

Analysis of Project Time Series Data Performed in R

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1 Introduction and Methodology

The analysis of the data set was performed using R `tseries` and `urca` packages. ADF tests were performed using the `ur.df` function. Optimal number of lags were found using AIC information criteria. The PP tests were performed using the `ur.pp` function with $Z\tau$ statistic. The Stationary/Not stationary values in the tables below were derived by comparing the test statistic and the 5% confidence interval threshold and they are not conclusive because rejection of the null hypothesis is stronger than acceptance. Therefore the ADF and PP tests that result in Not Stationary conclusion show weaker results than the ones that result in a Stationary conclusion.

The structure of this report is as follows: [section 2](#) describes the variables of the EA data set, with discussion on the plot ACF, PACF and unit root test results for each variable. [section 3](#) describes the variables of the US data set, with discussion on the plot ACF, PACF and unit root test results for each variable. [section 4](#) draws conclusions and suggests further work.

2 EA

2.1 CPI

The CPI plot ([Figure 1](#)) shows large fluctuations after around 2007 (probably caused by the Global Financial Crisis). This might be an indication that the time series is not stationary and the noise term accumulates. There doesn't seem to be much of a trend or seasonal component.

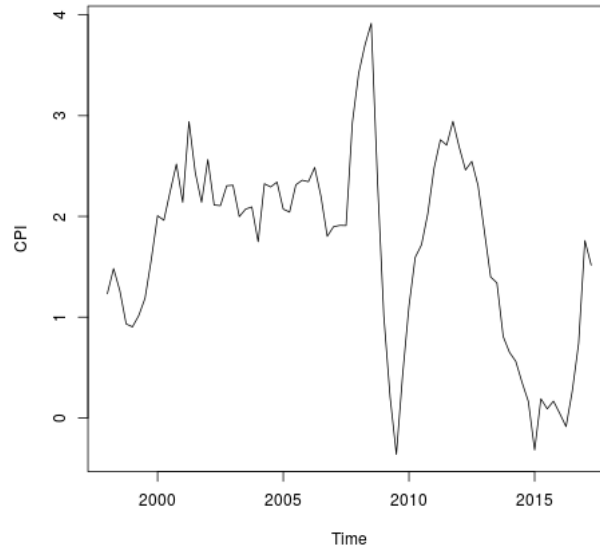


Figure 1: plot EA CPI

Looking at the ACF ([Figure 2](#)) of EA CPI, we see that it resembles that of an Autoregressive model. The PACF doesn't show strong evidence of a moving average component, although there are some minor fluctuations right after lag 0.

[Table 1](#) Shows the results of the Stationarity tests ran on the EA CPI variable. The ADF test with drift and both KPSS tests suggest the series is stationary. However the ADF and KPSS with drift test results are very close to the 0.05 significance threshold.

2.2 GDP

The plot of GDP ([Figure 3](#)) maybe suggests a downward trend. A fluctuation around 2008 is again observed. There is probably a drift as well.

ACF and PCF ([Figure 4](#)) again suggest an autoregressive model as expected.

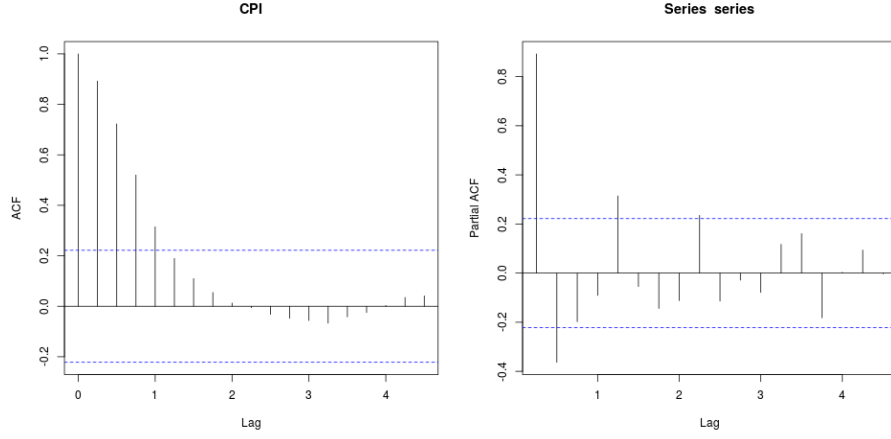


Figure 2: ACF and PACF EA CPI

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-1.367	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-2.918	-3.51	-2.89	-2.58	Stationary
ADF with drift and trend	-3.259	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-2.637	-3.516	-2.899	-2.587	Not Stationary
PP with drift and trend	-2.925	-4.08	-3.468	-3.161	Not Stationary
KPSS with drift	0.488	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.193	0.216	0.146	0.119	Stationary

Table 1: CPI EA Unit Root Tests

The unit root test results (Table 2) suggest the series is stationary, maybe with a drift or/and trend. The KPSS results show it is not stationary which might be due to the changing variance around 2008.

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-3.219	-2.6	-1.95	-1.61	Stationary
ADF with drift	-4.171	-3.51	-2.89	-2.58	Stationary
ADF with drift and trend	-4.473	-4.04	-3.45	-3.15	Stationary
PP with drift	-2.911	-3.517	-2.9	-2.587	Stationary
PP with drift and trend	-2.91	-4.082	-3.469	-3.161	Not Stationary
KPSS with drift	0.397	0.739	0.463	0.347	Not Stationary
KPSS with drift and trend	0.095	0.216	0.146	0.119	Not Stationary

Table 2: GDP EA Unit Root Tests

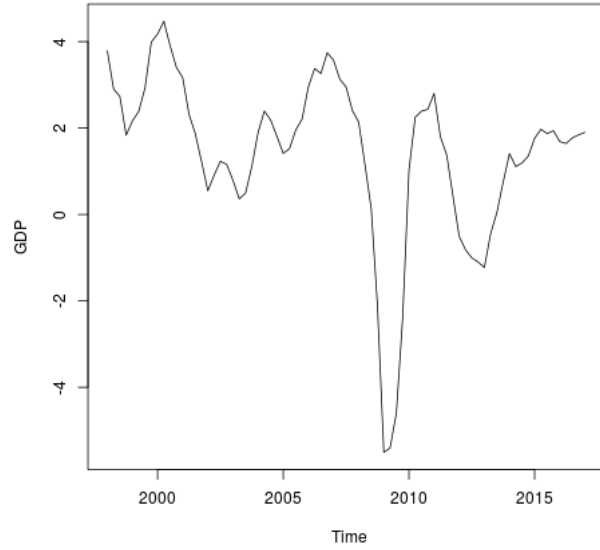


Figure 3: plot EA GDP

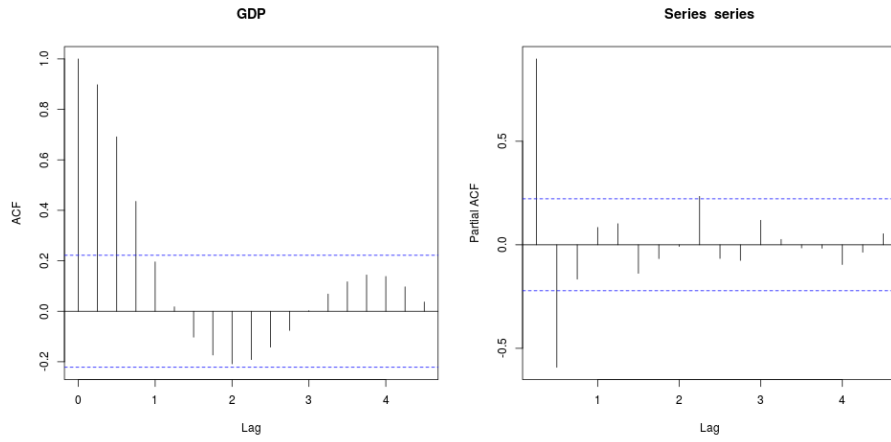


Figure 4: ACF and PACF EA GDP

2.3 UR

The EA unemployment rate curve ([Figure 5](#)) looks very quite smooth, therefore the effect of the noise term in the model is insignificant. The mean is shifted so there is most probably a drift. There doesn't seem to be a particular trend.

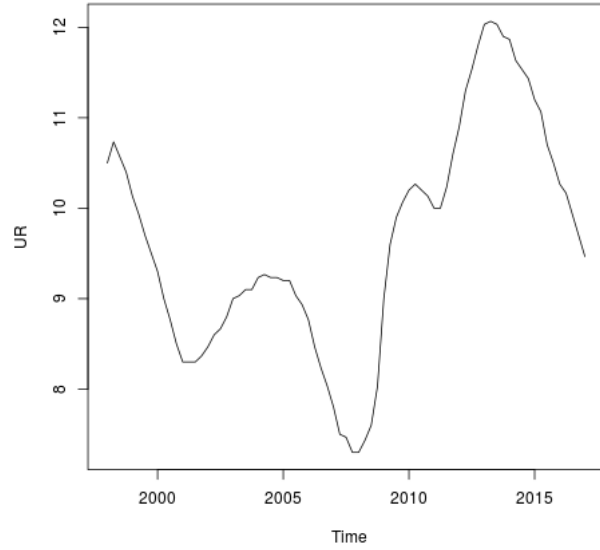


Figure 5: plot EA UR

UR ACF and PACF ([Figure 6](#)) show that there is a significant time dependence on previous values of the variable. There might be an MA(1) element as well but this is not obvious.

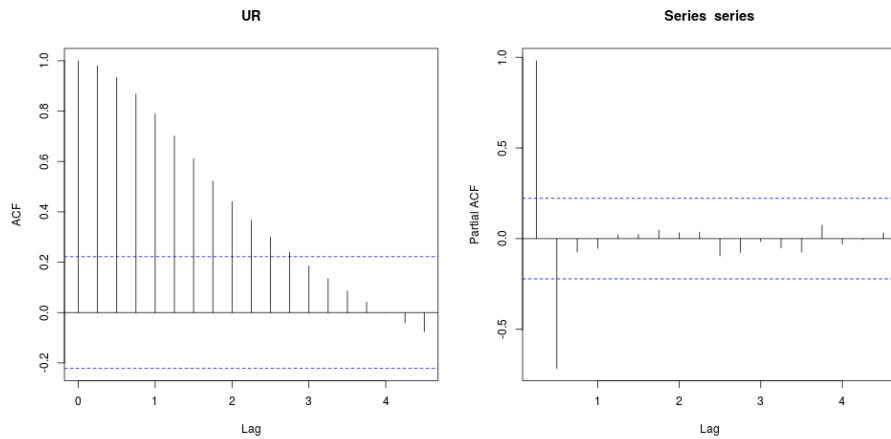


Figure 6: ACF and PACF EA UR

Only the KPSS tests suggest the variable is stationary ([Table 3](#)), which

isn't very strong evidence since rejection of the null hypothesis is stronger than acceptance and none of the tests with non-stationary null (ADF and PP) tell us otherwise.

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-0.853	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-2.641	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-3.366	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-1.45	-3.517	-2.9	-2.587	Not Stationary
PP with drift and trend	-1.865	-4.082	-3.469	-3.161	Not Stationary
KPSS with drift	0.762	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.263	0.216	0.146	0.119	Stationary

Table 3: UR EA Unit Root Tests

2.4 IR Policy Rate

There definitely seems to be a downward trend in the EA IR Policy Rate variable (Figure 7). It shows high but relatively constant variance. The mean is shifted.

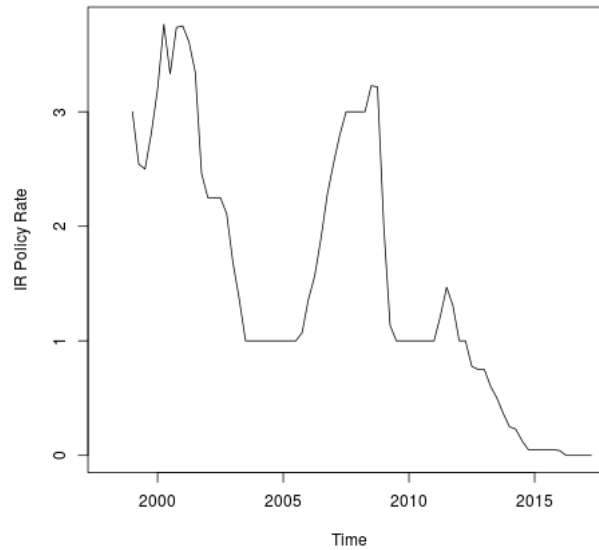


Figure 7: plot EA IR Policy Rate

ACF and PACF (Figure 8) exhibit the behaviour of an autoregressive model. The unit root tests (Figure 7) again show weak evidence of stationarity.

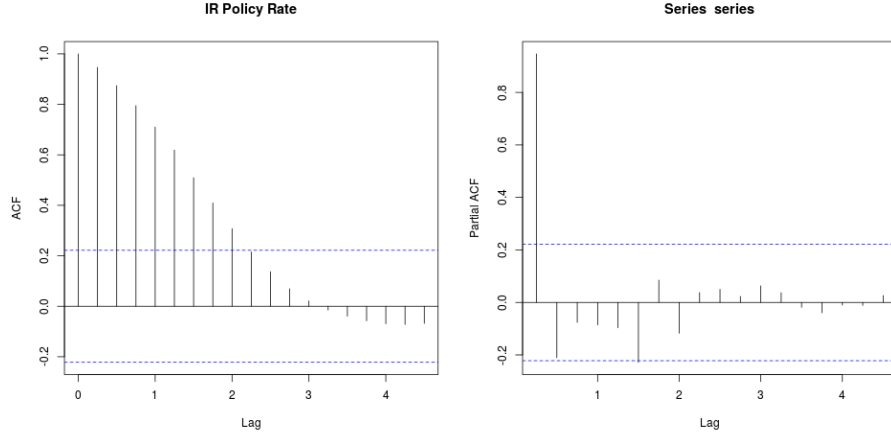


Figure 8: ACF and PACF EA IR Policy Rate

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-1.331	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-1.437	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-2.729	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-1.38	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-2.177	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	1.189	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.113	0.216	0.146	0.119	Not Stationary

Table 4: IR Policy Rate EA Unit Root Tests

2.5 LR10

The EA LR10 variable has a distinct trend (Figure 11). The mean is shifted and the decay might be considered exponential.

ACF and PACF (Figure 10) exhibit the typical behaviour of an autoregressive model.

Again only the KPSS tests show the variable might be stationary (Table 5).

2.6 LR10-IR

The LR10-IR (Figure 11) derived variable seems to have some periodic behaviour. A particular trend doesn't seem to be present. The mean is shifted.

The ACF (Figure 12) shows a strong autocorrelation even for lags after the initial decay.

Again weak evidence of stationarity from the tests (Table 6).

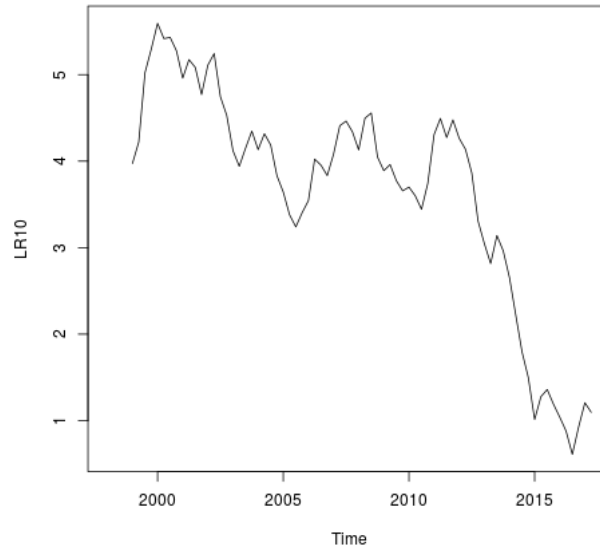


Figure 9: plot EA LR10

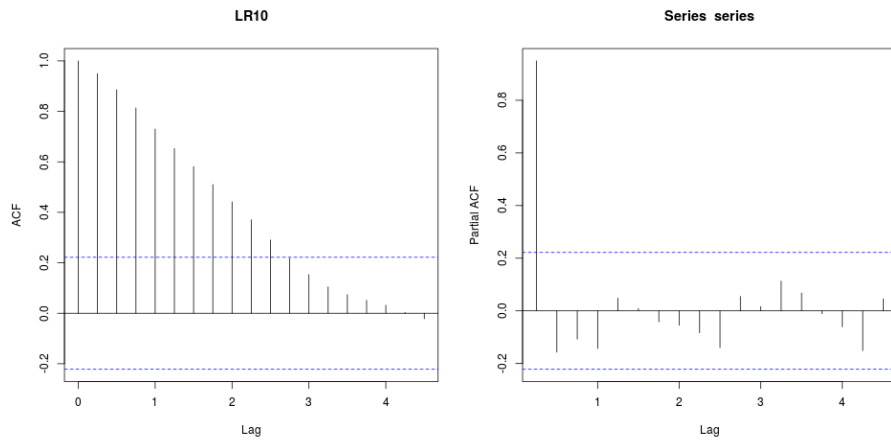


Figure 10: ACF and PACF EA LR10

2.7 Exchange Rate EUR to USD

The exchange rate between euro and dollar ([Figure 13](#)) has a non zero mean as expected. A trend is not present. There is some periodic behaviour but doesn't seem to be seasonal.

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-1.109	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-0.487	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-2.466	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-0.215	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-2.416	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	1.347	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.257	0.216	0.146	0.119	Stationary

Table 5: LR10 EA Unit Root Tests

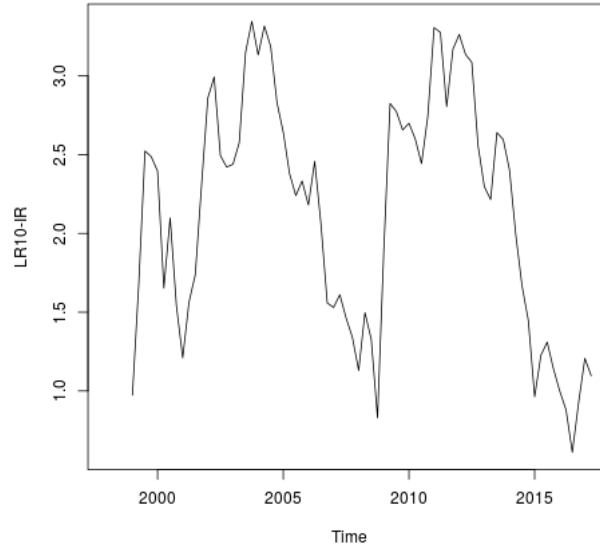


Figure 11: plot EA LR10-IR

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-0.923	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-2.364	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-2.616	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-2.423	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-2.742	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	0.259	0.739	0.463	0.347	Not Stationary
KPSS with drift and trend	0.161	0.216	0.146	0.119	Stationary

Table 6: LR10-IR EA Unit Root Tests

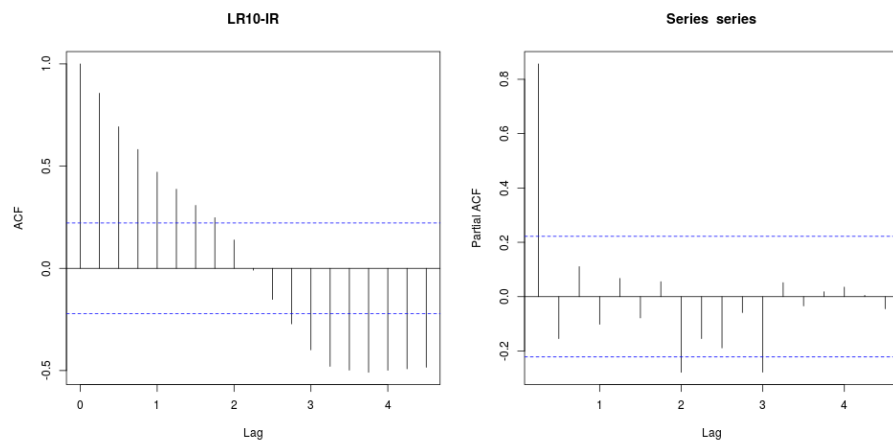


Figure 12: ACF and PACF EA LR10-IR

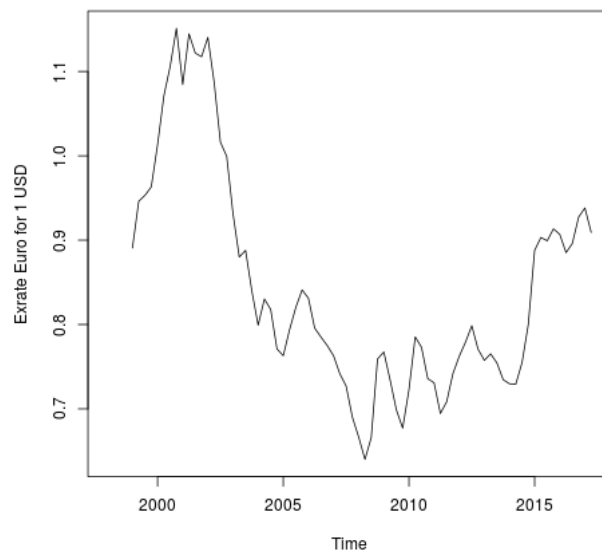


Figure 13: plot EA Exchange Rate EUR to USD

ACF and PACF ([Figure 14](#)) are typical for an autoregressive variable. Weak evidence of stationarity from unit root tests ([Table 7](#))

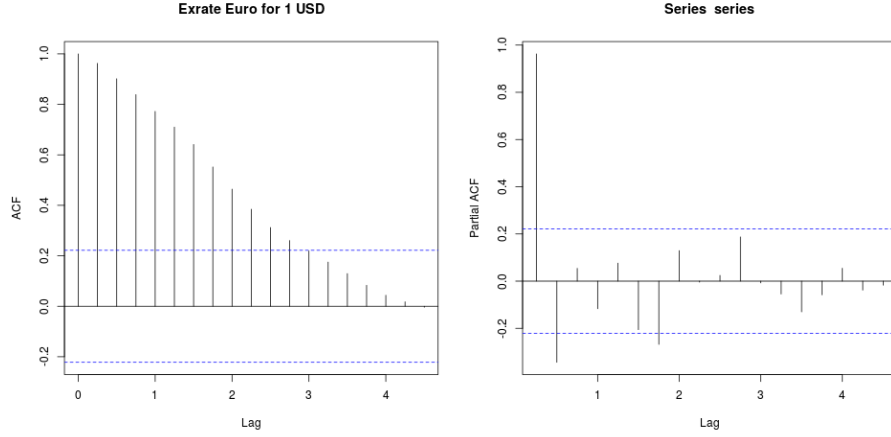


Figure 14: ACF and PACF EA Exchange Rate EUR to USD

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-0.426	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-1.631	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-1.43	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-1.375	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-1.283	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	0.795	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.367	0.216	0.146	0.119	Stationary

Table 7: Exchange Rate EA Unit Root Tests

3 US

3.1 CPI

The US CPI plot (Figure 15) shows evidence of a drift term but no trend. There is again a spike around 2009 but apart from that variance seems to be constant.

ACF and PACF plots (Figure 16) show behaviour of autoregressive model with some fluctuations in the PACF.

Unit root tests (Table 8) good show evidence of stationarity from both PP and ADF tests.

3.2 GDP

The plot of US GDP (Figure 17) shows a mean close to zero. A clear trend cannot be seen. Fluctuation around the Global financial crisis is present again.

An autoregressive model with a dependance on relatively few lags is suggested by the ACF and PACF (Figure 18)

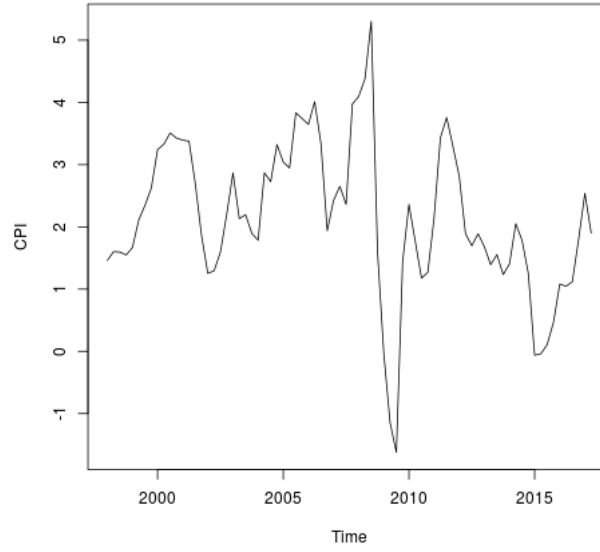


Figure 15: plot US CPI

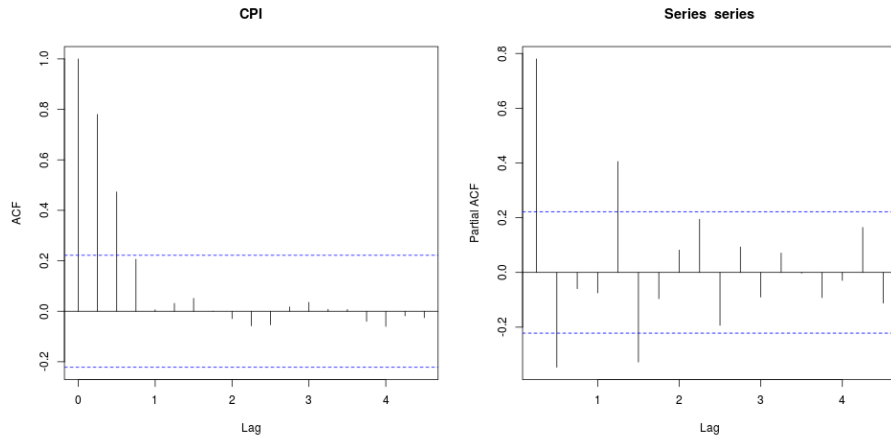


Figure 16: ACF and PACF US CPI

Strong evidence of stationarity by both ADF and KPSS tests ([Table 9](#)).

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-1.794	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-4.095	-3.51	-2.89	-2.58	Stationary
ADF with drift and trend	-4.548	-4.04	-3.45	-3.15	Stationary
PP with drift	-3.43	-3.516	-2.899	-2.587	Stationary
PP with drift and trend	-3.698	-4.08	-3.468	-3.161	Stationary
KPSS with drift	0.421	0.739	0.463	0.347	Not Stationary
KPSS with drift and trend	0.108	0.216	0.146	0.119	Not Stationary

Table 8: CPI US Unit Root Tests

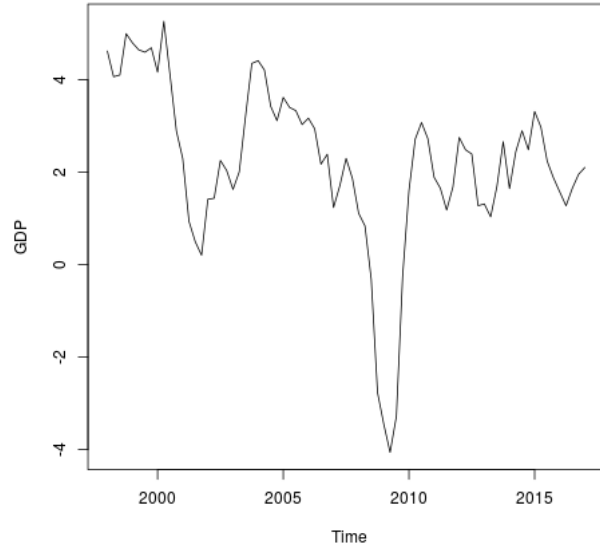


Figure 17: plot US GDP

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-1.994	-2.6	-1.95	-1.61	Stationary
ADF with drift	-3.059	-3.51	-2.89	-2.58	Stationary
ADF with drift and trend	-3.185	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-2.726	-3.517	-2.9	-2.587	Not Stationary
PP with drift and trend	-2.745	-4.082	-3.469	-3.161	Not Stationary
KPSS with drift	0.459	0.739	0.463	0.347	Not Stationary
KPSS with drift and trend	0.153	0.216	0.146	0.119	Stationary

Table 9: US Unit Root Tests

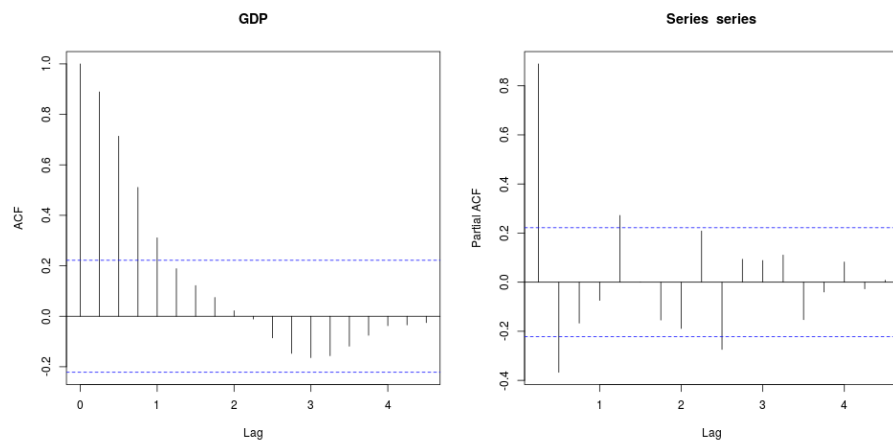


Figure 18: ACF and PACF US GDP

3.3 UR

Unemployment rate curve ([Figure 19](#)) is again very smooth as the EA one. The plot suggests an exponential growth. The mean is shifted so there is probably drift.

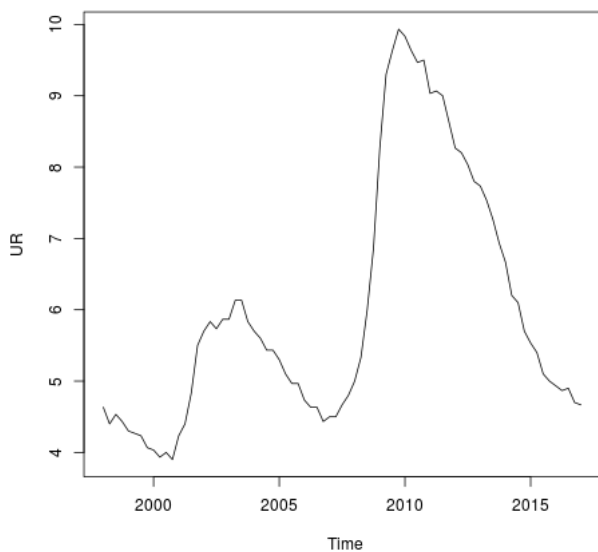


Figure 19: plot US UR

Strong autocorrelation in ACF ([Figure 20](#)).

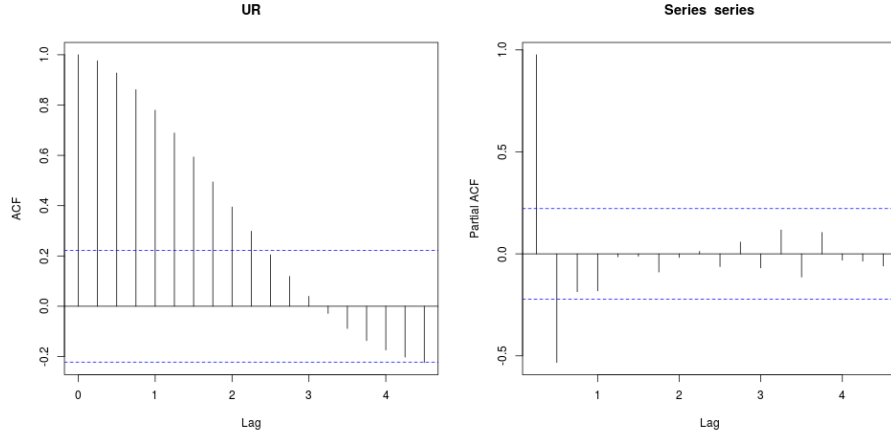


Figure 20: ACF and PACF US UR

Stationarity test results ([Table 10](#)) not very convincing. Only KPSS tests suggest stationarity.

Test Name	T-stat	1%	5%	10%	95% Confidence
ADF	-0.463	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-2.107	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-1.86	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-1.343	-3.517	-2.9	-2.587	Not Stationary
PP with drift and trend	-0.926	-4.082	-3.469	-3.161	Not Stationary
KPSS with drift	0.677	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.22	0.216	0.146	0.119	Stationary

Table 10: UR US Unit Root Tests

3.4 IR FEDFUNDS

US IR variable ([Figure 21](#)) shows high variance followed by a period of low variance. Drift is present. There is some evidence of a trend.

Again typical autoregressive model ACF and PACF ([Figure 22](#))

Evidence of stationarity from both ADF and KPSS tests ([Table 11](#)). A

3.5 IR10 premium

IR10 premium variable plot ([Figure 23](#)) show decaying variance. There is no apparent trend.

Autocorrelations of lags much after initial decline in ACF ([Figure 24](#)).

No evidence of stationarity from any of the tests ([Table 12](#))

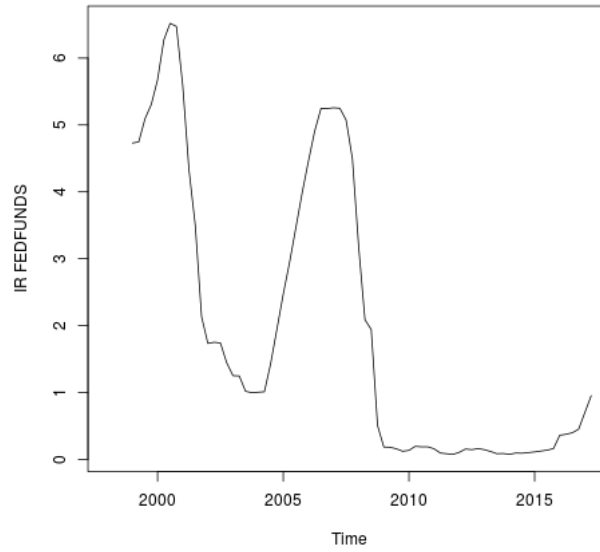


Figure 21: plot US IR10 fedfunds

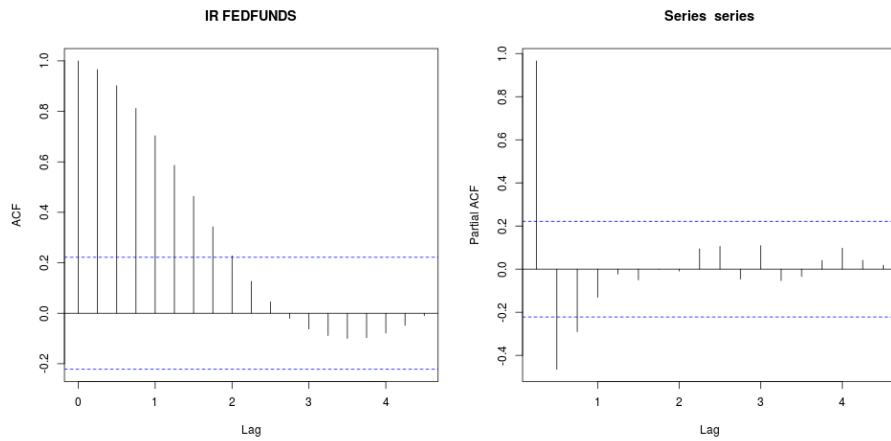


Figure 22: ACF and PACF US IR10 fedfunds

3.6 LR10 - IR

The plot of the LR10 - IR ([Figure 25](#)) suggests a very clear downward trend. Variance is relatively constant. There might be some seasonal behaviour but it is not obvious.

Test Name	T-stat	1%	5%	10%	¿95% Confidence
ADF	-1.986	-2.6	-1.95	-1.61	Stationary
ADF with drift	-2.36	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-2.849	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-1.7	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-1.887	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	1.058	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.09	0.216	0.146	0.119	Not Stationary

Table 11: IR Fedfunds US Unit Root Tests

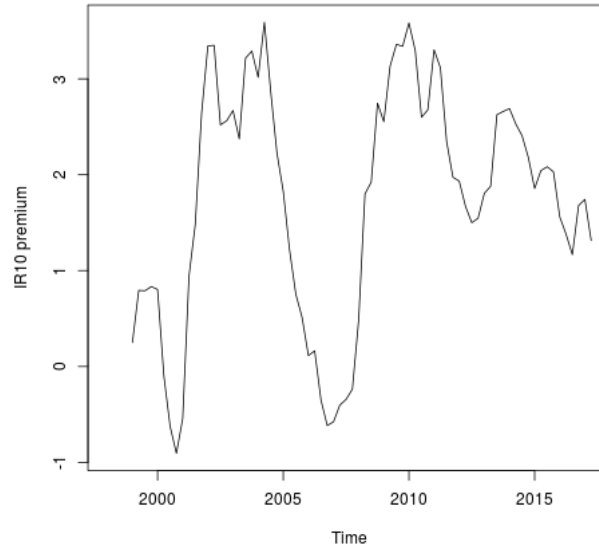


Figure 23: plot US IR10 premium

Test Name	T-stat	1%	5%	10%	¿95% Confidence
ADF	-1.388	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-2.491	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-2.455	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-2.409	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-2.31	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	0.223	0.739	0.463	0.347	Not Stationary
KPSS with drift and trend	0.083	0.216	0.146	0.119	Not Stationary

Table 12: IR 10 premium US Unit Root Tests

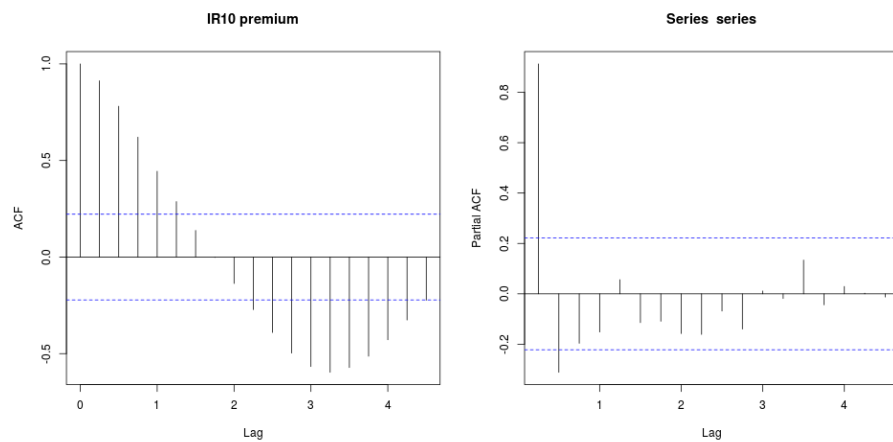


Figure 24: ACF and PACF US IR10 premium

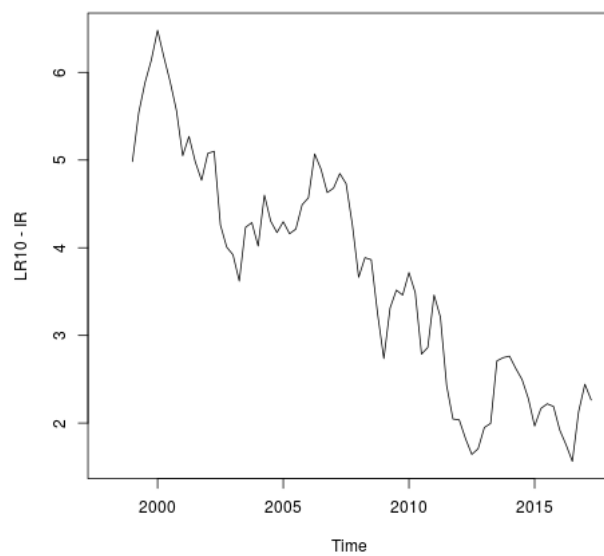


Figure 25: plot US LR10 - IR

Strong autocorrelation in ACF on many lags ([Figure 26](#)).
 Weak evidence of stationarity from only KPSS unit root test ([Table 13](#))

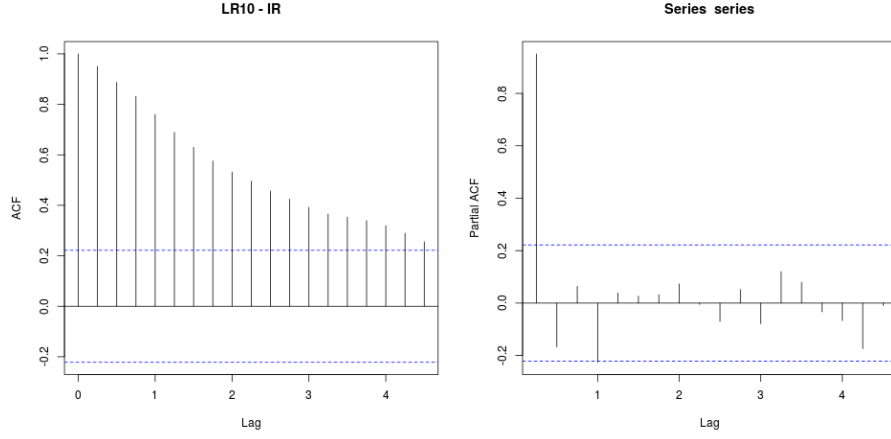


Figure 26: ACF and PACF US LR10 - IR

Test Name	T-stat	1%	5%	10%	¿95% Confidence
ADF	-1.46	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-1.485	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-3.341	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-1.104	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-3.227	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	1.687	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.082	0.216	0.146	0.119	Not Stationary

Table 13: LR10-IR US Unit Root Tests

3.7 Exchange Rate USD to EUR

Exchange rate USD to EUR is the naturally the opposite of EUR to USD (subsection 2.7) , therefore the properties are equivalent (Figure 27, Figure 28, Table 14).

Test Name	T-stat	1%	5%	10%	¿95% Confidence
ADF	-0.118	-2.6	-1.95	-1.61	Not Stationary
ADF with drift	-1.968	-3.51	-2.89	-2.58	Not Stationary
ADF with drift and trend	-1.804	-4.04	-3.45	-3.15	Not Stationary
PP with drift	-1.456	-3.521	-2.901	-2.588	Not Stationary
PP with drift and trend	-1.274	-4.087	-3.471	-3.162	Not Stationary
KPSS with drift	0.76	0.739	0.463	0.347	Stationary
KPSS with drift and trend	0.386	0.216	0.146	0.119	Stationary

Table 14: Exchange Rate US Unit Root Tests

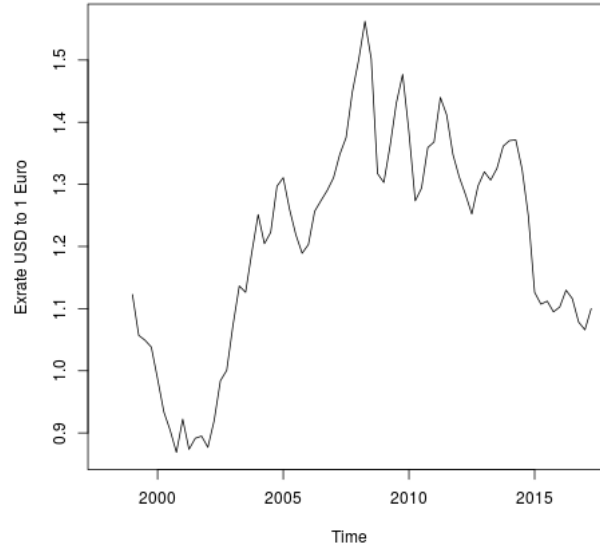


Figure 27: plot US Exchange Rate USD to EUR

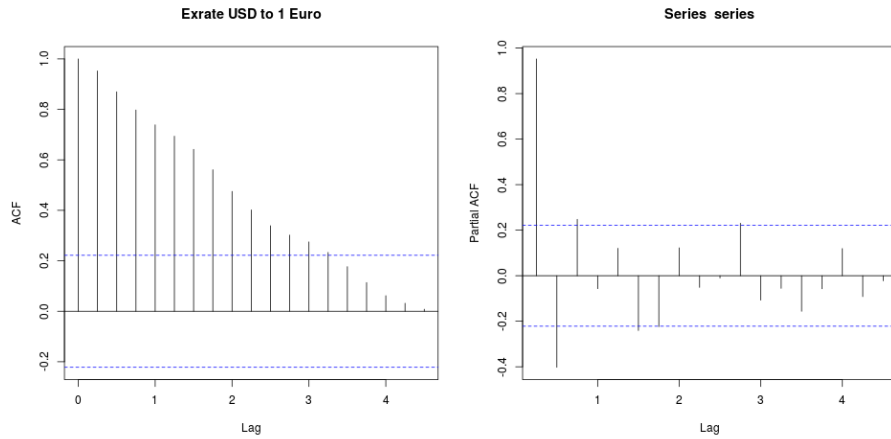


Figure 28: ACF and PACF US Exchange Rate USD to EUR

4 Conclusions

The majority of variables don't exhibit strong evidence of stationarity. Further tests need to be performed with different preprocessing techniques. The effect of differencing and/or log transformations needs to be tested. There are fluctu-

ations in the data around the global financial crisis which cause high variance. These fluctuations along with the small sample size of the data cause it to exhibit non stationary behaviour even for variable that have long been theorised to be stationary by economist - CPI. Furthermore the performance of ADF and PP tests is sensitive to the sample size and do not perform very well on small data samples such as the one used.