In [1]:
```
import numpy as np
import pandas as pd
from scipy import stats
# set up panel data
pdata = pd.read_csv("CB data-1.csv", index_col = ["ID", "Year"],
                    parse_dates = True)
pdata
# alternatively
# data = pd.read_csv("http://web.pdx.edu/~crkl/ceR/data/airline.txt", sep='\s+',
# Set data as panel data
# pdata = data.set_index(['I', 'T'], inplace=True)
```

Out[1]:

ID	Year	SL	Market Capitalization	Market Cap Growth	Debt / Equity Ratio	Debt / FCF Ratio	Return on Equity (ROE)	Return on Assets (ROA)	Return on Capital (ROIC)	Log Total Assets	L Curre Circulat ($
	2019-01-01	1	1,367,031,594	0.193	1.112	7.657	0.125	0.012	0.014	15.230	7.
	2018-01-01	1	1,145,996,404	-0.073	1.896	12.701	0.138	0.012	0.014	15.222	7.
TMP	2017-01-01	1	1,236,784,388	-0.131	2.024	22.846	0.091	0.008	0.013	15.308	7.
	2016-01-01	1	1,423,389,891	0.701	1.810	13.276	0.108	0.010	0.013	15.311	7.
	2015-01-01	1	836,855,660	0.025	1.379	9.279	0.115	0.011	0.015	15.317	7.
...	...	...	...	...	...	...	...	...	...	...	
	2014-01-01	54	60,465,197,835	0.090	11.887	-65.859	-0.003	0.000	0.000	15.319	7.
	2013-01-01	54	55,489,736,570	0.050	12.579	-27.133	0.010	0.000	0.001	15.200	7.
BCS	2012-01-01	54	52,823,723,087	0.578	17.739	-63.139	-0.012	0.000	0.000	14.881	7.
	2011-01-01	54	33,469,882,543	-0.290	17.875	34.557	0.056	0.002	0.002	14.877	6.
	2010-01-01	54	47,129,813,960	0.279	17.435	52.410	0.073	0.002	0.002	14.688	6.

540 rows × 12 columns

In [5]:
```
pdata.describe()
```

Out[5]:

	Market Cap Growth	Debt / Equity Ratio	Debt / FCF Ratio	Return on Equity (ROE)	Return on Assets (ROA)	Return on Capital (ROIC)	Log Total Assets	Cur Circu
count	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.0
mean	0.216502	1.136930	6.343000	0.086111	0.009646	0.013672	15.135300	7.2
std	0.376532	1.832502	38.175251	0.056684	0.006142	0.007287	0.219199	0.1
min	-0.466000	0.041000	-365.473000	-0.692000	-0.069000	-0.060000	14.688000	6.8
25%	-0.019250	0.433250	2.885500	0.072000	0.008000	0.011000	14.881000	7.0
50%	0.135500	0.768500	5.608000	0.090000	0.010000	0.014000	15.226000	7.2
75%	0.366500	1.148250	9.802000	0.109000	0.012000	0.017000	15.311000	7.3
max	3.730000	17.875000	530.212000	0.340000	0.036000	0.040000	15.319000	7.4

In [6]:
```
column_names = {'Debt / Equity Ratio':'DE',
                'Debt / FCF Ratio':'DF',
                'Liquidity Ratio': 'LR',
                'Return on Equity (ROE)':'ROE',
               'Return on Assets (ROA)': 'ROA',
               'Return on Capital (ROIC)': 'ROIC',
               'Log Total Assets': 'TA',
               'Log Currency in Circulation ($ Bil)': 'CC',
               'Effective Federal Funds Rate (%)': 'FFR',
               'Loss Function': 'LF'}

# rename columns
pdata =pdata.rename(columns = column_names)

pdata
```

Out[6]:

ID	Year	Market Capitalization	Market Cap Growth	DE	DF	ROE	ROA	ROIC	TA	CC	FFR	
	2019-01-01	1,367,031,594	0.193	1.112	7.657	0.125	0.012	0.014	15.230	7.492	1.551	(
	2018-01-01	1,145,996,404	-0.073	1.896	12.701	0.138	0.012	0.014	15.222	7.442	2.274	(
TMP	2017-01-01	1,236,784,388	-0.131	2.024	22.846	0.091	0.008	0.013	15.308	7.381	1.302	-(
	2016-01-01	1,423,389,891	0.701	1.810	13.276	0.108	0.010	0.013	15.311	7.313	0.540	-(
	2015-01-01	836,855,660	0.025	1.379	9.279	0.115	0.011	0.015	15.317	7.255	0.241	-
...	...	...	...	...	...	...	...	...	...	...	...	
	2014-01-01	60,465,197,835	0.090	11.887	-65.859	-0.003	0.000	0.000	15.319	7.190	0.123	-2
	2013-01-01	55,489,736,570	0.050	12.579	-27.133	0.010	0.000	0.001	15.200	7.115	0.085	-
BCS	2012-01-01	52,823,723,087	0.578	17.739	-63.139	-0.012	0.000	0.000	14.881	7.053	0.165	-15
	2011-01-01	33,469,882,543	-0.290	17.875	34.557	0.056	0.002	0.002	14.877	6.972	0.072	-2(
	2010-01-01	47,129,813,960	0.279	17.435	52.410	0.073	0.002	0.002	14.688	6.887	0.183	-2(

540 rows × 11 columns

In [8]:
```
df = pdata
df
```

Out[8]:

ID	Year	Market Capitalization	Market Cap Growth	DE	DF	ROE	ROA	ROIC	TA	CC	FFR	
	2019-01-01	1,367,031,594	0.193	1.112	7.657	0.125	0.012	0.014	15.230	7.492	1.551	(
	2018-01-01	1,145,996,404	-0.073	1.896	12.701	0.138	0.012	0.014	15.222	7.442	2.274	(
TMP	2017-01-01	1,236,784,388	-0.131	2.024	22.846	0.091	0.008	0.013	15.308	7.381	1.302	-(
	2016-01-01	1,423,389,891	0.701	1.810	13.276	0.108	0.010	0.013	15.311	7.313	0.540	-(
	2015-01-01	836,855,660	0.025	1.379	9.279	0.115	0.011	0.015	15.317	7.255	0.241	-1
...	...	...	...	...	...	...	...	...	...	...	...	
	2014-01-01	60,465,197,835	0.090	11.887	-65.859	-0.003	0.000	0.000	15.319	7.190	0.123	-2
	2013-01-01	55,489,736,570	0.050	12.579	-27.133	0.010	0.000	0.001	15.200	7.115	0.085	-1
BCS	2012-01-01	52,823,723,087	0.578	17.739	-63.139	-0.012	0.000	0.000	14.881	7.053	0.165	-15
	2011-01-01	33,469,882,543	-0.290	17.875	34.557	0.056	0.002	0.002	14.877	6.972	0.072	-20
	2010-01-01	47,129,813,960	0.279	17.435	52.410	0.073	0.002	0.002	14.688	6.887	0.183	-28

540 rows × 11 columns

In [9]:
```
# Descriptive statistics
df.describe()
```

Out[9]:

	Market Cap Growth	DE	DF	ROE	ROA	ROIC	TA	
count	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.0
mean	0.216502	1.136930	6.343000	0.086111	0.009646	0.013672	15.135300	7.2
std	0.376532	1.832502	38.175251	0.056684	0.006142	0.007287	0.219199	0.1
min	-0.466000	0.041000	-365.473000	-0.692000	-0.069000	-0.060000	14.688000	6.8
25%	-0.019250	0.433250	2.885500	0.072000	0.008000	0.011000	14.881000	7.0
50%	0.135500	0.768500	5.608000	0.090000	0.010000	0.014000	15.226000	7.2
75%	0.366500	1.148250	9.802000	0.109000	0.012000	0.017000	15.311000	7.3
max	3.730000	17.875000	530.212000	0.340000	0.036000	0.040000	15.319000	7.4

In [10]:
```
# Pooled OLS estimator
from linearmodels import PooledOLS
pooled = PooledOLS.from_formula('ROE ~ 1 + DE + DF + TA + CC + FFR', df).fit()
print(pooled)
```

```
                          PooledOLS Estimation Summary
================================================================================
=
Dep. Variable:                     ROE   R-squared:                         0.077
1
Estimator:                   PooledOLS   R-squared (Between):               0.053
7
No. Observations:                  540   R-squared (Within):                0.083
3
Date:                Thu, Apr 21 2022   R-squared (Overall):               0.077
1
Time:                        00:00:12   Log-likelihood                     805.8
9
Cov. Estimator:            Unadjusted
                                        F-statistic:                       8.926
9
Entities:                          54   P-value                            0.000
0
Avg Obs:                     10.0000   Distribution:                   F(5,53
4)
Min Obs:                     10.0000
Max Obs:                     10.0000   F-statistic (robust):              8.926
9
                                        P-value                            0.000
0
Time periods:                      10   Distribution:                   F(5,53
4)
Avg Obs:                     54.000
Min Obs:                     54.000
Max Obs:                     54.000

                             Parameter Estimates
==============================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
------------------------------------------------------------------------------
Intercept     -0.5927     0.1799    -3.2940     0.0011     -0.9462     -0.2392
CC             0.0719     0.0525     1.3690     0.1716     -0.0313      0.1750
DE            -0.0021     0.0013    -1.6112     0.1077     -0.0046      0.0005
DF          1.683e-05  6.231e-05     0.2700     0.7872     -0.0001      0.0001
FFR           -0.0018     0.0088    -0.2072     0.8359     -0.0190      0.0154
TA             0.0108     0.0294     0.3679     0.7131     -0.0470      0.0687
==============================================================================
```

In [11]:
```
# Between estimator
from linearmodels import BetweenOLS
between = BetweenOLS.from_formula('ROE ~ 1 + DE + DF + TA + CC + FFR', df).fit()
print(between)
```

```
                          BetweenOLS Estimation Summary
================================================================================
=
Dep. Variable:                    ROE   R-squared:                        0.073
4
Estimator:                  BetweenOLS   R-squared (Between):              0.073
4
No. Observations:                  54   R-squared (Within):               0.001
1
Date:                Thu, Apr 21 2022   R-squared (Overall):              0.016
2
Time:                        00:01:14   Log-likelihood                    122.8
2
Cov. Estimator:            Unadjusted
                                        F-statistic:                      0.760
7
Entities:                          54   P-value                           0.582
6
Avg Obs:                      10.0000   Distribution:                    F(5,4
8)
Min Obs:                      10.0000
Max Obs:                      10.0000   F-statistic (robust):             0.760
7
                                        P-value                           0.582
6
Time periods:                      10   Distribution:                    F(5,4
8)
Avg Obs:                      54.000
Min Obs:                      54.000
Max Obs:                      54.000

                             Parameter Estimates
================================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
--------------------------------------------------------------------------------
Intercept      0.0003  6.266e+04  5.193e-09     1.0000   -1.26e+05    1.26e+05
CC             0.0023  1.219e+04  1.924e-07     1.0000  -2.451e+04   2.451e+04
DE            -0.0044     0.0023    -1.9310     0.0594     -0.0089      0.0002
DF            -0.0001     0.0004    -0.3806     0.7052     -0.0008      0.0006
FFR            0.0002
TA             0.0049     1647.2   2.99e-06     1.0000     -3311.9      3311.9
================================================================================

C:\Users\HP\anaconda3\lib\site-packages\linearmodels\panel\results.py:87: Runti
meWarning: invalid value encountered in sqrt
  return Series(np.sqrt(np.diag(self.cov)), self._var_names, name="std_error")
```

In [12]:
```
# First differences estimator (without constant term)
from linearmodels import FirstDifferenceOLS
firstdiff = FirstDifferenceOLS.from_formula('ROE ~ DE + DF + TA + CC + FFR', df).
print(firstdiff)
```

```
                  FirstDifferenceOLS Estimation Summary
================================================================================
=
Dep. Variable:                    ROE   R-squared:                        0.041
5
Estimator:         FirstDifferenceOLS   R-squared (Between):             -54.45
8
No. Observations:                 486   R-squared (Within):               0.046
4
Date:                Thu, Apr 21 2022   R-squared (Overall):             -41.43
1
Time:                        00:02:40   Log-likelihood                    833.5
2
Cov. Estimator:            Unadjusted
                                        F-statistic:                      4.163
9
Entities:                          54   P-value                           0.001
0
Avg Obs:                      10.0000   Distribution:                  F(5,48
1)
Min Obs:                      10.0000
Max Obs:                      10.0000   F-statistic (robust):             4.163
9
                                        P-value                           0.001
0
Time periods:                      10   Distribution:                  F(5,48
1)
Avg Obs:                      54.000
Min Obs:                      54.000
Max Obs:                      54.000

                             Parameter Estimates
================================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
--------------------------------------------------------------------------------
CC             0.1047     0.0391     2.6750     0.0077      0.0278      0.1816
DE            -0.0008     0.0047    -0.1625     0.8710     -0.0100      0.0084
DF          3.782e-05  3.494e-05     1.0822     0.2797  -3.084e-05      0.0001
FFR            0.0067     0.0048     1.3907     0.1650     -0.0028      0.0161
TA            -0.0002     0.0193    -0.0114     0.9909     -0.0381      0.0377
================================================================================
```

In [13]:
```
from linearmodels.panel.results import compare
res1 = {'Pooled':pooled,'Between':between,'firstdiff':firstdiff}
print(compare(res1))
```

```
                          Model Comparison
=========================================================================
                            Pooled       Between            firstdiff
-------------------------------------------------------------------------
Dep. Variable                  ROE           ROE                  ROE
Estimator                PooledOLS    BetweenOLS   FirstDifferenceOLS
No. Observations               540            54                  486
Cov. Est.                Unadjusted    Unadjusted           Unadjusted
R-squared                    0.0771        0.0734               0.0415
R-Squared (Within)           0.0833        0.0011               0.0464
R-Squared (Between)          0.0537        0.0734              -54.458
R-Squared (Overall)          0.0771        0.0162              -41.431
F-statistic                  8.9269        0.7607               4.1639
P-value (F-stat)             0.0000        0.5826               0.0010
====================== ============ ============= ====================
Intercept                   -0.5927        0.0003
                          (-3.2940)   (5.193e-09)
CC                           0.0719        0.0023               0.1047
                           (1.3690)   (1.924e-07)             (2.6750)
DE                          -0.0021       -0.0044              -0.0008
                          (-1.6112)     (-1.9310)            (-0.1625)
DF                         1.683e-05       -0.0001           3.782e-05
                           (0.2700)     (-0.3806)             (1.0822)
FFR                         -0.0018        0.0002               0.0067
                          (-0.2072)                            (1.3907)
TA                           0.0108        0.0049              -0.0002
                           (0.3679)    (2.99e-06)            (-0.0114)
-------------------------------------------------------------------------

T-stats reported in parentheses
```

In [15]:
```
# Fixed effects or within estimator
# with constant inclued or not, will have the same results
# with constant term surpressed
from linearmodels import PanelOLS
fixed = PanelOLS.from_formula('ROE ~ DE + DF + TA + CC + FFR + EntityEffects', df
print(fixed)
# extract fixed effects
fixed.estimated_effects
fixed_effects = fixed.estimated_effects.unstack(level=0).values[0]
print(fixed_effects)
# F test for fixed effects versus OLS
print(fixed.f_pooled)
```

```
                          PanelOLS Estimation Summary
================================================================================
=
Dep. Variable:                    ROE   R-squared:                         0.109
9
Estimator:                   PanelOLS   R-squared (Between):              -67.31
2
No. Observations:                 540   R-squared (Within):                0.109
9
Date:                Thu, Apr 21 2022   R-squared (Overall):              -51.19
8
Time:                        00:05:20   Log-likelihood                     878.7
6
Cov. Estimator:            Unadjusted
                                        F-statistic:                      11.87
9
Entities:                          54   P-value                           0.000
0
Avg Obs:                      10.0000   Distribution:                   F(5,48
1)
Min Obs:                      10.0000
Max Obs:                      10.0000   F-statistic (robust):             11.87
9
                                        P-value                           0.000
0
Time periods:                      10   Distribution:                   F(5,48
1)
Avg Obs:                      54.000
Min Obs:                      54.000
Max Obs:                      54.000

                             Parameter Estimates
==============================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
------------------------------------------------------------------------------
CC             0.0849     0.0484     1.7524     0.0803     -0.0103      0.1801
DE             0.0101     0.0032     3.1429     0.0018      0.0038      0.0165
DF         -6.722e-07  6.001e-05    -0.0112     0.9911     -0.0001      0.0001
FFR           -0.0022     0.0081    -0.2688     0.7882     -0.0180      0.0137
TA             0.0136     0.0271     0.5024     0.6156     -0.0397      0.0669
==============================================================================

F-test for Poolability: 2.8116
P-value: 0.0000
```

```
Distribution: F(53,481)

Included effects: Entity
[-0.75102022 -0.75544832 -0.7694817  -0.92007384 -0.7310765  -0.7423119
 -0.72793233 -0.71660087 -0.73842161 -0.7471241  -0.7196085  -0.71755112
 -0.69902119 -0.72929546 -0.77850417 -0.75664868 -0.73428696 -0.74676802
 -0.70457462 -0.73489494 -0.72053978 -0.7360623  -0.75119472 -0.71635121
 -0.76546751 -0.73813533 -0.75354623 -0.74317909 -0.69689894 -0.72652242
 -0.78695378 -0.71942456 -0.73453788 -0.73736042 -0.7041424  -0.74723873
 -0.74485564 -0.69565661 -0.77202361 -0.73935229 -0.72717435 -0.73073287
 -0.71866045 -0.74560486 -0.83803986 -0.76517839 -0.75365448 -0.74699964
 -0.70380216 -0.71451607 -0.74568589 -0.74999114 -0.7408618  -0.75306237]
Pooled F-statistic
H0: Effects are zero
Statistic: 2.8116
P-value: 0.0000
Distributed: F(53,481)
```

In [16]:
```
# with constant term included
fixed1 = PanelOLS.from_formula('ROE ~ 1 + DE + DF + TA + CC + FFR + EntityEffects
print(fixed1)
# extract fixed effects
fixed1.estimated_effects
fixed1_effects = fixed1.params.Intercept + fixed1.estimated_effects.unstack(level
print(fixed1_effects)
```

```
                          PanelOLS Estimation Summary
================================================================================
=
Dep. Variable:                    ROE   R-squared:                        0.109
9
Estimator:                   PanelOLS   R-squared (Between):             -0.787
0
No. Observations:                 540   R-squared (Within):               0.109
9
Date:                Thu, Apr 21 2022   R-squared (Overall):             -0.077
0
Time:                        00:08:04   Log-likelihood                    878.7
6
Cov. Estimator:            Unadjusted
                                        F-statistic:                      11.87
9
Entities:                          54   P-value                           0.000
0
Avg Obs:                      10.0000   Distribution:                  F(5,48
1)
Min Obs:                      10.0000
Max Obs:                      10.0000   F-statistic (robust):             11.87
9
                                        P-value                           0.000
0
Time periods:                      10   Distribution:                  F(5,48
1)
Avg Obs:                      54.000
Min Obs:                      54.000
Max Obs:                      54.000

                             Parameter Estimates
==============================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
------------------------------------------------------------------------------
Intercept     -0.7423     0.1695    -4.3781     0.0000     -1.0754     -0.4092
CC             0.0849     0.0484     1.7524     0.0803     -0.0103      0.1801
DE             0.0101     0.0032     3.1429     0.0018      0.0038      0.0165
DF         -6.722e-07  6.001e-05    -0.0112     0.9911     -0.0001      0.0001
FFR           -0.0022     0.0081    -0.2688     0.7882     -0.0180      0.0137
TA             0.0136     0.0271     0.5024     0.6156     -0.0397      0.0669
==============================================================================

F-test for Poolability: 2.8116
P-value: 0.0000
Distribution: F(53,481)

Included effects: Entity
[-0.75102022 -0.75544832 -0.7694817  -0.92007384 -0.7310765  -0.7423119
```

```
-0.72793233 -0.71660087 -0.73842161 -0.7471241  -0.7196085  -0.71755112
-0.69902119 -0.72929546 -0.77850417 -0.75664868 -0.73428696 -0.74676802
-0.70457462 -0.73489494 -0.72053978 -0.7360623  -0.75119472 -0.71635121
-0.76546751 -0.73813533 -0.75354623 -0.74317909 -0.69689894 -0.72652242
-0.78695378 -0.71942456 -0.73453788 -0.73736042 -0.7041424  -0.74723873
-0.74485564 -0.69565661 -0.77202361 -0.73935229 -0.72717435 -0.73073287
-0.71866045 -0.74560486 -0.83803986 -0.76517839 -0.75365448 -0.74699964
-0.70380216 -0.71451607 -0.74568589 -0.74999114 -0.7408618  -0.75306237]
```

In [17]:
```
# F test for fixed effects versus OLS
print(fixed1.f_pooled)
```

```
Pooled F-statistic
H0: Effects are zero
Statistic: 2.8116
P-value: 0.0000
Distributed: F(53,481)
```

In [18]:
```
# Random effects estimator, constant term must be included
# should not have EntityEffects or TimeEffects in the formula
from linearmodels import RandomEffects
random = RandomEffects.from_formula('ROE ~ 1 + DE + DF + TA + CC + FFR', df).fit(
print(random)
# extract fixed effects
random.estimated_effects
random_effects = random.params.Intercept + random.estimated_effects.unstack(level
print(random_effects)
print(random.variance_decomposition)
```

```
                          RandomEffects Estimation Summary
================================================================================
=
Dep. Variable:                     ROE   R-squared:                         0.083
7
Estimator:              RandomEffects   R-squared (Between):              -0.009
0
No. Observations:                 540   R-squared (Within):                0.092
6
Date:                Thu, Apr 21 2022   R-squared (Overall):               0.071
4
Time:                        00:08:51   Log-likelihood                     846.2
1
Cov. Estimator:            Unadjusted
                                        F-statistic:                       9.755
9
Entities:                          54   P-value                            0.000
0
Avg Obs:                      10.0000   Distribution:                   F(5,53
4)
Min Obs:                      10.0000
Max Obs:                      10.0000   F-statistic (robust):              9.755
9
                                        P-value                            0.000
0
Time periods:                      10   Distribution:                   F(5,53
4)
Avg Obs:                      54.000
Min Obs:                      54.000
Max Obs:                      54.000

                             Parameter Estimates
================================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
--------------------------------------------------------------------------------
Intercept     -0.6232     0.1678    -3.7139     0.0002     -0.9529     -0.2936
CC             0.0746     0.0488     1.5295     0.1267     -0.0212      0.1703
DE             0.0003     0.0018     0.1505     0.8804     -0.0032      0.0038
DF          1.866e-05   5.93e-05     0.3146     0.7532  -9.783e-05      0.0001
FFR           -0.0019     0.0081    -0.2355     0.8139     -0.0179      0.0141
TA             0.0114     0.0273     0.4172     0.6767     -0.0423      0.0651
================================================================================
[-0.62895178 -0.62967337 -0.63722145 -0.65141869 -0.61752029 -0.62472332
 -0.61988231 -0.6158958  -0.62344079 -0.6288646  -0.61593738 -0.61426796
 -0.60856247 -0.62060387 -0.63703279 -0.62929595 -0.61837852 -0.62632259
 -0.6093808  -0.62065634 -0.61495394 -0.6181889  -0.63067895 -0.61436772
```

```
 -0.63423202 -0.62163232 -0.62976787 -0.62442547 -0.60738745 -0.61887655
 -0.62207593 -0.61455128 -0.62356593 -0.62279974 -0.6102221  -0.62442348
 -0.62646543 -0.60772057 -0.63663799 -0.62489058 -0.61555647 -0.6219407
 -0.61275883 -0.62623118 -0.66376693 -0.63537912 -0.62591989 -0.62512677
 -0.61094108 -0.60989269 -0.62347709 -0.62778243 -0.62130009 -0.62928946]
Effects                   0.000443
Residual                  0.002537
Percent due to Effects    0.148685
Name: Variance Decomposition, dtype: float64
```

In [19]:
```
# compare fixed effects and random effects models
res2 = {'Pooled':pooled,'Fixed+1':fixed1,'Fixed':fixed,'Random':random}
print(compare(res2))

effects = pd.DataFrame({'Fixed Effects':fixed_effects,'Random Effects':random_eff
                        index=pdata.index.levels[0])
print(effects)
```

```
                                Model Comparison
================================================================================
=======
                                Pooled        Fixed+1          Fixed
Random
--------------------------------------------------------------------------------
-------
Dep. Variable                      ROE            ROE            ROE
ROE
Estimator                   PooledOLS       PanelOLS       PanelOLS     Random
Effects
No. Observations                   540            540            540
540
Cov. Est.                  Unadjusted     Unadjusted     Unadjusted        Una
djusted
R-squared                      0.0771         0.1099         0.1099
0.0837
R-Squared (Within)             0.0833         0.1099         0.1099
0.0926
R-Squared (Between)            0.0537        -0.7870        -67.312
-0.0090
R-Squared (Overall)            0.0771        -0.0770        -51.198
0.0714
F-statistic                    8.9269         11.879         11.879
9.7559
P-value (F-stat)               0.0000         0.0000         0.0000
0.0000
====================     ============   ============   ============   ========
=======
Intercept                     -0.5927        -0.7423
-0.6232
                             (-3.2940)      (-4.3781)                     (-
3.7139)
CC                             0.0719         0.0849         0.0849
0.0746
                              (1.3690)       (1.7524)       (1.7524)
(1.5295)
DE                            -0.0021         0.0101         0.0101
0.0003
                             (-1.6112)       (3.1429)       (3.1429)
(0.1505)
DF                           1.683e-05     -6.722e-07     -6.722e-07         1.
866e-05
                              (0.2700)      (-0.0112)      (-0.0112)
(0.3146)
FFR                           -0.0018        -0.0022        -0.0022
-0.0019
                             (-0.2072)      (-0.2688)      (-0.2688)         (-
0.2355)
```

```
TA                             0.0108         0.0136         0.0136
0.0114
                              (0.3679)       (0.5024)       (0.5024)
(0.4172)
======================== ============== ============== ============== ==========
=======
Effects                                                     Entity         Entity
------------------------------------------------------------------------------
-------

T-stats reported in parentheses
       Fixed Effects  Random Effects
ID
ABCB       -0.751020       -0.628952
AUB        -0.755448       -0.629673
BANR       -0.769482       -0.637221
BCS        -0.920074       -0.651419
BOKF       -0.731077       -0.617520
CATY       -0.742312       -0.624723
CBU        -0.727932       -0.619882
CFR        -0.716601       -0.615896
CMA        -0.738422       -0.623441
COLB       -0.747124       -0.628865
CTBI       -0.719608       -0.615937
CVBF       -0.717551       -0.614268
EWBC       -0.699021       -0.608562
FCNCA      -0.729295       -0.620604
FHN        -0.778504       -0.637033
FNB        -0.756649       -0.629296
FNLC       -0.734287       -0.618379
FULT       -0.746768       -0.626323
GABC       -0.704575       -0.609381
GBCI       -0.734895       -0.620656
GSBC       -0.720540       -0.614954
HBNC       -0.736062       -0.618189
HFWA       -0.751195       -0.630679
HOMB       -0.716351       -0.614368
HTH        -0.765468       -0.634232
HTLF       -0.738135       -0.621632
HWC        -0.753546       -0.629768
IBAI       -0.743179       -0.624425
IKFN       -0.696899       -0.607387
INDB       -0.726522       -0.618877
MFG        -0.786954       -0.622076
NTRS       -0.719425       -0.614551
PB         -0.734538       -0.623566
PPBI       -0.737360       -0.622800
RJF        -0.704142       -0.610222
SASR       -0.747239       -0.624423
SFNC       -0.744856       -0.626465
SIVB       -0.695657       -0.607721
SNV        -0.772024       -0.636638
SSB        -0.739352       -0.624891
TCBI       -0.727174       -0.615556
THFF       -0.730733       -0.621941
TMP        -0.718660       -0.612759
UBSI       -0.745605       -0.626231
```

```
UCBI       -0.838040       -0.663767
UMPQ       -0.765178       -0.635379
VLY        -0.753654       -0.625920
WAFD       -0.747000       -0.625127
WAL        -0.703802       -0.610941
WASH       -0.714516       -0.609893
WBS        -0.745686       -0.623477
WSBC       -0.749991       -0.627782
WSFS       -0.740862       -0.621300
WTFC       -0.753062       -0.629289
```

In [20]:
```python
# LM test for random effects versus OLS
n = pdata.index.levels[0].size
T = pdata.index.levels[1].size
D = np.kron(np.eye(n), np.ones(T)).T
e = pooled.resids
LM = (e.dot(D).dot(D.T).dot(e) / e.dot(e) - 1) ** 2 * n * T / 2 / (T - 1)
LM_pvalue = stats.chi2(1).sf(LM)
print("LM Test: chisq = {0}, df = 1, p-value = {1}".format(LM, LM_pvalue))
```

```
LM Test: chisq = 38.781752018223955, df = 1, p-value = 4.739377680850834e-10
```

In [21]:
```python
# Hausman test for fixed versus random effects model
# null hypothesis: random effects model
psi = fixed.cov - random.cov.iloc[1:,1:]
diff = fixed.params - random.params[1:]
# psi = fixed1.cov.iloc[1:,1:] - random.cov.iloc[1:,1:]
# diff = fixed1.params[1:] - random.params[1:]
W = diff.dot(np.linalg.inv(psi)).dot(diff)
dof = random.params.size -1
pvalue = stats.chi2(dof).sf(W)
print("Hausman Test: chisq = {0}, df = {1}, p-value = {2}".format(W, dof, pvalue)
```

```
Hausman Test: chisq = 14.014889787657228, df = 5, p-value = 0.01551511032784552
5
```

In [24]:
```
# panel robust hetero cov
fixed_robust = PanelOLS.from_formula('ROE ~ 1 + DE + DF + TA + CC + FFR + EntityE
print(fixed_robust)
random_robust = RandomEffects.from_formula('ROE ~ 1 + DE + DF + TA + CC + FFR', d
print(random_robust)
```

```
                          PanelOLS Estimation Summary
================================================================================
=
Dep. Variable:                     ROE   R-squared:                        0.109
9
Estimator:                    PanelOLS   R-squared (Between):              -0.787
0
No. Observations:                  540   R-squared (Within):               0.109
9
Date:                 Thu, Apr 21 2022   R-squared (Overall):              -0.077
0
Time:                         00:21:47   Log-likelihood                    878.7
6
Cov. Estimator:             Clustered
                                         F-statistic:                      11.87
9
Entities:                           54   P-value                           0.000
0
Avg Obs:                       10.0000   Distribution:                   F(5,48
1)
Min Obs:                       10.0000
Max Obs:                       10.0000   F-statistic (robust):             12.01
9
                                         P-value                           0.000
0
Time periods:                       10   Distribution:                   F(5,48
1)
Avg Obs:                       54.000
Min Obs:                       54.000
Max Obs:                       54.000

                             Parameter Estimates
================================================================================
            Parameter  Std. Err.     T-stat    P-value    Lower CI    Upper CI
--------------------------------------------------------------------------------
Intercept     -0.7423     0.3341    -2.2216     0.0268     -1.3988     -0.0858
CC             0.0849     0.0250     3.4005     0.0007      0.0358      0.1340
DE             0.0101     0.0037     2.7018     0.0071      0.0028      0.0175
DF         -6.722e-07  4.252e-05    -0.0158     0.9874  -8.423e-05   8.288e-05
FFR           -0.0022     0.0039    -0.5541     0.5798     -0.0099      0.0055
TA             0.0136     0.0177     0.7713     0.4409     -0.0211      0.0483
================================================================================

F-test for Poolability: 2.8116
P-value: 0.0000
Distribution: F(53,481)

Included effects: Entity
                        RandomEffects Estimation Summary
================================================================================
```

=

Dep. Variable:	ROE	R-squared:	0.083
7			
Estimator:	RandomEffects	R-squared (Between):	-0.009
0			
No. Observations:	540	R-squared (Within):	0.092
6			
Date:	Thu, Apr 21 2022	R-squared (Overall):	0.071
4			
Time:	00:21:47	Log-likelihood	846.2
1			
Cov. Estimator:	Clustered		
		F-statistic:	9.755
9			
Entities:	54	P-value	0.000
0			
Avg Obs:	10.0000	Distribution:	F(5,53
4)			
Min Obs:	10.0000		
Max Obs:	10.0000	F-statistic (robust):	7.045
1			
		P-value	0.000
0			
Time periods:	10	Distribution:	F(5,53
4)			
Avg Obs:	54.000		
Min Obs:	54.000		
Max Obs:	54.000		

Parameter Estimates

	Parameter	Std. Err.	T-stat	P-value	Lower CI	Upper CI
Intercept	-0.6232	0.3373	-1.8476	0.0652	-1.2859	0.0394
CC	0.0746	0.0248	3.0025	0.0028	0.0258	0.1234
DE	0.0003	0.0028	0.0951	0.9243	-0.0053	0.0058
DF	1.866e-05	3.538e-05	0.5273	0.5982	-5.085e-05	8.816e-05
FFR	-0.0019	0.0039	-0.4854	0.6276	-0.0097	0.0058
TA	0.0114	0.0179	0.6357	0.5252	-0.0238	0.0466

In [25]:
```
# compare fixed effects and random effects models
res3 = {'Fixed (Panel-Robust)':fixed_robust,'Random (Panel-Robust)':random_robust
print(compare(res3))
```

```
                          Model Comparison
=========================================================================
                        Fixed (Panel-Robust) Random (Panel-Robust)
-------------------------------------------------------------------------
Dep. Variable                            ROE                       ROE
Estimator                           PanelOLS               RandomEffects
No. Observations                         540                       540
Cov. Est.                          Clustered                 Clustered
R-squared                             0.1099                    0.0837
R-Squared (Within)                    0.1099                    0.0926
R-Squared (Between)                  -0.7870                   -0.0090
R-Squared (Overall)                  -0.0770                    0.0714
F-statistic                           11.879                    9.7559
P-value (F-stat)                      0.0000                    0.0000
=====================          ============       ===============
Intercept                            -0.7423                   -0.6232
                                    (-2.2216)                 (-1.8476)
CC                                    0.0849                    0.0746
                                     (3.4005)                  (3.0025)
DE                                    0.0101                    0.0003
                                     (2.7018)                  (0.0951)
DF                                 -6.722e-07                 1.866e-05
                                    (-0.0158)                  (0.5273)
FFR                                  -0.0022                   -0.0019
                                    (-0.5541)                 (-0.4854)
TA                                    0.0136                    0.0114
                                     (0.7713)                  (0.6357)
======================       ==============     =================
Effects                                Entity
-------------------------------------------------------------------------

T-stats reported in parentheses
```

In [ ]: