#Import the dataset and make the required transformations

```
library(readxl)
Book1 <- read_excel("Demographic_crisis_revisited.xlsx",
    sheet = "Data")
head(Book1)
```

```
## # A tibble: 6 × 9
##    Year Capital `GDP_(constant US$)` Population Relative_Change_popu…¹ Indicator
##   <dbl>   <dbl>                <dbl>      <dbl>                  <dbl>     <dbl>
## 1  1971      NA                   NA      8536.                 NA            NA
## 2  1972      NA                   NA      8576.                  0.00466       0
## 3  1973      NA                   NA      8621.                  0.00522       0
## 4  1974      NA                   NA      8679.                  0.00670       0
## 5  1975      NA                   NA      8721.                  0.00484       0
## 6  1976      NA                   NA      8755.                  0.00393       0
## # ℹ abbreviated name: ¹Relative_Change_population
## # ℹ 3 more variables: Workers <dbl>, Pensions <dbl>, Delta_pensions <dbl>
```

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
Book1$log_GDP_growth <- log(Book1$`GDP_(constant US$)` / lag(Book1$`GDP_(constant US$)`))

Book1$log_Capital_growth <- log(Book1$Capital / lag(Book1$Capital))

Book1$log_Workers_growth <- log(Book1$Workers / lag(Book1$Workers))
```

#Granger causality tests and stationarity tests

```
library(tseries)
```

```
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo
```

```
library(lmtest)
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
Book1$workers_change<-(Book1$Workers-lag(Book1$Workers))/lag(Book1$Workers)
Book1$Population_change<-(Book1$Population-lag(Book1$Population))/lag(Book1$Population)
Book1$log_pop_change<-log(Book1$Population/lag(Book1$Population))
#The Granger causality tests show that the population change causes changes in the logged differences in GDP with
8 lags behind
grangertest(Book1$log_GDP_growth~Book1$log_pop_change,order=8)
```

```
## Granger causality test
##
## Model 1: Book1$log_GDP_growth ~ Lags(Book1$log_GDP_growth, 1:8) + Lags(Book1$log_pop_change, 1:8)
## Model 2: Book1$log_GDP_growth ~ Lags(Book1$log_GDP_growth, 1:8)
##   Res.Df Df      F  Pr(>F)
## 1     17
## 2     25 -8 2.7501 0.03787 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#The granger causality tests show that the population change causes changes in the logged differences of the work
ers with 5 laggs behind. To keep the statistical significance of the model we lag the population indicator 7 time
s.
grangertest(Book1$workers_change~Book1$Population_change,order=4)
```

```
## Granger causality test
##
## Model 1: Book1$workers_change ~ Lags(Book1$workers_change, 1:4) + Lags(Book1$Population_change, 1:4)
## Model 2: Book1$workers_change ~ Lags(Book1$workers_change, 1:4)
##   Res.Df Df      F  Pr(>F)
## 1     29
## 2     33 -4 2.7232 0.04867 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
grangertest(Book1$workers_change~Book1$Population_change,order=5)
```

```
## Granger causality test
##
## Model 1: Book1$workers_change ~ Lags(Book1$workers_change, 1:5) + Lags(Book1$Population_change, 1:5)
## Model 2: Book1$workers_change ~ Lags(Book1$workers_change, 1:5)
##   Res.Df Df      F  Pr(>F)
## 1     26
## 2     31 -5 2.1031 0.09714 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#The ADF tests for unit roots provide evidence against the possible lack of stationarity of the time series
adf.test(na.omit(Book1$log_GDP_growth),k=2)
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  na.omit(Book1$log_GDP_growth)
## Dickey-Fuller = -3.3049, Lag order = 2, p-value = 0.08455
## alternative hypothesis: stationary
```

```
adf.test(na.omit(Book1$log_Capital_growth),k=1)
```

```
## Warning in adf.test(na.omit(Book1$log_Capital_growth), k = 1): p-value smaller
## than printed p-value
```

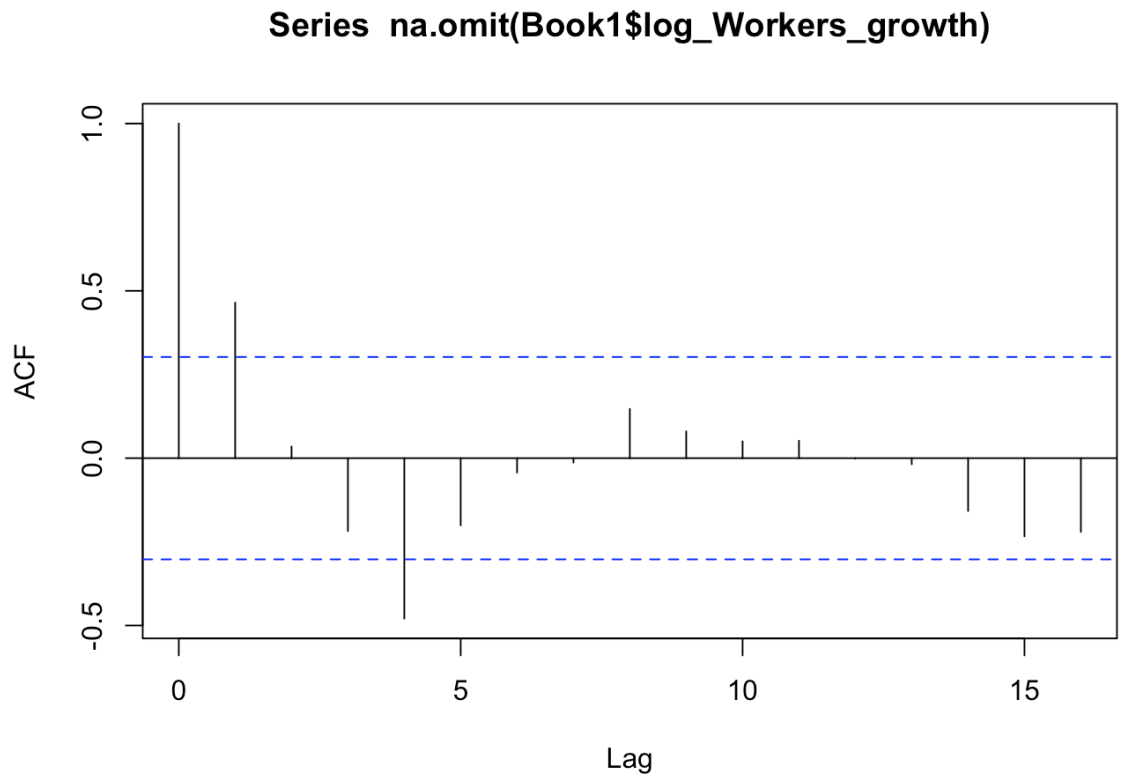
```
##
##  Augmented Dickey-Fuller Test
##
## data:  na.omit(Book1$log_Capital_growth)
## Dickey-Fuller = -4.6052, Lag order = 1, p-value = 0.01
## alternative hypothesis: stationary
```

```
adf.test(na.omit(Book1$log_Workers_growth),k=3)
```

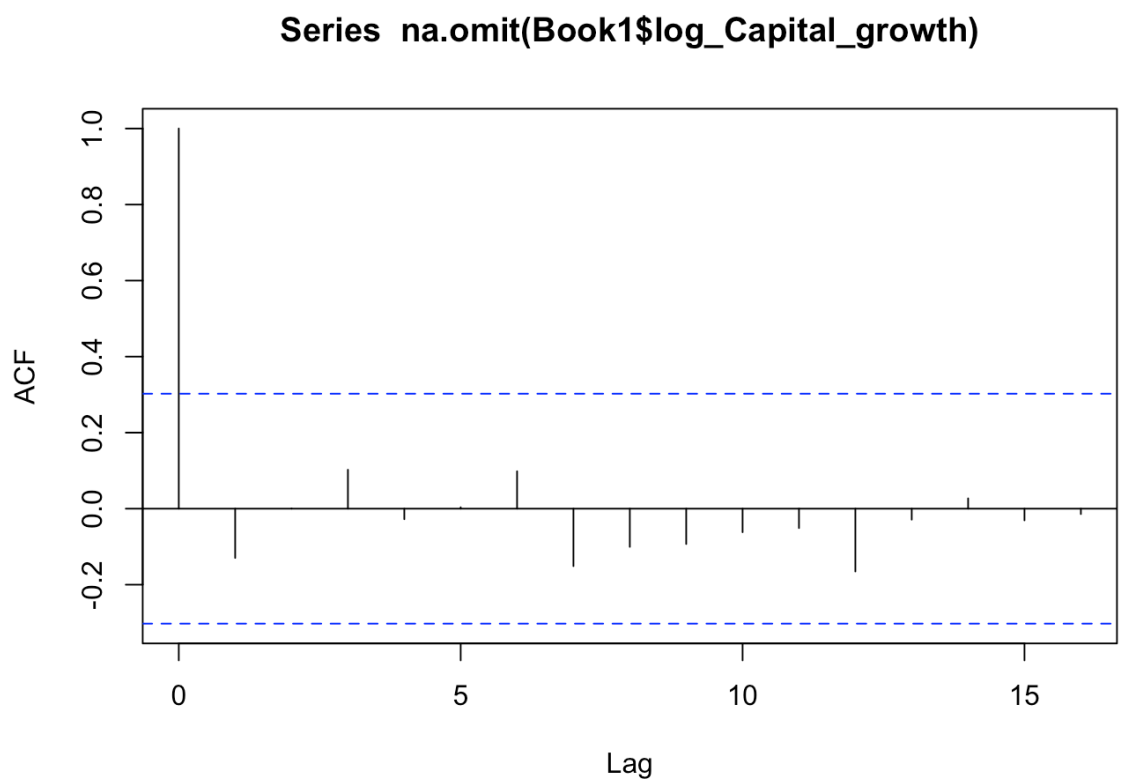
```
## Warning in adf.test(na.omit(Book1$log_Workers_growth), k = 3): p-value smaller
## than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  na.omit(Book1$log_Workers_growth)
## Dickey-Fuller = -4.8724, Lag order = 3, p-value = 0.01
## alternative hypothesis: stationary
```

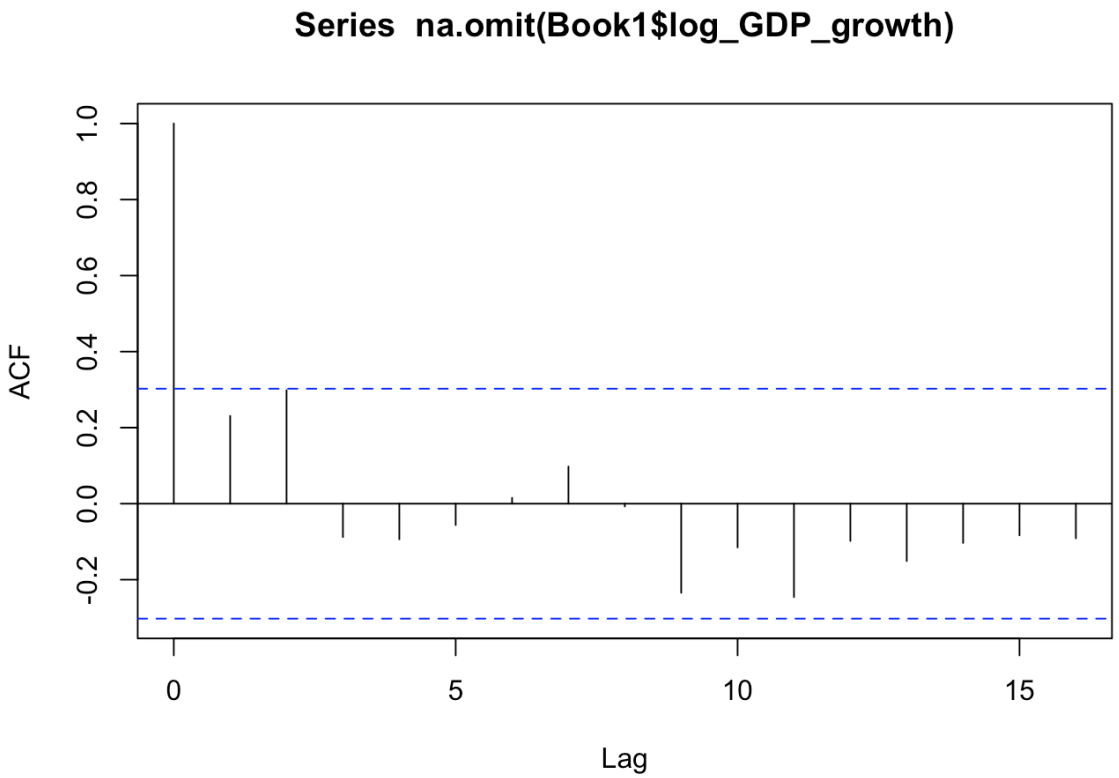
```
#The ACF plot further demonstrate that those series cannot be non-stationary because in all of them the autocorre
lation either vanishes after the first lag or is not statistically significant
acf(na.omit(Book1$log_Workers_growth))
```




```
acf(na.omit(Book1$log_Capital_growth))
```




```
acf(na.omit(Book1$log_GDP_growth))
```



#Table 1 models

```
library(lmtest)
Book1$lag_workers_ind <- Book1$log_Workers_growth*lag(Book1$Indicator,7)
model1 <- lm(log_GDP_growth ~ log_Capital_growth + lag_workers_ind, data = Book1)
model2<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth , data = Book1)
model3<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth +lag_workers_ind, data = Book1)
stargazer::stargazer(model1,model2,model3,type="text")
```

```
##
## ================================================================================================
##                                          Dependent variable:
##                      ------------------------------------------------------------------
##                                                log_GDP_growth
##                                (1)                    (2)                    (3)
## ------------------------------------------------------------------------------------------------
## log_Capital_growth          -0.014                 -0.018                 -0.016
##                             (0.027)                (0.025)                (0.024)
##
## lag_workers_ind            1.603***                                       0.892**
##                             (0.412)                                       (0.430)
##
## log_Workers_growth                                 0.952***               0.717***
##                                                    (0.199)                (0.222)
##
## Constant                    0.019**                0.021***               0.021***
##                             (0.007)                (0.007)                (0.006)
##
## ------------------------------------------------------------------------------------------------
## Observations                  42                     42                     42
## R2                           0.286                  0.376                  0.439
## Adjusted R2                  0.249                  0.344                  0.395
## Residual Std. Error    0.046 (df = 39)        0.043 (df = 39)        0.041 (df = 38)
## F Statistic         7.792*** (df = 2; 39) 11.739*** (df = 2; 39) 9.923*** (df = 3; 38)
## ================================================================================================
## Note:                                                            *p<0.1; **p<0.05; ***p<0.01
```

```
#Table 2 adequacy checks
bptest(model1)
```

```
##
##  studentized Breusch-Pagan test
##
## data:  model1
## BP = 2.1084, df = 2, p-value = 0.3485
```

```
dwtest(model1)
```

```
##
##  Durbin-Watson test
##
## data:  model1
## DW = 1.264, p-value = 0.004973
## alternative hypothesis: true autocorrelation is greater than 0
```

```
bptest(model2)
```

```
##
##  studentized Breusch-Pagan test
##
## data:  model2
## BP = 2.3059, df = 2, p-value = 0.3157
```

```
dwtest(model2)
```

```
##
##  Durbin-Watson test
##
## data:  model2
## DW = 1.9753, p-value = 0.445
## alternative hypothesis: true autocorrelation is greater than 0
```

```
bptest(model3)
```

```
##
##  studentized Breusch-Pagan test
##
## data:  model3
## BP = 3.6861, df = 3, p-value = 0.2974
```

```
dwtest(model3)
```

```
##
##  Durbin-Watson test
##
## data:  model3
## DW = 1.7634, p-value = 0.1739
## alternative hypothesis: true autocorrelation is greater than 0
```

```
car::vif(model1)
```

```
## log_Capital_growth    lag_workers_ind
##           1.001096           1.001096
```

```
car::vif(model2)
```

```
## log_Capital_growth log_Workers_growth
##           1.000014           1.000014
```

```
car::vif(model3)
```

```
## log_Capital_growth log_Workers_growth    lag_workers_ind
##           1.001679           1.355129           1.356594
```

#Robustness checks

```
# Create Separate Crisis Dummies
Book1$lag_workers_ind <- Book1$log_Workers_growth*lag(Book1$Indicator,7)
Book1$Year<-as.numeric(Book1$Year)
Book1$BulgarianCrisis <- ifelse(Book1$Year >= 1995 & Book1$Year <= 1997, 1, 0)
Book1$FinancialCrisis <- ifelse(Book1$Year >= 2007 & Book1$Year <= 2009, 1, 0)
Book1$CovidCrisis <- ifelse(Book1$Year >= 2020 & Book1$Year <= 2022, 1, 0)

# Create Combined Crisis Dummy
Book1$AnyCrisis <- ifelse(Book1$BulgarianCrisis == 1 |
                          Book1$FinancialCrisis == 1 |
                          Book1$CovidCrisis == 1, 1, 0)

model4<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth +lag_workers_ind+BulgarianCrisis, data = Book
1)
model5<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth +lag_workers_ind+FinancialCrisis, data = Book
1)
model6<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth +lag_workers_ind+CovidCrisis, data = Book1)
model7<-lm(log_GDP_growth ~ log_Capital_growth+lag_workers_ind+BulgarianCrisis, data = Book1)
model8<-lm(log_GDP_growth ~ log_Capital_growth +lag_workers_ind+FinancialCrisis, data = Book1)
model9<-lm(log_GDP_growth ~ log_Capital_growth +lag_workers_ind+CovidCrisis, data = Book1)
model10<-lm(log_GDP_growth ~ log_Capital_growth+log_Workers_growth+BulgarianCrisis, data = Book1)
model11<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth+FinancialCrisis, data = Book1)
model12<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth+CovidCrisis, data = Book1)
#Table 3 robustnes checks
stargazer::stargazer(model4,model7,model8,model9,model10,model11,model12,type="text")
```

```
##
## ================================================================================================================
================================================================
##                                                                                  Dependent variable:
##                     ---------------------------------------------------------------------------------------------
----------------------------------------------------------------
##                                                                                        log_GDP_growth
##                               (1)                    (2)                   (3)                   (4)
(5)                    (6)                   (7)
## ----------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------
## log_Capital_growth          -0.025                -0.018                -0.014                -0.014
-0.027                -0.018                -0.018
##                            (0.023)               (0.027)               (0.028)               (0.027)
(0.023)                (0.026)               (0.026)
##
## log_Workers_growth         0.966***
1.110***               0.952***              0.956***
##                            (0.219)
(0.180)                (0.203)               (0.201)
##
## lag_workers_ind             0.478                1.532***              1.618***              1.637***
##                            (0.417)               (0.415)               (0.424)               (0.417)
##
## BulgarianCrisis           -0.073***              -0.031
-0.083***
##                            (0.025)               (0.028)
(0.023)
##
## FinancialCrisis                                                        -0.005
0.0003
##                                                                        (0.028)
(0.026)
##
## CovidCrisis                                                                                   0.020
0.012
##                                                                                              (0.028)
(0.026)
##
## Constant                   0.027***              0.021***              0.019**               0.018**
0.027***               0.021***              0.020***
##                            (0.006)               (0.007)               (0.008)               (0.007)
(0.006)                (0.007)               (0.007)
```

```
##
## ------------------------------------------------------------------------------------------------------------------------
-------------------------------------------------------------------
## Observations                  42                    42                    42                    42
42                    42                    42
## R2                          0.546                 0.308                 0.286                 0.295
0.530                 0.376                 0.379
## Adjusted R2                 0.497                 0.253                 0.230                 0.239
0.493                 0.326                 0.330
## Residual Std. Error    0.038 (df = 37)       0.046 (df = 38)       0.047 (df = 38)       0.046 (df = 38)
0.038 (df = 38)       0.043 (df = 38)       0.043 (df = 38)
## F Statistic         11.116*** (df = 4; 37) 5.638*** (df = 3; 38) 5.078*** (df = 3; 38) 5.299*** (df = 3; 38) 1
4.265*** (df = 3; 38) 7.625*** (df = 3; 38) 7.737*** (df = 3; 38)
## ========================================================================================================================
===================================================================
## Note:
*p<0.1; **p<0.05; ***p<0.01
```

```
#Table 4 robustness checks
model_pensions<-lm(log_GDP_growth ~ log_Capital_growth +log_Workers_growth +lag_workers_ind+BulgarianCrisis+Delta
_pensions, data = Book1)
stargazer::stargazer(model4,model_pensions,type="text")
```

```
##
## ================================================================
##                                Dependent variable:
##                     ---------------------------------------------
##                                     log_GDP_growth
##                               (1)                    (2)
## ----------------------------------------------------------------
## log_Capital_growth          -0.025                -0.038*
##                            (0.023)                (0.020)
##
## log_Workers_growth         0.966***                0.297
##                            (0.219)                (0.280)
##
## lag_workers_ind             0.478                 0.863**
##                            (0.417)                (0.378)
##
## BulgarianCrisis           -0.073***               -0.049**
##                            (0.025)                (0.023)
##
## Delta_pensions                                   -2.083***
##                                                   (0.635)
##
## Constant                   0.027***                0.014*
##                            (0.006)                (0.007)
##
## ----------------------------------------------------------------
## Observations                  42                     33
## R2                           0.546                  0.721
## Adjusted R2                  0.497                  0.669
## Residual Std. Error    0.038 (df = 37)        0.032 (df = 27)
## F Statistic         11.116*** (df = 4; 37) 13.922*** (df = 5; 27)
## ================================================================
## Note:                                *p<0.1; **p<0.05; ***p<0.01
```

```
bptest(model_pensions)
```

```
##
##  studentized Breusch-Pagan test
##
## data:  model_pensions
## BP = 17.539, df = 5, p-value = 0.003583
```

```
dwtest(model_pensions)
```

```
##
##  Durbin-Watson test
##
## data:  model_pensions
## DW = 2.1684, p-value = 0.5289
## alternative hypothesis: true autocorrelation is greater than 0
```

```
shapiro.test(model_pensions$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  model_pensions$residuals
## W = 0.98363, p-value = 0.8869
```

```
stargazer::stargazer(model4,model7,model8,model10,model11,model_pensions,type="text")
```

```
##
## ================================================================================================================
==========================================
##                                                                                 Dependent variable:
##                     ---------------------------------------------------------------------------------------------
----------------------------------------
##                                                                                      log_GDP_growth
##                               (1)                    (2)                    (3)                    (4)
(5)                   (6)
## ----------------------------------------------------------------------------------------------------------------
----------------------------------------
## log_Capital_growth          -0.025                 -0.018                 -0.014                 -0.027
-0.018                -0.038*
##                            (0.023)                (0.027)                (0.028)                (0.023)
(0.026)               (0.020)
##
## log_Workers_growth         0.966***                                                             1.110***
0.952***                0.297
##                            (0.219)                                                              (0.180)
(0.203)               (0.280)
##
## lag_workers_ind             0.478                 1.532***               1.618***
0.863**
##                            (0.417)                (0.415)                (0.424)
(0.378)
##
## BulgarianCrisis           -0.073***               -0.031                                      -0.083***
-0.049**
##                            (0.025)                (0.028)                                      (0.023)
(0.023)
##
## FinancialCrisis                                                         -0.005
0.0003
##                                                                         (0.028)
(0.026)
##
## Delta_pensions
-2.083***
##
(0.635)
##
## Constant                   0.027***               0.021***               0.019**                0.027***
0.021***               0.014*
```

```
##                             (0.006)               (0.007)               (0.008)               (0.006)
(0.007)              (0.007)
##
## ------------------------------------------------------------------------------------------------------------------
-----------------------------------------
## Observations                  42                    42                    42                    42
42                    33
## R2                          0.546                 0.308                 0.286                 0.530
0.376                 0.721
## Adjusted R2                 0.497                 0.253                 0.230                 0.493
0.326                 0.669
## Residual Std. Error    0.038 (df = 37)       0.046 (df = 38)       0.047 (df = 38)       0.038 (df = 38)
0.043 (df = 38)       0.032 (df = 27)
## F Statistic         11.116*** (df = 4; 37) 5.638*** (df = 3; 38) 5.078*** (df = 3; 38) 14.265*** (df = 3; 38)
7.625*** (df = 3; 38) 13.922*** (df = 5; 27)
## ==================================================================================================================
=========================================
## Note:
*p<0.1; **p<0.05; ***p<0.01
```

```
library(sandwich)
library(lmtest)
#Robust SE to back up the claim in the paper
model_pensions <- lm(log_GDP_growth ~ log_Capital_growth + log_Workers_growth +
                     lag_workers_ind + BulgarianCrisis + Delta_pensions,
                     data = Book1)

robust_se <- vcovHC(model_pensions, type = "HC1")

summary_robust <- coeftest(model_pensions, vcov = robust_se)

print(summary_robust)
```

```
##
## t test of coefficients:
##
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)         0.0138868  0.0091625  1.5156  0.14124
## log_Capital_growth -0.0383071  0.0191742 -1.9978  0.05590 .
## log_Workers_growth  0.2967344  0.3807385  0.7794  0.44254
## lag_workers_ind     0.8627166  0.4396196  1.9624  0.06010 .
## BulgarianCrisis    -0.0492922  0.0259107 -1.9024  0.06784 .
## Delta_pensions     -2.0826030  0.9849246 -2.1145  0.04385 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```