(chicken)



In case of ln(chicken) there two spikes outside the confidence interval. However, the Ljung-Box tests encouraged us to go on with our estimated models[12].

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[11] Figure 2A, in appendix, has the details of the estimated models.

[12] After all, we cannot make an omelet without breaking some eggs (or chickens?).

Table 1 - Ljung-Box Test (Null Hypothesis: no autocorrelation)

Ln(egg) model	Ln(chicken) model
$\chi 2$ = 8.9555, df = 10, p-value = 0.5363	$\chi 2$ = 6.8238, df = 10, p-value = 0.742

Source: Authors' calculations

The Ljung-Box shows us that the residuals of the models do not suffer from serious serial correlation. We also run unit root tests for them and we did not find evidence of nonstationarity[13]. As the time series seem to be stationary, we proceed with the Granger causality tests[14]. Using lag length criteria, under BIC, the optimal lag is 1 and under AIC, 5. We compare the results for these two models in Table 2.

Table 2 - Results[15]

	Lag length = 1	**Lag length =5**
Egg does not Granger-cause Chicken?	**Do not reject H0**	**Reject H0 ***
Chicken does not Granger-cause Egg?	**Reject H0 ****	**Reject H0 ****

Source: Author's calculations
Note: * p-value < 0.05, ** p-value < 0.01

From Table 2 we can see that our previous result of bi-causality is found again in the model with 5 lags. However, for the most parsimonious one, we found that chicken Granger-cause egg[16]. Comparing the residuals of both models (using the Ljung-Box test), we found that the model with 5 lags has more well-behaved residuals. Under this criteria, the bi-causality would be our preferred result.

3. TWO ADDITIONAL ROBUSTNESS CHECKS: TODA-YAMAMOTO AND VINOD GRANGER CAUSALITY TESTS

One way to check our conclusion is through the Toda-Yamamoto approach (Toda and Yamamoto (1995)). One advantage of this method is that you do not need to check

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[13] We used the *ndiffs* and *ndiffs* commands from the *forecast* package. (Hyndman et al (2020)).

[14] We used the *grangertest* from the *lmtest* package (Zeileis, Hothom (2002)).

[15] See Figure 3a, in Appendix, for the R output of these models.

[16] According to the famous scientist, Neil deGrasse Tyson: "Which came first: the chicken or the egg? The egg—laid by a bird that was not a chicken." (Dickinson (2018)). This could be thought of a classical problem of omission of relevant variables in the model. However, we do not have a long time series showing chicken's ancestors at their very first observations, so this problem cannot be addressed here.

for cointegration. For this exercise we filtered both series in order to avoid seasonality related complications[17].

The implementation of the method, in general, is didactically explained by Giles (2011) and translated to R environment by Pfeiffer (2012). We checked the seasonally adjusted series for unit roots and found, again, that both are I(1).

The information criteria selected two lag lengths for the levels of the two series the VAR: 1 and 6. Applying the Ljung-Box test allowed us to choose the VAR(6). Following Toda-Yamamoto, we estimated a VAR(p+m), where p is the lag of the chosen VAR (in our case, p = 6) and m is the maximum order of integration (in our case, m=1). The estimation of the VAR(7) is presented in Figures 4a and 4b in the Appendix..

The final step is to apply a Wald test on the p terms of each equation of the VAR. The results are presented in Table 3.

Table 3 - Wald Tests for Toda-Yamamoto Analysis

```
H0: ln(chicken_dessaz) does not Granger-cause ln(egg_dessaz)
Wald test (test for the p=6 lags of ln(chicken_dessaz):
----------
Chi-squared test:
χ2 = 38.7, df = 6, P(> χ2) = 8.2e-07
```

```
H0: ln(egg_dessaz) does not Granger-cause ln(chicken_dessaz)

Wald test (test for the p=6 lags of ln(egg_dessaz)
----------
Chi-squared test:
χ2 = 17.8, df = 6, P(> χ2) = 0.0066
```

Source: Authors' calculation.

Following the results in Table 4, we can reject any of the null hypotheses. The bi-causality result emerges again from Toda-Yamamoto analysis.

Alternatively, Vinod (2020a) introduced a nonlinear Granger causality test replacing the usual ordinary least squares (OLS) for kernel regressions and using maximum entropy bootstrap. The test is implemented in his R package *generalCorr*[18]. To perform this test we used the same non seasonal series from the last section. The results are reported in Table 4.

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[17] To remove the seasonality we used the output of the additive decomposition we run in section 2.

[18] See Vinod (2020b)

Table 4 - Vinod's nonlinear Granger causality test, eggs and chickens

	R^2 Egg on Chicken [1]	R^2 Chicken on Egg [2]	dif [1]-[2]
2.5%	0.9978698	0.9981856	-0.0009700890
97.5%	0.9988607	0.9991358	0.0002746497

Source: Authors' calculations.

In Table 4, [1] has R^2 for the null of egg on chicken and [2] has R2 for the null of chicken on egg. According to Vinod (2020b), if the difference between them is positive (negative), then we would conclude that egg causes chicken (chicken causes egg). In case the difference is close to zero, we have the bidirectional causality (bicausality).

In conclusion, upon allowing for nonlinearity, Table 4 shows that the bootstrap inference based on n = 999 resamples agrees with the bi-causality hypothesis.

4. FINAL THOUGHTS ON EGGS AND CHICKENS

Some years ago, Shikida, Araujo Jr and Figueiredo (2011) tried to find an answer to the secular question about eggs and chicken. Using Brazilian quarterly data Shikida, Araujo Jr and Figueiredo (2011) found bi-causality between them. In this paper, we extended the temporal length of the sample and used monthly observations and found evidence in favor of the bi-causality. We checked this result with two posterior developments of the same Granger causality test. Toda-Yamamoto and Vinod's versions of the test, again, corroborated the bi-causaility result. We concluded that the bi-causality between eggs and chicken still prevails for Brazilian data.

As one commentator observed: we found more evidence of stability in the eggs-chicken relationship than in the Phillips curve. Maybe policymakers should consider this. Of course, there are many possible ways to extend our work. Few suggestions are: (a) to study causality under other methodologies; (b) to investigate the (non-)existence of cointegration between eggs and chicken; (c) to extend the model including the possibility of political manipulation of eggs and chicken relationship (the eggs-chicken-political-business cycle) or even (d) a panel data analysis that could help us understand if different results in chicken-egg's causality is related to some omitted variables such as, for example, the type of colonization[19].

A final remark: is the persistence of the bi-causality a sign that we are closer to a definitive answer for one of the most important questions about chicken and eggs? We cannot say for sure. However, we can say that, from time immemorial, economists are known for their lack of talent for jokes and this paper does not reject this popular claim.

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[19] Maybe this could explain the difference between Brazil and the US that we found in the previous and in this paper.

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APPENDIX

Figure 1A - Observations (in log scale)

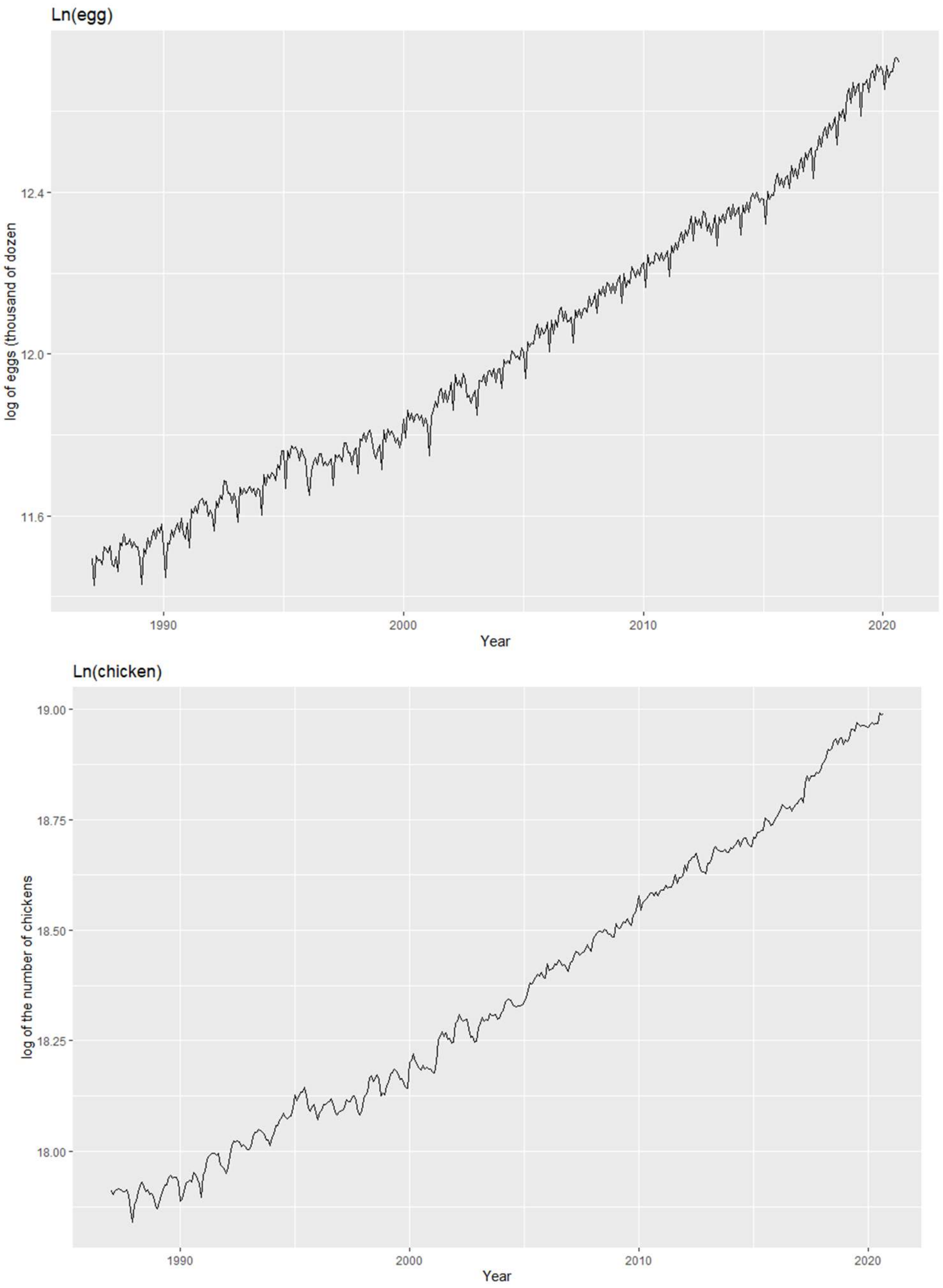

Figure 2A - SARIMA Models for log(egg) and log(chicken)

```
Series: log(egg)
ARIMA(4,1,1)(2,1,2)[12]
```

```
Coefficients:
        ar1      ar2     ar3      ar4      ma1     sar1     sar2     sma1     sma2
      0.6550  -0.0820  0.0414  -0.0449  -0.7795  0.4271  -0.1794  -1.3254  0.4629
s.e.  0.1602   0.0637  0.0649   0.0625   0.1539  0.2002   0.0676   0.2005  0.1701

sigma^2 estimated as 0.0001657:  log likelihood=1150.98
AIC=-2281.95   AICc=-2281.37   BIC=-2242.24
```

```
Series: log(chicken)
ARIMA(1,1,2)(0,1,2)[12]

Coefficients:
        ar1      ma1      ma2     sma1    sma2
      0.6394  -0.6882  -0.114  -0.9453  0.0918
s.e.  0.1231   0.1242   0.054   0.0560  0.0599

sigma^2 estimated as 0.0001308:  log likelihood=1207.28
AIC=-2402.57   AICc=-2402.35   BIC=-2378.74
```

Figure 3A - R output for Granger Test for lag lengths 1 and 5

```
Granger causality test - H0 Does chicken cause egg?

Model 1: egg$residuals ~ Lags(egg$residuals, 1:1) + Lags(chicken$residuals, 1:1)
Model 2: egg$residuals ~ Lags(egg$residuals, 1:1)
  Res.Df Df      F   Pr(>F)
1    401
2    402 -1 10.467 0.001316 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
Granger causality test

Model 1: egg$residuals ~ Lags(egg$residuals, 1:5) + Lags(chicken$residuals, 1:5)
Model 2: egg$residuals ~ Lags(egg$residuals, 1:5)
  Res.Df Df     F   Pr(>F)
1    389
2    394 -5 3.919 0.001771 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
Granger causality test
```

```
Model 1: chicken$residuals ~ Lags(chicken$residuals, 1:1) + Lags(egg$residuals, 1:1)
Model 2: chicken$residuals ~ Lags(chicken$residuals, 1:1)
  Res.Df Df      F Pr(>F)
1    401
2    402 -1 1.1725 0.2795
```

```
Granger causality test

Model 1: chicken$residuals ~ Lags(chicken$residuals, 1:5) + Lags(egg$residuals, 1:5)
Model 2: chicken$residuals ~ Lags(chicken$residuals, 1:5)
  Res.Df Df      F  Pr(>F)
1    389
2    394 -5 2.4969 0.03047 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 4A - Estimation results for equation log(egg)_dessaz

```
===========================================
                         Estimate  Std. Error t  value  Pr(>|t|)
log(egg)_dessaz.l1        5.742e-01  7.246e-02  7.925  2.71e-14 ***
log(chicken)_dessaz.l1    4.693e-01  8.385e-02  5.596  4.27e-08 ***
log(egg)_dessaz.l2        6.449e-02  8.341e-02  0.773  0.439939
log(chicken)_dessaz.l2   -1.964e-01  1.032e-01 -1.903  0.057788 .
log(egg)_dessaz.l3        1.602e-01  8.319e-02  1.926  0.054933 .
log(chicken)_dessaz.l3   -1.597e-01  1.023e-01 -1.561  0.119360
log(egg)_dessaz.l4       -1.777e-01  8.335e-02 -2.131  0.033719 *
log(chicken)_dessaz.l4    1.860e-01  1.030e-01  1.806  0.071750 .
log(egg)_dessaz.l5        4.536e-02  8.383e-02  0.541  0.588729
log(chicken)_dessaz.l5    3.305e-02  1.026e-01  0.322  0.747618
log(egg)_dessaz.l6        3.025e-01  8.444e-02  3.582  0.000386 ***
log(chicken)_dessaz.l6   -2.563e-01  1.023e-01 -2.505  0.012659 *
log(egg)_dessaz.l7       -9.958e-02  7.365e-02 -1.352  0.177213
log(chicken)_dessaz.l7    7.161e-02  8.631e-02  0.830  0.407203
const                    -1.135e+00  7.397e-01 -1.535  0.125707
trend                    -8.126e-06  5.092e-05 -0.160 0.873309
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.01194 on 370 degrees of freedom
Multiple R-Squared: 0.9988, Adjusted R-squared: 0.9987
F-statistic: 2.047e+04 on 15 and 370 DF,  p-value: < 2.2e-16
```

Figure 4B - Estimation results for equation log(chicken)_dessaz

```
==============================================
                        Estimate   Std. Error t   value   Pr(>|t|)
log(egg)_dessaz.l1       1.916e-02  6.239e-02  0.307   0.758953
```

```
log(chicken)_dessaz.l1     9.567e-01  7.220e-02  13.251  < 2e-16 ***
log(egg)_dessaz.l2        -4.244e-02  7.182e-02  -0.591   0.554938
log(chicken)_dessaz.l2    -4.212e-02  8.885e-02  -0.474   0.635706
log(egg)_dessaz.l3         1.360e-01  7.163e-02   1.898   0.058428 .
log(chicken)_dessaz.l3    -2.158e-01  8.811e-02  -2.449   0.014797 *
log(egg)_dessaz.l4        -8.872e-02  7.177e-02  -1.236   0.217140
log(chicken)_dessaz.l4     1.695e-01  8.866e-02   1.911   0.056754 .
log(egg)_dessaz.l5        -1.059e-01  7.217e-02  -1.468   0.142962
log(chicken)_dessaz.l5     1.334e-01  8.836e-02   1.509   0.132058
log(egg)_dessaz.l6         2.526e-01  7.270e-02   3.475   0.000572 ***
log(chicken)_dessaz.l6    -2.232e-01  8.807e-02  -2.534   0.011678 *
log(egg)_dessaz.l7        -7.498e-02  6.341e-02  -1.182   0.237792
log(chicken)_dessaz.l7     8.511e-02  7.431e-02   1.145   0.252787
const                      1.340e+00  6.368e-01   2.105   0.036007 *
trend                      9.973e-05  4.385e-05   2.275   0.023501 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.01028 on 370 degrees of freedom
Multiple R-Squared: 0.999,   Adjusted R-squared: 0.9989
F-statistic: 2.358e+04 on 15 and 370 DF,  p-value: < 2.2e-16
```