

Dynamic Linkages of stock prices between the BRICs and the United States: Effects of 2008-09 Financial Crisis

In [1]:

```
#Importing Libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

In [2]:

```
import pandas_datareader.data as web
import datetime
```

In [3]:

```
start = datetime.datetime(2004,5,2)
end = datetime.datetime(2020,5,2)
```

In [10]:

```
us = web.DataReader('^DJI', 'yahoo', start, end)
brazil = web.DataReader('^BVSP', 'yahoo', start, end)
russia = pd.read_csv("RTSI-dailyhistory.csv", index_col='Date', parse_dates =True, dayfirst=True)
india = web.DataReader('^BSESN', 'yahoo', start, end)
china = web.DataReader('000001.SS', 'yahoo', start, end)
south_africa = web.DataReader('EZA', 'yahoo', start, end)
```

In [11]:

```
russia.head()
russia.index
```

Out[11]:

```
DatetimeIndex(['2004-05-05', '2004-05-06', '2004-05-07', '2004-05-11',
               '2004-05-12', '2004-05-13', '2004-05-14', '2004-05-17',
               '2004-05-18', '2004-05-19',
               ...,
               '2020-04-17', '2020-04-20', '2020-04-21', '2020-04-22',
               '2020-04-23', '2020-04-24', '2020-04-27', '2020-04-28',
               '2020-04-29', '2020-04-30'],
              dtype='datetime64[ns]', name='Date', length=4003, freq=None)
```

In [16]:

```
china.head()
```

Out[16]:

	High	Low	Open	Close	Volume	Adj Close
Date						
2004-05-03	1595.589966	1595.589966	1595.589966	1595.589966	0.0	1595.589966
2004-05-04	1595.589966	1595.589966	1595.589966	1595.589966	0.0	1595.589966
2004-05-05	1595.589966	1595.589966	1595.589966	1595.589966	0.0	1595.589966
2004-05-06	1595.589966	1595.589966	1595.589966	1595.589966	0.0	1595.589966
2004-05-07	1595.589966	1595.589966	1595.589966	1595.589966	0.0	1595.589966

In [15]:

```
south_africa.head()
```

Out[15]:

	High	Low	Open	Close	Volume	Adj Close
Date						
2004-05-03	26.174999	26.055000	26.055000	26.155001	53800.0	15.021152
2004-05-04	27.004999	26.930000	27.004999	26.930000	3000.0	15.466248
2004-05-05	27.620001	27.389999	27.495001	27.620001	5600.0	15.862519
2004-05-06	26.870001	26.555000	26.870001	26.695000	2000.0	15.331284
2004-05-07	26.500000	25.850000	26.500000	25.850000	38600.0	14.845991

In [17]:

```
us['US'] = np.log(us['Adj Close']/us['Adj Close'].shift(1))
brazil['Brazil'] = np.log(brazil['Adj Close']/brazil['Adj Close'].shift(1))
russia['Russia'] = np.log(russia['Close']/russia['Close'].shift(1))
india['India'] = np.log(india['Adj Close']/india['Adj Close'].shift(1))
china['China'] = np.log(china['Adj Close']/china['Adj Close'].shift(1))
south_africa['South Africa'] = np.log(south_africa['Adj Close']/south_africa['Adj Close'].shift(1))
```

In [18]:

```
south_africa.head()
```

Out[18]:

	High	Low	Open	Close	Volume	Adj Close	South Africa
Date							
2004-05-03	26.174999	26.055000	26.055000	26.155001	53800.0	15.021152	NaN
2004-05-04	27.004999	26.930000	27.004999	26.930000	3000.0	15.466248	0.029201
2004-05-05	27.620001	27.389999	27.495001	27.620001	5600.0	15.862519	0.025299
2004-05-06	26.870001	26.555000	26.870001	26.695000	2000.0	15.331284	-0.034064
2004-05-07	26.500000	25.850000	26.500000	25.850000	38600.0	14.845991	-0.032166

In [19]:

```
russia.head()
```

Out[19]:

	Open	Max	Min	Close	Trading Volume, USD	Market Capitalization, USD	Russia
Date							
2004-05-05	643.43	646.66	636.38	636.38	17070685.0	1.626580e+11	NaN
2004-05-06	638.77	640.03	632.77	633.05	12407763.0	1.618040e+11	-0.005246
2004-05-07	621.01	621.01	601.13	601.13	20753378.0	1.536470e+11	-0.051738
2004-05-11	581.01	581.33	573.65	576.63	29490603.0	1.473840e+11	-0.041610
2004-05-12	589.77	592.63	587.28	589.57	23738481.0	1.506910e+11	0.022193

In [20]:

```
brazil.head()
```

Out[20]:

	High	Low	Open	Close	Volume	Adj Close	Brazil
Date							
2004-05-03	19777.0	19086.0	19622.0	19709.0	0.0	19709.0	NaN
2004-05-04	20195.0	19709.0	19709.0	19988.0	0.0	19988.0	0.014057
2004-05-05	20342.0	19835.0	20013.0	20026.0	0.0	20026.0	0.001899
2004-05-06	20019.0	19189.0	20019.0	19190.0	0.0	19190.0	-0.042642
2004-05-07	19184.0	18573.0	19184.0	18620.0	0.0	18620.0	-0.030153

In [22]:

```
df = pd.concat([us['US'],brazil['Brazil'],russia['Russia'],india['India'],china['China'],south_africa['South Africa']],axis=1,join='inner')
```

In [23]:

```
df.dropna(inplace=True)
df.head()
```

Out[23]:

	US	Brazil	Russia	India	China	South Africa
Date						
2004-05-05	-0.000606	0.001899	NaN	0.006889	0.000000	0.025299
2004-05-06	-0.006782	-0.042642	-0.005246	0.012428	0.000000	-0.034064
2004-05-07	-0.012174	-0.030153	-0.051738	-0.015354	0.000000	-0.032166
2004-05-11	0.002944	0.051643	-0.041610	-0.042268	0.005015	0.027701
2004-05-12	0.002561	-0.011448	0.022193	0.006074	0.022517	0.001742

In [30]:

```
df['GFC']=-1
df['Covid']=-1
```

In [33]:

```
df.head()
```

Out[33]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
Date								
2004-05-06	-0.006782	-0.042642	-0.005246	0.012428	0.000000	-0.034064	-1	-1
2004-05-07	-0.012174	-0.030153	-0.051738	-0.015354	0.000000	-0.032166	-1	-1
2004-05-11	0.002944	0.051643	-0.041610	-0.042268	0.005015	0.027701	-1	-1
2004-05-12	0.002561	-0.011448	0.022193	0.006074	0.022517	0.001742	-1	-1
2004-05-13	-0.003432	0.004139	0.010310	0.007645	-0.003872	-0.000194	-1	-1

In [43]:

```
#Date stock market fell more than 6% in light of GFC - 29th Sep, 2008  
#Date first case of coronavirus was detected in China - 17th Nov, 2019  
  
df['GFC']['2004-05-06':'2008-09-28'] = 0  
df['GFC']['2008-09-29':'2012-05-01'] = 1  
df['Covid']['2012-05-02':'2019-11-16'] = 0  
df['Covid']['2019-11-17':'2020-05-02'] = 1  
df.tail()
```

```
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\ipykernel_launcher.py:4:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame
```

See the caveats in the documentation: <http://pandas.pydata.org/pandas-docs/stable/indexing.html#indexing-view-versus-copy>
after removing the cwd from sys.path.

```
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\ipykernel_launcher.py:5:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame
```

See the caveats in the documentation: <http://pandas.pydata.org/pandas-docs/stable/indexing.html#indexing-view-versus-copy>
"""

```
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\ipykernel_launcher.py:6:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame
```

See the caveats in the documentation: <http://pandas.pydata.org/pandas-docs/stable/indexing.html#indexing-view-versus-copy>

```
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\ipykernel_launcher.py:7:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame
```

See the caveats in the documentation: <http://pandas.pydata.org/pandas-docs/stable/indexing.html#indexing-view-versus-copy>
import sys

Out[43]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
Date								
2020-04-24	0.010996	-0.056039	-0.016828	-0.016961	-0.010615	0.020565	-1	1
2020-04-27	0.014967	0.037877	0.002180	0.013187	0.002477	0.034208	-1	1
2020-04-28	-0.001336	0.038525	0.023637	0.011633	-0.001945	-0.006365	-1	1
2020-04-29	0.021846	0.022605	0.031091	0.018683	0.004409	0.052554	-1	1
2020-04-30	-0.011766	-0.032567	-0.017280	0.030029	0.013248	-0.052234	-1	1

In [44]:

df.info()

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 3340 entries, 2004-05-06 to 2020-04-30
Data columns (total 8 columns):
US                3340 non-null float64
Brazil            3340 non-null float64
Russia            3340 non-null float64
India             3340 non-null float64
China             3340 non-null float64
South Africa      3340 non-null float64
GFC               3340 non-null int64
Covid            3340 non-null int64
dtypes: float64(6), int64(2)
memory usage: 394.8 KB
```

In [45]:

```
df_pre_gfc = df[df['GFC']==0]
df_pre_gfc.tail()
```

Out[45]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
Date								
2008-09-22	-0.033278	-0.028952	0.010432	-0.003378	0.074867	0.001177	0	-1
2008-09-23	-0.014771	-0.038528	-0.028953	-0.030813	-0.015728	-0.071292	0	-1
2008-09-24	-0.002675	0.005028	0.033471	0.008965	0.006926	0.003992	0	-1
2008-09-25	0.018025	0.039052	-0.007968	-0.010671	0.035752	0.030156	0	-1
2008-09-26	0.010924	-0.020369	-0.015071	-0.033400	-0.001619	-0.006123	0	-1

In [46]:

```
df_post_gfc = df[df['GFC']==1]
df_post_gfc.head()
```

Out[46]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
Date								
2008-10-06	-0.036480	-0.055800	-0.211994	-0.059588	-0.053755	-0.073206	1	-1
2008-10-07	-0.052416	-0.047698	-0.009545	-0.009062	-0.007341	-0.071221	1	-1
2008-10-08	-0.020210	-0.039277	-0.119330	-0.031873	-0.030880	0.037444	1	-1
2008-10-13	0.105083	0.136766	-0.065490	0.071583	0.035838	0.123339	1	-1
2008-10-14	-0.008195	0.017962	0.094379	0.015296	-0.027500	-0.028285	1	-1

In [47]:

```
df_pre_covid = df[df['Covid']==0]
df_pre_covid.tail()
```

Out[47]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
Date								
2019-11-07	0.006607	0.011426	0.010580	0.004535	0.000037	0.004052	-1	0
2019-11-08	0.000233	-0.017974	-0.012764	-0.008154	-0.004890	-0.015916	-1	0
2019-11-11	0.000370	0.005430	-0.005005	0.000532	-0.018458	-0.004707	-1	0
2019-11-13	0.003320	-0.008190	-0.007966	-0.005693	-0.003292	-0.000593	-1	0
2019-11-14	-0.000059	0.006053	-0.000605	0.004239	0.001592	0.006507	-1	0

In [48]:

```
df_post_covid = df[df['Covid']==1]
df_post_covid.head()
```

Out[48]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
Date								
2019-11-18	0.001118	-0.001973	-0.004425	-0.001798	0.006158	-0.000586	-1	1
2019-11-19	-0.003652	-0.006879	0.005956	0.004594	0.008485	0.006817	-1	1
2019-11-21	-0.001972	0.017634	0.004368	-0.001883	-0.002549	-0.001928	-1	1
2019-11-22	0.003930	0.011055	0.000467	-0.005332	-0.006340	-0.007749	-1	1
2019-11-25	0.006823	-0.002469	-0.000543	0.013042	0.007211	-0.006243	-1	1

In [49]:

```
#Saving the table
df.to_csv('Final return table.csv')
```

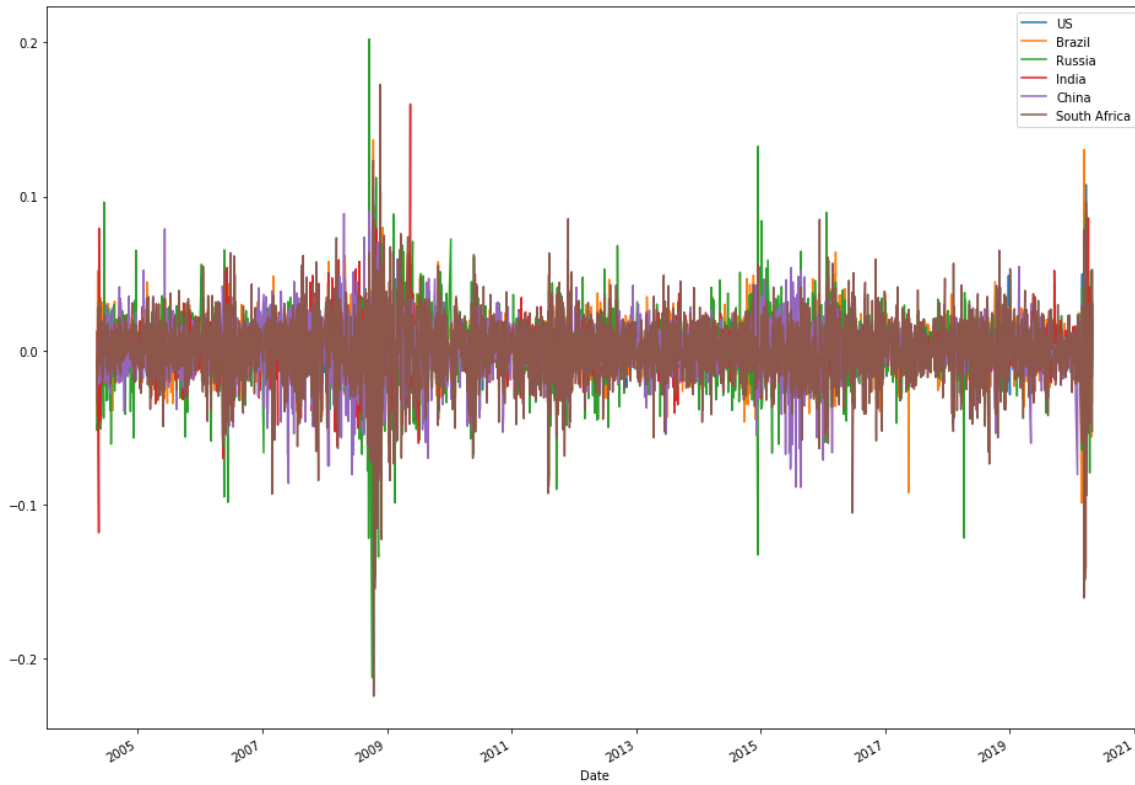
GRAPH VISUALIZATION

In [53]:

```
df.iloc[:,0:6].plot(figsize=(16,12))
```

Out[53]:

<matplotlib.axes._subplots.AxesSubplot at 0x209cd9ba908>

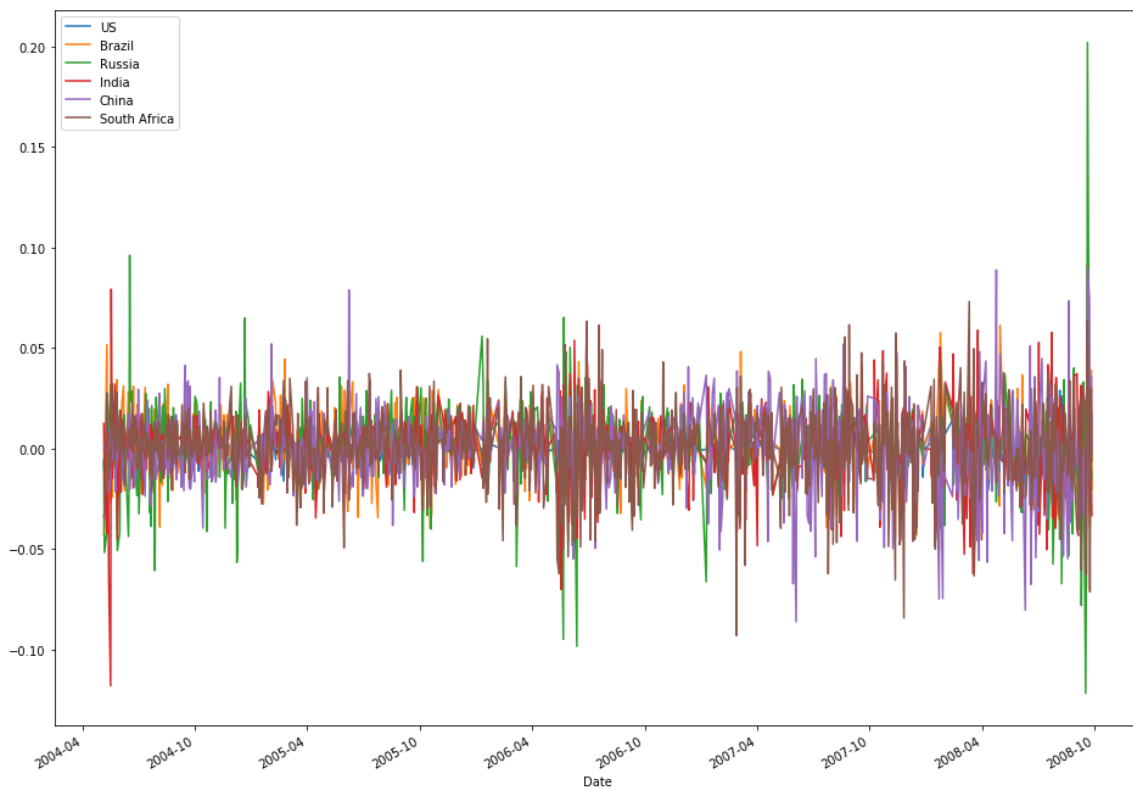


In [54]:

```
df_pre_gfc.iloc[:,0:6].plot(figsize=(16,12))
```

Out[54]:

<matplotlib.axes._subplots.AxesSubplot at 0x209cc3387b8>

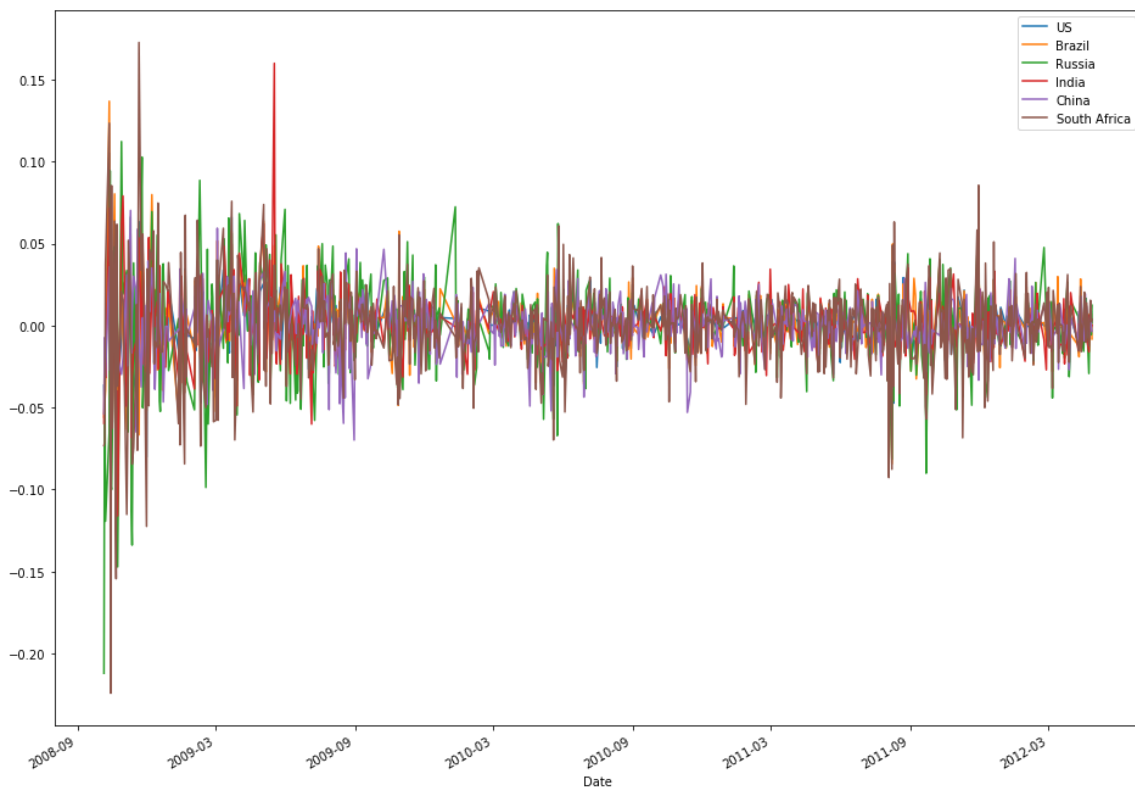


In [55]:

```
df_post_gfc.iloc[:,0:6].plot(figsize=(16,12))
```

Out[55]:

<matplotlib.axes._subplots.AxesSubplot at 0x209cc233240>

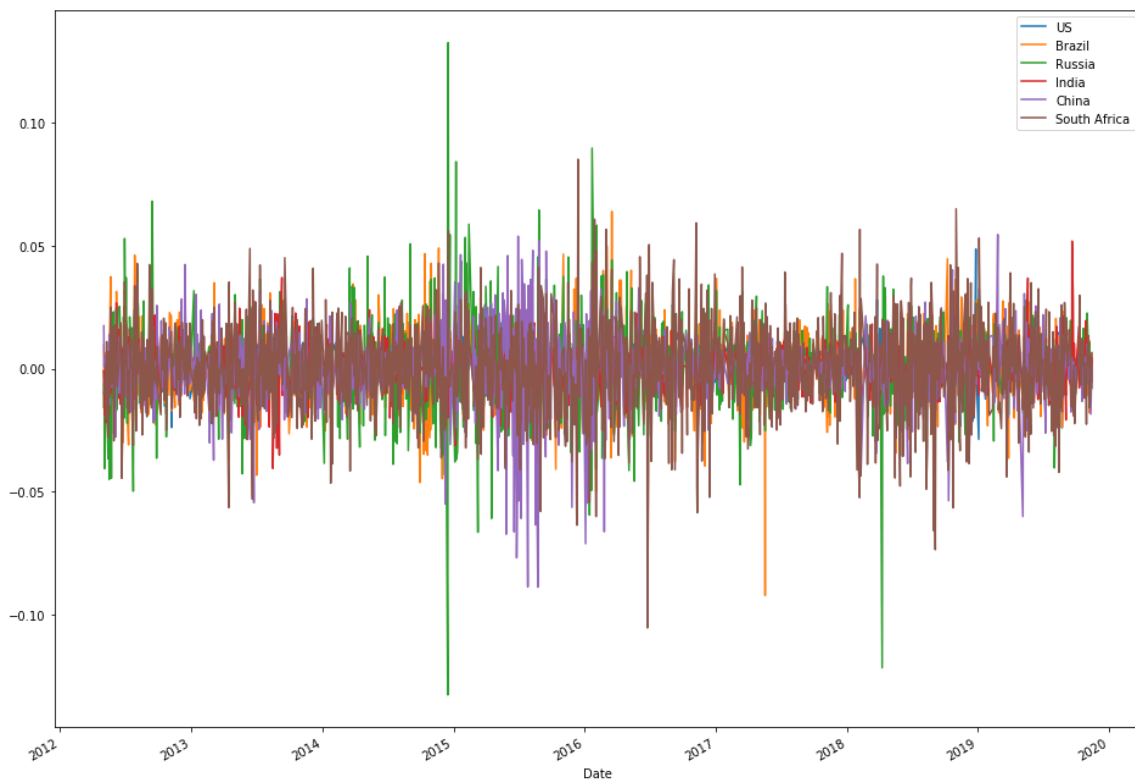


In [56]:

```
df_pre_covid.iloc[:,0:6].plot(figsize=(16,12))
```

Out[56]:

<matplotlib.axes._subplots.AxesSubplot at 0x209cdaa9a20>

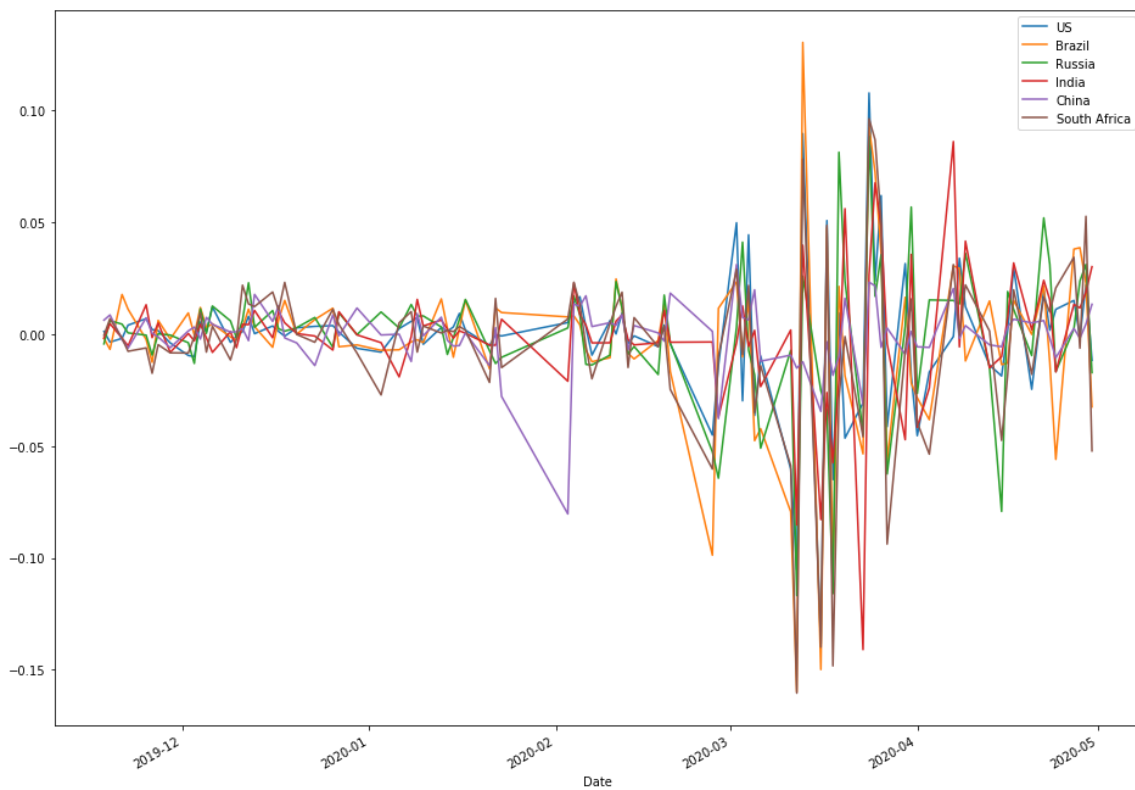


In [57]:

```
df_post_covid.iloc[:,0:6].plot(figsize=(16,12))
```

Out[57]:

<matplotlib.axes._subplots.AxesSubplot at 0x209cd52f860>



Summmary Statistics

In [58]:

df.describe()

Out[58]:

	US	Brazil	Russia	India	China	Sout Afric
count	3340.000000	3340.000000	3340.000000	3340.000000	3340.000000	3340.000000
mean	0.000197	0.000292	0.000090	0.000441	-0.000035	0.000154
std	0.011584	0.017519	0.020967	0.014520	0.015974	0.022097
min	-0.138418	-0.159930	-0.211994	-0.141017	-0.092561	-0.224168
25%	-0.003912	-0.008562	-0.009059	-0.005872	-0.006843	-0.010606
50%	0.000544	0.000611	0.000997	0.000725	0.000456	0.001151
75%	0.005133	0.009865	0.010305	0.007244	0.007503	0.012568
max	0.107643	0.136766	0.202039	0.159900	0.090345	0.172598

In [59]:

df_pre_gfc.describe()

Out[59]:

	US	Brazil	Russia	India	China	South Africa	GFC
count	940.000000	940.000000	940.000000	940.000000	940.000000	940.000000	940.000000
mean	0.000129	0.001108	0.000694	0.000838	0.000194	0.000854	0.0
std	0.008904	0.017252	0.019597	0.016681	0.019141	0.019890	0.0
min	-0.041481	-0.069822	-0.121775	-0.118092	-0.092561	-0.093061	0.0
25%	-0.004211	-0.008678	-0.007138	-0.006498	-0.008549	-0.009289	0.0
50%	0.000433	0.001498	0.002329	0.001635	0.000427	0.002144	0.0
75%	0.004769	0.011967	0.010717	0.010094	0.010001	0.012836	0.0
max	0.037919	0.091354	0.202039	0.079311	0.090345	0.073183	0.0

In [60]:

```
df_post_gfc.describe()
```

Out[60]:

	US	Brazil	Russia	India	China	South Africa	GFC
count	731.000000	731.000000	731.000000	731.000000	731.000000	731.000000	731.000000
mean	-0.000179	-0.000421	-0.000602	0.000082	-0.000210	-0.000347	1.0
std	0.015681	0.019917	0.027815	0.018333	0.016343	0.028755	0.0
min	-0.082005	-0.120961	-0.211994	-0.116044	-0.069829	-0.224168	1.0
25%	-0.006451	-0.009412	-0.011693	-0.009213	-0.008461	-0.013521	1.0
50%	0.000498	0.000300	0.000724	-0.000118	0.000553	0.001631	1.0
75%	0.006485	0.009220	0.012937	0.008795	0.009101	0.014186	1.0
max	0.105083	0.136766	0.112216	0.159900	0.070194	0.172598	1.0

In [61]:

```
df_pre_covid.describe()
```

Out[61]:

	US	Brazil	Russia	India	China	South Africa
count	1578.000000	1578.000000	1578.000000	1578.000000	1578.000000	1578.000000
mean	0.000485	0.000344	0.000082	0.000423	-0.000065	0.000220
std	0.008166	0.014101	0.016976	0.008801	0.013659	0.018040
min	-0.047143	-0.092107	-0.132545	-0.061197	-0.088732	-0.105320
25%	-0.002937	-0.008113	-0.008847	-0.004398	-0.005527	-0.010524
50%	0.000583	0.000268	0.000366	0.000564	0.000383	0.000525
75%	0.004637	0.008801	0.008973	0.005480	0.005955	0.011244
max	0.048643	0.063887	0.132462	0.051859	0.054495	0.085134

In [62]:

```
df_post_covid.describe()
```

Out[62]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
count	91.000000	91.000000	91.000000	91.000000	91.000000	91.000000	91.0	91.0
mean	-0.001071	-0.003309	-0.000477	-0.000478	-0.000463	-0.004217	-1.0	1.0
std	0.031373	0.039442	0.031137	0.028848	0.014430	0.039400	0.0	0.0
min	-0.138418	-0.159930	-0.116844	-0.141017	-0.080392	-0.160438	-1.0	1.0
25%	-0.007275	-0.011602	-0.009450	-0.005194	-0.005565	-0.012895	-1.0	1.0
50%	0.001107	-0.000215	0.002662	0.000183	0.000846	-0.000206	-1.0	1.0
75%	0.007082	0.012566	0.012801	0.009284	0.006406	0.012789	-1.0	1.0
max	0.107643	0.130223	0.088251	0.085947	0.030980	0.096127	-1.0	1.0

In [63]:

```
from statsmodels.stats.stattools import jarque_bera
```

In [64]:

```
name = ['JB Stat', 'p-value', 'Skewness', 'Kurtosis']
zipped = zip(name, jarque_bera(df_pre_gfc))
list(zipped)
```

Out[64]:

```
[('JB Stat', array([ 265.54587052,   75.4625735 , 9444.6673257 ,  909.1341
9156,
                485.34776721,  151.55197055,  352.5          ,  352.5          ])),
 ('p-value',
  array([2.17493795e-058, 4.10686445e-017, 0.00000000e+000, 3.83723723e-19
8,
        4.05575254e-106, 1.23284289e-033, 2.85494381e-077, 2.85494381e-07
7])),
 ('Skewness',
  array([-0.19817139, -0.05119987,  0.29569101, -0.64652692, -0.27256285,
        -0.45220303,  0.          ,  0.          ])),
 ('Kurtosis',
  array([ 5.57348149,  4.38427537, 18.51743244,  7.64111501,  6.47774293,
        4.74684335,  0.          ,  0.          ]))]
```

In [65]:

```
zipped = zip(name,jarque_bera(df_post_gfc))
list(zipped)
```

Out[65]:

```
[('JB Stat', array([1177.7123655 , 1863.89799075, 1982.87132243, 3824.8440
4103,
          152.2056029 , 2534.29562465, 274.125      , 274.125      ])),
 ('p-value',
  array([1.83235323e-256, 0.00000000e+000, 0.00000000e+000, 0.00000000e+00
0,
          8.89146397e-034, 0.00000000e+000, 2.98203389e-060, 2.98203389e-06
0])),
 ('Skewness',
  array([-0.17601214, -0.13569981, -1.0964229 , 0.6876404 , -0.31077619,
        -0.86922398, 0.          , 0.          ])),
 ('Kurtosis',
  array([ 9.20825434, 10.81801455, 10.76482696, 14.12137031,  5.14728829,
        11.95450317, 0.          , 0.          ]))]
```

In [66]:

```
name = ['JB Stat', 'p-value', 'Skewness', 'Kurtosis']
zipped = zip(name,jarque_bera(df_pre_covid))
list(zipped)
```

Out[66]:

```
[('JB Stat', array([1030.28408724, 217.550095 , 4710.30687815, 683.4088
5137,
          3469.42275091, 206.42013178, 591.75      , 591.75      ])),
 ('p-value',
  array([1.89083250e-224, 5.74906345e-048, 0.00000000e+000, 3.97789654e-14
9,
          0.00000000e+000, 1.50119776e-045, 3.18507869e-129, 3.18507869e-12
9])),
 ('Skewness',
  array([-0.48153946, -0.06170704, -0.16717328, -0.15961999, -0.98819757,
        -0.20718553, 0.          , 0.          ])),
 ('Kurtosis',
  array([ 6.83955713,  4.81480458, 11.45741454,  6.20813603,  9.99004637,
        4.72272061, 0.          , 0.          ]))]
```

In [67]:

```
zipped = zip(name, jarque_bera(df_post_covid))
list(zipped)
```

Out[67]:

```
[('JB Stat', array([138.17743419, 125.05713028, 76.02743375, 210.0203096
9,
412.42920455, 126.06450492, 34.125, 34.125])),
('p-value',
array([9.88897783e-31, 6.98536651e-28, 3.09636768e-17, 2.48124247e-46,
2.76780917e-90, 4.22124515e-28, 3.88911157e-08, 3.88911157e-0
8])),
('Skewness',
array([-0.66908439, -1.07284961, -0.97980484, -1.32628241, -2.09895504,
-1.40867534, 0., 0.])),
('Kurtosis',
array([ 8.88656985, 8.32710758, 7.02630367, 9.95369482, 12.54725554,
8.03093597, 0., 0.]])]
```

In [68]:

```
df_pre_gfc.corr()
```

Out[68]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
US	1.000000	0.604403	0.144531	0.108746	-0.009945	0.625063	NaN	NaN
Brazil	0.604403	1.000000	0.305007	0.155029	0.117031	0.645289	NaN	NaN
Russia	0.144531	0.305007	1.000000	0.319960	0.139101	0.333216	NaN	NaN
India	0.108746	0.155029	0.319960	1.000000	0.184508	0.153713	NaN	NaN
China	-0.009945	0.117031	0.139101	0.184508	1.000000	0.079443	NaN	NaN
South Africa	0.625063	0.645289	0.333216	0.153713	0.079443	1.000000	NaN	NaN
GFC	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Covid	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

In [69]:

```
df_post_gfc.corr()
```

Out[69]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
US	1.000000	0.750021	0.399262	0.379626	0.099985	0.861042	NaN	NaN
Brazil	0.750021	1.000000	0.452522	0.438156	0.229171	0.705064	NaN	NaN
Russia	0.399262	0.452522	1.000000	0.494221	0.258002	0.404968	NaN	NaN
India	0.379626	0.438156	0.494221	1.000000	0.284027	0.376577	NaN	NaN
China	0.099985	0.229171	0.258002	0.284027	1.000000	0.114125	NaN	NaN
South Africa	0.861042	0.705064	0.404968	0.376577	0.114125	1.000000	NaN	NaN
GFC	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Covid	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

In [70]:

```
df_pre_covid.corr()
```

Out[70]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
US	1.000000	0.416229	0.359661	0.227253	0.140342	0.588074	NaN	NaN
Brazil	0.416229	1.000000	0.383050	0.187228	0.102757	0.496157	NaN	NaN
Russia	0.359661	0.383050	1.000000	0.292835	0.155129	0.390132	NaN	NaN
India	0.227253	0.187228	0.292835	1.000000	0.205029	0.221704	NaN	NaN
China	0.140342	0.102757	0.155129	0.205029	1.000000	0.145056	NaN	NaN
South Africa	0.588074	0.496157	0.390132	0.221704	0.145056	1.000000	NaN	NaN
GFC	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Covid	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

In [71]:

```
df_post_covid.corr()
```

Out[71]:

	US	Brazil	Russia	India	China	South Africa	GFC	Covid
US	1.000000	0.871392	0.563296	0.471670	0.276527	0.855032	NaN	NaN
Brazil	0.871392	1.000000	0.620635	0.560498	0.257706	0.876686	NaN	NaN
Russia	0.563296	0.620635	1.000000	0.580510	0.300432	0.672528	NaN	NaN
India	0.471670	0.560498	0.580510	1.000000	0.540417	0.622741	NaN	NaN
China	0.276527	0.257706	0.300432	0.540417	1.000000	0.334046	NaN	NaN
South Africa	0.855032	0.876686	0.672528	0.622741	0.334046	1.000000	NaN	NaN
GFC	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
Covid	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Testing Stationarity

In [74]:

```
from statsmodels.tsa.stattools import adfuller
```

In [76]:

```
result = adfuller(us['Adj Close'])
result
```

Out[76]:

```
(-0.4695691892896162,
 0.8978193168638735,
 31,
 3996,
 {'1%': -3.4319875139327345,
  '5%': -2.862263564080849,
  '10%': -2.567155160899137},
 52781.22488977309)
```

In [77]:

```
result = adfuller(brazil['Adj Close'])  
result
```

Out[77]:

```
(-2.078374020941076,  
 0.25329895058875745,  
 19,  
 3935,  
 {'1%': -3.4320129151078773,  
  '5%': -2.8622747848972327,  
  '10%': -2.5671611343964584},  
 65539.97421369138)
```

In [78]:

```
result = adfuller(russia['Close'])  
result
```

Out[78]:

```
(-2.3421484071264143,  
 0.15873424753747573,  
 1,  
 4001,  
 {'1%': -3.4319854662367453,  
  '5%': -2.862262659519293,  
  '10%': -2.567154679348783},  
 36682.39062375232)
```

In [79]:

```
result = adfuller(india['Adj Close'])  
result
```

Out[79]:

```
(-1.2664757203955734,  
 0.6443668042677114,  
 15,  
 3911,  
 {'1%': -3.4320231263589913,  
  '5%': -2.862279295629063,  
  '10%': -2.567163535727597},  
 54682.35270960886)
```

In [80]:

```
result = adfuller(china['Adj Close'])  
result
```

Out[80]:

```
(-2.290975414976637,  
 0.17489510162259542,  
 19,  
 3896,  
 {'1%': -3.4320295723189704,  
  '5%': -2.8622821430681555,  
  '10%': -2.5671650515903215},  
 41287.16537257767)
```

In [81]:

```
result = adfuller(south_africa['Adj Close'])  
result
```

Out[81]:

```
(-2.7156346733005328,  
 0.07137164294628105,  
 9,  
 4018,  
 {'1%': -3.431978542215164,  
  '5%': -2.8622596008557037,  
  '10%': -2.5671530510462994},  
 9938.5898234622)
```

In [83]:

```
result = adfuller(us['US'].dropna())  
result
```

Out[83]:

```
(-15.383511872432049,  
 3.3828837077296803e-28,  
 17,  
 4009,  
 {'1%': -3.431982200554095,  
  '5%': -2.8622612169156896,  
  '10%': -2.5671539113677935},  
 -24301.062868097193)
```


In [84]:

```
result = adfuller(brazil['Brazil'].dropna())  
result
```

Out[84]:

```
(-13.142229969329398,  
 1.421649779245906e-24,  
 19,  
 3934,  
 {'1%': -3.432013338087558,  
  '5%': -2.8622749717451534,  
  '10%': -2.5671612338666803},  
 -20504.288342051077)
```

In [85]:

```
result = adfuller(russia['Russia'].dropna())  
result
```

Out[85]:

```
(-9.714362430069395,  
 9.920588862560345e-17,  
 30,  
 3971,  
 {'1%': -3.4319978298121763,  
  '5%': -2.862268121070097,  
  '10%': -2.5671575868492806},  
 -19506.247941741443)
```

In [87]:

```
result = adfuller(india['India'].dropna())  
result
```

Out[87]:

```
(-13.403705186191274,  
 4.513649974274689e-25,  
 16,  
 3909,  
 {'1%': -3.4320239829601653,  
  '5%': -2.8622796740245176,  
  '10%': -2.5671637371701475},  
 -22078.73365897837)
```

In [88]:

```
result = adfuller(china['China'].dropna())  
result
```

Out[88]:

```
(-14.395196706830513,  
 8.691069092439562e-27,  
 14,  
 3900,  
 {'1%': -3.4320278485448674,  
  '5%': -2.8622813816085912,  
  '10%': -2.5671646462195925},  
 -21088.050131566502)
```

In [90]:

```
result = adfuller(south_africa['South Africa'].dropna())  
result
```

Out[90]:

```
(-14.391119572993276,  
 8.821290015218144e-27,  
 19,  
 4007,  
 {'1%': -3.4319830157514812,  
  '5%': -2.86226157702636,  
  '10%': -2.56715410307542},  
 -19014.554085282543)
```

It is revealed that the null hypothesis of unit root is rejected for all the time series in returns format whilst unit root hypothesis fails to get rejected for the stock price data itself.

COINTEGRATION

In [91]:

```
from statsmodels.tsa.vector_ar.vecm import coint_johansen
```

In [108]:

```
result = coint_johansen(pd.concat([us['Adj Close'], brazil['Adj Close']], axis=1, join=  
'inner'), -1, 4)  
result.lr1
```

Out[108]:

```
array([4.68487136, 1.06450846])
```

In [109]:

```
result.cvt
```

Out[109]:

```
array([[10.4741, 12.3212, 16.364 ],  
       [ 2.9762,  4.1296,  6.9406]])
```

US and Brazil are not cointegrated

In [110]:

```
result = coint_johansen(pd.concat([us['Adj Close'],russia['Close']], axis=1, join='inner'), -1, 4)
result.lr1
```

Out[110]:

```
array([2.4205302 , 0.64551053])
```

In [111]:

```
result.cvt
```

Out[111]:

```
array([[10.4741, 12.3212, 16.364 ],
       [ 2.9762,  4.1296,  6.9406]])
```

US and Russia are not cointegrated

In [112]:

```
result = coint_johansen(pd.concat([us['Adj Close'],india['Adj Close']], axis=1, join='inner'), -1, 4)
result.lr1
```

Out[112]:

```
array([9.40955776, 1.24320138])
```

In [113]:

```
result.cvt
```

Out[113]:

```
array([[10.4741, 12.3212, 16.364 ],
       [ 2.9762,  4.1296,  6.9406]])
```

US and India are weakly cointegrated

In [114]:

```
result = coint_johansen(pd.concat([us['Adj Close'],china['Adj Close']], axis=1, join='inner'), -1, 4)
result.lr1
```

Out[114]:

```
array([3.59128703, 1.11201678])
```

In [115]:

```
result.cvt
```

Out[115]:

```
array([[10.4741, 12.3212, 16.364 ],
       [ 2.9762,  4.1296,  6.9406]])
```

US and China are not cointegrated

In [116]:

```
result = coint_johansen(pd.concat([us['Adj Close'],south_africa['Adj Close']], axis=1,
join='inner'), -1, 4)
result.lr1
```

Out[116]:

```
array([4.0785211 , 0.02658894])
```

In [117]:

```
result.cvt
```

Out[117]:

```
array([[10.4741, 12.3212, 16.364 ],
       [ 2.9762,  4.1296,  6.9406]])
```

US and South Africa are not cointegrated

In [118]:

```
result = coint_johansen(pd.concat([india['Adj Close'],china['Adj Close']], axis=1, join
='inner'), -1, 4)
result.lr1
```

Out[118]:

```
array([4.01300735, 0.4938463 ])
```

In [119]:

```
result.cvt
```

Out[119]:

```
array([[10.4741, 12.3212, 16.364 ],
       [ 2.9762,  4.1296,  6.9406]])
```

India and China are not cointegrated

All nations stock prices are not cointegrated with each other as per the above results except for US and India which is weakly cointegrated

Finding out causality between the stock prices

In [120]:

```
data = pd.concat([us['Adj Close'], brazil['Adj Close'], russia['Close'], india['Adj Close'],
                  china['Adj Close'], south_africa['Adj Close']],
                  axis =1 , join = 'inner')
```

In [124]:

```
data.columns = df.columns[0:-2]
data.head()
```

Out[124]:

	US	Brazil	Russia	India	China	South Africa
Date						
2004-05-05	10310.950195	20026.0	636.38	5686.189941	1595.589966	15.862519
2004-05-06	10241.259766	19190.0	633.05	5757.299805	1595.589966	15.331284
2004-05-07	10117.339844	18620.0	601.13	5669.580078	1595.589966	14.845991
2004-05-11	10019.469727	18537.0	576.63	5325.899902	1568.058960	14.820147
2004-05-12	10045.160156	18326.0	589.57	5358.350098	1603.767944	14.845991

In [134]:

```
data_pre_gfc = data['2004-05-06':'2008-09-28']
data_post_gfc= data['2008-09-29':'2012-05-01']
data_pre_covid = data['2012-05-02':'2019-11-16']
data_post_covid = data['2019-11-17':'2020-05-02']
```

In [125]:

```
#VECM Model
from statsmodels.tsa.vector_ar.vecm import VECM
```

PRE GFC

In [136]:

```
model = VECM(endog=data_pre_gfc.iloc[:,[0,1]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[136]:

Det. terms outside the coint. relation & lagged endog.

parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	-33.4299	51.781	-0.646	0.519	-134.919	68.059
L1.US	-0.0609	0.043	-1.422	0.155	-0.145	0.023
L1.Brazil	-0.0130	0.006	-2.246	0.025	-0.024	-0.002

Det. terms outside the coint. relation & lagged endog. parameters for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
const	-1034.4789	384.524	-2.690	0.007	-1788.131	-280.827
L1.US	0.3285	0.318	1.032	0.302	-0.295	0.952
L1.Brazil	-0.0488	0.043	-1.135	0.256	-0.133	0.035

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0041	0.006	0.678	0.498	-0.008	0.016

Loading coefficients (alpha) for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.1239	0.044	2.790	0.005	0.037	0.211

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-0.0715	0.013	-5.552	0.000	-0.097	-0.046

Short run causality from Brazil to US Long run causality from US to Brazil

In [137]:

```
model = VECM(endog=data_pre_gfc.iloc[:,[0,2]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[137]:

Det. terms outside the coint. relation & lagged endog.

parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	15.7915	56.648	0.279	0.780	-95.237	126.820
L1.US	-0.0966	0.033	-2.894	0.004	-0.162	-0.031
L1.Russia	-0.3848	0.125	-3.067	0.002	-0.631	-0.139

Det. terms outside the coint. relation & lagged endog.

parameters for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
const	-46.2790	14.544	-3.182	0.001	-74.785	-17.773
L1.US	0.0650	0.009	7.584	0.000	0.048	0.082
L1.Russia	0.0079	0.032	0.246	0.806	-0.055	0.071

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0016	0.006	-0.254	0.800	-0.014	0.011

Loading coefficients (alpha) for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0053	0.002	3.234	0.001	0.002	0.008

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-1.8792	0.277	-6.787	0.000	-2.422	-1.337

Short run bidirectional causality Long run causality from US to Russia

In [138]:

```
model = VECM(endog=data_pre_gfc.iloc[:,[0,3]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.
' ignored when e.g. forecasting.', ValueWarning)

Out[138]:

Det. terms outside the coint. relation & lagged endog.
parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	-15.7929	61.350	-0.257	0.797	-136.037	104.451
L1.US	-0.1070	0.033	-3.209	0.001	-0.172	-0.042
L1.India	-0.0391	0.015	-2.560	0.010	-0.069	-0.009

Det. terms outside the coint. relation & lagged endog. parameters
for equation India

	coef	std err	z	P> z	[0.025	0.975]
const	-473.7870	124.955	-3.792	0.000	-718.695	-228.879
L1.US	0.7039	0.068	10.366	0.000	0.571	0.837
L1.India	-0.0887	0.031	-2.851	0.004	-0.150	-0.028

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0020	0.007	0.282	0.778	-0.012	0.016

Loading coefficients (alpha) for equation India

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0561	0.015	3.862	0.000	0.028	0.084

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-0.2618	0.030	-8.607	0.000	-0.321	-0.202

Short run bidirectional causality Long run causality from US to India

In [139]:

```
model = VECM(endog=data_pre_gfc.iloc[:,[0,4]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[139]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	59.5924	71.583	0.832	0.405	-80.708	199.893
L1.US	-0.1161	0.033	-3.522	0.000	-0.181	-0.051
L1.China	0.0050	0.054	0.093	0.926	-0.100	0.110

Det. terms outside the coint. relation & lagged endog. parameters for equation China

	coef	std err	z	P> z	[0.025	0.975]
const	-223.3422	42.058	-5.310	0.000	-305.774	-140.911
L1.US	0.1125	0.019	5.808	0.000	0.075	0.150
L1.China	-0.0181	0.032	-0.572	0.567	-0.080	0.044

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0060	0.007	-0.817	0.414	-0.021	0.008

Loading coefficients (alpha) for equation China

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0231	0.004	5.332	0.000	0.015	0.032

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-0.7835	0.066	-11.815	0.000	-0.914	-0.654

Short run causality from US to China Long run causality from US to China

In [140]:

```
model = VECM(endog=data_pre_gfc.iloc[:,[0,5]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.
' ignored when e.g. forecasting.', ValueWarning)

Out[140]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	-7.3001	45.552	-0.160	0.873	-96.580	81.979
L1.US	-0.0337	0.043	-0.783	0.433	-0.118	0.051
L1.South Africa	-21.0540	6.767	-3.111	0.002	-34.317	-7.791

Det. terms outside the coint. relation & lagged endog. parameters for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
const	-0.6829	0.288	-2.368	0.018	-1.248	-0.118
L1.US	0.0001	0.000	0.375	0.707	-0.000	0.001
L1.South Africa	-0.1521	0.043	-3.550	0.000	-0.236	-0.068

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0013	0.007	0.193	0.847	-0.012	0.014

Loading coefficients (alpha) for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0001	4.25e-05	2.445	0.014	2.06e-05	0.000

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-159.6976	22.064	-7.238	0.000	-202.943	-116.452

Short run causality from South Africa to US Long run causality from US to South Africa

POST GFC

In [141]:

```
model = VECM(endog=data_post_gfc.iloc[:,[0,1]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[141]:

Det. terms outside the coint. relation & lagged endog.
parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	-4.6504	36.129	-0.129	0.898	-75.462	66.161
L1.US	-0.1404	0.053	-2.646	0.008	-0.244	-0.036
L1.Brazil	-0.0019	0.008	-0.235	0.814	-0.017	0.014

Det. terms outside the coint. relation & lagged endog. parameters
for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
const	567.8479	245.441	2.314	0.021	86.792	1048.904
L1.US	0.1290	0.361	0.358	0.721	-0.578	0.836
L1.Brazil	-0.0365	0.054	-0.682	0.495	-0.142	0.068

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0002	0.001	0.294	0.768	-0.001	0.002

Loading coefficients (alpha) for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0111	0.005	-2.217	0.027	-0.021	-0.001

Cointegration relations for loading-coefficients-column
1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	0.6368	0.210	3.038	0.002	0.226	1.048

No Short run causality

Long run causality from US to Brazil

In [142]:

```
model = VECM(endog=data_post_gfc.iloc[:,[0,2]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[142]:

Det. terms outside the coint. relation & lagged endog.

parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	7.9603	10.024	0.794	0.427	-11.686	27.607
L1.US	-0.1361	0.042	-3.217	0.001	-0.219	-0.053
L1.Russia	-0.1139	0.201	-0.566	0.571	-0.508	0.280

Det. terms outside the coint. relation & lagged endog.

parameters for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
const	-1.9358	2.095	-0.924	0.355	-6.042	2.170
L1.US	0.0458	0.009	5.181	0.000	0.028	0.063
L1.Russia	-0.0014	0.042	-0.033	0.974	-0.084	0.081

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0011	0.004	-0.247	0.805	-0.010	0.007

Loading coefficients (alpha) for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0014	0.001	1.577	0.115	-0.000	0.003

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-6.2251	1.520	-4.094	0.000	-9.205	-3.245

Short run causality from US to Russia

No Long run causality

In [143]:

```
model = VECM(endog=data_post_gfc.iloc[:,[0,3]],k_ar_diff = 1, coint_rank=1, determinist
ic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[143]:

Det. terms outside the coint. relation & lagged endog.
parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	-12.3748	26.059	-0.475	0.635	-63.450	38.700
L1.US	-0.1526	0.038	-4.011	0.000	-0.227	-0.078
L1.India	0.0062	0.022	0.278	0.781	-0.038	0.050

Det. terms outside the coint. relation & lagged endog.
parameters for equation India

	coef	std err	z	P> z	[0.025	0.975]
const	81.2543	43.626	1.863	0.063	-4.251	166.759
L1.US	0.4245	0.064	6.666	0.000	0.300	0.549
L1.India	-0.0403	0.038	-1.073	0.283	-0.114	0.033

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0006	0.001	-0.715	0.475	-0.002	0.001

Loading coefficients (alpha) for equation India

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0023	0.001	1.769	0.077	-0.000	0.005

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-2.6904	1.023	-2.631	0.009	-4.695	-0.686

Short run causality from US to India

Long run causality from US to India

In [144]:

```
model = VECM(endog=data_post_gfc.iloc[:,[0,4]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[144]:

Det. terms outside the coint. relation & lagged endog.

parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	-16.7960	51.186	-0.328	0.743	-117.118	83.526
L1.US	-0.1541	0.037	-4.219	0.000	-0.226	-0.083
L1.China	0.1623	0.122	1.325	0.185	-0.078	0.402

Det. terms outside the coint. relation & lagged endog.

parameters for equation China

	coef	std err	z	P> z	[0.025	0.975]
const	40.8474	15.133	2.699	0.007	11.187	70.507
L1.US	0.0639	0.011	5.920	0.000	0.043	0.085
L1.China	-0.0134	0.036	-0.370	0.711	-0.084	0.058

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0008	0.002	0.444	0.657	-0.003	0.004

Loading coefficients (alpha) for equation China

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0014	0.001	-2.712	0.007	-0.002	-0.000

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	6.6440	3.002	2.213	0.027	0.760	12.528

Short run causality from US to China

Long run causality from US to China

In [145]:

```
model = VECM(endog=data_post_gfc.iloc[:,[0,5]],k_ar_diff = 1, coint_rank=1, determinist
ic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[145]:

Det. terms outside the coint. relation & lagged endog. parameters
for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	31.0115	15.969	1.942	0.052	-0.288	62.310
L1.US	-0.2697	0.065	-4.164	0.000	-0.397	-0.143
L1.South Africa	21.8651	10.162	2.152	0.031	1.948	41.782

Det. terms outside the coint. relation & lagged endog. parameters
for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
const	0.0007	0.102	0.007	0.994	-0.199	0.200
L1.US	-0.0017	0.000	-4.132	0.000	-0.003	-0.001
L1.South Africa	0.0938	0.065	1.446	0.148	-0.033	0.221

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0122	0.007	-1.696	0.090	-0.026	0.002

Loading coefficients (alpha) for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
ec1	1.926e-05	4.61e-05	0.418	0.676	-7.1e-05	0.000

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-215.9751	22.742	-9.497	0.000	-260.549	-171.401

Bidirectional Short run causality

Long run causality from South Africa to US

PRE COVID

In [146]:

```
model = VECM(endog=data_pre_covid.iloc[:,[0,1]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[146]:

Det. terms outside the coint. relation & lagged endog.

parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	18.5214	11.866	1.561	0.119	-4.735	41.777
L1.US	-0.0168	0.028	-0.604	0.546	-0.071	0.038
L1.Brazil	0.0083	0.005	1.682	0.093	-0.001	0.018

Det. terms outside the coint. relation & lagged endog.

parameters for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
const	-95.2796	66.731	-1.428	0.153	-226.071	35.511
L1.US	0.0903	0.156	0.577	0.564	-0.216	0.397
L1.Brazil	-0.0113	0.028	-0.407	0.684	-0.066	0.043

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0017	0.002	-0.847	0.397	-0.006	0.002

Loading coefficients (alpha) for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0221	0.011	1.982	0.048	0.000	0.044

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-0.2145	0.048	-4.468	0.000	-0.309	-0.120

Short run causality from Brazil to US

Long run causality from US to Brazil

In [147]:

```
model = VECM(endog=data_pre_covid.iloc[:,[0,2]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.
' ignored when e.g. forecasting.', ValueWarning)

Out[147]:

Det. terms outside the coint. relation & lagged endog.
parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	9.1474	18.194	0.503	0.615	-26.513	44.808
L1.US	-0.0112	0.027	-0.414	0.679	-0.064	0.042
L1.Russia	0.3431	0.238	1.443	0.149	-0.123	0.809

Det. terms outside the coint. relation & lagged endog.
parameters for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
const	4.3552	2.044	2.130	0.033	0.348	8.362
L1.US	0.0143	0.003	4.731	0.000	0.008	0.020
L1.Russia	-0.0038	0.027	-0.140	0.888	-0.056	0.049

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-3.239e-06	0.000	-0.013	0.990	-0.000	0.000

Loading coefficients (alpha) for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
ec1	6.366e-05	2.77e-05	2.300	0.021	9.42e-06	0.000

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-78.5407	33.660	-2.333	0.020	-144.514	-12.567

Short run causality from US to Russia

Long run causality from US to Russia

In [148]:

```
model = VECM(endog=data_pre_covid.iloc[:,[0,3]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[148]:

Det. terms outside the coint. relation & lagged endog.

parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	13.2220	4.866	2.717	0.007	3.685	22.759
L1.US	0.0056	0.026	0.216	0.829	-0.045	0.056
L1.India	0.0017	0.017	0.100	0.920	-0.031	0.035

Det. terms outside the coint. relation & lagged endog.

parameters for equation India

	coef	std err	z	P> z	[0.025	0.975]
const	3.7847	7.291	0.519	0.604	-10.505	18.074
L1.US	0.2746	0.039	7.085	0.000	0.199	0.351
L1.India	0.0132	0.025	0.522	0.602	-0.036	0.063

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0074	0.004	-1.900	0.057	-0.015	0.000

Loading coefficients (alpha) for equation India

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0149	0.006	2.560	0.010	0.003	0.026

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-0.6750	0.048	-14.102	0.000	-0.769	-0.581

Short run causality from US to India

Bidirectional Long run causality

In [149]:

```
model = VECM(endog=data_pre_covid.iloc[:,[0,4]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.
' ignored when e.g. forecasting.', ValueWarning)

Out[149]:

Det. terms outside the coint. relation & lagged endog.
parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	23.6827	17.304	1.369	0.171	-10.233	57.598
L1.US	0.0044	0.025	0.172	0.863	-0.045	0.054
L1.China	-0.0531	0.090	-0.593	0.553	-0.229	0.122

Det. terms outside the coint. relation & lagged endog.
parameters for equation China

	coef	std err	z	P> z	[0.025	0.975]
const	8.4420	4.855	1.739	0.082	-1.074	17.958
L1.US	0.0418	0.007	5.858	0.000	0.028	0.056
L1.China	0.0303	0.025	1.204	0.229	-0.019	0.080

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0003	0.000	0.864	0.388	-0.000	0.001

Loading coefficients (alpha) for equation China

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0002	8.93e-05	1.818	0.069	-1.27e-05	0.000

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-25.3816	12.141	-2.091	0.037	-49.177	-1.586

Short run causality from US to China

Long run causality from US to China

In [150]:

```
model = VECM(endog=data_pre_covid.iloc[:,[0,5]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[150]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	49.0140	43.781	1.120	0.263	-36.795	134.823
L1.US	-0.0323	0.031	-1.055	0.291	-0.092	0.028
L1.South Africa	12.0130	5.658	2.123	0.034	0.924	23.102

Det. terms outside the coint. relation & lagged endog. parameters for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
const	0.8731	0.235	3.708	0.000	0.412	1.335
L1.US	-0.0007	0.000	-3.949	0.000	-0.001	-0.000
L1.South Africa	0.0721	0.030	2.369	0.018	0.012	0.132

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	2.466e-05	2.72e-05	0.905	0.365	-2.87e-05	7.81e-05

Loading coefficients (alpha) for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
ec1	5.433e-07	1.47e-07	3.708	0.000	2.56e-07	8.3e-07

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-3.347e+04	8337.070	-4.014	0.000	-4.98e+04	-1.71e+04

Bidirectional Short run causality

Long run causality from US to South Africa

POST COVID

In [151]:

```
model = VECM(endog=data_post_covid.iloc[:,[0,1]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.
' ignored when e.g. forecasting.', ValueWarning)

Out[151]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	1527.8368	1385.244	1.103	0.270	-1187.191	4242.864
L1.US	-0.3377	0.224	-1.508	0.132	-0.777	0.101
L1.Brazil	0.0506	0.051	0.998	0.318	-0.049	0.150

Det. terms outside the coint. relation & lagged endog. parameters for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
const	-1164.4621	6076.432	-0.192	0.848	-1.31e+04	1.07e+04
L1.US	-1.4133	0.983	-1.438	0.150	-3.339	0.513
L1.Brazil	0.2086	0.222	0.938	0.348	-0.227	0.644

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.1473	0.130	-1.134	0.257	-0.402	0.107

Loading coefficients (alpha) for equation Brazil

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0829	0.569	0.146	0.884	-1.033	1.199

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-0.1562	0.013	-11.797	0.000	-0.182	-0.130

No Short run causality

No Long run causality

In [152]:

```
model = VECM(endog=data_post_covid.iloc[:,[0,2]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[152]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	3973.1301	1282.425	3.098	0.002	1459.624	6486.636
L1.US	-0.1807	0.145	-1.243	0.214	-0.466	0.104
L1.Russia	3.1401	2.748	1.143	0.253	-2.245	8.526

Det. terms outside the coint. relation & lagged endog. parameters for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
const	71.6014	68.500	1.045	0.296	-62.657	205.859
L1.US	0.0050	0.008	0.649	0.516	-0.010	0.020
L1.Russia	0.1767	0.147	1.204	0.229	-0.111	0.464

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.4221	0.135	-3.131	0.002	-0.686	-0.158

Loading coefficients (alpha) for equation Russia

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.0078	0.007	-1.089	0.276	-0.022	0.006

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-12.5223	0.688	-18.200	0.000	-13.871	-11.174

No Short run causality

Long run causality from Russia to US

In [153]:

```
model = VECM(endog=data_post_covid.iloc[:,[0,3]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[153]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	-622.6995	569.958	-1.093	0.275	-1739.797	494.398
L1.US	-0.1575	0.143	-1.100	0.271	-0.438	0.123
L1.India	-0.1445	0.114	-1.266	0.205	-0.368	0.079

Det. terms outside the coint. relation & lagged endog. parameters for equation India

	coef	std err	z	P> z	[0.025	0.975]
const	-2320.7282	554.793	-4.183	0.000	-3408.102	-1233.355
L1.US	0.3252	0.139	2.334	0.020	0.052	0.598
L1.India	-0.4148	0.111	-3.735	0.000	-0.632	-0.197

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.1179	0.117	1.006	0.314	-0.112	0.348

Loading coefficients (alpha) for equation India

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.4645	0.114	4.073	0.000	0.241	0.688

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-0.5763	0.030	-19.519	0.000	-0.634	-0.518

Short run causality from US to India

Long run causality from US to India

In [154]:

```
model = VECM(endog=data_post_covid.iloc[:,[0,4]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[154]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	5356.6401	2641.426	2.028	0.043	179.540	1.05e+04
L1.US	-0.2500	0.116	-2.164	0.030	-0.476	-0.024
L1.China	1.0697	2.171	0.493	0.622	-3.186	5.326

Det. terms outside the coint. relation & lagged endog. parameters for equation China

	coef	std err	z	P> z	[0.025	0.975]
const	386.0258	135.619	2.846	0.004	120.217	651.835
L1.US	0.0075	0.006	1.266	0.205	-0.004	0.019
L1.China	0.0593	0.111	0.532	0.595	-0.159	0.278

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0567	0.028	2.047	0.041	0.002	0.111

Loading coefficients (alpha) for equation China

	coef	std err	z	P> z	[0.025	0.975]
ec1	0.0041	0.001	2.851	0.004	0.001	0.007

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-41.8197	9.295	-4.499	0.000	-60.037	-23.602

No Short run causality

Bidirectional Long run causality

In [155]:

```
model = VECM(endog=data_post_covid.iloc[:,[0,5]],k_ar_diff = 1, coint_rank=1, deterministic='co').fit()
model.summary()
```

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.py:225: ValueWarning: A date index has been provided, but it has no associated frequency information and so will be ignored when e.g. forecasting.

' ignored when e.g. forecasting.', ValueWarning)

Out[155]:

Det. terms outside the coint. relation & lagged endog. parameters for equation US

	coef	std err	z	P> z	[0.025	0.975]
const	1401.0914	1347.407	1.040	0.298	-1239.779	4041.961
L1.US	-0.2499	0.216	-1.156	0.248	-0.674	0.174
L1.South Africa	68.3679	123.892	0.552	0.581	-174.455	311.191

Det. terms outside the coint. relation & lagged endog. parameters for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
const	-0.1509	2.384	-0.063	0.950	-4.823	4.522
L1.US	-0.0002	0.000	-0.444	0.657	-0.001	0.001
L1.South Africa	0.0233	0.219	0.106	0.916	-0.406	0.453

Loading coefficients (alpha) for equation US

	coef	std err	z	P> z	[0.025	0.975]
ec1	-0.1112	0.104	-1.072	0.284	-0.314	0.092

Loading coefficients (alpha) for equation South Africa

	coef	std err	z	P> z	[0.025	0.975]
ec1	-1.967e-06	0.000	-0.011	0.991	-0.000	0.000

Cointegration relations for loading-coefficients-column 1

	coef	std err	z	P> z	[0.025	0.975]
beta.1	1.0000	0	0	0.000	1.000	1.000
beta.2	-328.8832	44.253	-7.432	0.000	-415.617	-242.150

No Short run causality

No Long run causality

VOLATILITY MODELLING

In [172]:

```
from arch import arch_model  
from statsmodels.stats.diagnostic import acorr_ljungbox
```

PRE-GFC

In [173]:

```
#Fitting the model AR(1)-EGARCH(1,1)  
res = arch_model(y=df_pre_gfc['US'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1, q=  
1 , dist ='ged', rescale = False).fit()
```

Iteration:	1,	Func. Count:	9,	Neg. LLF:	-3066.256555769116
Iteration:	2,	Func. Count:	28,	Neg. LLF:	134774.4547155163
Iteration:	3,	Func. Count:	40,	Neg. LLF:	42438.28071411085
Iteration:	4,	Func. Count:	54,	Neg. LLF:	32458.94196408092
Iteration:	5,	Func. Count:	67,	Neg. LLF:	4252.1398602372
Iteration:	6,	Func. Count:	81,	Neg. LLF:	3020.4944915458236
Iteration:	7,	Func. Count:	95,	Neg. LLF:	1162.6852017182637
Iteration:	8,	Func. Count:	109,	Neg. LLF:	911.0052936887087
Iteration:	9,	Func. Count:	124,	Neg. LLF:	763.5671207662842
Iteration:	10,	Func. Count:	139,	Neg. LLF:	94.07567374341825
Iteration:	11,	Func. Count:	154,	Neg. LLF:	-19.698320895864185
Iteration:	12,	Func. Count:	169,	Neg. LLF:	-503.14547726537967
Iteration:	13,	Func. Count:	185,	Neg. LLF:	-1047.5617628284976
Iteration:	14,	Func. Count:	202,	Neg. LLF:	-1650.6972847227587
Iteration:	15,	Func. Count:	218,	Neg. LLF:	-1852.6764312775022
Iteration:	16,	Func. Count:	232,	Neg. LLF:	-1899.0644375380316
Iteration:	17,	Func. Count:	247,	Neg. LLF:	-1937.2026372505443
Iteration:	18,	Func. Count:	263,	Neg. LLF:	-1997.3024864822178
Iteration:	19,	Func. Count:	280,	Neg. LLF:	-2075.0707219459855
Iteration:	20,	Func. Count:	292,	Neg. LLF:	-2362.2146912960607
Iteration:	21,	Func. Count:	309,	Neg. LLF:	-2647.500258108729
Iteration:	22,	Func. Count:	324,	Neg. LLF:	-2664.8989650504263
Iteration:	23,	Func. Count:	336,	Neg. LLF:	-2884.7382922268744
Iteration:	24,	Func. Count:	346,	Neg. LLF:	-2993.952726175277
Iteration:	25,	Func. Count:	357,	Neg. LLF:	-3029.248427850687
Iteration:	26,	Func. Count:	368,	Neg. LLF:	-3054.871096323516
Iteration:	27,	Func. Count:	378,	Neg. LLF:	-3087.550832004992
Iteration:	28,	Func. Count:	388,	Neg. LLF:	-3151.85324962684
Iteration:	29,	Func. Count:	398,	Neg. LLF:	-3164.7093579108796
Iteration:	30,	Func. Count:	408,	Neg. LLF:	-3196.7306987994293
Iteration:	31,	Func. Count:	417,	Neg. LLF:	-3198.4217990603515
Iteration:	32,	Func. Count:	426,	Neg. LLF:	-3200.4942719808705
Iteration:	33,	Func. Count:	436,	Neg. LLF:	-3204.0661350130563
Iteration:	34,	Func. Count:	445,	Neg. LLF:	-3206.9415752309233
Iteration:	35,	Func. Count:	454,	Neg. LLF:	-3210.845817451829
Iteration:	36,	Func. Count:	464,	Neg. LLF:	-3214.208966142134
Iteration:	37,	Func. Count:	474,	Neg. LLF:	-3221.058899183834
Iteration:	38,	Func. Count:	483,	Neg. LLF:	-3225.2363637183985
Iteration:	39,	Func. Count:	494,	Neg. LLF:	-3225.9440375438667
Iteration:	40,	Func. Count:	504,	Neg. LLF:	-3228.438618009148
Iteration:	41,	Func. Count:	513,	Neg. LLF:	-3232.6385910896224
Iteration:	42,	Func. Count:	522,	Neg. LLF:	-3232.9150634242596
Iteration:	43,	Func. Count:	531,	Neg. LLF:	-3232.997238007838
Iteration:	44,	Func. Count:	540,	Neg. LLF:	-3233.0679394988265
Iteration:	45,	Func. Count:	549,	Neg. LLF:	-3233.0703057821793
Iteration:	46,	Func. Count:	558,	Neg. LLF:	-3233.071218319129
Iteration:	47,	Func. Count:	567,	Neg. LLF:	-3233.0714847961704
Iteration:	48,	Func. Count:	576,	Neg. LLF:	-3233.071494883064
Iteration:	49,	Func. Count:	585,	Neg. LLF:	-3233.0714961467147

Optimization terminated successfully. (Exit mode 0)

Current function value: -3233.071496146759

Iterations: 53

Function evaluations: 585

Gradient evaluations: 49

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\arch\univariate\distribution.py:1064: RuntimeWarning: overflow encountered in power

lls -= 0.5 * abs(resids / (sqrt(sigma2) * c)) ** nu

In [174]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          US    R-squared:
0.009
Mean Model:            AR    Adj. R-squared:
0.008
Vol Model:            EGARCH  Log-Likelihood:
3233.07
Distribution:    Generalized Error Distribution  AIC:
-6452.14
Method:            Maximum Likelihood  BIC:
-6418.23

No. Observations:
939
Date:            Tue, May 05 2020  Df Residuals:
932
Time:            11:45:21  Df Model:
7
```

Mean Model

```
=====
===
              coef      std err          t      P>|t|      95.0% Conf. I
nt.
-----
---
Const      3.9662e-04  3.488e-04      1.137      0.255  [-2.870e-04,1.080e-
03]
US[1]      -0.0626  4.374e-02     -1.431      0.152   [ -0.148,2.312e-
02]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega      -0.2448      0.194     -1.263      0.207   [ -0.625,  0.13
5]
alpha[1]    0.1302  3.194e-02      4.076  4.583e-05  [6.758e-02,  0.19
3]
gamma[1]    -0.0927  3.654e-02     -2.537  1.117e-02  [-0.164,-2.109e-0
2]
beta[1]     0.9742  2.025e-02     48.118      0.000   [  0.935,  1.01
4]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu          1.2738      0.114     11.170  5.723e-29  [  1.050,  1.497]
=====
```

Covariance estimator: robust

In [175]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[175]:

```
(array([ 2.52025034,  6.7064041 ,  6.74147922,  6.83320167, 12.07127463,
        20.47261547, 22.33365866, 25.45013809, 29.50626576, 35.64622934,
        35.67996807, 35.98667503, 37.55835232, 37.67289092, 38.66754998,
        38.69315355, 40.14213804, 41.16096981, 43.07186982, 43.10942379])),
array([1.12392741e-01, 3.49721919e-02, 8.06104777e-02, 1.44969707e-01,
        3.38240980e-02, 2.28071789e-03, 2.22476376e-03, 1.30363946e-03,
        5.32132127e-04, 9.68076837e-05, 1.91266398e-04, 3.25595081e-04,
        3.38505276e-04, 5.83006313e-04, 7.18352458e-04, 1.20415210e-03,
        1.23575920e-03, 1.44642768e-03, 1.26728550e-03, 1.97732695e-03]))
```

In [176]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_gfc['Brazil'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,
q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -2532.2053873566615
Iteration:      2,  Func. Count:     25,  Neg. LLF: -2532.207059223912
Iteration:      3,  Func. Count:     37,  Neg. LLF: -2533.6684629083666
Iteration:      4,  Func. Count:     49,  Neg. LLF: -2534.307255010105
Iteration:      5,  Func. Count:     62,  Neg. LLF: -2534.477575558264
Iteration:      6,  Func. Count:     74,  Neg. LLF: -2534.929998932574
Iteration:      7,  Func. Count:     86,  Neg. LLF: -2534.9770079050068
Iteration:      8,  Func. Count:     96,  Neg. LLF: -2535.5078514456677
Iteration:      9,  Func. Count:    107,  Neg. LLF: -2535.7530462452105
Iteration:     10,  Func. Count:    116,  Neg. LLF: -2536.382406348951
Iteration:     11,  Func. Count:    125,  Neg. LLF: -2536.3928468321537
Iteration:     12,  Func. Count:    134,  Neg. LLF: -2536.3936604453893
Iteration:     13,  Func. Count:    143,  Neg. LLF: -2536.393761691581
Iteration:     14,  Func. Count:    152,  Neg. LLF: -2536.393768948884
```

```
Optimization terminated successfully. (Exit mode 0)
Current function value: -2536.3937699456164
Iterations: 14
Function evaluations: 153
Gradient evaluations: 14
```

In [177]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          Brazil    R-squared:
0.003
Mean Model:            AR        Adj. R-squared:
0.002
Vol Model:             EGARCH    Log-Likelihood:
2536.39
Distribution:          Generalized Error Distribution    AIC:
-5058.79
Method:                Maximum Likelihood              BIC:
-5024.87
                                           No. Observations:
939
Date:                  Tue, May 05 2020    Df Residuals:
932
Time:                  11:45:43            Df Model:
7
```

Mean Model

```
=====
==
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
--
Const        1.0370e-03  5.168e-04      2.007  4.480e-02  [2.407e-05,2.050e-0
3]
Brazil[1]    -0.0629   3.215e-02     -1.956  5.043e-02  [ -0.126,1.178e-0
4]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega        -0.5944     0.221     -2.685  7.244e-03  [ -1.028, -0.16
1]
alpha[1]      0.1463   3.211e-02      4.558  5.172e-06  [8.341e-02,  0.20
9]
gamma[1]     -0.1443   3.737e-02     -3.863  1.122e-04  [ -0.218,-7.109e-0
2]
beta[1]       0.9275   2.702e-02     34.322  3.702e-258  [  0.875,  0.98
0]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu           1.6768     0.150     11.153  6.923e-29  [  1.382,  1.971]
=====
```

Covariance estimator: robust

In [178]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[178]:

```
(array([ 0.06705739,  8.39050087,  9.40164051, 10.46488851, 11.94425434,
        14.27381884, 15.64308204, 15.85829341, 19.3385943 , 19.53972472,
        22.98047839, 23.63019265, 23.96319039, 24.1754284 , 25.11372909,
        25.35303806, 25.53753598, 25.89943985, 26.22502998, 27.03500825])),
array([0.79567041, 0.01506697, 0.02440109, 0.03328409, 0.03555966,
        0.02672262, 0.02858494, 0.04445387, 0.02246297, 0.03391929,
        0.01778751, 0.02282805, 0.03147034, 0.04363566, 0.04843676,
        0.06383865, 0.08330842, 0.10207954, 0.1240399 , 0.13428193]))
```

In [179]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_gfc['Russia'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,
q=1 , dist = 'ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -2536.111270009662
Iteration:      2,  Func. Count:     27,  Neg. LLF: -2537.2031402587427
Iteration:      3,  Func. Count:     39,  Neg. LLF: -2542.694817940278
Iteration:      4,  Func. Count:     51,  Neg. LLF: -2544.5133559315655
Iteration:      5,  Func. Count:     63,  Neg. LLF: -2544.8691479010467
Iteration:      6,  Func. Count:     75,  Neg. LLF: -2544.9191957450257
Iteration:      7,  Func. Count:     86,  Neg. LLF: -2545.469737780407
Iteration:      8,  Func. Count:     95,  Neg. LLF: -2552.7401538877393
Iteration:      9,  Func. Count:    105,  Neg. LLF: -2554.3065365384145
Iteration:     10,  Func. Count:    115,  Neg. LLF: -2556.707809975419
Iteration:     11,  Func. Count:    124,  Neg. LLF: -2557.260027403515
Iteration:     12,  Func. Count:    133,  Neg. LLF: -2557.3031553582623
Iteration:     13,  Func. Count:    142,  Neg. LLF: -2557.306755880365
Iteration:     14,  Func. Count:    151,  Neg. LLF: -2557.307501869025
Iteration:     15,  Func. Count:    160,  Neg. LLF: -2557.307636890171
Iteration:     16,  Func. Count:    169,  Neg. LLF: -2557.307671311346
Iteration:     17,  Func. Count:    179,  Neg. LLF: -2557.3076743802444
```

Optimization terminated successfully. (Exit mode 0)

Current function value: -2557.3076743801985

Iterations: 17

Function evaluations: 179

Gradient evaluations: 17

In [180]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:                Russia    R-squared:
-0.005
Mean Model:                  AR        Adj. R-squared:
-0.006
Vol Model:                   EGARCH    Log-Likelihood:
2557.31
Distribution:      Generalized Error Distribution    AIC:
-5100.62
Method:           Maximum Likelihood    BIC:
-5066.70
                                           No. Observations:
939
Date:              Tue, May 05 2020    Df Residuals:
932
Time:              11:45:58    Df Model:
7
```

Mean Model

```
=====
==
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
--
Const      2.2797e-03  6.887e-04      3.310  9.319e-04 [9.299e-04,3.630e-0
3]
Russia[1]   0.0187  6.115e-03      3.059  2.221e-03 [6.720e-03,3.069e-0
2]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega      -0.7492      0.213      -3.514  4.421e-04 [ -1.167, -0.33
1]
alpha[1]    0.2013  5.003e-02      4.024  5.728e-05 [ 0.103, 0.29
9]
gamma[1]    -0.1433  3.711e-02      -3.860  1.132e-04 [ -0.216,-7.052e-0
2]
beta[1]     0.9082  2.598e-02     34.956  1.045e-267 [ 0.857, 0.95
9]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu          1.1284  7.582e-02     14.882  4.324e-50 [ 0.980, 1.277]
=====
```

Covariance estimator: robust

In [181]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[181]:

```
(array([ 1.57725786,  2.68700541,  4.7233525 ,  9.5025679 , 12.6037946 ,
        12.98561918, 15.59125754, 15.59215991, 15.66297494, 16.83325492,
        19.39954356, 19.91606381, 20.02592123, 26.21204099, 26.3982129 ,
        26.40065452, 27.74779932, 28.33083256, 29.00444365, 29.40966487]),
 array([0.20915612, 0.2609301 , 0.19321221, 0.04969451, 0.02738849,
        0.04326488, 0.02912462, 0.04860375, 0.07426193, 0.07813602,
        0.05428792, 0.06869051, 0.0945658 , 0.02432548, 0.03403967,
        0.04864499, 0.04797273, 0.05719586, 0.06591526, 0.08000066]))
```

In [182]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_gfc['India'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,
q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -2675.0999000266006
Iteration:      2,  Func. Count:     27,  Neg. LLF: -2676.2973314644046
Iteration:      3,  Func. Count:     40,  Neg. LLF: -2677.504295505608
Iteration:      4,  Func. Count:     53,  Neg. LLF: -2677.832376718712
Iteration:      5,  Func. Count:     65,  Neg. LLF: -2678.810172153758
Iteration:      6,  Func. Count:     76,  Neg. LLF: -2682.1199440277724
Iteration:      7,  Func. Count:     87,  Neg. LLF: -2682.9964381136133
Iteration:      8,  Func. Count:     97,  Neg. LLF: -2683.822168464124
Iteration:      9,  Func. Count:    107,  Neg. LLF: -2684.8587278501677
Iteration:     10,  Func. Count:    116,  Neg. LLF: -2685.820533854548
Iteration:     11,  Func. Count:    125,  Neg. LLF: -2685.9050374824533
Iteration:     12,  Func. Count:    134,  Neg. LLF: -2685.9277262153496
Iteration:     13,  Func. Count:    143,  Neg. LLF: -2685.936177962756
Iteration:     14,  Func. Count:    152,  Neg. LLF: -2685.9365944318283
Iteration:     15,  Func. Count:    162,  Neg. LLF: -2685.936600269411
Iteration:     16,  Func. Count:    171,  Neg. LLF: -2685.9366021658543
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -2685.936602165854
```

```
Iterations: 16
```

```
Function evaluations: 171
```

```
Gradient evaluations: 16
```

In [183]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:                India    R-squared:
-0.003
Mean Model:                  AR      Adj. R-squared:
-0.004
Vol Model:                   EGARCH   Log-Likelihood:
2685.94
Distribution:      Generalized Error Distribution    AIC:
-5357.87
Method:           Maximum Likelihood              BIC:
-5323.96
                                           No. Observations:
939
Date:                Tue, May 05 2020    Df Residuals:
932
Time:                11:46:11           Df Model:
7
```

Mean Model

```
=====
==
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
--
Const      1.5291e-03  3.382e-04      4.521  6.156e-06 [8.662e-04,2.192e-0
3]
India[1]    0.0558    7.618e-03      7.326  2.378e-13 [4.088e-02,7.074e-0
2]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega      -0.5288      0.157      -3.361  7.776e-04 [ -0.837, -0.22
0]
alpha[1]    0.2287    4.334e-02      5.278  1.306e-07 [ 0.144, 0.31
4]
gamma[1]    -0.1506    3.734e-02     -4.035  5.466e-05 [ -0.224,-7.747e-0
2]
beta[1]     0.9380    1.857e-02     50.501  0.000 [ 0.902, 0.97
4]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu          1.4621    9.451e-02     15.470  5.499e-54 [ 1.277, 1.647]
=====
```

Covariance estimator: robust

In [184]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[184]:

```
(array([ 0.76210144,  4.19857456,  6.2501029 ,  6.28286224,  7.64313323,
        8.66952749,  9.5096938 , 11.53771133, 11.68369206, 11.77048192,
        12.19639026, 13.4490692 , 16.89702867, 17.46787671, 17.47219243,
        17.77836884, 20.23296395, 21.06331096, 24.3027311 , 24.35597765])),
array([0.38267168, 0.12254374, 0.10005632, 0.17899638, 0.17703098,
        0.19303427, 0.21810209, 0.17305223, 0.2317342 , 0.30071099,
        0.34906377, 0.33726223, 0.2040542 , 0.2321007 , 0.29142871,
        0.33703402, 0.26248735, 0.27623098, 0.18479511, 0.22718809]))
```

In [185]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_gfc['China'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,
q=1 , dist = 'ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -2501.48885455014
Iteration:      2,  Func. Count:     28,  Neg. LLF: -2501.9230825957047
Iteration:      3,  Func. Count:     41,  Neg. LLF: -2503.9609689303916
Iteration:      4,  Func. Count:     54,  Neg. LLF: -2504.3316162742126
Iteration:      5,  Func. Count:     67,  Neg. LLF: -2504.417525917122
Iteration:      6,  Func. Count:     77,  Neg. LLF: -2505.0219636317647
Iteration:      7,  Func. Count:     86,  Neg. LLF: -2508.5246692926225
Iteration:      8,  Func. Count:     98,  Neg. LLF: -2508.598319399746
Iteration:      9,  Func. Count:    110,  Neg. LLF: -2509.0230784645873
Iteration:     10,  Func. Count:    120,  Neg. LLF: -2513.4346748866874
Iteration:     11,  Func. Count:    129,  Neg. LLF: -2513.875922950659
Iteration:     12,  Func. Count:    138,  Neg. LLF: -2513.9155229977023
Iteration:     13,  Func. Count:    147,  Neg. LLF: -2513.945156374546
Iteration:     14,  Func. Count:    157,  Neg. LLF: -2513.9457513500656
Iteration:     15,  Func. Count:    166,  Neg. LLF: -2513.945991175302
Iteration:     16,  Func. Count:    175,  Neg. LLF: -2513.9461868185367
Iteration:     17,  Func. Count:    185,  Neg. LLF: -2513.9462638377377
Iteration:     18,  Func. Count:    195,  Neg. LLF: -2513.946284462785
```

Optimization terminated successfully. (Exit mode 0)

Current function value: -2513.946284946831

Iterations: 18

Function evaluations: 200

Gradient evaluations: 18

In [186]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          China    R-squared:
-0.000
Mean Model:            AR      Adj. R-squared:
-0.001
Vol Model:            EGARCH   Log-Likelihood:
2513.95
Distribution:    Generalized Error Distribution    AIC:
-5013.89
Method:          Maximum Likelihood    BIC:
-4979.98
                                           No. Observations:
939
Date:            Tue, May 05 2020    Df Residuals:
932
Time:            11:46:30    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
-----
Const      4.8090e-04  2.700e-04      1.781  7.493e-02  [-4.835e-05,1.010
e-03]
China[1]   -7.5183e-03  7.435e-04     -10.112  4.866e-24  [-8.975e-03,-6.061
e-03]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
-----
omega      -0.0531  7.478e-02     -0.710    0.478  [-0.200,9.347e
-02]
alpha[1]    0.1317  4.722e-02      2.789  5.291e-03  [3.913e-02, 0.
224]
gamma[1]   -4.7336e-03  2.094e-02     -0.226    0.821  [-4.577e-02,3.630e
-02]
beta[1]     0.9921  9.474e-03     104.718  0.000  [ 0.974, 1.
011]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
-----
nu          1.1557  8.333e-02     13.869  9.803e-44  [ 0.992, 1.319]
=====
```

Covariance estimator: robust

In [187]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[187]:

```
(array([3.37477845e-04, 2.53147631e+00, 5.67790386e+00, 5.71950986e+00,
        6.20439193e+00, 6.29805250e+00, 7.64316401e+00, 8.30529169e+00,
        8.34826146e+00, 1.46612331e+01, 1.53606014e+01, 1.86735787e+01,
        1.98769665e+01, 2.04299201e+01, 2.26526415e+01, 2.42165656e+01,
        2.77096990e+01, 2.77100748e+01, 2.79011154e+01, 2.79012358e+01]),
 array([0.98534323, 0.28203104, 0.12837684, 0.22109756, 0.28683573,
        0.3906435 , 0.36510786, 0.40423074, 0.49946629, 0.14490944,
        0.16657636, 0.09671637, 0.09832082, 0.11715921, 0.09179856,
        0.08488002, 0.04844669, 0.06660648, 0.08535025, 0.11175802]))
```

In [188]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_gfc['South Africa'],lags =1, mean='AR', vol = 'EGARCH', p =1,
o =1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -2431.36387971481
Iteration:      2,  Func. Count:     27,  Neg. LLF: -2434.442921993895
Iteration:      3,  Func. Count:     40,  Neg. LLF: -2435.9064432719515
Iteration:      4,  Func. Count:     53,  Neg. LLF: -2436.1888166678145
Iteration:      5,  Func. Count:     65,  Neg. LLF: -2436.394251007049
Iteration:      6,  Func. Count:     76,  Neg. LLF: -2436.8026127236535
Iteration:      7,  Func. Count:     88,  Neg. LLF: -2436.940532609574
Iteration:      8,  Func. Count:     99,  Neg. LLF: -2437.0569204557414
Iteration:      9,  Func. Count:    109,  Neg. LLF: -2438.2718541854138
Iteration:     10,  Func. Count:    118,  Neg. LLF: -2438.372500713622
Iteration:     11,  Func. Count:    127,  Neg. LLF: -2438.3961551493785
Iteration:     12,  Func. Count:    136,  Neg. LLF: -2438.399132957148
Iteration:     13,  Func. Count:    145,  Neg. LLF: -2438.399274832256
Iteration:     14,  Func. Count:    154,  Neg. LLF: -2438.3992762362404
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -2438.3992762362427
```

```
Iterations: 14
```

```
Function evaluations: 154
```

```
Gradient evaluations: 14
```

In [189]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          South Africa    R-squared:
0.004
Mean Model:              AR    Adj. R-squared:
0.003
Vol Model:              EGARCH    Log-Likelihood:
2438.40
Distribution:    Generalized Error Distribution    AIC:
-4862.80
Method:          Maximum Likelihood    BIC:
-4828.88
No. Observations:
939
Date:            Tue, May 05 2020    Df Residuals:
932
Time:            11:46:44    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
-----
Const          2.1142e-03  5.471e-04      3.865  1.112e-04 [1.042e-03,3.186
e-03]
Sout...ica[1]  -0.0666  3.449e-02     -1.931  5.353e-02 [ -0.134,1.012
e-03]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-----
-
omega          -0.3220      0.146     -2.203  2.757e-02 [ -0.608,-3.558e-0
2]
alpha[1]        0.1992  4.515e-02      4.412  1.024e-05 [ 0.111, 0.28
8]
gamma[1]        -0.0757  3.708e-02     -2.042  4.114e-02 [ -0.148,-3.047e-0
3]
beta[1]         0.9594  1.826e-02     52.539  0.000 [ 0.924, 0.99
5]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
-----
nu              1.5078      0.137     10.990  4.251e-28 [ 1.239, 1.777]
=====
```

Covariance estimator: robust

In [190]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[190]:

```
(array([ 0.63646429,  2.15056276,  2.35315061,  3.04975853,  4.23375651,
         5.68291748,  5.94449489,  6.16175447,  6.74398358,  7.95376094,
         8.25298839,  9.15447592,  9.66870724, 12.14438125, 12.87244556,
        12.87474859, 13.65671902, 15.36709795, 15.59496983, 15.60959735])),
array([0.42499404, 0.34120173, 0.50241519, 0.54953324, 0.51627489,
        0.45962995, 0.54624519, 0.6291185 , 0.66375461, 0.63335362,
        0.69047824, 0.68968257, 0.72077488, 0.59470897, 0.61214961,
        0.68189278, 0.69123491, 0.6366258 , 0.68410733, 0.74052966]))
```

POST GFC

In [191]:

```
#Fitting the model AR(1)-EGARCH(1,1)  
res = arch_model(y=df_post_gfc['US'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1, q  
=1 , dist ='ged', rescale = False).fit()
```

Iteration:	1,	Func. Count:	9,	Neg. LLF:	-2219.530302555351
Iteration:	2,	Func. Count:	28,	Neg. LLF:	-487.0351340643234
Iteration:	3,	Func. Count:	41,	Neg. LLF:	-489.12493185061106
Iteration:	4,	Func. Count:	53,	Neg. LLF:	-518.9106265667933
Iteration:	5,	Func. Count:	64,	Neg. LLF:	-549.8753704191546
Iteration:	6,	Func. Count:	75,	Neg. LLF:	-589.5254057140934
Iteration:	7,	Func. Count:	86,	Neg. LLF:	-634.3271906964459
Iteration:	8,	Func. Count:	97,	Neg. LLF:	-785.0565736670519
Iteration:	9,	Func. Count:	108,	Neg. LLF:	-860.7137423703846
Iteration:	10,	Func. Count:	123,	Neg. LLF:	-963.4726997054676
Iteration:	11,	Func. Count:	139,	Neg. LLF:	-1019.2363384247683
Iteration:	12,	Func. Count:	152,	Neg. LLF:	-1067.9059733891504
Iteration:	13,	Func. Count:	165,	Neg. LLF:	-1122.3206755463552
Iteration:	14,	Func. Count:	177,	Neg. LLF:	-1171.7173517769177
Iteration:	15,	Func. Count:	190,	Neg. LLF:	-1311.3974378438259
Iteration:	16,	Func. Count:	202,	Neg. LLF:	-1361.226876725871
Iteration:	17,	Func. Count:	212,	Neg. LLF:	-1840.813073132993
Iteration:	18,	Func. Count:	223,	Neg. LLF:	-1949.0299990206731
Iteration:	19,	Func. Count:	233,	Neg. LLF:	-1989.5723683443186
Iteration:	20,	Func. Count:	243,	Neg. LLF:	-2067.306437201951
Iteration:	21,	Func. Count:	253,	Neg. LLF:	-2087.7566480560927
Iteration:	22,	Func. Count:	263,	Neg. LLF:	-2117.167142019844
Iteration:	23,	Func. Count:	272,	Neg. LLF:	-2133.474291271961
Iteration:	24,	Func. Count:	282,	Neg. LLF:	-2143.3528596311185
Iteration:	25,	Func. Count:	293,	Neg. LLF:	-2144.148939337755
Iteration:	26,	Func. Count:	303,	Neg. LLF:	-2159.49458905991
Iteration:	27,	Func. Count:	313,	Neg. LLF:	-2170.311654980889
Iteration:	28,	Func. Count:	323,	Neg. LLF:	-2178.936663865953
Iteration:	29,	Func. Count:	333,	Neg. LLF:	-2189.7048464049362
Iteration:	30,	Func. Count:	343,	Neg. LLF:	-2197.1336380413445
Iteration:	31,	Func. Count:	353,	Neg. LLF:	-2202.805272775554
Iteration:	32,	Func. Count:	363,	Neg. LLF:	-2207.105749706634
Iteration:	33,	Func. Count:	373,	Neg. LLF:	-2224.3745422978513
Iteration:	34,	Func. Count:	383,	Neg. LLF:	-2225.6974699091393
Iteration:	35,	Func. Count:	393,	Neg. LLF:	-2227.4148798594997
Iteration:	36,	Func. Count:	403,	Neg. LLF:	-2228.519142325104
Iteration:	37,	Func. Count:	413,	Neg. LLF:	-2229.546268550081
Iteration:	38,	Func. Count:	423,	Neg. LLF:	-2229.660443822614
Iteration:	39,	Func. Count:	432,	Neg. LLF:	-2229.6961519333145
Iteration:	40,	Func. Count:	441,	Neg. LLF:	-2229.732631732162
Iteration:	41,	Func. Count:	450,	Neg. LLF:	-2229.751819854459
Iteration:	42,	Func. Count:	459,	Neg. LLF:	-2229.7673334262213
Iteration:	43,	Func. Count:	468,	Neg. LLF:	-2229.835175885774
Iteration:	44,	Func. Count:	477,	Neg. LLF:	-2229.877795585985
Iteration:	45,	Func. Count:	486,	Neg. LLF:	-2229.8787901137584
Iteration:	46,	Func. Count:	495,	Neg. LLF:	-2229.8789111715982
Iteration:	47,	Func. Count:	504,	Neg. LLF:	-2229.87891227729

Optimization terminated successfully. (Exit mode 0)

Current function value: -2229.878912277307

Iterations: 48

Function evaluations: 504

Gradient evaluations: 47

C:\Users\Divyam Jain\Anaconda3\lib\site-packages\arch\univariate\distribution.py:1064: RuntimeWarning: overflow encountered in power

lls -= 0.5 * abs(resids / (sqrt(sigma2) * c)) ** nu

In [192]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          US    R-squared:
0.003
Mean Model:            AR    Adj. R-squared:
0.002
Vol Model:            EGARCH  Log-Likelihood:
2229.88
Distribution:    Generalized Error Distribution  AIC:
-4445.76
Method:            Maximum Likelihood  BIC:
-4413.61

No. Observations:
730
Date:            Tue, May 05 2020  Df Residuals:
723
Time:            11:47:13  Df Model:
7
```

Mean Model

```
=====
==
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
--
Const          5.8370e-04  2.576e-04      2.266  2.347e-02  [7.876e-05,1.089e-0
3]
US[1]          -0.0343  3.902e-02     -0.880    0.379  [ -0.111,4.216e-0
2]
```

Volatility Model

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
omega          -0.2571  7.643e-02     -3.363  7.698e-04  [ -0.407, -0.107]
alpha[1]         0.1395  3.920e-02      3.558  3.731e-04  [6.266e-02,  0.216]
gamma[1]        -0.1702  3.307e-02     -5.147  2.653e-07  [ -0.235, -0.105]
beta[1]          0.9722  8.631e-03    112.640    0.000  [  0.955,  0.989]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu              1.4314      0.105     13.619  3.104e-42  [  1.225,  1.637]
=====
```

Covariance estimator: robust



In [193]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[193]:

```
(array([ 3.58907827,  5.41633162, 11.96095416, 12.02234617, 14.35048683,
        14.92892344, 15.02484874, 16.91725618, 17.36997777, 18.36043836,
        21.47600043, 23.04462782, 33.11182594, 40.28768097, 40.49156825,
        64.82733681, 66.02369982, 66.03211314, 66.03302738, 66.12242442])),
array([5.81604937e-02, 6.66589600e-02, 7.51811894e-03, 1.71858647e-02,
        1.35298629e-02, 2.08167930e-02, 3.56821963e-02, 3.09823100e-02,
        4.32277249e-02, 4.91795173e-02, 2.87618804e-02, 2.73494466e-02,
        1.63935139e-03, 2.30053531e-04, 3.82109195e-04, 7.88807039e-08,
        1.03121354e-07, 2.09446481e-07, 4.14429079e-07, 7.72226593e-07]))
```

In [194]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_gfc['Brazil'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1
, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -1991.0146213964467
Iteration:      2,  Func. Count:     25,  Neg. LLF: -1991.0168650376202
Iteration:      3,  Func. Count:     37,  Neg. LLF: -1992.2688909330486
Iteration:      4,  Func. Count:     50,  Neg. LLF: -1992.6147991882772
Iteration:      5,  Func. Count:     63,  Neg. LLF: -1992.8915760110112
Iteration:      6,  Func. Count:     75,  Neg. LLF: -1992.9355213469833
Iteration:      7,  Func. Count:     85,  Neg. LLF: -1993.423131624756
Iteration:      8,  Func. Count:     97,  Neg. LLF: -1993.9696994975443
Iteration:      9,  Func. Count:    108,  Neg. LLF: -1994.036316590949
Iteration:     10,  Func. Count:    118,  Neg. LLF: -1994.1389082124715
Iteration:     11,  Func. Count:    127,  Neg. LLF: -1994.178015773315
Iteration:     12,  Func. Count:    136,  Neg. LLF: -1994.1828983149478
Iteration:     13,  Func. Count:    145,  Neg. LLF: -1994.1831026906532
Iteration:     14,  Func. Count:    154,  Neg. LLF: -1994.1831178267253
```

```
Optimization terminated successfully.      (Exit mode 0)
Current function value: -1994.1831178267287
Iterations: 14
Function evaluations: 154
Gradient evaluations: 14
```

In [195]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          Brazil    R-squared:
0.000
Mean Model:            AR      Adj. R-squared:
-0.001
Vol Model:            EGARCH    Log-Likelihood:
1994.18
Distribution:          Generalized Error Distribution    AIC:
-3974.37
Method:                Maximum Likelihood    BIC:
-3942.21

                                No. Observations:
730
Date:                  Tue, May 05 2020    Df Residuals:
723
Time:                  11:48:25    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
----
Const      -1.6378e-04  5.806e-04    -0.282    0.778 [-1.302e-03,9.743e
-04]
Brazil[1]   -0.0152  3.636e-02    -0.419    0.676 [-8.648e-02,5.604e
-02]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega      -0.1538  8.092e-02    -1.901  5.731e-02 [-0.312,4.776e-0
3]
alpha[1]    0.1116  5.246e-02     2.127  3.343e-02 [8.757e-03, 0.21
4]
gamma[1]    -0.0912  3.381e-02    -2.696  7.012e-03 [-0.157,-2.490e-0
2]
beta[1]     0.9817  9.905e-03    99.109    0.000 [ 0.962, 1.00
1]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu          1.5179    0.125    12.134  6.968e-34 [ 1.273, 1.763]
=====
```

Covariance estimator: robust

In [196]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[196]:

```
(array([ 0.31004961,  5.82574448,  8.26609932,  8.48922964, 24.85832827,
        25.93108366, 26.45335903, 26.79311067, 27.58208168, 37.48660289,
        37.59709113, 42.23808437, 42.28703699, 47.15817838, 47.73539217,
        61.92523085, 65.56977434, 65.60594434, 67.63173384, 67.70520013])),
array([5.77649742e-01, 5.43194870e-02, 4.08207427e-02, 7.52143667e-02,
        1.48389110e-04, 2.29320753e-04, 4.17833735e-04, 7.67542541e-04,
        1.11988667e-03, 4.66078592e-05, 9.14764193e-05, 3.03684962e-05,
        5.87794655e-05, 1.81031694e-05, 2.80537362e-05, 2.47207327e-07,
        1.23098674e-07, 2.46569815e-07, 2.26664836e-07, 4.29620134e-07]))
```

In [197]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_gfc['Russia'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1
, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -1778.187609814148
Iteration:      2,  Func. Count:     25,  Neg. LLF: -1778.4081785399658
Iteration:      3,  Func. Count:     37,  Neg. LLF: -1779.8536174097446
Iteration:      4,  Func. Count:     50,  Neg. LLF: -1780.0724309097482
Iteration:      5,  Func. Count:     62,  Neg. LLF: -1780.1998429533867
Iteration:      6,  Func. Count:     74,  Neg. LLF: -1780.2695205245896
Iteration:      7,  Func. Count:     86,  Neg. LLF: -1780.355479572957
Iteration:      8,  Func. Count:     99,  Neg. LLF: -1780.3568987090366
Iteration:      9,  Func. Count:    109,  Neg. LLF: -1781.2536488913267
Iteration:     10,  Func. Count:    118,  Neg. LLF: -1781.5596213647054
Iteration:     11,  Func. Count:    127,  Neg. LLF: -1781.6999713274372
Iteration:     12,  Func. Count:    136,  Neg. LLF: -1781.713369604603
Iteration:     13,  Func. Count:    145,  Neg. LLF: -1781.7140407324227
Iteration:     14,  Func. Count:    154,  Neg. LLF: -1781.7141387601064
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -1781.7141387601234
```

```
Iterations: 14
```

```
Function evaluations: 154
```

```
Gradient evaluations: 14
```

In [198]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:                Russia    R-squared:
0.006
Mean Model:                  AR        Adj. R-squared:
0.004
Vol Model:                   EGARCH    Log-Likelihood:
1781.71
Distribution:      Generalized Error Distribution    AIC:
-3549.43
Method:           Maximum Likelihood    BIC:
-3517.28
                                           No. Observations:
730
Date:              Tue, May 05 2020    Df Residuals:
723
Time:              11:48:36    Df Model:
7
```

Mean Model

```
=====
===
              coef      std err          t      P>|t|      95.0% Conf. I
nt.
-----
---
Const      4.3727e-04  6.633e-04      0.659      0.510 [-8.628e-04,1.737e-
03]
Russia[1]   0.0741  4.009e-02      1.847  6.472e-02  [-4.523e-03, 0.1
53]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega      -0.1300  5.349e-02     -2.431  1.506e-02 [ -0.235,-2.519e-0
2]
alpha[1]    0.1384  4.217e-02      3.281  1.033e-03 [5.573e-02, 0.22
1]
gamma[1]    -0.0534  2.613e-02     -2.042  4.111e-02 [ -0.105,-2.154e-0
3]
beta[1]     0.9834  7.070e-03    139.092      0.000 [ 0.970, 0.99
7]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu          1.5862      0.143     11.062  1.928e-28 [ 1.305, 1.867]
=====
```

Covariance estimator: robust

In [199]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[199]:

```
(array([9.35575009e-03, 7.66706001e-01, 7.96553995e-01, 1.38036065e+00,
        1.46760365e+00, 7.25582690e+00, 1.39382234e+01, 1.74861048e+01,
        2.04110651e+01, 2.88553373e+01, 2.90139870e+01, 2.91722455e+01,
        2.91724878e+01, 3.98492426e+01, 4.22706173e+01, 4.84712525e+01,
        4.95728029e+01, 5.05438965e+01, 5.22530903e+01, 5.29611610e+01]),
array([9.22944685e-01, 6.81572261e-01, 8.50291094e-01, 8.47601147e-01,
        9.16777794e-01, 2.97835181e-01, 5.22910820e-02, 2.54270832e-02,
        1.55382879e-02, 1.31502639e-03, 2.25864496e-03, 3.71441080e-03,
        6.18686149e-03, 2.69303549e-04, 2.04180324e-04, 4.00454055e-05,
        4.91973121e-05, 6.24353161e-05, 6.06297760e-05, 8.23481446e-05]))
```

In [200]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_gfc['India'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,
q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,   Func. Count:      9,   Neg. LLF: -2056.3151550962875
Iteration:      2,   Func. Count:     25,   Neg. LLF: -2056.3392364492465
Iteration:      3,   Func. Count:     38,   Neg. LLF: -2059.653145364999
Iteration:      4,   Func. Count:     51,   Neg. LLF: -2059.7646207417856
Iteration:      5,   Func. Count:     64,   Neg. LLF: -2059.883324271993
Iteration:      6,   Func. Count:     75,   Neg. LLF: -2060.0076295821627
Iteration:      7,   Func. Count:     87,   Neg. LLF: -2060.0162086728105
Iteration:      8,   Func. Count:     97,   Neg. LLF: -2060.5294962670214
Iteration:      9,   Func. Count:    108,   Neg. LLF: -2060.5625514346543
Iteration:     10,   Func. Count:    118,   Neg. LLF: -2060.748561649321
Iteration:     11,   Func. Count:    127,   Neg. LLF: -2060.7566120957053
Iteration:     12,   Func. Count:    136,   Neg. LLF: -2060.7572539826715
Iteration:     13,   Func. Count:    145,   Neg. LLF: -2060.757261509466
Iteration:     14,   Func. Count:    154,   Neg. LLF: -2060.757264959078
```

```
Optimization terminated successfully.      (Exit mode 0)
Current function value: -2060.7572649590857
Iterations: 14
Function evaluations: 154
Gradient evaluations: 14
```

In [201]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          India    R-squared:
0.000
Mean Model:            AR      Adj. R-squared:
-0.001
Vol Model:            EGARCH   Log-Likelihood:
2060.76
Distribution:          Generalized Error Distribution    AIC:
-4107.51
Method:                Maximum Likelihood             BIC:
-4075.36
                                           No. Observations:
730
Date:                  Tue, May 05 2020    Df Residuals:
723
Time:                  11:48:46           Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
----
Const      -1.5705e-04  4.803e-04    -0.327    0.744  [-1.098e-03, 7.842e
-04]
India[1]     0.0256  3.898e-02     0.656    0.512  [-5.082e-02, 0.
102]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. I
nt.
-----
---
omega      -0.0976  5.778e-02    -1.689  9.129e-02  [ -0.211, 1.568e-
02]
alpha[1]    0.1554  5.364e-02     2.898  3.758e-03  [5.030e-02, 0.2
61]
gamma[1]   -0.0406  2.769e-02    -1.468    0.142  [-9.492e-02, 1.363e-
02]
beta[1]     0.9886  6.687e-03   147.827    0.000  [ 0.975, 1.0
02]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu           1.5645     0.174     8.995  2.359e-19  [ 1.224, 1.905]
=====
```

Covariance estimator: robust

In [202]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[202]:

```
(array([7.74637561e-05, 1.71757411e+01, 1.71757420e+01, 2.13203009e+01,
        2.13206427e+01, 2.20742501e+01, 2.21057432e+01, 2.34219090e+01,
        2.34520232e+01, 2.64426903e+01, 2.79261693e+01, 3.07603988e+01,
        3.17501159e+01, 4.14796506e+01, 4.58359347e+01, 5.00879779e+01,
        5.08953609e+01, 5.49467435e+01, 5.80949025e+01, 5.81104932e+01]),
array([9.92977630e-01, 1.86352490e-04, 6.50291822e-04, 2.73564433e-04,
        7.04493532e-04, 1.17392433e-03, 2.43593155e-03, 2.86276290e-03,
        5.25712325e-03, 3.18826954e-03, 3.32270376e-03, 2.14263417e-03,
        2.61576545e-03, 1.49449475e-04, 5.64596197e-05, 2.21965704e-05,
        3.06383784e-05, 1.30525779e-05, 7.71458553e-06, 1.39065456e-05]))
```

In [203]:

```
#Fitting the model AR(1)-EGARCH(1,1)  
res = arch_model(y=df_post_gfc['China'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,  
q=1 , dist ='ged', rescale = False).fit()
```

Iteration:	1,	Func. Count:	9,	Neg. LLF:	-2034.4635388368704
Iteration:	2,	Func. Count:	25,	Neg. LLF:	-2034.526821977465
Iteration:	3,	Func. Count:	38,	Neg. LLF:	-2034.647616960549
Iteration:	4,	Func. Count:	51,	Neg. LLF:	-2034.7042085583462
Iteration:	5,	Func. Count:	63,	Neg. LLF:	-2034.7501926030895
Iteration:	6,	Func. Count:	73,	Neg. LLF:	-2035.1790303664682
Iteration:	7,	Func. Count:	83,	Neg. LLF:	-2038.4577073717996
Iteration:	8,	Func. Count:	93,	Neg. LLF:	-2038.5241616365865
Iteration:	9,	Func. Count:	103,	Neg. LLF:	-2038.5827094062552
Iteration:	10,	Func. Count:	113,	Neg. LLF:	-2038.6273448804436
Iteration:	11,	Func. Count:	123,	Neg. LLF:	-2038.6354805136518
Iteration:	12,	Func. Count:	133,	Neg. LLF:	-2038.6710437925294
Iteration:	13,	Func. Count:	142,	Neg. LLF:	-2038.6822498524227
Iteration:	14,	Func. Count:	151,	Neg. LLF:	-2038.6849342249036
Iteration:	15,	Func. Count:	160,	Neg. LLF:	-2038.6870841977384
Iteration:	16,	Func. Count:	169,	Neg. LLF:	-2038.721034211763
Iteration:	17,	Func. Count:	179,	Neg. LLF:	-2038.7649147064224
Iteration:	18,	Func. Count:	189,	Neg. LLF:	-2038.836929932441
Iteration:	19,	Func. Count:	199,	Neg. LLF:	-2038.939098051394
Iteration:	20,	Func. Count:	209,	Neg. LLF:	-2039.0681791433237
Iteration:	21,	Func. Count:	220,	Neg. LLF:	-2039.0718884877083
Iteration:	22,	Func. Count:	236,	Neg. LLF:	-2039.073052498209
Iteration:	23,	Func. Count:	250,	Neg. LLF:	-2039.1045565326613
Iteration:	24,	Func. Count:	264,	Neg. LLF:	-2039.267578906886
Iteration:	25,	Func. Count:	277,	Neg. LLF:	-2039.7750093727677
Iteration:	26,	Func. Count:	288,	Neg. LLF:	-2039.790273228073
Iteration:	27,	Func. Count:	298,	Neg. LLF:	-2041.7720421525207
Iteration:	28,	Func. Count:	310,	Neg. LLF:	-2041.9722358536424
Iteration:	29,	Func. Count:	323,	Neg. LLF:	-2042.1714203394113
Iteration:	30,	Func. Count:	336,	Neg. LLF:	-2042.366627632578
Iteration:	31,	Func. Count:	353,	Neg. LLF:	-2042.369298513501
Iteration:	32,	Func. Count:	368,	Neg. LLF:	-2042.443685382474
Iteration:	33,	Func. Count:	383,	Neg. LLF:	-2042.7945502775947
Iteration:	34,	Func. Count:	398,	Neg. LLF:	-2043.1300285702955
Iteration:	35,	Func. Count:	417,	Neg. LLF:	-2043.1344843403617
Iteration:	36,	Func. Count:	436,	Neg. LLF:	-2043.1337032761364
Iteration:	37,	Func. Count:	453,	Neg. LLF:	-2043.140241372578
Iteration:	38,	Func. Count:	468,	Neg. LLF:	-2043.1620086333048
Iteration:	39,	Func. Count:	483,	Neg. LLF:	-2043.2886109473661
Iteration:	40,	Func. Count:	498,	Neg. LLF:	-2043.3652793659119
Iteration:	41,	Func. Count:	513,	Neg. LLF:	-2043.4323600177518
Iteration:	42,	Func. Count:	527,	Neg. LLF:	-2043.4905604841033
Iteration:	43,	Func. Count:	540,	Neg. LLF:	-2043.805431290666
Iteration:	44,	Func. Count:	559,	Neg. LLF:	-2043.8052735118022
Iteration:	45,	Func. Count:	577,	Neg. LLF:	-2043.8082233371545
Iteration:	46,	Func. Count:	596,	Neg. LLF:	-2043.8089843884743
Iteration:	47,	Func. Count:	615,	Neg. LLF:	-2043.8100253754415
Iteration:	48,	Func. Count:	633,	Neg. LLF:	-2043.8915626254125
Iteration:	49,	Func. Count:	649,	Neg. LLF:	-2043.932430091175
Iteration:	50,	Func. Count:	664,	Neg. LLF:	-2043.956607275634
Iteration:	51,	Func. Count:	679,	Neg. LLF:	-2044.1304682790455
Iteration:	52,	Func. Count:	694,	Neg. LLF:	-2044.2903157290536

Optimization terminated successfully. (Exit mode 0)

Current function value: -2044.2903076767718

Iterations: 56

Function evaluations: 705

Gradient evaluations: 52

```
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\arch\univariate\distribution.py:1064: RuntimeWarning: overflow encountered in power
  lls -= 0.5 * abs(resids / (sqrt(sigma2) * c)) ** nu
```

In [204]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          China    R-squared:
-0.000
Mean Model:            AR      Adj. R-squared:
-0.002
Vol Model:             EGARCH   Log-Likelihood:
2044.29
Distribution:          Generalized Error Distribution    AIC:
-4074.58
Method:                Maximum Likelihood             BIC:
-4042.43
                                           No. Observations:
730
Date:                  Tue, May 05 2020    Df Residuals:
723
Time:                  11:48:55           Df Model:
7
```

Mean Model

```
=====
===
              coef      std err          t      P>|t|      95.0% Conf. I
nt.
-----
---
Const        1.0760e-04  1.264e-04      0.851      0.395  [-1.402e-04,3.554e-
04]
China[1]     2.7307e-03  2.689e-02      0.102      0.919  [-4.996e-02,5.543e-
02]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
----
omega        -0.0323  1.393e-06 -2.321e+04      0.000  [-3.234e-02,-3.234e
-02]
alpha[1]     -0.0318  9.306e-04 -34.168  7.202e-256  [-3.362e-02,-2.997e
-02]
gamma[1]     8.2378e-04  3.405e-04      2.419  1.554e-02  [1.564e-04,1.491e
-03]
beta[1]       0.9966  2.895e-10  3.442e+09      0.000      [ 0.997, 0.
997]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu           1.2174  6.106e-03  199.358      0.000  [ 1.205, 1.229]
=====
```

Covariance estimator: robust

In [205]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[205]:

```
(array([ 0.05681871,  0.06256439,  0.42419998,  1.39526647,  4.09963906,
         4.14735476,  8.00731647,  8.15305697,  8.85603148, 10.91246791,
        11.26643146, 11.47198048, 11.50004396, 11.50089791, 13.54757615,
        13.90739308, 15.83889308, 16.68901359, 16.71773418, 25.93776181])),
array([0.81159664, 0.96920203, 0.9351992 , 0.84501731, 0.53516147,
        0.65674297, 0.33194919, 0.41866378, 0.45066863, 0.36437815,
        0.42122008, 0.48896031, 0.56900282, 0.64631575, 0.56008093,
        0.60561283, 0.5352834 , 0.54457499, 0.60898404, 0.16787727]))
```

In [208]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_gfc['South Africa'],lags =1, mean='AR', vol = 'EGARCH', p =1
, o =1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -1737.6190805273113
Iteration:      2,  Func. Count:     25,  Neg. LLF: -1738.2995222354139
Iteration:      3,  Func. Count:     37,  Neg. LLF: -1741.8139942203152
Iteration:      4,  Func. Count:     50,  Neg. LLF: -1742.336150499612
Iteration:      5,  Func. Count:     62,  Neg. LLF: -1742.93839173946
Iteration:      6,  Func. Count:     74,  Neg. LLF: -1743.0087346464402
Iteration:      7,  Func. Count:     86,  Neg. LLF: -1743.0151562467506
Iteration:      8,  Func. Count:     96,  Neg. LLF: -1743.3353078002297
Iteration:      9,  Func. Count:    106,  Neg. LLF: -1744.0689669232665
Iteration:     10,  Func. Count:    116,  Neg. LLF: -1744.220313370748
Iteration:     11,  Func. Count:    125,  Neg. LLF: -1744.238792522012
Iteration:     12,  Func. Count:    134,  Neg. LLF: -1744.24307193285
Iteration:     13,  Func. Count:    143,  Neg. LLF: -1744.2434610352466
Iteration:     14,  Func. Count:    153,  Neg. LLF: -1744.2434735122133
Iteration:     15,  Func. Count:    163,  Neg. LLF: -1744.2434775996671
```

```
Optimization terminated successfully. (Exit mode 0)
Current function value: -1744.2434784154261
Iterations: 15
Function evaluations: 165
Gradient evaluations: 15
```


In [209]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          South Africa    R-squared:
0.005
Mean Model:              AR    Adj. R-squared:
0.004
Vol Model:              EGARCH    Log-Likelihood:
1744.24
Distribution:    Generalized Error Distribution    AIC:
-3474.49
Method:          Maximum Likelihood    BIC:
-3442.34
No. Observations:
730
Date:            Tue, May 05 2020    Df Residuals:
723
Time:            11:49:20    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Con
f. Int.
-----
Const          8.8119e-04  5.961e-04      1.478      0.139  [-2.872e-04, 2.0
50e-03]
Sout...ica[1]  -0.0595  2.770e-03     -21.492  1.852e-102 [-6.497e-02, -5.4
11e-02]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega          -0.1423  5.506e-02     -2.584  9.761e-03 [ -0.250, -3.437e-0
2]
alpha[1]         0.0840  4.526e-02      1.857  6.334e-02 [-4.670e-03,  0.17
3]
gamma[1]        -0.0894  2.428e-02     -3.681  2.320e-04 [ -0.137, -4.179e-0
2]
beta[1]          0.9822  7.325e-03    134.100      0.000  [  0.968,  0.99
7]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu              1.5410      0.140     11.003  3.691e-28 [  1.266,  1.815]
=====
```

Covariance estimator: robust

In [210]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[210]:

```
(array([ 1.06624815,  2.9018797 ,  2.98671968,  3.08546711,  4.15554078,
         4.35653846,  5.70261364,  5.94172616,  7.6416609 , 10.20588228,
        19.0705238 , 21.7643132 , 26.12286559, 36.68561356, 37.64826777,
        48.13702744, 48.14254286, 52.07212816, 53.43131219, 54.22766936])),
array([3.01794439e-01, 2.34349931e-01, 3.93677275e-01, 5.43625955e-01,
        5.27246303e-01, 6.28546286e-01, 5.74870480e-01, 6.53759468e-01,
        5.70621753e-01, 4.22620119e-01, 5.98392730e-02, 4.02477761e-02,
        1.63664433e-02, 8.23040015e-04, 1.01675914e-03, 4.52024043e-05,
        8.16664400e-05, 3.64726641e-05, 4.02857404e-05, 5.35180556e-05]))
```

PRE COVID

In [211]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_covid['US'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,
q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -5580.278347773461
Iteration:      2,  Func. Count:     26,  Neg. LLF: -5580.310394320715
Iteration:      3,  Func. Count:     39,  Neg. LLF: -5600.4213067670125
Iteration:      4,  Func. Count:     51,  Neg. LLF: -5601.620671205506
Iteration:      5,  Func. Count:     63,  Neg. LLF: -5601.711965252262
Iteration:      6,  Func. Count:     74,  Neg. LLF: -5602.312139358798
Iteration:      7,  Func. Count:     84,  Neg. LLF: -5611.17098014576
Iteration:      8,  Func. Count:     95,  Neg. LLF: -5611.282636605485
Iteration:      9,  Func. Count:    106,  Neg. LLF: -5611.294203693226
Iteration:     10,  Func. Count:    116,  Neg. LLF: -5611.49492513223
Iteration:     11,  Func. Count:    125,  Neg. LLF: -5611.536784436759
Iteration:     12,  Func. Count:    134,  Neg. LLF: -5611.5396985211255
Iteration:     13,  Func. Count:    143,  Neg. LLF: -5611.539789731589
Iteration:     14,  Func. Count:    152,  Neg. LLF: -5611.539791870489
```

Optimization terminated successfully. (Exit mode 0)

Current function value: -5611.539791870465

Iterations: 14

Function evaluations: 152

Gradient evaluations: 14

In [212]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          US    R-squared:
-0.000
Mean Model:            AR    Adj. R-squared:
-0.001
Vol Model:             EGARCH Log-Likelihood:
5611.54
Distribution:          Generalized Error Distribution AIC:
-11209.1
Method:                Maximum Likelihood BIC:
-11171.5

No. Observations:
1577
Date:                  Tue, May 05 2020 Df Residuals:
1570
Time:                  11:50:11 Df Model:
7
```

Mean Model

```
=====
===
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nt.
---
Const          5.8576e-04  1.512e-04      3.874  1.073e-04  [2.894e-04,8.822e-04]
US[1]          -0.0205    2.291e-02     -0.894    0.371 [-6.539e-02,2.442e-02]
```

Volatility Model

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
omega          -0.6881      0.128     -5.375  7.675e-08 [-0.939, -0.437]
alpha[1]         0.2086   3.700e-02      5.637  1.735e-08 [ 0.136,  0.281]
gamma[1]        -0.1975   2.643e-02     -7.473  7.841e-14 [-0.249, -0.146]
beta[1]          0.9299   1.311e-02     70.959    0.000 [ 0.904,  0.956]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu              1.2628   7.126e-02     17.721  2.913e-70 [ 1.123,  1.402]
=====
```

Covariance estimator: robust



In [213]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[213]:

```
(array([ 0.14834428,  4.24550032,  5.16457582,  6.37881404, 11.53258952,
        11.54058526, 11.61978289, 12.86001682, 12.98840429, 15.39091856,
        15.49956045, 15.5749091 , 18.15067571, 18.45064937, 18.50046325,
        18.56832741, 19.35903688, 21.53402289, 30.41733073, 33.39835777]),
 array([0.70012267, 0.11970198, 0.16013521, 0.17258804, 0.04178514,
        0.07303845, 0.1137764 , 0.11675761, 0.16313166, 0.1184463 ,
        0.16074955, 0.21149064, 0.15188175, 0.1870198 , 0.23726889,
        0.29168213, 0.30831718, 0.25333134, 0.04672162, 0.03049456]))
```

In [214]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_covid['Brazil'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =
1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -4542.356512869454
Iteration:      2,  Func. Count:     25,  Neg. LLF: -4542.399101848944
Iteration:      3,  Func. Count:     38,  Neg. LLF: -4547.418790732227
Iteration:      4,  Func. Count:     52,  Neg. LLF: -4547.497672505573
Iteration:      5,  Func. Count:     65,  Neg. LLF: -4547.579860350085
Iteration:      6,  Func. Count:     77,  Neg. LLF: -4547.7830031019275
Iteration:      7,  Func. Count:     89,  Neg. LLF: -4547.787809838255
Iteration:      8,  Func. Count:    101,  Neg. LLF: -4547.788119298722
Iteration:      9,  Func. Count:    111,  Neg. LLF: -4547.8200498347705
Iteration:     10,  Func. Count:    120,  Neg. LLF: -4547.821255285227
Iteration:     11,  Func. Count:    130,  Neg. LLF: -4547.821279604117
Iteration:     12,  Func. Count:    140,  Neg. LLF: -4547.8212831424
```

Optimization terminated successfully. (Exit mode 0)

Current function value: -4547.821284060574

Iterations: 12

Function evaluations: 141

Gradient evaluations: 12

In [215]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          Brazil    R-squared:
0.000
Mean Model:            AR      Adj. R-squared:
-0.000
Vol Model:            EGARCH    Log-Likelihood:
4547.82
Distribution:          Generalized Error Distribution    AIC:
-9081.64
Method:                Maximum Likelihood    BIC:
-9044.10
                                No. Observations:
1577
Date:                  Tue, May 05 2020    Df Residuals:
1570
Time:                  11:53:08    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|          95.0% Conf.
Int.
-----
----
Const      3.1204e-04  3.154e-04      0.989      0.323  [-3.062e-04, 9.303e
-04]
Brazil[1]   -0.0204    3.123e-03     -6.516    7.207e-11 [-2.647e-02, -1.423e
-02]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|          95.0% Conf.
Int.
-----
----
omega      -0.2177    9.347e-02     -2.329    1.984e-02  [ -0.401, -3.452e
-02]
alpha[1]    0.1050    2.458e-02      4.272    1.936e-05  [5.683e-02, 0.
153]
gamma[1]    -0.0455    1.551e-02     -2.935    3.338e-03 [-7.593e-02, -1.512e
-02]
beta[1]     0.9744    1.097e-02     88.821      0.000      [ 0.953, 0.
996]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|          95.0% Conf. Int.
-----
nu           1.5403      0.116     13.252    4.367e-40 [ 1.313, 1.768]
=====
```

Covariance estimator: robust

In [216]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[216]:

```
(array([ 0.04422755,  1.11718436,  1.4269712 ,  3.79873364,  3.80204019,
         3.92815849,  5.67840004,  9.71803969, 12.0049004 , 12.00668376,
        14.25772406, 14.30579122, 14.55911681, 15.20805254, 15.21513304,
        15.6261333 , 17.9961362 , 21.6539591 , 21.82055553, 22.57841983])),
array([0.83343082, 0.57201379, 0.69922489, 0.43392896, 0.57825473,
        0.68639805, 0.57776167, 0.28537616, 0.21303318, 0.28460943,
        0.21905919, 0.28160876, 0.33567815, 0.36408201, 0.43603469,
        0.47934433, 0.38908468, 0.24771119, 0.29327778, 0.30996578]))
```

In [217]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_covid['Russia'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =
1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -4425.012884158
Iteration:      2,  Func. Count:     28,  Neg. LLF: -4425.613428037687
Iteration:      3,  Func. Count:     41,  Neg. LLF: -4427.46125432635
Iteration:      4,  Func. Count:     54,  Neg. LLF: -4427.491571129488
Iteration:      5,  Func. Count:     67,  Neg. LLF: -4427.587795533436
Iteration:      6,  Func. Count:     80,  Neg. LLF: -4427.612772259753
Iteration:      7,  Func. Count:     90,  Neg. LLF: -4428.967348931055
Iteration:      8,  Func. Count:    100,  Neg. LLF: -4429.383448194398
Iteration:      9,  Func. Count:    111,  Neg. LLF: -4429.402150006626
Iteration:     10,  Func. Count:    121,  Neg. LLF: -4429.66724565175
Iteration:     11,  Func. Count:    130,  Neg. LLF: -4429.677260754083
Iteration:     12,  Func. Count:    139,  Neg. LLF: -4429.68369716274
Iteration:     13,  Func. Count:    148,  Neg. LLF: -4429.695067359284
Iteration:     14,  Func. Count:    157,  Neg. LLF: -4429.695736106491
Iteration:     15,  Func. Count:    166,  Neg. LLF: -4429.695792516773
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -4429.695793312121
```

```
Iterations: 15
```

```
Function evaluations: 167
```

```
Gradient evaluations: 15
```

In [218]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:                Russia    R-squared:
0.003
Mean Model:                  AR        Adj. R-squared:
0.002
Vol Model:                  EGARCH     Log-Likelihood:
4429.70
Distribution:    Generalized Error Distribution    AIC:
-8845.39
Method:                Maximum Likelihood    BIC:
-8807.85
                                No. Observations:
1577
Date:                Tue, May 05 2020    Df Residuals:
1570
Time:                11:53:17    Df Model:
7
```

Mean Model

```
=====
===
              coef      std err          t      P>|t|      95.0% Conf. I
nt.
-----
---
Const      1.3899e-04  3.392e-04      0.410      0.682  [-5.259e-04,8.038e-
04]
Russia[1]   0.0404    2.656e-02      1.520      0.129  [-1.168e-02,9.242e-
02]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
----
omega      -0.1058    3.560e-02     -2.971    2.971e-03    [ -0.176,-3.599e
-02]
alpha[1]    0.0836    1.609e-02      5.193    2.070e-07    [5.203e-02, 0.
115]
gamma[1]    -0.0697    1.415e-02     -4.925    8.448e-07    [-9.742e-02,-4.195e
-02]
beta[1]     0.9873    4.309e-03    229.142      0.000      [ 0.979, 0.
996]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu          1.4322      0.101     14.189    1.074e-45    [ 1.234, 1.630]
=====
```

Covariance estimator: robust

In [219]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[219]:

```
(array([ 0.32239441,  2.58543332,  3.46205158,  7.89255162,  8.44997796,
         8.54381099, 11.2977833 , 15.07554654, 21.69628569, 21.72770511,
        22.2518403 , 23.29617259, 25.92847982, 26.03477352, 26.46358163,
        27.22261593, 30.70827099, 30.77244383, 30.81717999, 31.01711269])),
array([0.57017224, 0.27452398, 0.32571736, 0.09559442, 0.1331183 ,
        0.20090546, 0.12614699, 0.05769304, 0.00989301, 0.01655348,
        0.0224932 , 0.02531421, 0.01738061, 0.02562468, 0.03342329,
        0.03907415, 0.02166693, 0.03058028, 0.04227658, 0.05496495]))
```

In [227]:

```
#Fitting the model AR(2)-EGARCH(1,1)
res = arch_model(y=df_pre_covid['India'],lags =2, mean='AR', vol = 'EGARCH', p =1, o =1
, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      10,  Neg. LLF: -4960.1903342409405
Iteration:      2,  Func. Count:      30,  Neg. LLF: 626961.6730978657
Iteration:      3,  Func. Count:      44,  Neg. LLF: 559598.1164905126
Positive directional derivative for linesearch (Exit mode 8)
Current function value: 559598.0537983617
Iterations: 7
Function evaluations: 44
Gradient evaluations: 3
```

```
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\arch\univariate\distribut
ion.py:1064: RuntimeWarning: overflow encountered in power
  lls -= 0.5 * abs(resids / (sqrt(sigma2) * c)) ** nu
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\arch\univariate\base.py:7
11: ConvergenceWarning: The optimizer returned code 8. The message is:
Positive directional derivative for linesearch
See scipy.optimize.fmin_slsqp for code meaning.
```

ConvergenceWarning,

In [228]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:                India    R-squared:
-54344455.654
Mean Model:                  AR      Adj. R-squared:
-54413552.229
Vol Model:                  EGARCH   Log-Likelihood:
-559598.
Distribution:      Generalized Error Distribution    AIC:
1.11921e+06
Method:              Maximum Likelihood    BIC:
1.11926e+06
                                No. Observations:
1576
Date:                  Tue, May 05 2020    Df Residuals:
1568
Time:                  11:54:22    Df Model:
8
```

Mean Model

```
=====
      coef    std err          t      P>|t|  95.0% Conf. Int.
-----
Const      64.8770    4.902e-02   1323.613    0.000 [ 64.781, 64.973]
India[1]     0.1275     0.991         0.129    0.898 [ -1.815,  2.070]
India[2]     0.0462     0.561     8.239e-02    0.934 [ -1.053,  1.146]
```

Volatility Model

```
=====
      coef    std err          t      P>|t|  95.0% Conf. Int.
-----
omega      -0.2591     0.598        -0.433    0.665 [ -1.432,  0.914]
alpha[1]    1.6655     1.811         0.919    0.358 [ -1.885,  5.216]
gamma[1]    -0.2771     1.501        -0.185    0.854 [ -3.219,  2.665]
beta[1]     0.9797    1.593e-03   614.840    0.000 [  0.977,  0.983]
```

Distribution

```
=====
      coef    std err          t      P>|t|  95.0% Conf. Int.
-----
nu          1.5496    6.465e-02   23.970 5.680e-127 [  1.423,  1.676]
=====
```

Covariance estimator: robust

WARNING: The optimizer did not indicate successful convergence. The message was Positive directional derivative for linesearch.
See convergence_flag.

In [230]:

```
acorr_ljungbox(res.resid[2:], lags=20,boxpierce=False)
```

Out[230]:

```
(array([11.55694353, 18.73239926, 19.16659285, 20.99655471, 20.99830687,
        21.01399401, 21.17032446, 21.18116483, 21.3911284 , 21.79220159,
        22.49972482, 24.82504829, 24.82537155, 24.98187287, 26.14311928,
        26.14966927, 26.61099761, 27.71369427, 29.16177888, 32.11899204])),
array([6.74967170e-04, 8.55679612e-05, 2.52548219e-04, 3.17167629e-04,
        8.10656479e-04, 1.82402488e-03, 3.52607308e-03, 6.68143749e-03,
        1.10225201e-02, 1.61989158e-02, 2.07753746e-02, 1.56740222e-02,
        2.43334999e-02, 3.47467716e-02, 3.65450028e-02, 5.19583347e-02,
        6.40250694e-02, 6.65479188e-02, 6.34826503e-02, 4.20467778e-02]))
```

In [231]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_covid['China'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1
, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -4911.7693685268605
Iteration:      2,  Func. Count:     28,  Neg. LLF: -3698.2751747471143
Iteration:      3,  Func. Count:     43,  Neg. LLF: -3698.791606989712
Iteration:      4,  Func. Count:     55,  Neg. LLF: -3707.812336231529
Iteration:      5,  Func. Count:     67,  Neg. LLF: -3713.0645278547345
Iteration:      6,  Func. Count:     77,  Neg. LLF: -4271.062632553922
Iteration:      7,  Func. Count:     91,  Neg. LLF: -4642.728440032011
Iteration:      8,  Func. Count:    103,  Neg. LLF: -4682.932086920249
Iteration:      9,  Func. Count:    115,  Neg. LLF: -4745.898440911482
Iteration:     10,  Func. Count:    125,  Neg. LLF: -4782.741648354715
Iteration:     11,  Func. Count:    135,  Neg. LLF: -4831.1255208932835
Iteration:     12,  Func. Count:    145,  Neg. LLF: -4850.224323239567
Iteration:     13,  Func. Count:    155,  Neg. LLF: -4913.328579744782
Iteration:     14,  Func. Count:    165,  Neg. LLF: -4917.031556165826
Iteration:     15,  Func. Count:    175,  Neg. LLF: -4918.226035617386
Iteration:     16,  Func. Count:    185,  Neg. LLF: -4921.514212284814
Iteration:     17,  Func. Count:    195,  Neg. LLF: -4923.033482447547
Iteration:     18,  Func. Count:    204,  Neg. LLF: -4925.547404138037
Iteration:     19,  Func. Count:    213,  Neg. LLF: -4928.643730244199
Iteration:     20,  Func. Count:    223,  Neg. LLF: -4931.650549158823
Iteration:     21,  Func. Count:    232,  Neg. LLF: -4931.741957973427
Iteration:     22,  Func. Count:    242,  Neg. LLF: -4931.8874131907905
Iteration:     23,  Func. Count:    251,  Neg. LLF: -4931.940799826394
Iteration:     24,  Func. Count:    260,  Neg. LLF: -4931.974859585749
Iteration:     25,  Func. Count:    270,  Neg. LLF: -4931.980949726993
Iteration:     26,  Func. Count:    279,  Neg. LLF: -4931.985234848275
Iteration:     27,  Func. Count:    288,  Neg. LLF: -4932.000811826563
Iteration:     28,  Func. Count:    297,  Neg. LLF: -4932.002628475688
Iteration:     29,  Func. Count:    306,  Neg. LLF: -4932.002664815305
Iteration:     30,  Func. Count:    315,  Neg. LLF: -4932.0026667529955
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -4932.002666753009
```

```
Iterations: 30
```

```
Function evaluations: 315
```

```
Gradient evaluations: 30
```

```
C:\Users\Divyam Jain\Anaconda3\lib\site-packages\arch\univariate\distributed.py:1064: RuntimeWarning: overflow encountered in power
lls -= 0.5 * abs(resids / (sqrt(sigma2) * c)) ** nu
```

In [232]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          China    R-squared:
-0.001
Mean Model:            AR      Adj. R-squared:
-0.002
Vol Model:            EGARCH   Log-Likelihood:
4932.00
Distribution:    Generalized Error Distribution    AIC:
-9850.01
Method:          Maximum Likelihood    BIC:
-9812.46
No. Observations:
1577
Date:            Tue, May 05 2020    Df Residuals:
1570
Time:            11:54:37    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
----
Const      3.5971e-04  2.674e-04      1.345      0.179  [-1.644e-04,8.838e
-04]
China[1]   -2.5265e-03  2.613e-02  -9.670e-02      0.923  [-5.374e-02,4.868e
-02]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
----
omega      -0.0603  3.903e-02     -1.546      0.122  [ -0.137,1.616e
-02]
alpha[1]     0.1551  2.762e-02      5.615  1.969e-08  [ 0.101, 0.
209]
gamma[1]    -6.9118e-03  1.613e-02     -0.429      0.668  [-3.853e-02,2.470e
-02]
beta[1]      0.9923  4.359e-03    227.623      0.000  [ 0.984, 1.
001]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu           1.1906  6.421e-02    18.541  9.695e-77  [ 1.065, 1.316]
=====
```

Covariance estimator: robust

In [233]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[233]:

```
(array([ 4.95512615,  9.17908357, 10.98909509, 16.29031854, 17.23787882,
        19.53805783, 23.5370013 , 25.04064397, 31.8367961 , 32.67332357,
        33.12499506, 33.14727416, 34.42660975, 34.47504824, 34.63146701,
        36.5601295 , 36.83588305, 36.88920271, 42.61232492, 42.78718579])),
array([0.02601343, 0.01015751, 0.01178499, 0.00265334, 0.00407006,
        0.00334516, 0.00137363, 0.00153009, 0.00021248, 0.00030904,
        0.00050218, 0.00091809, 0.00103636, 0.00175691, 0.00277399,
        0.00241738, 0.00354172, 0.00541742, 0.00146413, 0.00218088]))
```

In [234]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_pre_covid['South Africa'],lags =1, mean='AR', vol = 'EGARCH', p =
1, o =1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -4164.416495885588
Iteration:      2,  Func. Count:     25,  Neg. LLF: -4164.526590562233
Iteration:      3,  Func. Count:     38,  Neg. LLF: -4165.10221586873
Iteration:      4,  Func. Count:     51,  Neg. LLF: -4165.4245139426675
Iteration:      5,  Func. Count:     63,  Neg. LLF: -4165.707352885998
Iteration:      6,  Func. Count:     75,  Neg. LLF: -4165.777161017922
Iteration:      7,  Func. Count:     87,  Neg. LLF: -4165.790599550291
Iteration:      8,  Func. Count:     97,  Neg. LLF: -4166.662487661981
Iteration:      9,  Func. Count:    107,  Neg. LLF: -4167.155314266581
Iteration:     10,  Func. Count:    116,  Neg. LLF: -4167.400925538408
Iteration:     11,  Func. Count:    126,  Neg. LLF: -4167.5655981734035
Iteration:     12,  Func. Count:    136,  Neg. LLF: -4167.585531094064
Iteration:     13,  Func. Count:    146,  Neg. LLF: -4167.586410444039
Iteration:     14,  Func. Count:    156,  Neg. LLF: -4167.586593046217
Iteration:     15,  Func. Count:    165,  Neg. LLF: -4167.5866309389185
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -4167.586631781061
```

```
Iterations: 15
```

```
Function evaluations: 166
```

```
Gradient evaluations: 15
```

In [235]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          South Africa    R-squared:
-0.000
Mean Model:              AR    Adj. R-squared:
-0.001
Vol Model:              EGARCH    Log-Likelihood:
4167.59
Distribution:    Generalized Error Distribution    AIC:
-8321.17
Method:          Maximum Likelihood    BIC:
-8283.63
No. Observations:
1577
Date:            Tue, May 05 2020    Df Residuals:
1570
Time:            11:54:49    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Con
f. Int.
-----
Const          1.2627e-04  5.691e-04      0.222      0.824 [-9.892e-04,1.2
42e-03]
Sout...ica[1] -6.4789e-03  2.863e-02     -0.226      0.821 [-6.259e-02,4.9
63e-02]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega          -0.2903      0.537     -0.541      0.589 [ -1.342,  0.76
2]
alpha[1]        0.1386      0.133      1.039      0.299 [ -0.123,  0.40
0]
gamma[1]       -0.0581  2.631e-02     -2.207  2.730e-02 [ -0.110,-6.504e-0
3]
beta[1]         0.9639  6.661e-02     14.470  1.883e-47 [  0.833,  1.09
4]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu           1.5736  9.326e-02     16.873  7.150e-64 [  1.391,  1.756]
=====
```

Covariance estimator: robust

In [236]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[236]:

```
(array([ 0.03451255,  3.25636074,  7.65893746,  9.90172898, 10.1490075 ,
        10.44333047, 11.6687158 , 11.71324185, 13.78768472, 14.40155819,
        14.46465262, 15.66462495, 20.43697681, 20.9224479 , 23.05242456,
        23.053411 , 23.09938379, 23.14557165, 25.92696353, 26.008923 ]),
array([0.8526208 , 0.19628642, 0.05361227, 0.04211598, 0.07112162,
        0.1071815 , 0.11199326, 0.1644642 , 0.13008066, 0.1554505 ,
        0.20833973, 0.20708415, 0.08483722, 0.10363643, 0.08303312,
        0.11231414, 0.14604308, 0.18505793, 0.13223701, 0.16551738]))
```

POST COVID

In [237]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_covid['US'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =1,
q=1 , dist ='ged', rescale = False).fit()
```

Iteration:	1,	Func. Count:	9,	Neg. LLF:	-231.24293107374552
Iteration:	2,	Func. Count:	25,	Neg. LLF:	-232.22336337983046
Iteration:	3,	Func. Count:	38,	Neg. LLF:	-246.51002796738308
Iteration:	4,	Func. Count:	50,	Neg. LLF:	-248.35643134355183
Iteration:	5,	Func. Count:	61,	Neg. LLF:	-248.99086233705896
Iteration:	6,	Func. Count:	72,	Neg. LLF:	-249.21676653483047
Iteration:	7,	Func. Count:	82,	Neg. LLF:	-251.85367338377785
Iteration:	8,	Func. Count:	93,	Neg. LLF:	-251.95022890764315
Iteration:	9,	Func. Count:	102,	Neg. LLF:	-252.57408980317737
Iteration:	10,	Func. Count:	112,	Neg. LLF:	-252.6124643261412
Iteration:	11,	Func. Count:	122,	Neg. LLF:	-253.04150256645093
Iteration:	12,	Func. Count:	131,	Neg. LLF:	-253.0881376952543
Iteration:	13,	Func. Count:	140,	Neg. LLF:	-253.09585188574667
Iteration:	14,	Func. Count:	152,	Neg. LLF:	-253.09608599557578
Iteration:	15,	Func. Count:	162,	Neg. LLF:	-253.09719678277173
Iteration:	16,	Func. Count:	172,	Neg. LLF:	-253.0976541848415
Iteration:	17,	Func. Count:	181,	Neg. LLF:	-253.09942620420907
Iteration:	18,	Func. Count:	193,	Neg. LLF:	-253.0994308053046
Iteration:	19,	Func. Count:	202,	Neg. LLF:	-253.09969938375133
Iteration:	20,	Func. Count:	211,	Neg. LLF:	-253.0997881173278
Iteration:	21,	Func. Count:	220,	Neg. LLF:	-253.0998581562714
Iteration:	22,	Func. Count:	230,	Neg. LLF:	-253.09986265792892
Iteration:	23,	Func. Count:	240,	Neg. LLF:	-253.09986570554753
Iteration:	24,	Func. Count:	250,	Neg. LLF:	-253.09986877502692
Iteration:	25,	Func. Count:	260,	Neg. LLF:	-253.0998719210348
Iteration:	26,	Func. Count:	270,	Neg. LLF:	-253.0998754734303
Iteration:	27,	Func. Count:	280,	Neg. LLF:	-253.09988010656573
Iteration:	28,	Func. Count:	289,	Neg. LLF:	-253.09988544817685
Iteration:	29,	Func. Count:	300,	Neg. LLF:	-253.09989013243955
Iteration:	30,	Func. Count:	311,	Neg. LLF:	-253.0998912133008
Iteration:	31,	Func. Count:	320,	Neg. LLF:	-253.09989775460377
Iteration:	32,	Func. Count:	330,	Neg. LLF:	-253.09990064352212
Iteration:	33,	Func. Count:	339,	Neg. LLF:	-253.09990376563294
Iteration:	34,	Func. Count:	348,	Neg. LLF:	-253.09990506815348

Optimization terminated successfully. (Exit mode 0)

Current function value: -253.09990579844916

Iterations: 34

Function evaluations: 350

Gradient evaluations: 34

In [238]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          US    R-squared:
0.058
Mean Model:           AR    Adj. R-squared:
0.047
Vol Model:           EGARCH  Log-Likelihood:
253.100
Distribution:    Generalized Error Distribution  AIC:
-492.200
Method:           Maximum Likelihood  BIC:
-474.701

No. Observations:
90
Date:           Tue, May 05 2020  Df Residuals:
83
Time:           11:56:00  Df Model:
7
```

Mean Model

```
=====
==
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
--
Const      1.4976e-03  5.667e-05     26.426  6.837e-154  [1.387e-03,1.609e-0
3]
US[1]      -0.1096   1.706e-04    -642.195      0.000      [ -0.110, -0.10
9]
```

Volatility Model

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
omega      -0.4049      0.210     -1.932  5.338e-02  [ -0.816,5.890e-03]
alpha[1]     0.5639      0.149      3.796  1.468e-04  [ 0.273, 0.855]
gamma[1]    -0.2290      0.130     -1.763  7.791e-02  [-0.484,2.559e-02]
beta[1]      0.9474   2.622e-02    36.134  6.619e-286  [ 0.896, 0.999]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu           1.0858      0.276      3.937  8.258e-05  [ 0.545, 1.626]
=====
```

Covariance estimator: robust

In [239]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[239]:

```
(array([ 4.72722184, 14.17924923, 15.77490838, 16.1049631 , 18.5185259 ,
        33.44158941, 47.72883776, 53.20785403, 54.76929577, 57.57516727,
        58.35341433, 59.03550102, 59.78629804, 64.69214104, 64.76331802,
        65.02303065, 65.05174241, 66.73752974, 66.83572752, 68.59411154])),
array([2.96888029e-02, 8.33710269e-04, 1.26106485e-03, 2.88150479e-03,
        2.36206841e-03, 8.62121169e-06, 4.02268944e-08, 9.83038006e-09,
        1.34766735e-08, 1.03921036e-08, 1.87214924e-08, 3.38180617e-08,
        5.73650832e-08, 1.73598698e-08, 3.75922155e-08, 7.29979609e-08,
        1.50606330e-07, 1.59763880e-07, 3.06274918e-07, 3.08458557e-07]))
```

In [240]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_covid['Brazil'],lags =1, mean='AR', vol = 'EGARCH', p =1, o
=1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -201.5109594371654
Iteration:      2,  Func. Count:     26,  Neg. LLF: -203.5250890149456
Iteration:      3,  Func. Count:     38,  Neg. LLF: -211.96689490260886
Iteration:      4,  Func. Count:     50,  Neg. LLF: -216.0365852609705
Iteration:      5,  Func. Count:     61,  Neg. LLF: -217.53539490273693
Iteration:      6,  Func. Count:     72,  Neg. LLF: -217.76892412379172
Iteration:      7,  Func. Count:     83,  Neg. LLF: -218.24445725201275
Iteration:      8,  Func. Count:     93,  Neg. LLF: -218.7924966538008
Iteration:      9,  Func. Count:    104,  Neg. LLF: -219.0121536606142
Iteration:     10,  Func. Count:    113,  Neg. LLF: -219.68767534854055
Iteration:     11,  Func. Count:    122,  Neg. LLF: -219.9677464588264
Iteration:     12,  Func. Count:    131,  Neg. LLF: -220.07607224148288
Iteration:     13,  Func. Count:    140,  Neg. LLF: -220.2718670147022
Iteration:     14,  Func. Count:    149,  Neg. LLF: -220.4317044819675
Iteration:     15,  Func. Count:    158,  Neg. LLF: -220.4464716171509
Iteration:     16,  Func. Count:    167,  Neg. LLF: -220.4574841781055
Iteration:     17,  Func. Count:    176,  Neg. LLF: -220.45849706056626
Iteration:     18,  Func. Count:    185,  Neg. LLF: -220.4586618874169
Iteration:     19,  Func. Count:    194,  Neg. LLF: -220.45867133597875
```

Optimization terminated successfully. (Exit mode 0)

Current function value: -220.45867133598182

Iterations: 19

Function evaluations: 194

Gradient evaluations: 19

In [241]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          Brazil    R-squared:
-0.115
Mean Model:            AR        Adj. R-squared:
-0.128
Vol Model:            EGARCH    Log-Likelihood:
220.459
Distribution:          Generalized Error Distribution    AIC:
-426.917
Method:                Maximum Likelihood    BIC:
-409.419
                                No. Observations:
90
Date:                  Tue, May 05 2020    Df Residuals:
83
Time:                  11:56:30    Df Model:
7
```

Mean Model

```
=====
===
              coef      std err          t      P>|t|      95.0% Conf. I
nt.
-----
---
Const        5.5836e-04  9.761e-04      0.572      0.567 [-1.355e-03,2.471e-
03]
Brazil[1]     0.1604    7.014e-02      2.286    2.224e-02    [2.289e-02, 0.2
98]
```

Volatility Model

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
omega        -0.9101      0.324      -2.808    4.990e-03 [-1.545, -0.275]
alpha[1]       1.1014      0.310       3.555    3.786e-04 [ 0.494, 1.709]
gamma[1]      -0.5343      0.199      -2.690    7.139e-03 [-0.924, -0.145]
beta[1]        0.8887    3.931e-02     22.604    3.950e-113 [ 0.812, 0.966]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu            2.0275      0.367       5.530    3.205e-08 [ 1.309, 2.746]
=====
```

Covariance estimator: robust

In [242]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[242]:

```
(array([15.97447662, 22.77145011, 24.97486824, 25.2342018 , 26.66748981,
        32.46766389, 38.42454417, 38.5040484 , 38.91205595, 39.93887369,
        40.41256922, 40.42714638, 40.51203375, 40.59070924, 41.73913026,
        41.96229864, 45.87501897, 45.92142545, 46.87244873, 47.21408354])),
array([6.42022496e-05, 1.13564459e-05, 1.56284490e-05, 4.51385244e-05,
        6.62074546e-05, 1.32718012e-05, 2.51592916e-06, 6.07400393e-06,
        1.19488843e-05, 1.73698886e-05, 3.04039503e-05, 6.10628810e-05,
        1.14297880e-04, 2.06247040e-04, 2.46489123e-04, 3.99738147e-04,
        1.80186904e-04, 3.04604004e-04, 3.72483271e-04, 5.47760326e-04]))
```

In [243]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_covid['Russia'],lags =1, mean='AR', vol = 'EGARCH', p =1, o
=1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -222.33120233892123
Iteration:      2,  Func. Count:     28,  Neg. LLF: -204.30127237819713
Iteration:      3,  Func. Count:     39,  Neg. LLF: -206.2172087111114
Iteration:      4,  Func. Count:     51,  Neg. LLF: -208.91807212907176
Iteration:      5,  Func. Count:     63,  Neg. LLF: -211.2198946988378
Iteration:      6,  Func. Count:     75,  Neg. LLF: -212.8617181190392
Iteration:      7,  Func. Count:     86,  Neg. LLF: -215.1698499154858
Iteration:      8,  Func. Count:     97,  Neg. LLF: -216.50533319044453
Iteration:      9,  Func. Count:    107,  Neg. LLF: -220.45836448056684
Iteration:     10,  Func. Count:    117,  Neg. LLF: -221.90523810003097
Iteration:     11,  Func. Count:    127,  Neg. LLF: -223.43165273620843
Iteration:     12,  Func. Count:    137,  Neg. LLF: -224.80318391506702
Iteration:     13,  Func. Count:    147,  Neg. LLF: -225.59617576367748
Iteration:     14,  Func. Count:    157,  Neg. LLF: -226.5066649315545
Iteration:     15,  Func. Count:    167,  Neg. LLF: -227.0739540850752
Iteration:     16,  Func. Count:    177,  Neg. LLF: -227.8295481165866
Iteration:     17,  Func. Count:    187,  Neg. LLF: -228.00555934068694
Iteration:     18,  Func. Count:    197,  Neg. LLF: -228.10061858091265
Iteration:     19,  Func. Count:    207,  Neg. LLF: -228.1360986972297
Iteration:     20,  Func. Count:    216,  Neg. LLF: -228.18010616124033
Iteration:     21,  Func. Count:    225,  Neg. LLF: -228.28340590555712
Iteration:     22,  Func. Count:    234,  Neg. LLF: -228.31004067238302
Iteration:     23,  Func. Count:    243,  Neg. LLF: -228.32771895008992
Iteration:     24,  Func. Count:    252,  Neg. LLF: -228.3456921814956
Iteration:     25,  Func. Count:    261,  Neg. LLF: -228.35101724707732
Iteration:     26,  Func. Count:    270,  Neg. LLF: -228.35177703777347
Iteration:     27,  Func. Count:    279,  Neg. LLF: -228.35182715313238
Iteration:     28,  Func. Count:    288,  Neg. LLF: -228.35183201075824
```

Optimization terminated successfully. (Exit mode 0)

Current function value: -228.35183201074858

Iterations: 28

Function evaluations: 288

Gradient evaluations: 28

In [244]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          Russia    R-squared:
-0.029
Mean Model:            AR        Adj. R-squared:
-0.041
Vol Model:            EGARCH    Log-Likelihood:
228.352
Distribution:          Generalized Error Distribution    AIC:
-442.704
Method:                Maximum Likelihood    BIC:
-425.205

                                No. Observations:
90
Date:                  Tue, May 05 2020    Df Residuals:
83
Time:                  11:56:37    Df Model:
7
```

Mean Model

```
=====
===
              coef      std err          t      P>|t|      95.0% Conf. I
nt.
-----
---
Const      1.3535e-03  1.567e-03      0.864      0.388 [-1.718e-03,4.425e-
03]
Russia[1]   0.1054      0.127      0.830      0.406 [ -0.143,  0.3
54]
```

Volatility Model

```
=====
=
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
-
omega      -0.2810      0.124     -2.261  2.378e-02 [ -0.525,-3.737e-0
2]
alpha[1]    0.1905  9.093e-02      2.095  3.615e-02 [1.230e-02,  0.36
9]
gamma[1]    -0.2890      0.102     -2.836  4.574e-03 [ -0.489,-8.924e-0
2]
beta[1]     0.9633  1.690e-02     57.017      0.000 [  0.930,  0.99
6]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu          1.6516      0.430      3.844  1.211e-04 [  0.809,  2.494]
=====
```

Covariance estimator: robust

In [245]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[245]:

```
(array([ 2.51623547,  3.13622412,  3.44449488,  5.53589899,  5.67557355,
         6.44360587,  9.93478323, 10.29606005, 10.52718134, 10.5612209 ,
        15.18325317, 15.99706055, 16.56891889, 16.6830262 , 17.08605505,
        19.51169693, 20.33493202, 20.94567796, 21.29334914, 22.06741858])),
array([0.11267929, 0.20843833, 0.32803262, 0.2365919 , 0.33907734,
        0.37537204, 0.19229947, 0.24485818, 0.30951408, 0.39270776,
        0.1742603 , 0.19137073, 0.21976711, 0.27346323, 0.31374612,
        0.24302275, 0.2574575 , 0.28216252, 0.32082049, 0.33686356]))
```

In [246]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_covid['India'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =
1, q=1 , dist = 'ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -240.15046295562107
Iteration:      2,  Func. Count:     28,  Neg. LLF: -240.8586149078919
Iteration:      3,  Func. Count:     41,  Neg. LLF: -244.47763547236536
Iteration:      4,  Func. Count:     53,  Neg. LLF: -244.89023389338064
Iteration:      5,  Func. Count:     65,  Neg. LLF: -245.84684575326273
Iteration:      6,  Func. Count:     77,  Neg. LLF: -246.53570317203588
Iteration:      7,  Func. Count:     87,  Neg. LLF: -247.15670841984826
Iteration:      8,  Func. Count:     98,  Neg. LLF: -247.36696632181423
Iteration:      9,  Func. Count:    108,  Neg. LLF: -248.02020117938176
Iteration:     10,  Func. Count:    118,  Neg. LLF: -248.42478908394574
Iteration:     11,  Func. Count:    128,  Neg. LLF: -248.542711369841
Iteration:     12,  Func. Count:    138,  Neg. LLF: -248.5889824607171
Iteration:     13,  Func. Count:    148,  Neg. LLF: -248.63730566476553
Iteration:     14,  Func. Count:    157,  Neg. LLF: -248.65641119787952
Iteration:     15,  Func. Count:    166,  Neg. LLF: -248.69065618031752
Iteration:     16,  Func. Count:    176,  Neg. LLF: -248.69443260126798
Iteration:     17,  Func. Count:    185,  Neg. LLF: -248.69845708205702
Iteration:     18,  Func. Count:    194,  Neg. LLF: -248.70142586788643
Iteration:     19,  Func. Count:    206,  Neg. LLF: -248.7015778120981
Iteration:     20,  Func. Count:    215,  Neg. LLF: -248.70356545002593
Iteration:     21,  Func. Count:    224,  Neg. LLF: -248.70645962658563
Iteration:     22,  Func. Count:    233,  Neg. LLF: -248.7084102639232
Iteration:     23,  Func. Count:    242,  Neg. LLF: -248.7096758846622
Iteration:     24,  Func. Count:    252,  Neg. LLF: -248.70975627035267
Iteration:     25,  Func. Count:    262,  Neg. LLF: -248.70995012341177
Iteration:     26,  Func. Count:    272,  Neg. LLF: -248.71011020912758
Iteration:     27,  Func. Count:    282,  Neg. LLF: -248.7102032927235
Iteration:     28,  Func. Count:    292,  Neg. LLF: -248.71027770172674
Iteration:     29,  Func. Count:    302,  Neg. LLF: -248.71036144345268
Iteration:     30,  Func. Count:    312,  Neg. LLF: -248.71047430995486
Iteration:     31,  Func. Count:    323,  Neg. LLF: -248.71051091774726
Iteration:     32,  Func. Count:    335,  Neg. LLF: -248.7105197150778
Iteration:     33,  Func. Count:    347,  Neg. LLF: -248.71052128198153
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -248.71052142000656
```

```
Iterations: 33
```

```
Function evaluations: 352
```

```
Gradient evaluations: 33
```

In [247]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          India    R-squared:
0.018
Mean Model:            AR      Adj. R-squared:
0.007
Vol Model:            EGARCH   Log-Likelihood:
248.711
Distribution:          Generalized Error Distribution    AIC:
-483.421
Method:              Maximum Likelihood    BIC:
-465.922

                               No. Observations:
90
Date:                  Tue, May 05 2020    Df Residuals:
83
Time:                  11:56:47    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf.
Int.
-----
-----
Const      -9.1902e-04  6.705e-05    -13.706  9.293e-43  [-1.050e-03, -7.876
e-04]
India[1]    -0.0565    1.304e-04   -433.631  0.000  [-5.680e-02, -5.629
e-02]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
-----
omega      -0.2513    5.670e-02    -4.432  9.315e-06  [-0.362, -0.140]
alpha[1]   -0.0608      0.145      -0.421    0.674  [-0.344, 0.223]
gamma[1]   -0.5040      0.161     -3.139  1.694e-03  [-0.819, -0.189]
beta[1]     0.9692    5.822e-03   166.466  0.000  [0.958, 0.981]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
-----
nu          1.0301      0.227      4.535  5.760e-06  [0.585, 1.475]
=====
```

Covariance estimator: robust

In [248]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[248]:

```
(array([ 1.73894834,  2.03008679,  2.36337104,  2.37497053,  7.33578373,
        12.06539727, 20.75084344, 20.84662384, 21.51836649, 21.53477952,
        22.00210606, 23.76934845, 24.22868398, 24.44128388, 24.46435288,
        26.19042786, 26.96510673, 28.79721347, 29.35424326, 30.17455971])),
array([0.18727213, 0.3623867 , 0.50048951, 0.66715514, 0.19684121,
        0.06052567, 0.00415696, 0.00756621, 0.01053739, 0.0176582 ,
        0.02435693, 0.02186078, 0.02909051, 0.04050083, 0.05761597,
        0.05140698, 0.05858153, 0.05091443, 0.06061346, 0.06707411]))
```

In [249]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_covid['China'],lags =1, mean='AR', vol = 'EGARCH', p =1, o =
1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -270.03010205544416
Iteration:      2,  Func. Count:     24,  Neg. LLF: -270.1948698824057
Iteration:      3,  Func. Count:     36,  Neg. LLF: -272.12707476674274
Iteration:      4,  Func. Count:     48,  Neg. LLF: -272.7825422501792
Iteration:      5,  Func. Count:     58,  Neg. LLF: -275.1384403304085
Iteration:      6,  Func. Count:     68,  Neg. LLF: -275.86909730881695
Iteration:      7,  Func. Count:     78,  Neg. LLF: -276.1913134968901
Iteration:      8,  Func. Count:     87,  Neg. LLF: -277.42500835311165
Iteration:      9,  Func. Count:     96,  Neg. LLF: -277.7158716278114
Iteration:     10,  Func. Count:    107,  Neg. LLF: -277.7284593481317
Iteration:     11,  Func. Count:    116,  Neg. LLF: -277.8342920129433
Iteration:     12,  Func. Count:    125,  Neg. LLF: -277.9013398507872
Iteration:     13,  Func. Count:    135,  Neg. LLF: -277.90360451186024
Iteration:     14,  Func. Count:    145,  Neg. LLF: -277.90771005197485
Iteration:     15,  Func. Count:    155,  Neg. LLF: -277.9103556299411
Iteration:     16,  Func. Count:    164,  Neg. LLF: -277.91348115238674
Iteration:     17,  Func. Count:    176,  Neg. LLF: -277.9137850975402
Iteration:     18,  Func. Count:    185,  Neg. LLF: -277.91410988187624
Iteration:     19,  Func. Count:    194,  Neg. LLF: -277.91533527655514
Iteration:     20,  Func. Count:    203,  Neg. LLF: -277.9156312848529
Iteration:     21,  Func. Count:    212,  Neg. LLF: -277.9158577670059
Iteration:     22,  Func. Count:    221,  Neg. LLF: -277.9158970530356
Iteration:     23,  Func. Count:    230,  Neg. LLF: -277.91596080601795
Iteration:     24,  Func. Count:    242,  Neg. LLF: -277.91596344763025
Iteration:     25,  Func. Count:    252,  Neg. LLF: -277.9159650776943
```

```
Optimization terminated successfully.      (Exit mode 0)
```

```
Current function value: -277.9159652452763
```

```
Iterations: 25
```

```
Function evaluations: 254
```

```
Gradient evaluations: 25
```

In [250]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          China    R-squared:
-0.023
Mean Model:            AR      Adj. R-squared:
-0.034
Vol Model:            EGARCH   Log-Likelihood:
277.916
Distribution:    Generalized Error Distribution    AIC:
-541.832
Method:          Maximum Likelihood    BIC:
-524.333
                                           No. Observations:
90
Date:            Tue, May 05 2020    Df Residuals:
83
Time:            11:56:58    Df Model:
7
```

Mean Model

```
=====
==
              coef      std err          t      P>|t|      95.0% Conf. In
t.
-----
--
Const          7.1158e-04  5.541e-05     12.841  9.618e-38 [6.030e-04,8.202e-04]
China[1]       -0.1010  6.609e-05   -1528.387    0.000    [ -0.101, -0.101]
```

Volatility Model

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
omega          -2.8926      1.356     -2.133  3.294e-02 [ -5.551, -0.234]
alpha[1]         0.4384      0.485      0.904    0.366 [ -0.512, 1.388]
gamma[1]        -0.3714      0.235     -1.583    0.113 [ -0.831,8.851e-02]
beta[1]          0.6743      0.156      4.333  1.473e-05 [ 0.369, 0.979]
```

Distribution

```
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu              1.0100      0.221      4.576  4.738e-06 [ 0.577, 1.443]
=====
```

Covariance estimator: robust

In [251]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[251]:

```
(array([ 1.24068463,  1.241022 ,  1.54091682,  4.10406854,  4.10408852,
        4.11134885,  5.46492559,  5.59858168,  5.72328452,  6.67031901,
        6.76714095,  6.77785139,  7.51924777, 13.27540159, 13.90427057,
        19.27177442, 19.29843603, 23.21842462, 23.38168263, 24.21616856])),
array([0.26533915, 0.53766962, 0.67285945, 0.39210488, 0.53452926,
        0.66161083, 0.60341781, 0.69209521, 0.7672618 , 0.75615901,
        0.81761519, 0.87193807, 0.87345067, 0.50496209, 0.53280155,
        0.25482205, 0.31167358, 0.18233549, 0.22094826, 0.233077 ]))
```

In [252]:

```
#Fitting the model AR(1)-EGARCH(1,1)
res = arch_model(y=df_post_covid['South Africa'],lags =1, mean='AR', vol = 'EGARCH', p
=1, o =1, q=1 , dist ='ged', rescale = False).fit()
```

```
Iteration:      1,  Func. Count:      9,  Neg. LLF: -196.8276305378713
Iteration:      2,  Func. Count:     28,  Neg. LLF: -145.22150738669723
Iteration:      3,  Func. Count:     39,  Neg. LLF: -148.73319694069338
Iteration:      4,  Func. Count:     50,  Neg. LLF: -162.36940517629327
Iteration:      5,  Func. Count:     61,  Neg. LLF: -189.84283483772288
Iteration:      6,  Func. Count:     73,  Neg. LLF: -191.5447508377563
Iteration:      7,  Func. Count:     83,  Neg. LLF: -193.87417510972972
Iteration:      8,  Func. Count:     92,  Neg. LLF: -198.28474678061167
Iteration:      9,  Func. Count:    101,  Neg. LLF: -201.38896482589954
Iteration:     10,  Func. Count:    111,  Neg. LLF: -202.446926662049
Iteration:     11,  Func. Count:    121,  Neg. LLF: -203.74433620614738
Iteration:     12,  Func. Count:    132,  Neg. LLF: -204.89098467518625
Iteration:     13,  Func. Count:    142,  Neg. LLF: -205.7268918211924
Iteration:     14,  Func. Count:    151,  Neg. LLF: -205.8676634392634
Iteration:     15,  Func. Count:    161,  Neg. LLF: -205.97184058262405
Iteration:     16,  Func. Count:    170,  Neg. LLF: -206.1218810401562
Iteration:     17,  Func. Count:    179,  Neg. LLF: -206.16646809768167
Iteration:     18,  Func. Count:    188,  Neg. LLF: -206.19043438599144
Iteration:     19,  Func. Count:    197,  Neg. LLF: -206.23761358876772
Iteration:     20,  Func. Count:    206,  Neg. LLF: -206.25757082770357
Iteration:     21,  Func. Count:    215,  Neg. LLF: -206.27194457137173
Iteration:     22,  Func. Count:    224,  Neg. LLF: -206.28830726745653
Iteration:     23,  Func. Count:    233,  Neg. LLF: -206.3166446692424
Iteration:     24,  Func. Count:    242,  Neg. LLF: -206.31752730538753
Iteration:     25,  Func. Count:    251,  Neg. LLF: -206.3176073395071
Iteration:     26,  Func. Count:    261,  Neg. LLF: -206.3176116865782
Iteration:     27,  Func. Count:    271,  Neg. LLF: -206.31761343322563
Iteration:     28,  Func. Count:    281,  Neg. LLF: -206.3176144961876
```

```
Optimization terminated successfully. (Exit mode 0)
```

```
Current function value: -206.3176153182494
```

```
Iterations: 28
```

```
Function evaluations: 283
```

```
Gradient evaluations: 28
```

In [253]:

```
print(res.summary())
```

AR - EGARCH Model Results

```
=====
=====
Dep. Variable:          South Africa    R-squared:
-0.031
Mean Model:              AR    Adj. R-squared:
-0.043
Vol Model:              EGARCH    Log-Likelihood:
206.318
Distribution:    Generalized Error Distribution    AIC:
-398.635
Method:          Maximum Likelihood    BIC:
-381.137

No. Observations:
90
Date:              Tue, May 05 2020    Df Residuals:
83
Time:              11:57:10    Df Model:
7
```

Mean Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Co
nf. Int.
-----
Const          -9.9877e-04  2.221e-04    -4.498  6.869e-06 [-1.434e-03, -5.
635e-04]
Sout...ica[1]    0.0692  1.891e-02     3.662  2.498e-04  [3.219e-02,
0.106]
```

Volatility Model

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
omega          -0.3831    0.228    -1.678  9.341e-02 [-0.831, 6.447e-02]
alpha[1]        0.5981    0.239     2.498  1.247e-02 [ 0.129, 1.067]
gamma[1]        -0.0929    0.115    -0.810    0.418 [-0.318, 0.132]
beta[1]         0.9422  3.186e-02   29.575  3.111e-192 [ 0.880, 1.005]
```

Distribution

```
=====
=====
              coef      std err          t      P>|t|      95.0% Conf. Int.
-----
nu              1.4553    0.274     5.314  1.072e-07 [ 0.919, 1.992]
=====
```

Covariance estimator: robust

In [254]:

```
acorr_ljungbox(res.resid[1:], lags=20,boxpierce=False)
```

Out[254]:

```
(array([ 4.92867917, 11.38432595, 12.16817027, 12.19285847, 13.14143762,
        19.04782465, 23.52214712, 24.08781544, 24.16475614, 24.52701653,
        24.52714126, 24.53087547, 25.00557076, 25.62724282, 26.91353498,
        26.93640803, 26.93830371, 27.72274293, 28.15115775, 28.29771417]),
array([0.0264145 , 0.00337229, 0.00682873, 0.01597329, 0.02208879,
        0.00408362, 0.00138187, 0.00221536, 0.0040483 , 0.0063179 ,
        0.01068491, 0.01720921, 0.02304485, 0.02885706, 0.02944878,
        0.0421954 , 0.05897886, 0.06640171, 0.08056244, 0.10253705]))
```