INDIAN INSTITUTE OF TECHNOLOGY

(INDIAN SCHOOL OF MINES) DHANBAD

MANAGEMENT STUDIES DEPARTMENT

"FINANCIAL ECONOMETRICS ASSIGNMENT"

Group - 2

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Course: Financial Econometrics

Course Instructor: Prof. Aparna Krishna

Financial Econometrics Assignment

Question 1

INTRODUCTION

The time series under consideration is the Gross Domestic Product (GDP).

The time series analysis utilizes numeric time variables, spanning from the year 1970 to 1991, divided into quarterly intervals. This dataset comprises 88 data points, each representing a quarter, for a total of 22 years with four quarters each.

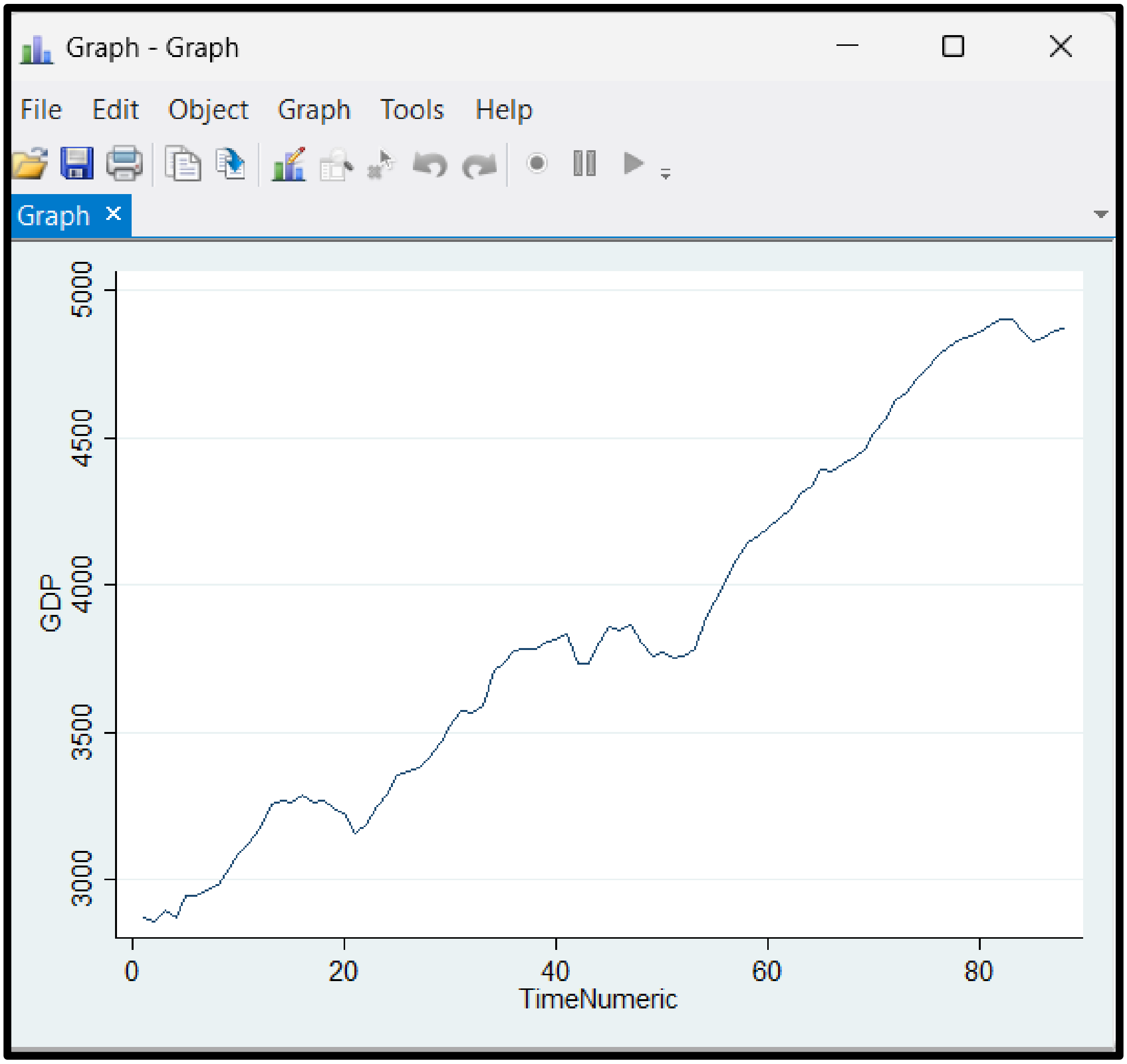
IDENTIFICATION

The Time variable used in the dataset by us is represented by the index of observation. Eg- the first observation has time period 1, the second observation has time period 2, and so on.

Creating a time series plot

Stata command used : tsline GDP

Output :



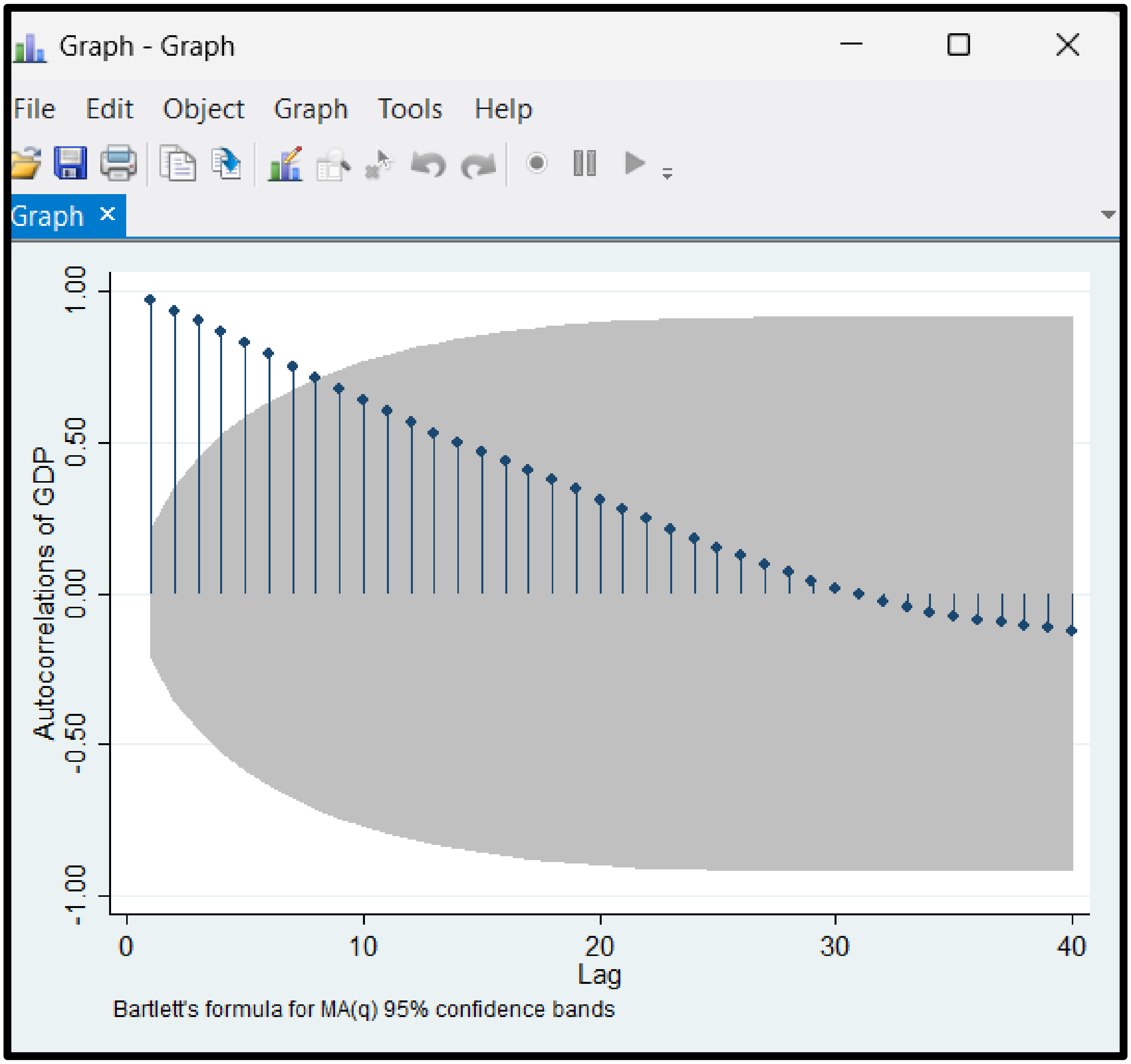
Interpretation:

The visual representation obtained from plotting the GDP time series indicates an increasing trend over time. Furthermore, the mean and variance of the data exhibit non-stationarity, suggesting that the time series plot lacks stationarity.

Analyzing autocorrelation Patterns in GDP Data

Stata command used: ac GDP

Output :



Interpretation:

- **Autocorrelations of GDP:** The blue spikes represent the autocorrelation coefficients for the GDP variable at different lags. Autocorrelation measures the correlation of a time series with its own past values.

- **Lag:** The x-axis shows the lag, which is the number of time periods separating the past values from the current value. The graph shows lags up to 40.

- **Confidence Bands:** The grey shaded area represents the 95% confidence bands according to Bartlett's formula for an MA(q) process. If the blue spikes fall within this area, the autocorrelation is not statistically significant at that lag.

- **Decreasing Spikes:** The fact that the spikes decrease as the lag increases suggests that the immediate past values have more influence on the current value than the distant past values.

<u>Analysis of GDP Time Series Stationarity Using the Dickey-Fuller Test</u>

The Dickey-Fuller test was conducted with the inclusion of a trend component to account for possible deterministic trends in the GDP data. The test statistic, critical values, and p-value were computed to assess the null hypothesis that the GDP series has a unit root.

Stata command used : dfuller GDP , trend regress

Output :

```
. dfuller GDP, trend regress

Dickey-Fuller test for unit root                   Number of obs   =        87

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.625            -4.069            -3.463            -3.158
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7824

------------------------------------------------------------------------------
D.GDP        |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         GDP |
         L1. |  -.0603169   .0371113    -1.63   0.108    -.1341169     .013483
      _trend |   1.477641   .9172439     1.61   0.111     -.346399    3.301681
       _cons |   190.3837   103.5257     1.84   0.069    -15.48857    396.2559
------------------------------------------------------------------------------
```

Results

The test statistic obtained was **-1.625**, which is compared against the critical values at the 1%, 5%, and 10% significance levels. The critical values for the respective significance levels are **-4.069**, **-3.463**, and **-3.158**. The MacKinnon approximate p-value for the test statistic is **0.7824**.

Interpretation

Given that the test statistic does not fall beyond the critical values and the p-value exceeds the conventional threshold of 0.05, we fail to reject the null hypothesis. Consequently, there is insufficient evidence to conclude that the GDP time series is stationary.

Conclusion

The application of the Dickey-Fuller test to the GDP time series data suggests the presence of a unit root, indicating that the series is not stationary. The test statistic of -1.625 and a MacKinnon approximate p-value of 0.7824 provide strong evidence that the null hypothesis of a unit root cannot be rejected.

Reassessment of GDP Time Series Stationarity Post-Differencing

Following the initial analysis, which suggested the presence of a unit root in the GDP time series, a subsequent Dickey-Fuller test was conducted on the first-differenced data to reassess stationarity.

Methodology

The Dickey-Fuller test was applied to the first-differenced GDP data with a trend component. The test statistic, critical values, and p-value were evaluated to determine the presence of a unit root in the differenced series.

Stata Command used : dfuller d.GDP , trend regress

Output:

```
. dfuller D.GDP, trend regress

Dickey-Fuller test for unit root                   Number of obs   =        86

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value            Value
------------------------------------------------------------------------------
 Z(t)             -6.588            -4.071            -3.464           -3.158
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D2.GDP       |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       D.GDP |
         L1. |  -.6824587   .1035842    -6.59   0.000    -.8884835    -.476434
      _trend |  -.0282464   .1497305    -0.19   0.851    -.3260544    .2695615
       _cons |   17.22668   7.841891     2.20   0.031     1.629475    32.82389
------------------------------------------------------------------------------
```

Results

The test statistic for the differenced data is -6.588, which is significantly lower than the critical values at the 1%, 5%, and 10% significance levels of -4.071, -3.464, and -3.158, respectively. The MacKinnon approximate p-value is 0.0000, indicating strong evidence against the null hypothesis.

Interpretation

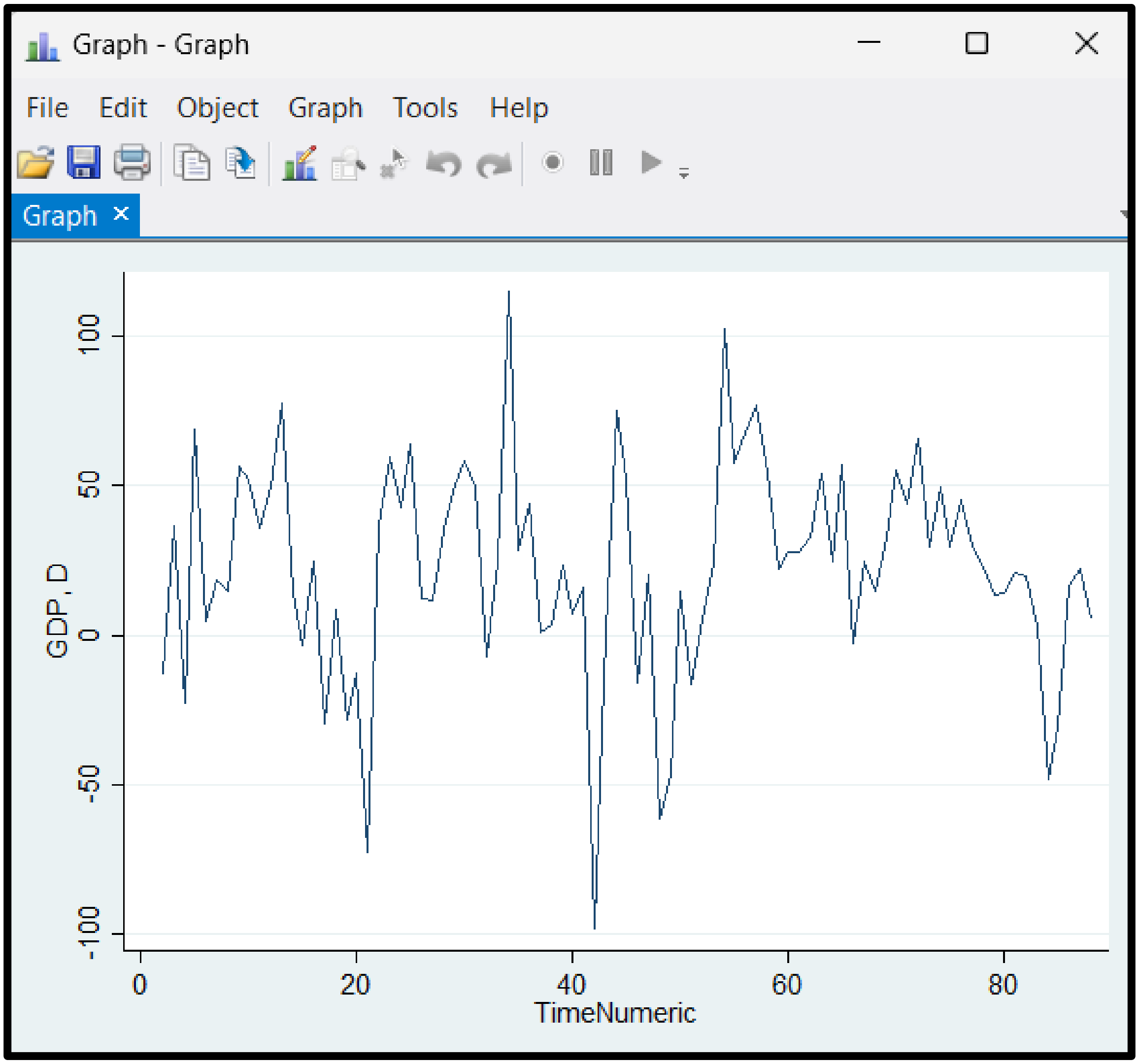
The test statistic being well below the critical values and the p-value being effectively zero suggest that the null hypothesis of a unit root can be rejected for the first-differenced GDP data. This implies that the differencing process has successfully rendered the time series stationary.

Conclusion

The Dickey-Fuller test results for the first-differenced GDP data indicate that the series is now stationary. The lag 1 of the differenced series is statistically significant, with a p-value of 0.000, confirming its importance in the differenced model..

<u>Time Series Analysis of GDP Growth</u>

Stata command used : tsline d.GDP

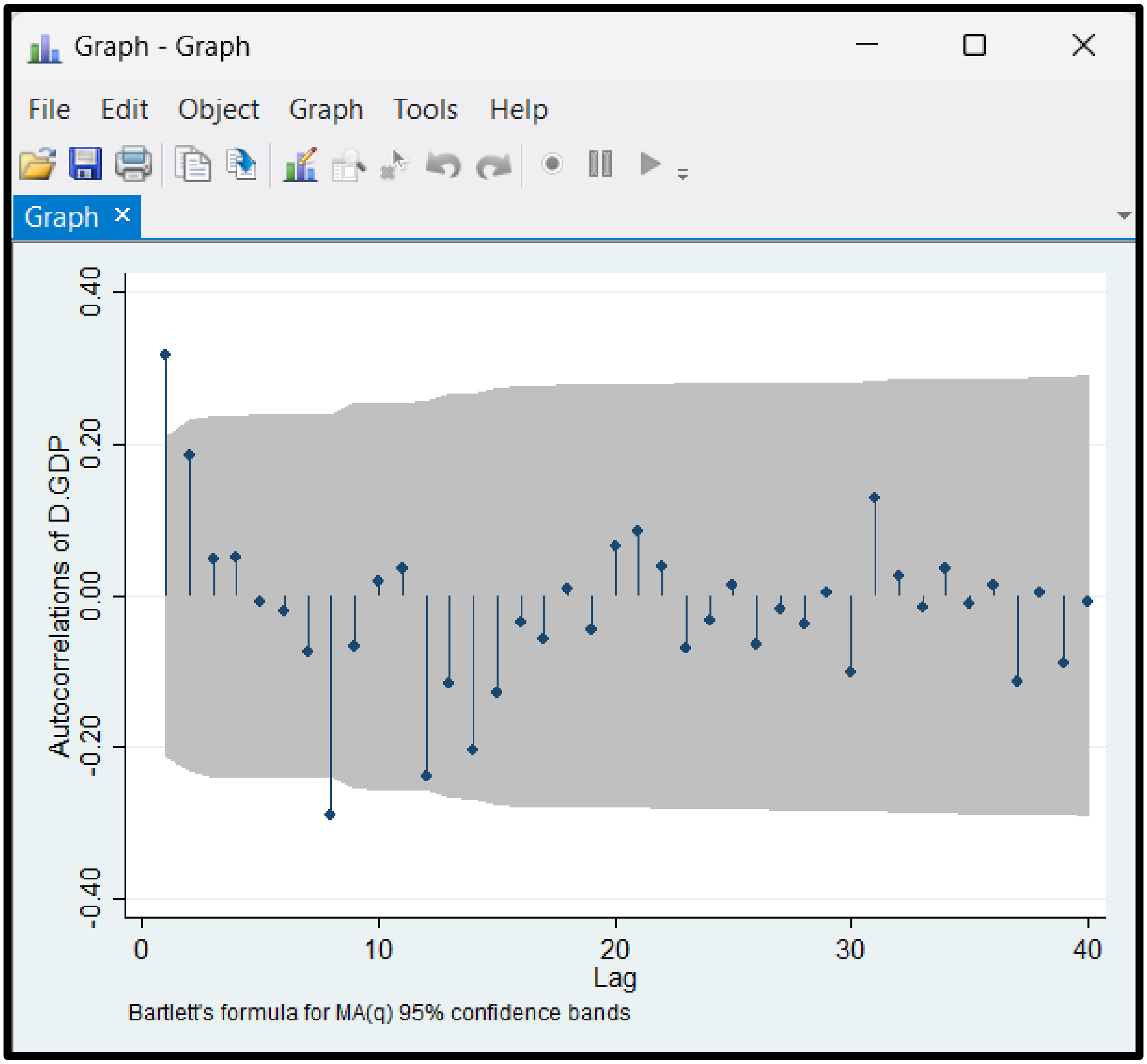


Conclusion:

The mean of the first difference of GDP appears to fluctuate around mean.The variance of the first difference of GDP doesn't show too much fluctuations.There doesn't appear to be a unit root (i.e., a non-stationary behavior) in the first difference of GDP.

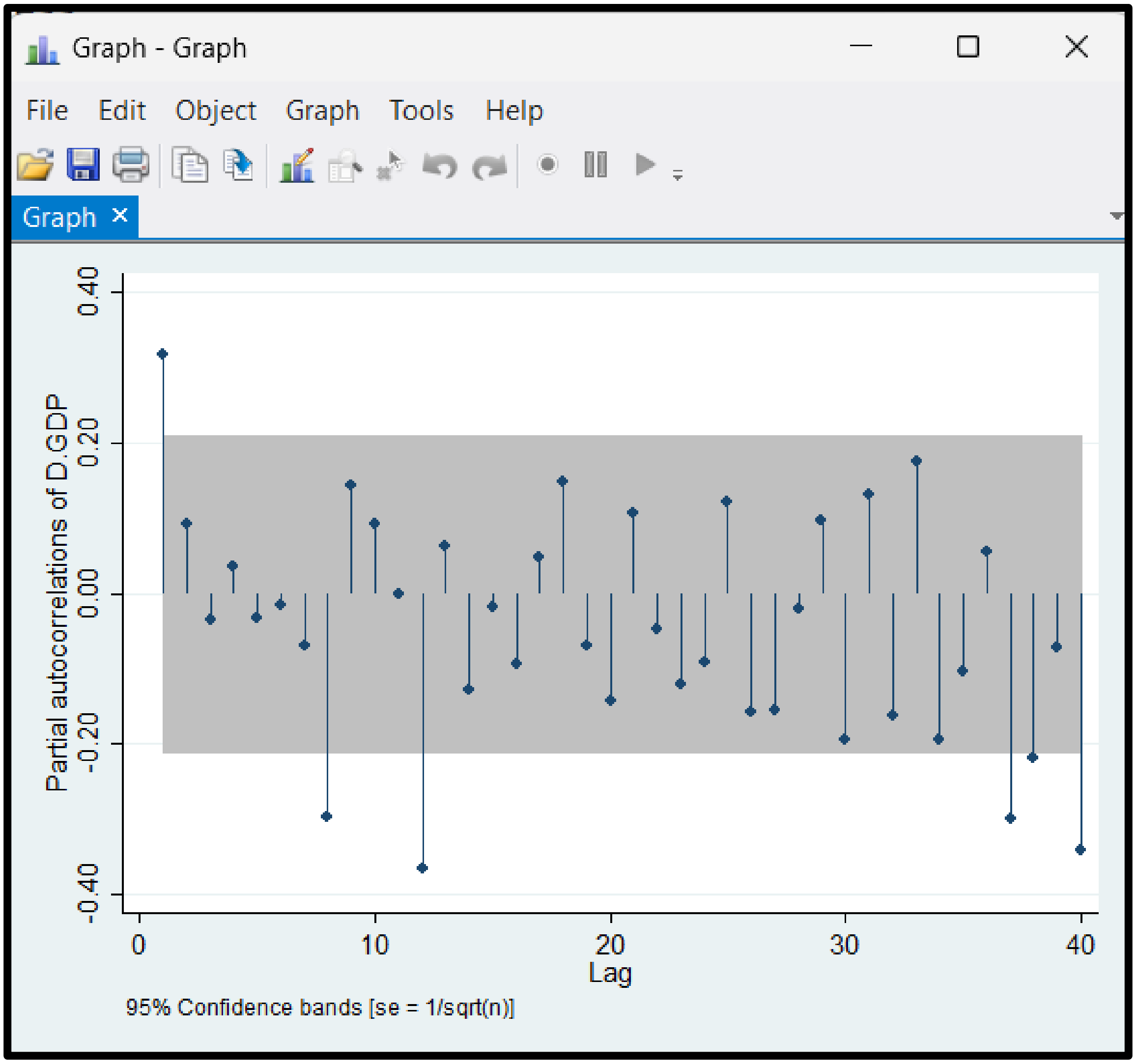
Degree of ACF and PACF

ACF plot



It suggests that we have only **1 significant lag** at 95% confidence. The MA model has degree 1.

PACF PLOT



There is only 1 significant lag. The AR model has degree 1.

Our Identified Model is ARIMA(1,1,1).
The other model that we will check is ARIMA(2,1,1).

ESTIMATION

Arima GDP, arima(1,1,1)

```
. arima GDP, arima(1,1,1)

(setting optimization to BHHH)
Iteration 0:   log likelihood = -431.61324
Iteration 1:   log likelihood = -429.85445
Iteration 2:   log likelihood = -429.66798
Iteration 3:   log likelihood = -429.65889
Iteration 4:   log likelihood = -429.65638
(switching optimization to BFGS)
Iteration 5:   log likelihood = -429.64546
Iteration 6:   log likelihood = -429.64505
Iteration 7:   log likelihood = -429.64501

ARIMA regression

Sample:  2 - 88                                 Number of obs     =         87
                                                Wald chi2(2)      =      11.32
Log likelihood =  -429.645                      Prob > chi2       =     0.0035
```

D.GDP	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
GDP						
_cons	22.57289	6.468824	3.49	0.000	9.894223	35.25155
ARMA						
ar L1.	.5211587	.2976916	1.75	0.080	-.0623061	1.104623
ma L1.	-.2264486	.3641402	-0.62	0.534	-.9401502	.487253
/sigma	33.74378	1.983092	17.02	0.000	29.85699	37.63057

Note: The test of the variance against zero is one sided, and the two-sided confidence interval is truncated at zero.

```
. estat ic

Akaike's information criterion and Bayesian information criterion
```

Model	Obs	ll(null)	ll(model)	df	AIC	BIC
.	87	.	-429.645	4	867.29	877.1536

Note: N=Obs used in calculating BIC; see [R] BIC note.

ARIMA(2,1,1)

```
. arima GDP, arima(2,1,1)

(setting optimization to BHHH)
Iteration 0:   log likelihood = -431.36024
Iteration 1:   log likelihood = -429.82267
Iteration 2:   log likelihood = -429.68462
Iteration 3:   log likelihood =  -429.5435
Iteration 4:   log likelihood =  -429.5144
(switching optimization to BFGS)
Iteration 5:   log likelihood = -429.50089
Iteration 6:   log likelihood = -429.48632
Iteration 7:   log likelihood = -429.48047
Iteration 8:   log likelihood = -429.47969
Iteration 9:   log likelihood = -429.47964
Iteration 10:  log likelihood = -429.47964

ARIMA regression

Sample:  2 - 88                                 Number of obs     =         87
                                                Wald chi2(3)      =       4.89
Log likelihood = -429.4796                      Prob > chi2       =     0.1798

------------------------------------------------------------------------------
             |                 OPG
       D.GDP |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
GDP          |
       _cons |   22.64445   6.381394     3.55   0.000     10.13715    35.15175
-------------+----------------------------------------------------------------
ARMA         |
          ar |
         L1. |  -.1360914      1.004    -0.14   0.892    -2.103895    1.831712
         L2. |   .2283343    .322455     0.71   0.479    -.4036659    .8603345
             |
          ma |
         L1. |   .4260338   1.054128     0.40   0.686    -1.640018    2.492086
-------------+----------------------------------------------------------------
      /sigma |   33.67806   2.001968    16.82   0.000     29.75428    37.60185
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.
```

```
. estat ic

Akaike's information criterion and Bayesian information criterion

-----------------------------------------------------------------------------
       Model |        Obs  ll(null)  ll(model)      df         AIC        BIC
-------------+---------------------------------------------------------------
           . |         87         .  -429.4796       5    868.9593   881.2888
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note.
```

MODEL SELECTION CRITERIA

Criteria	Model A ARIMA(1,1,1)	Model B ARIMA(2,1,1)	Best Model
C,AR&MA	3/3	2/2	A=B
SigmaSQ	33.74378	33.67806	B
Log Likelihood	-429.645	-429.4796	B
AIC	867.29	868.9593	A
BIC	877.1536	881.2888	A
Best Model			**A**

We prefer to choose Model A because of the following reasons:-

- According to AIC and BIC values , Model A has lower values in both the cases , so A is better.
- To resolve the clash between the SigmaSQ and Log Likelihood values vs the AIC and BIC values , higher priority goes to the AIC and BIC values.
- Also observing the AR and MA graphs , we can visualise that they both are also significant at one lag .

Thus,our Model A works fine.

<u>Checking for white noise error term</u>

Stata command : Predict error resid

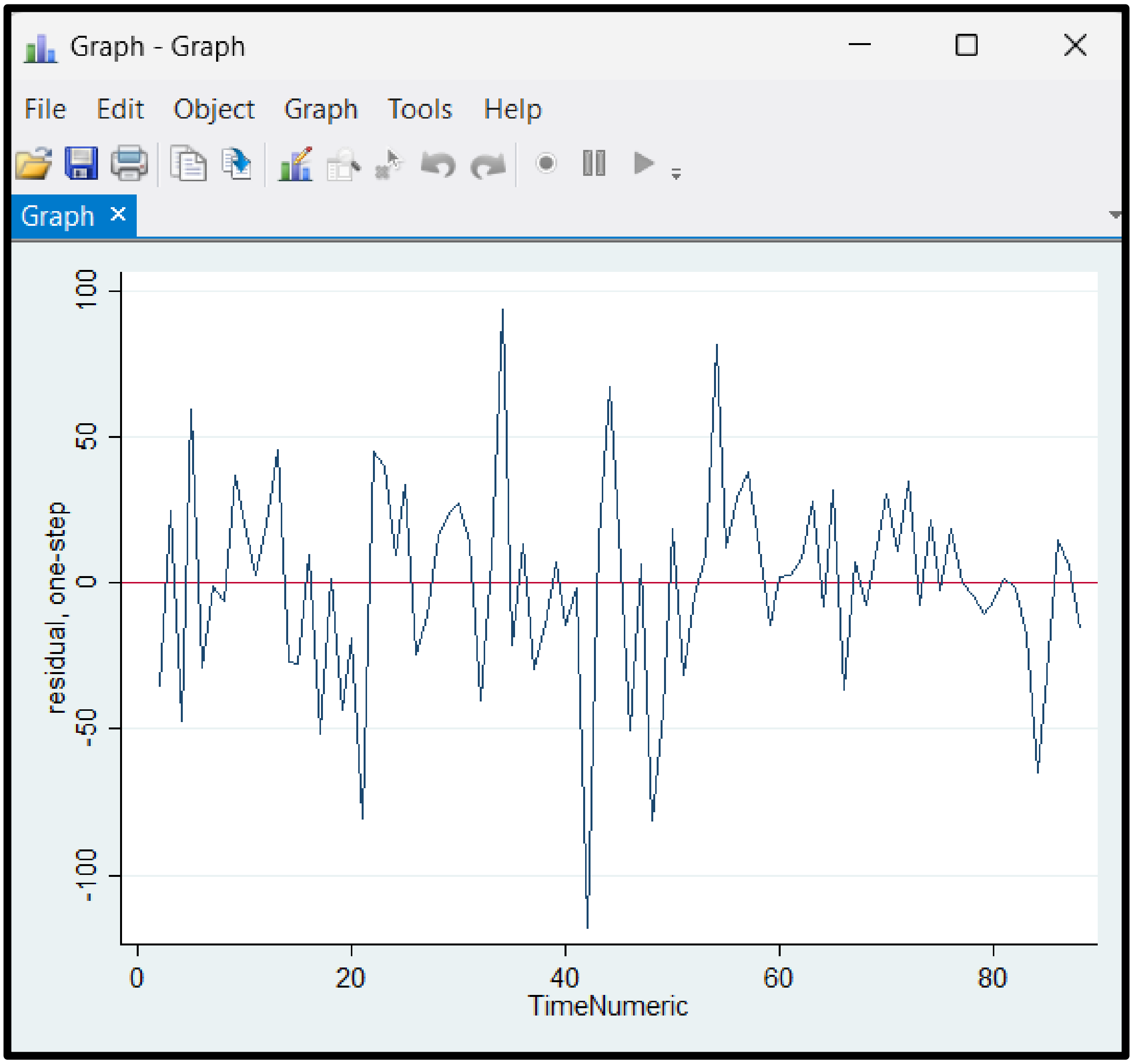
	YEAR	GDP	PDI	PCE	PROFITS	DIVIDENDS	year	quarter	TimeVariable	min_year	TimeNumeric	error
1	1970.1	2872.8	1990.6	1800.5	44.7	24.5	1970	1	1970q1	1970	1	.
2	1970.2	2860.3	2020.1	1807.5	44.4	23.9	1970	2	1970q2	1970	2	-35.07289
3	1970.3	2896.6	2045.3	1824.7	44.9	23.3	1970	3	1970q3	1970	3	24.90959
4	1970.4	2873.7	2045.2	1821.2	42.1	23.1	1970	4	1970q4	1970	4	-47.0168
5	1971.1	2942.9	2073.9	1849.9	48.8	23.8	1971	1	1971q1	1970	5	59.68178
6	1971.2	2947.4	2098	1863.5	50.7	23.7	1971	2	1971q2	1970	6	-28.85835
7	1971.3	2966	2106.6	1876.9	54.2	23.8	1971	3	1971q3	1970	7	-1.088973
8	1971.4	2980.8	2121.1	1904.6	55.7	23.7	1971	4	1971q4	1970	8	-5.948978
9	1972.1	3037.3	2129.7	1929.3	59.4	25	1972	1	1972q1	1970	9	36.63088
10	1972.2	3089.7	2149.1	1963.3	60.1	25.5	1972	2	1972q2	1970	10	20.44072
11	1972.3	3125.8	2193.9	1989.1	62.8	26.1	1972	3	1972q3	1970	11	2.611227
12	1972.4	3175.5	2272	2032.1	68.3	26.5	1972	4	1972q4	1970	12	20.66865
13	1973.1	3253.3	2300.7	2063.9	79.1	27	1973	1	1973q1	1970	13	45.76997
14	1973.2	3267.6	2315.2	2062	81.2	27.8	1973	2	1973q2	1970	14	-26.69043
15	1973.3	3264.3	2337.9	2073.7	81.3	28.3	1973	3	1973q3	1970	15	-27.60541
16	1973.4	3289.1	2382.7	2067.4	85	29.4	1973	4	1973q4	1970	16	9.459786
17	1974.1	3259.4	2334.7	2050.8	89	29.8	1974	1	1974q1	1970	17	-51.29141
18	1974.2	3267.6	2304.5	2059	91.2	30.4	1974	2	1974q2	1970	18	1.254713
19	1974.3	3239.1	2315	2065.5	97.1	30.9	1974	3	1974q3	1970	19	-43.2982
20	1974.4	3226.4	2313.7	2039.9	86.8	30.5	1974	4	1974q4	1970	20	-18.46063
21	1975.1	3154	2282.5	2051.8	75.8	30	1975	1	1975q1	1970	21	-80.7705
22	1975.2	3190.4	2390.3	2086.9	81	29.7	1975	2	1975q2	1970	22	45.03269
23	1975.3	3249.9	2354.4	2114.4	97.8	30.1	1975	3	1975q3	1970	23	39.91858
24	1975.4	3292.5	2389.4	2137	103.4	30.6	1975	4	1975q4	1970	24	9.821737
25	1976.1	3356.7	2424.5	2179.3	108.4	32.6	1976	1	1976q1	1970	25	33.41393
26	1976.2	3369.2	2434.9	2194.7	109.2	35	1976	2	1976q2	1970	26	-24.20068
27	1976.3	3381	2444.7	2213	110	36.6	1976	3	1976q3	1970	27	-11.00352
28	1976.4	3416.3	2459.5	2242	110.3	38.3	1976	4	1976q4	1970	28	15.84976
29	1977.1	3466.4	2463	2271.3	121.5	39.2	1977	1	1977q1	1970	29	24.48343
30	1977.2	3525	2490.3	2280.8	129.7	40	1977	2	1977q2	1970	30	27.22536
31	1977.3	3574.4	2541	2302.6	135.1	41.4	1977	3	1977q3	1970	31	14.21642
32	1977.4	3567.2	2556.2	2331.6	134.8	42.4	1977	4	1977q4	1970	32	-40.53478

```
. summarize error

    Variable |        Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
       error |         87    .1541573    33.96331  -117.7946   93.46479

.
```

Stata command : tsline error, yline(0.1541573)



<u>Portmanteau Test for white noise error term</u>

```
. wntestq error

Portmanteau test for white noise
---------------------------------------
 Portmanteau (Q) statistic =    41.7468
 Prob > chi2(40)           =     0.3948
```

Clearly , p value is greater than 0.05 , so we accept the null hypothesis and hence , we conclude that there is existence of white noise error term.

Hence , the model that we estimated is fine.

<u>FORECASTING</u>

Stata Command : tsappend, add(10)

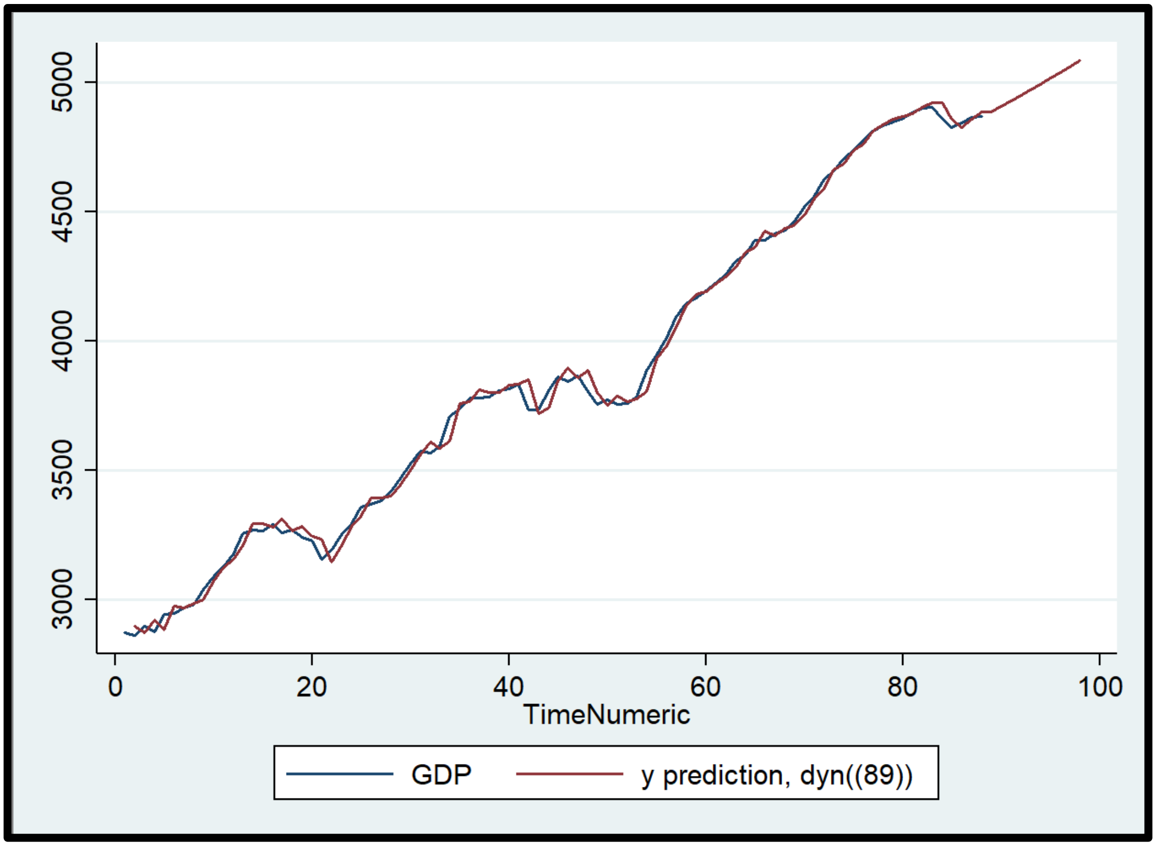
In Stata, the tsappend command is used to append or add new observations to an existing time-series dataset.

	YEAR	GDP	PDI	PCE	PROFITS	DIVIDENDS	year	quarter	TimeVariable	min_year	TimeNumeric	error
82	1990.2	4900.3	3545.3	3258.6	193.7	132.5	1990	2	1990q2	1970	82	-1.942172
83	1990.3	4903.3	3547	3281.2	196.3	133.8	1990	3	1990q3	1970	83	-18.41123
84	1990.4	4855.1	3529.5	3251.8	199	136.2	1990	4	1990q4	1970	84	-64.7415
85	1991.1	4824	3514.8	3241.1	189.7	137.8	1991	1	1991q1	1970	85	-31.44961
86	1991.2	4840.7	3537.4	3252.4	182.7	136.7	1991	2	1991q2	1970	86	14.97748
87	1991.3	4862.7	3539.9	3271.2	189.6	138.1	1991	3	1991q3	1970	87	5.879451
88	1991.4	4868	3547.5	3271.1	190.3	138.5	1991	4	1991q4	1970	88	-15.64293
89	.	.	.	.	.	.	.	.		.	89	.
90	.	.	.	.	.	.	.	.		.	90	.
91	.	.	.	.	.	.	.	.		.	91	.
92	.	.	.	.	.	.	.	.		.	92	.
93	.	.	.	.	.	.	.	.		.	93	.
94	.	.	.	.	.	.	.	.		.	94	.
95	.	.	.	.	.	.	.	.		.	95	.
96	.	.	.	.	.	.	.	.		.	96	.
97	.	.	.	.	.	.	.	.		.	97	.
98	.	.	.	.	.	.	.	.		.	98	.

Stata Command : Predict FGDP, y dynamic(89)

85	1991.1	4824	3514.8	3241.1	189.7	137.8	1991	1	1991q1	1970	85	-31.44961	4855.45
86	1991.2	4840.7	3537.4	3252.4	182.7	136.7	1991	2	1991q2	1970	86	14.97748	4825.723
87	1991.3	4862.7	3539.9	3271.2	189.6	138.1	1991	3	1991q3	1970	87	5.879451	4856.82
88	1991.4	4868	3547.5	3271.1	190.3	138.5	1991	4	1991q4	1970	88	-15.64293	4883.643
89	.	.	.	.	.	.	.	.		.	89	.	4885.113
90	.	.	.	.	.	.	.	.		.	90	.	4904.841
91	.	.	.	.	.	.	.	.		.	91	.	4925.931
92	.	.	.	.	.	.	.	.		.	92	.	4947.731
93	.	.	.	.	.	.	.	.		.	93	.	4969.901
94	.	.	.	.	.	.	.	.		.	94	.	4992.264
95	.	.	.	.	.	.	.	.		.	95	.	5014.728
96	.	.	.	.	.	.	.	.		.	96	.	5037.244
97	.	.	.	.	.	.	.	.		.	97	.	5059.787
98	.	.	.	.	.	.	.	.		.	98	.	5082.344

Stata Command : tsline GPD, FGDP



As can be seen , we have forecasted values for the next 10 quarters .
So , this is our ARIMA Model built for GDP.

QUESTION 2

We are trying to understand the dependence of GDP and PDI on its own past values and past values of the other variables.

Our understanding of their mutual dependence-

How does GDP increase and decrease affect PDI?

1. **GDP(Gross Domestic Product):**
   - Imagine that the economy is like a big pie, and GDP represents the total size of that pie.
   - When the economy produces more goods and services (like cars, phones, or haircuts), the pie gets bigger, and GDP increases.
   - Conversely, if the economy slows down and produces fewer goods and services, the pie shrinks, and GDP decreases.
2. **PDI(Personal Disposable Income):**
   - PDI is like the slice of the pie that each person gets to take home after taxes and other deductions.

    - It’s the money left in your pocket to spend or save after paying taxes and essential expenses (like rent, bills, and groceries).
3. **How are they connected ?**
    - When GDP goes up (the economy grows), it usually has a positive effect on PDI.
        - **More Jobs**: A growing economy creates more jobs. When people work and earn money, their PDI increases.
        - **Higher Wages**: Companies may pay higher wages when they’re doing well. So, your paycheck might get a boost.
        - **Business Profits**: When businesses make more profit (part of GDP), they might share it with employees through bonuses or raises.
    - On the flip side, if GDP decreases (the economy shrinks):
        - **Job Losses**: Companies might cut jobs, leading to lower PDI for those who lose employment.
        - **Reduced Wages**: Businesses struggling to make money might freeze wages or even reduce them.
        - **Less Spending**: When people feel uncertain about the economy, they tend to spend less, affecting PDI.
4. **Example :**
    - Imagine a small town where everyone works at the local bakery. If the bakery sells more cakes (increased GDP), they hire more people, pay higher wages, and everyone’s PDI goes up.
    - But if the bakery sells fewer cakes (decreased GDP), they might lay off workers, cut wages, and people have less money to spend.
5. **Overall Impact :**
    - A healthy economy (higher GDP) generally leads to better PDI for most people.
    - However, it’s not always straightforward. Other factors like taxes, inflation, and government policies also play a role.

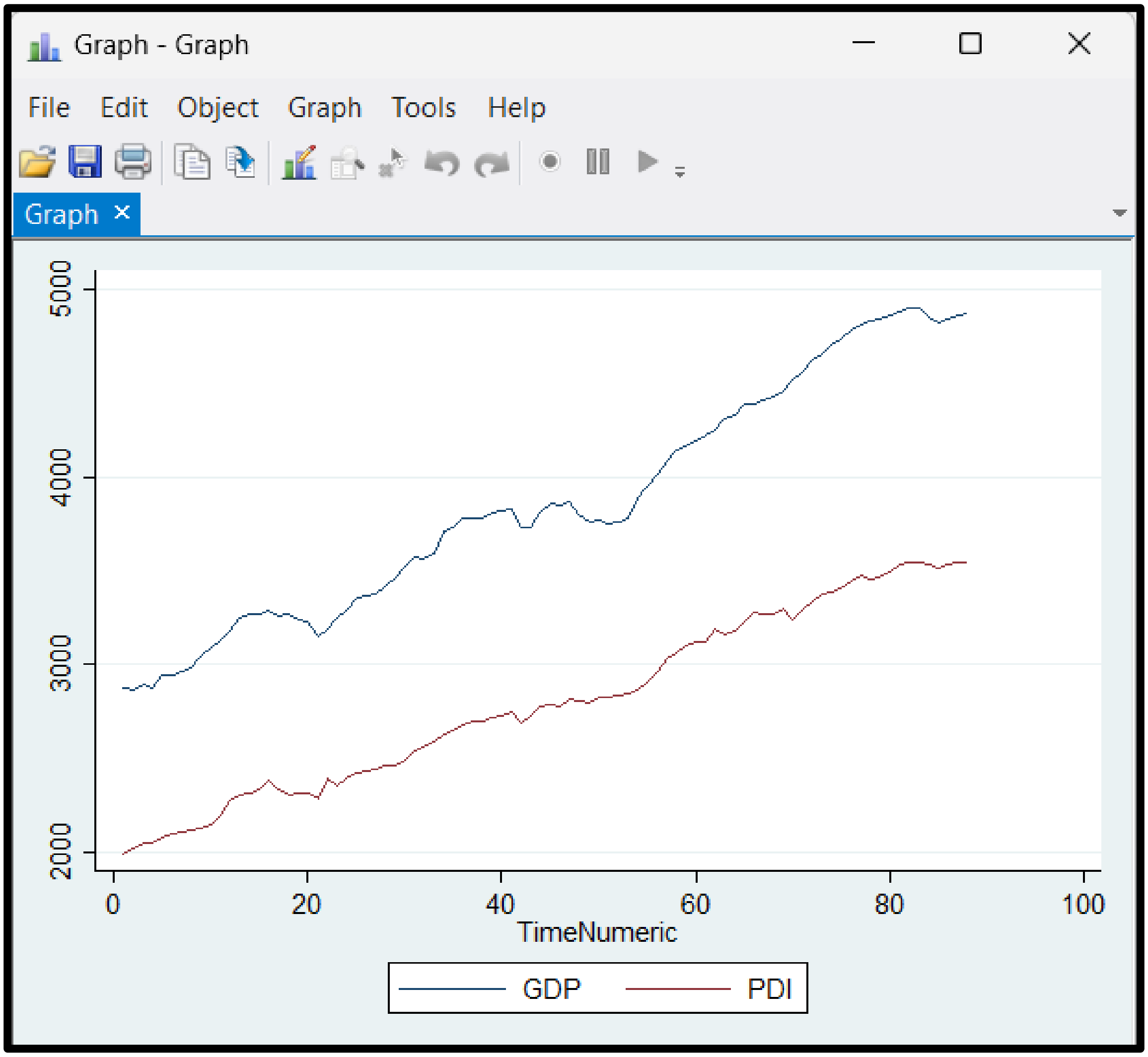
How increase and decrease in PDI affect GDP?

1. **PDI(Personal Disposable Income):**

    - Imagine you’ re getting your allowance or paycheck. That’ s your PDI.
    - It’ s the money you have left after paying taxes and other necessary stuff (like rent or bills).
2. **GDP(Gross Domestic Product):**
    - Think of GDP as the total money made by everyone in the whole country.
    - It includes everything people produce or buy, like cars, pizzas, or haircuts.
3. **How are they connected ?**
    - When your PDI goes up (you have more money to spend):
        - You might buy more stuff (like that cool video game or a new dress).
        - Other people also spend more because they have more money.
        - Businesses notice this and produce more goods and services.
        - The economy grows, and GDP increases.
    - But if your PDI goes down (you have less money):
        - You might cut back on spending (no more eating out or shopping sprees).
        - Others do the same.
        - Businesses sell fewer things, and the economy slows down.
        - GDP decreases.
4. **Example :**
    - Imagine a town where everyone gets a raise (higher PDI).
    - People start buying more ice cream, going to movies, and fixing their houses.
    - Businesses hire more workers, produce more, and GDP goes up.
5. **Overall Impact:**
    - When people have more money (higher PDI), they spend more.
    - This spending boosts businesses, jobs, and the whole economy (higher GDP).
    - So, PDI and GDP are like best friends—they help each other grow!

Checking for stationarity

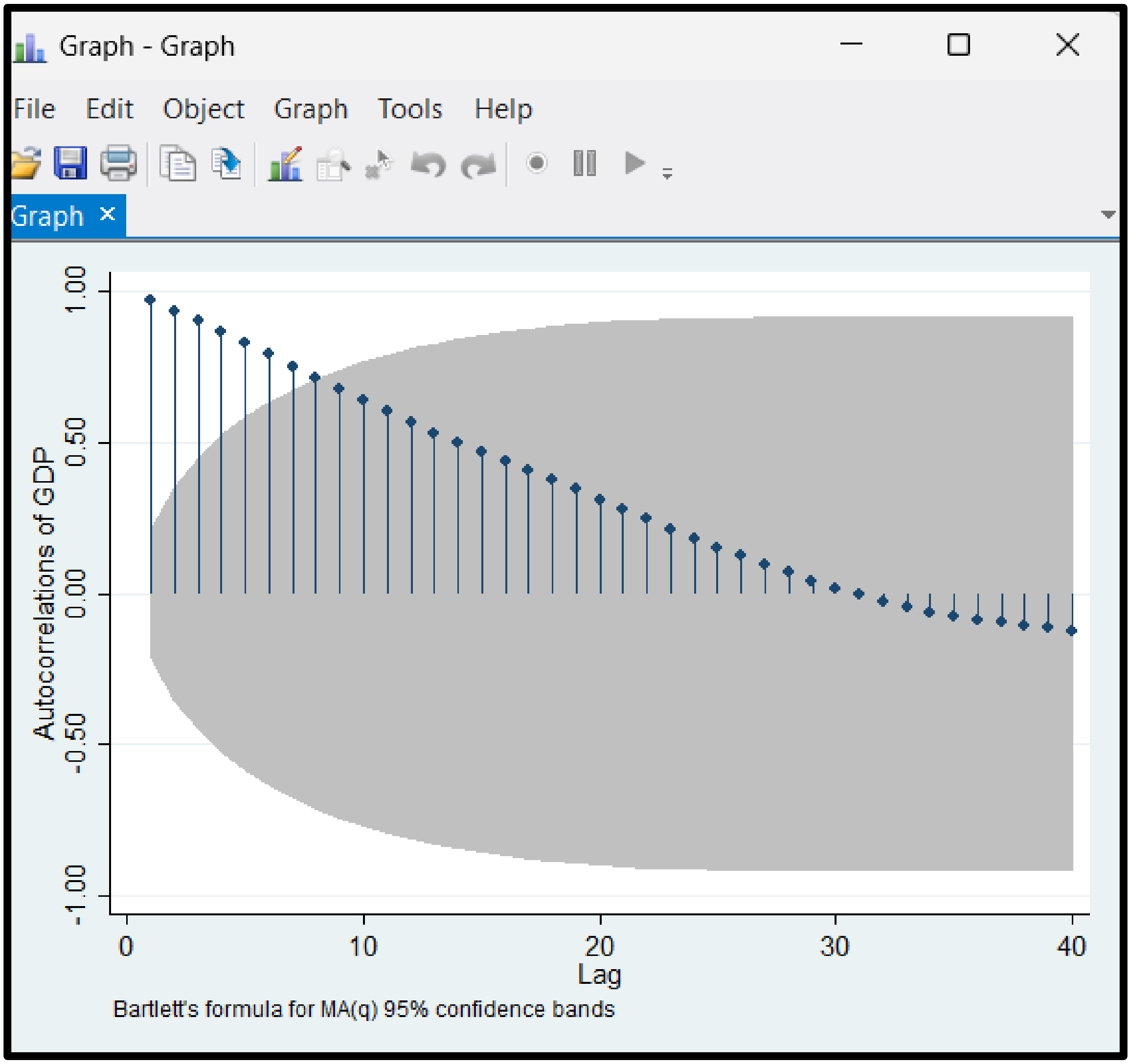
Stata Command : tsline GDP PDI



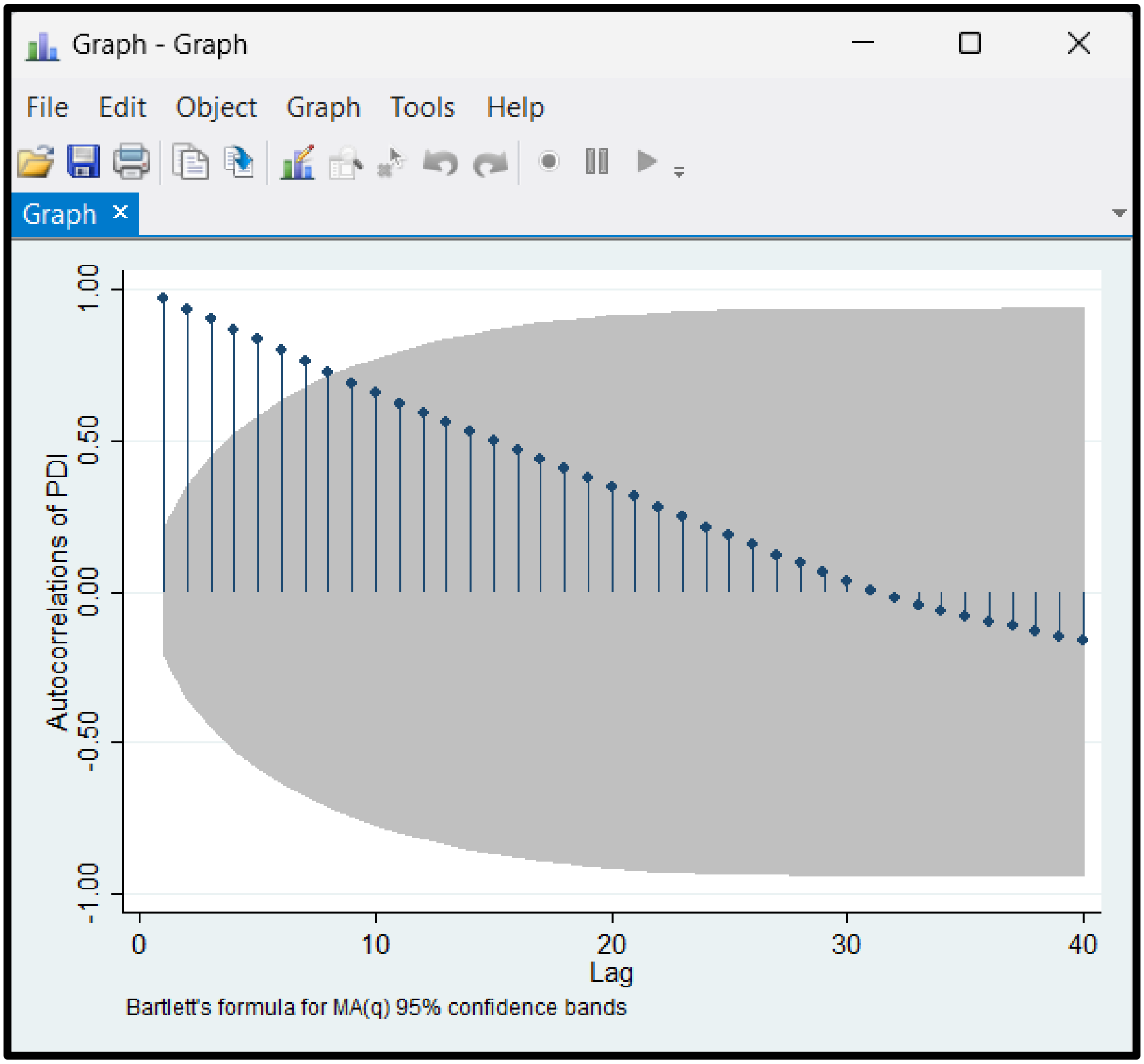
Clearly , both are non-stationary.

Stata command: ac GDP

In Stata, the "ac" command is used to perform autocorrelation tests on a time-series variable. Autocorrelation refers to the correlation between a variable and its lagged values over time.



Stata command: ac PDI



Stata command: dfuller GDP, trend regress

```
. dfuller GDP, trend regress

Dickey-Fuller test for unit root                   Number of obs   =        87

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -1.625            -4.069            -3.463            -3.158
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.7824

------------------------------------------------------------------------------
D.GDP        |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         GDP |
         L1. |  -.0603169   .0371113    -1.63   0.108    -.1341169     .013483
      _trend |   1.477641   .9172439     1.61   0.111    -.346399     3.301681
       _cons |   190.3837   103.5257     1.84   0.069    -15.48857    396.2559
------------------------------------------------------------------------------
```

Stata command: dfuller PDI, trend regress

```
. dfuller PDI, trend regress

Dickey-Fuller test for unit root                   Number of obs   =        87

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.588            -4.069            -3.463            -3.158
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.2853

------------------------------------------------------------------------------
D.PDI        |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         PDI |
         L1. |   -.156942   .0606363    -2.59   0.011    -.2775239   -.0363602
      _trend |   2.875152   1.136078     2.53   0.013     .6159357    5.134368
       _cons |    329.508   119.6902     2.75   0.007     91.49091    567.5252
------------------------------------------------------------------------------
```

Both are non stationary

```
. dfuller D.GDP, trend regress

Dickey-Fuller test for unit root                   Number of obs   =        86

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -6.588            -4.071            -3.464            -3.158
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D2.GDP       |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       D.GDP |
         L1. |  -.6824587   .1035842    -6.59   0.000    -.8884835    -.476434
      _trend |  -.0282464   .1497305    -0.19   0.851    -.3260544    .2695615
       _cons |   17.22668   7.841891     2.20   0.031     1.629475    32.82389
------------------------------------------------------------------------------
```

After 1st differencing , it becomes stationary.

Stata command: var D.GDP D.PDI

```
. var d.GDP d.PDI

Vector autoregression

Sample:  4 - 88                              Number of obs     =         85
Log likelihood =  -804.4051                  AIC               =   19.16247
FPE            =   719988.6                  HQIC              =   19.27806
Det(Sigma_ml)  =   568879.9                  SBIC              =   19.44984

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_GDP                 5     34.0327   0.1547   15.55194   0.0037
D_PDI                 5      27.131   0.1196   11.54804   0.0210
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_GDP        |
         GDP |
         LD. |   .2691171   .1246462     2.16   0.031     .0248151    .5134191
        L2D. |   .1874404   .1178853     1.59   0.112    -.0436105    .4184912
             |
         PDI |
         LD. |   .1202326   .1525295     0.79   0.431    -.1787198     .419185
        L2D. |  -.2518658   .1529432    -1.65   0.100    -.5516289    .0478973
             |
       _cons |   14.94721   5.005273     2.99   0.003     5.137052    24.75736
-------------+----------------------------------------------------------------
D_PDI        |
         GDP |
         LD. |   .1609622   .0993684     1.62   0.105    -.0337964    .3557207
        L2D. |   .2459483   .0939786     2.62   0.009     .0617536     .430143
             |
         PDI |
         LD. |  -.2097618   .1215972    -1.73   0.085    -.4480878    .0285643
        L2D. |  -.2702654   .1219269    -2.22   0.027    -.5092378    -.031293
             |
       _cons |   16.85565   3.990225     4.22   0.000     9.034952    24.67635
------------------------------------------------------------------------------
```

```
. dfuller D.PDI, trend regress

Dickey-Fuller test for unit root                   Number of obs   =        86

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -9.593            -4.071            -3.464            -3.158
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D2.PDI       |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       D.PDI |
         L1. |  -1.051376   .1095995    -9.59   0.000    -1.269365   -.8333875
      _trend |  -.0444036   .1232052    -0.36   0.719    -.2894538    .2006466
       _cons |   20.61757   6.540397     3.15   0.002     7.608987    33.62616
------------------------------------------------------------------------------
```

Clearly , stationarity can be seen after 1st differencing.So, after first differencing we have solved the problem of non stationarity.

Estimating VAR model

```
. gen D_GDP = GDP - L.GDP
(11 missing values generated)

. gen D_PDI = PDI - L.PDI
(11 missing values generated)

. var D_GDP D_PDI

Vector autoregression

Sample:  4 - 88                              Number of obs     =         85
Log likelihood =  -804.4051                  AIC               =   19.16247
FPE            =   719988.6                  HQIC              =   19.27806
Det(Sigma_ml)  =   568879.8                  SBIC              =   19.44984

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_GDP                5     34.0327   0.1547   15.55194   0.0037
D_PDI                5      27.131   0.1196   11.54804   0.0210
----------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
D_GDP        |
       D_GDP |
         L1. |   .2691171   .1246462     2.16   0.031     .0248151    .5134191
         L2. |   .1874404   .1178853     1.59   0.112    -.0436105    .4184912
             |
       D_PDI |
         L1. |   .1202326   .1525295     0.79   0.431    -.1787198    .4191849
         L2. |  -.2518658   .1529432    -1.65   0.100    -.5516289    .0478973
             |
       _cons |   14.94721   5.005273     2.99   0.003     5.137052    24.75736
-------------+----------------------------------------------------------------
D_PDI        |
       D_GDP |
         L1. |   .1609621   .0993684     1.62   0.105    -.0337964    .3557207
         L2. |   .2459483   .0939786     2.62   0.009     .0617536     .430143
             |
       D_PDI |
         L1. |  -.2097618   .1215972    -1.73   0.085    -.4480878    .0285643
         L2. |  -.2702654   .1219269    -2.22   0.027    -.5092378    -.031293
             |
       _cons |   16.85565   3.990225     4.22   0.000     9.034952    24.67635
------------------------------------------------------------------------------
```

D_GDP is the value of GDP obtained after 1st differencing.
D_PDI is the value of PDI obtained after 1st dfiferencing.

At 5% significance level, the following two results can be observed :-

1. D_GDP is affected by its own 1st lag and no lags of D_PDI.
2.D_PDI is affected by its own second lag and second lag of D_GDP.

Stata command : vargranger

In Stata, the “vargranger” command is used to conduct Granger causality tests for vector autoregressive (VAR) models. Granger causality tests help determine whether one time series variable "Granger causes" another, meaning that past values of one variable contain information that helps predict future values of another variable.

```
vargranger

 Granger causality Wald tests
```

Equation	Excluded	chi2	df	Prob > chi2
D_GDP	D_PDI	4.1454	2	0.126
D_GDP	ALL	4.1454	2	0.126
D_PDI	D_GDP	11.063	2	0.004
D_PDI	ALL	11.063	2	0.004

From the probability values, when probability value is < 0.05, we can say that the result is significant and we can reject the null hypothesis.

Null hypothesis of Granger causality event states that one time series is not causing the other time series.

So, from the probability values we can say that,

D_PDI is affected by D_GDP,but the opposite is not true. Thus ,D_GDP granger causes D_PDI.

Conclusion

We selected two economic variables, GDP (Gross Domestic Product) and PDI (Personal Disposable Income), under the assumption that they are interrelated. Initially, to ensure our analysis was robust, we made both variables time stationary through differencing and we got D_GDP and D_PDI. Following this, we proceeded to estimate a VAR (Vector Autoregression) model.

To determine the direction of causality between the two variables, we conducted a Granger Causality test. This test helps identify whether one variable influences the behavior of the other over time. The results of the test indicated that changes in D_GDP, cause changes in D_PDI.

Therefore, our initial assumption that GDP and PDI are interrelated variables appears to be valid, as the Granger Causality test confirmed that changes in GDP have a causal effect on changes in PDI. This finding underscores the interconnectedness of economic variables and highlights the significance of understanding their dynamic relationships for economic analysis and policy-making.