The European Central Bank, the Federal Reserve and the Bank of England: is the Taylor Rule an useful benchmark for the last decade?

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Abstract

The Taylor rule has been used in many studies in order to analyse the monetary policies. In my work I focus on the Euro era and compare the ECB with other two central banks, the Fed and the BoE. A very interesting result comes out from the analysis: it seems that these central banks do not observe the inflation course before deciding about the variation of the interest rates. This result can be linked to two ideas: firstly, the use of stationary time series drops out the significance of the inflation gap as regressor; secondly, a really forward looking central bank focuses on other macroeconomic leading indicators instead of examining the realized or expected inflation gap.

Key words: Taylor rule, monetary policy, European Central Bank, Federal Reserve, Bank of England, Euro, Exchange rates.
J.E.L.: E52, E58

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1 Introduction

Since 1993, when Taylor published his work “Discretion versus policy rules in practice”, there has been a large debate about the possibility that a simple rule, the so called Taylor Rule, might mimic the monetary policy of a Central Bank or another type of monetary policy-maker which used the interest rate as the key monetary policy tool.

The great simplicity of this formula and the good fit of the Federal Reserve monetary policy (Taylor applied his rule with very good results to FED monetary policy from 1987 to 1992) gave a big impulse to different strand of research focused on the implementation of this rule.

It is possible to identify three macro types of Modified Taylor Rule.

On the one hand economists have tried to add a large number of explanatory variables (there were only two explanatory variables in the original Taylor Rule: inflation gap and output gap) in order to understand which macroeconomic variables Central Banks analyse before taking monetary policy decisions and what the economic weight of these variables is.

The other two strands have tried to change the basic structure of the Taylor Rule. In fact, Taylor used contemporaneous variables in origin. Nominal interest rate, output gap and inflation gap are referred to the same time. So, many studies have tried to understand if this kind of formulation was really plausible. Thus, two types of Taylor Rule were created: the backward looking Taylor Rule, with real time data, and the forward looking Taylor Rule, with expectations.

In the first case the independent variables are lagged with respect to dependent ones: information about macroeconomic aggregates are not immediately at disposal and so it seemed to be correct linking the interest rate with lagged explanatory variables.

In the other case economists used expectations in the right hand side of the Taylor Rule: Central Banks move the interest rate if future trends of the variables, that is, expectations, have a different value compared with their target.

Given the simplicity and the validity of the formula, since 1993 many papers and articles have studied these questions (see Carare and Tchaidze (2005) for a short excursus about different types of Taylor Rule), but it is not possible to be sure about the optimal type of Taylor Rule. It is likely to get good results with both a backward looking rule and a forward looking one even the study is focused on the same period and on the same policy-maker.

In recent literature it seems to be a preference for using the forward looking Taylor Rule, but I think that it is always the economist that should explain his choices and find valid economic pillars to his results.

Moreover, it is very difficult to cite the literature related to the Taylor Rule, cause of its extension. There are many important works on this issue and, obviously, it is impossible to remember all of them.

As a consequence I decided to cite only the papers and the articles that I used as guide in my work without any intention to be exhaustive. Obviously, the work by Taylor (1993) is the seminal paper for all the works in this field. In that study, Taylor proposed for the first time the rule and tested its effectiveness with respect to the US Federal Reserve from 1987 to 1992. The particular feature of that article is that Taylor did not estimate the rule using econometric procedures. Starting from that study, many other economists have tried to implement that rule and to estimate the relationship between the interest rate and some regressors.

Clarida and Gertler (1996) employed a modified Taylor Rule to study the monetary policy of the Bundesbank. In this study they used instrumental variables and examined the period from 1974 to 1993. They found that a modified Taylor rule could be useful in order to explain the behaviour of the monetary policy in Germany. Clarida, Galì and Gertler (1998) tested the Taylor Rule, using the GMM estimation in this case, for the US, Japan, Germany, Italy, France and the UK from 1979 to 1993. This study is fundamental for the use of GMM estimations with the Taylor Rule. Indeed, many following papers use the same structure given by these three economists with respect to the instrumental variables used in the regression.

Judd and Rudebusch (1998) tried to compare the monetary policy of three Fed Chairmen (Burns, Volcker and Greenspan) using a modified Taylor Rule. They find that the original Taylor Rule fits the Greenspan period very well, but they also stressed that the monetary policy of Burns was easier than the one of Greenspan and that Volcker’s monetary policy has been the tightest among the three chairmen.

Gerlach and Schnabel (1999) used GMM for the estimation of a Taylor Rule applied on the EMU area in the period 1990-1998 and stressed the role of the inflation expectations. They also analysed other regressors, such as the Euro-Us Dollar exchange rate, the money growth and the lagged inflation, but these regressors have been not significant in their study.

Florens, Jondeau and Le Bihan (2001), using GMM and ML estimations, estimated a reaction function for the Federal Reserve. They employed a Taylor rule and found that coefficients show differences in the esteems if they use the iterative or the continuous-updating GMM. The coefficients they computed have a very high value with GMM estimations in comparison with the usual values computed in other studies.

Ball and Tchaidze (2002) used the Taylor Rule to analyse and compare two periods of the Greenspan's tenure (the old economy period 1987-1995 vs the new economy one 1995-2000). They tested the importance of the NAIRU (non-accelerating inflation rate of unemployment) as regressor in the Taylor rule and highlighted that, using this type of regression, the rule can mimic in a good way the behaviour of Greenspan during the entire period of his presidency.

Fourçans and Vranceanu (2002) estimated different policy rules for the ECB from 1999 to 2002, using OLS and GMM. They showed that the ECB is a conservative central bank, that is the increase in the interest rate is not so big when the inflation grows, and that the ECB is also focused on real economy. Furthermore, they also found that the monetary aggregate M3 did not influence the conduct of the monetary policy.

Ullrich (2003), using 2SLS, made a comparison between the Fed and the ECB from 1995 to 2002. This study uses time series in first difference because of the lack of stationary. This approach is similar to the one I adopt in my study and it is important to stress that some studies on the Taylor Rule did not consider the problem of the possible presence of unit root in the time series (on this issue see Österholm (2005)). So, in order to have a robust estimation I prefer to follow this approach and use time series in first difference in my study, as I will explain in the following pages.

Sauer and Sturm (2003) used Taylor Rule to study the ECB during the first years of the Euro era. They employed OLS and NLS and found that, with the use of expectations, the coefficient on inflation seems to comply with the Taylor principle. On the contrary, using contemporaneous data, it emerged an ECB that accommodates the changes in the inflation rate. They also stressed the poor role of the real-time industrial production data, differently from the US case.

Clausen and Meier (2005) used the Taylor Rule (GMM estimation) in the period 1973-1998 in order to evaluate the Bundesbank monetary policy. They used different types of output gap and find that the Taylor rule mimic "quite well" the Bundesbank monetary policy. They also found a very limited role of the monetary aggregate M3. At the end, also in this case, the Taylor rule is a good formula to replicate the monetary policy of a central bank.

Apergis, Miller, Panethimitakis and Vamvakidis (2005) studied a model in which they insert a Taylor-type rule. They examined forward looking and spontaneous adjustment rules, with an international view, and found that the forward looking approach gave a better contribute to macroeconomic stability. Moreover, they find that a positive inflation target gave a better result than the zero inflation target.

Carstensen (2006), using a probit model, estimated the coefficients of a rule similar to the one proposed by Taylor. He focused on ECB from January 1999 to January 2003. At the end, he stressed that the revision of the monetary policy strategy, done in 2002, did not affect the coefficients of the rule.

Rotondi and Vaciago (2007) used a Taylor-type rule and GMM estimation in order to compare the ECB and the Bundesbank monetary policy. Even in this case the coefficient on the inflation gap using the backward looking Taylor rule is lower than the one obtained with the forward looking version of the rule.

Gorter, Jacobs and de Haan (2007) tested different types of Taylor rule and focused on the comparison between Consensus data and ex-post data for the Euro area. They also tried to deeply analyse the role and the significance of the interest rate smoothing. They found an important difference in the coefficients on ex-post data in comparison with the ones on the Consensus data: the ECB's policy is stabilizing only using the survey data (that is, the Consensus data). In this study they employ NLS.

Another interesting and recent paper is the one by Parsley and Popper (2009) that, using standard and data-rich GMM, estimated three equations for the Korean economy from January 1999 to April 2008. One of these equations is a policy reaction function that resembles a Taylor rule. They use the exchange rate in the formula and often find a significant relationship between this regressor and the interest rate. Usually the exchange rate is not used in a monetary policy rule, but some of the works I cited use it and, recently, even Engle (2009) demonstrates the usefulness of the exchange rate in an open-economy two-country model. Indeed, Engel affirms that the exchange rate misalignments create loss of welfare and so, an optimal policy has to target currency misalignment together with inflation and output gap.

Starting from this literature I present an analysis based on a comparison among three areas: the Euro Area, the US and the UK. I use a threefold econometric approach (OLS, TSLS, GMM) in order to examine, through a Taylor-type rule, the monetary policy of the

ECB, the Federal Reserve and the Bank of England. Furthermore, with this work, I follow both the backward and the forward looking Taylor Rule strands and I try to find some empirical evidence on the ECB's behaviour from the onset of its operations, January 1999, to June 2008. The study, as I will deeply explain in the following pages, uses standard OLS, TSLS and iterative GMM estimations. I adopted the OLS estimation with the backward looking formula while the TSLS and the iterative GMM are employed with the forward looking version of the Taylor rule.

It is worth noting that the rule I present in the next sections is not very similar to the one widely adopted in the literature, since problems of stationary induced me to use the first difference of the time series. As a consequence, it is not possible to directly compare the results of this study with the ones of the dominant literature. But, in so doing, I have avoided all the possible problems linked to a spurious regression. I preferred to follow this methodology instead of having problems with the quality of my analysis.

Before introducing the equations I studied and the results obtained with the different estimations, I show, in the following paragraph, the course of the real interest rate in these three areas as a simple and immediate indicator of the stance of the monetary policy. Indeed, the real interest rate can show the strength used by the central banks against the inflation pressures. This simple vision will be useful to introduce the econometric section of this paper.

The rest of the paper is organized as follows: in the second paragraph I depict the course of the real interest rate in the UK, the US and the Euro area from January 1999 to June 2008. Then I expand the analysis and show the real interest rate in the US, the UK, Germany, France and Italy from January 1984 to December 1998; in the third paragraph I present the backward and forward looking equations and the data; in the fourth section I show the results of the regressions with OLS, TSLS and iterative GMM estimations; the fifth paragraph is focused on the ECB's behaviour and I try to stress the particular features of the monetary policy in the Euro area; the last section concludes the paper with final remarks.

2 The course of the interest rates

In order to examine the role of the monetary policy in dampening and controlling the trend of the inflation rate, an examination of the course of the real interest rate is of primary importance. This simple indicator can reveal the behaviour of the central banks and their approach towards inflation pressures. For this reason, in this paragraph I present a simple visual analysis of the course of the real interest rate in three areas: the Euro area, the US and the UK. More precisely, I calculated the real interest rate in these three areas from January 1999 to June 2008 in order to compare these three central banks during the Euro age.

Moreover, I go another step further by calculating the real interest rate from January 1984 to December 1998 in the US, the UK, Germany, France and Italy. In this way one can built a twofold analysis: a comparison among the ECB, the Fed and the Bank of England during the last decade and a comparison among the ECB and the pre-existing national central banks.

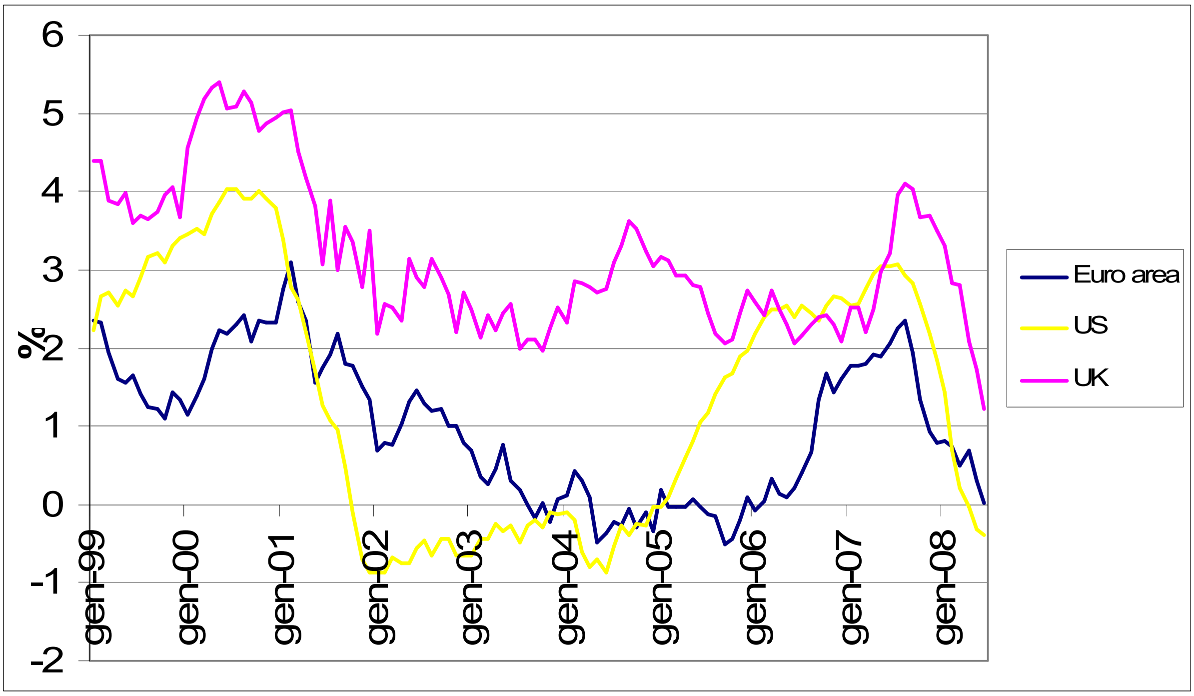
Obviously, the course of the real interest rate is linked with the global situation that a central bank has to face and so this fact can reduce the importance of the intertemporal comparison. But I think that this approach, although simple and probably limited, can help us to draw some important and preliminary judgements on this issue. Indeed, the period examined is that of the "Great Moderation". During this period the central banks faced a quite good situation in terms of prices and growth. This can help us in the comparison. Except for national and temporary shocks (for example in Italy and in the UK in first years of the nineties, or in the US in 2001), the twenty-four years of the sample represent an exceptionally good period for the central banks. As a consequence it is possible to compare their behaviours along the time.

Figure 1 shows the first part of the analysis. We can observe the trend of the real interest rate in the Euro area, the US and the UK. The real interest rate is given by the difference between the monthly average of the day-to-day rate and the monthly inflation rates. I used data from OECD and Eurostat websites.

It is widely known that these central banks have a different approach. For example, the ECB has an explicit inflation target while the Federal Reserve has an implicit target. Furthermore, they have different inflation rates as target of their monetary policy. As a consequence, in order to built a precise graph I used the HICP (all items) for the Euro area, the core inflation (CPI, all items less energy and food) for the US and the CPI (all items) for the UK. These are the inflation rates that these three central banks use as their target. The lines depicted in the figure show the difference between these inflation rates and the respective day-to-day rates.

Globally speaking, the image shows that during the last years these Central banks did not adopt a so tight monetary policy. The Bank of England has had the higher real interest rate during almost the entire period. In this case, the real interest rate lays within a narrow range, from 2 to 5 per cent, in almost all the sample. On the contrary, the Fed moved the real interest rate in an ampler way, from 4 to -1 per cent. It is important to notice that the Fed adopted a very expansive monetary policy from the end of 2001 to the end of 2004, with a negative real interest rate during this period.

Figure: 1 Real interest rate in the Euro area, the US and the UK.
January 1999 - June 2008



Source: Personal elaboration using Eurostat, Bank of England and Bureau of Labor Statistics data

The ECB have had a mixed strategy: it has moved the real interest rate in a range similar to the one of the BoE, but it always had a lower rate than the BoE, more similar to the one of the Fed. We can even observe a period of negative real interest rate from the first half of 2004 to the end of 2006. For the ECB, the range goes from -0.5 to 3 per cent. It is of great importance to notice that during two periods (from February 1999 to January 2001 and from February 2005 to January 2008) the ECB had the lowest real interest rate.

This international comparison shows that the ECB did not implement a very tight monetary policy during the last decade. So, the first finding is that the direct role of the monetary policy in dampening and controlling the inflation rate, through the use of the interest rate as main tool, is probably softer than we can typically believe.

As I have previously announced, in order to build a wider study on the behaviour of central banks I also decided to compare a longer period. Figure 2 shows the real interest rate (day-to-day rate minus CPI in all the cases) for the US, the UK, the Euro area, Germany, Italy and France from January 1984 to June 2008. Obviously, the Figure shows the real interest rate of the Euro area from January 1999 ahead and the real interest rate of Germany, France and Italy from January 1984 to December 1998. Even in this case I use monthly data.

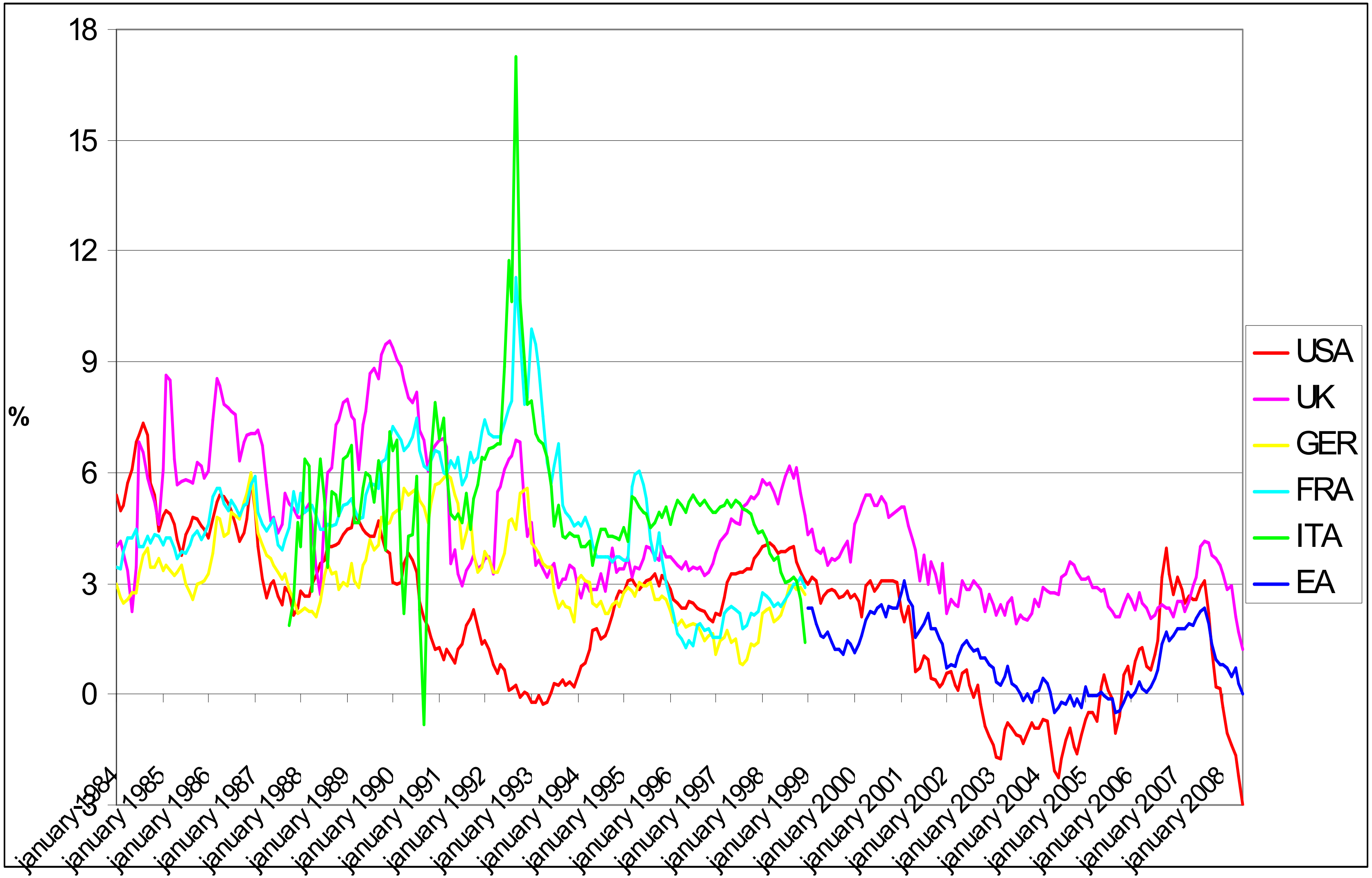
The figure shows that the BoE usually has a tighter monetary policy in comparison with the other nations. The central banks of Italy and France adopted a tighter monetary policy than the UK but only for a limited period.

With the onset of the Euro, the monetary policy of this area probably has changed. Indeed, it seems that the national central banks adopted a tighter monetary policy during their life in comparison with the one chosen by the ECB during these first years of its activity. Clearly, the ECB faces a different economic environment and different economic pressures but it seems that during the Euro era the monetary policy has been easier than in the previous years.

Indeed, the crucial feature of this analysis is that the monetary policy during the Euro era has not been particularly tight both historically and internationally. This is only a simple analysis but the result is that the course of the real interest rate cannot give explanation for the low inflation rate we registered in the Euro area. As a consequence, this preliminary study induces to deepen the analysis on the monetary policy in search of some other more robust explanations.

This is what I will present in the following pages: an econometric study on the monetary policy using a Taylor-type rule.

Figure 2: Real interest rate in the US, the UK, the Euro Area, Germany, France Italy from January 1984 to June 2008.



Source: Personal elaboration using OECD and EUROSTAT data.

3 *Equations and data*

In this section I present the equations I estimate and the data I use for the regressions. It is worth nothing that in a large part of the literature it is often assumed the stationary of the time series used in the Taylor Rule. Furthermore, many works do not treat this argument at all (see Österholm (2005) for a critics about these issues). In my work I deeply analyse this issue before starting with regressions in order to exclude the possibility of spurious regressions. The results of the ADF, Phillips-Perron and KPSS tests on the time series leave no doubts. There is the presence of unit root in some of the time series I should use in my analysis following the traditional form of the Taylor rule. For example, the monthly average of the day-to-day interest rate time series shows the presence of the unit root in the three areas that I analyse (the Euro area, the US and the UK). The same *problem* is present in other time series (for example in the inflation gaps, or in the exchange rates). As a consequence, in order to estimate the same equation for the three areas and in order to avoid the presence of errors in the estimations I decided to use the first difference form for all the equations and for all the time series. In this way I eliminate the possibility of spurious regressions, even if the value of the coefficients is completely different from the one obtained with the original Taylor rule. This is a problem if one want to compare the analysis of these pages with other works, but in this way we are sure that the significance of the relationships is not linked to the presence of the unit root.

After this procedure, all the time series I employ in this study are stationary (see table 10 for the results of the tests). The results clearly highlight the absence of a unit root.

But this procedure has changed the structure of the Taylor rule. The formula proposed by Taylor in 1993 is similar to the following one:

$$i_t = \beta_1 + \beta_2 \Pi_t^{gap} + \beta_3 x_t^{gap} + \beta_4 z_t + \varepsilon_t$$

where the dependent variable, the interest rate, i_t, is regressed on a constant, an inflation gap Π_t^{gap}, an output gap x_t^{gap} and other regressors z_t. The formula of my study is different because, as I said, I employ time series in first difference.

The first equation I estimate, the baseline version, is the following one:

$$\Delta i_t = \beta_1 + \beta_2 \Delta \Pi_{t-1}^{gap} + \beta_3 x_{t-1}^{gap} + \beta_4 \Delta e_{t-1} + \beta_5 \Delta i_{t-1} + \varepsilon_t \text{ , (1)}$$

where i_t is the day to day interest rate, Π_{t-1}^{gap} is the inflation gap in period t-1, x_{t-1}^{gap} is the output gap in period t-1, e_{t-1} is the log of the exchange rate index in period t-1 and Δ denotes series in first difference.

This equation is backward looking, since we have lagged independent variables in the right hand side of the equation. I estimated this equation through OLS and it represents the first step of my analysis. The two fundamental differences, in comparison with the original rule, are the use of the first difference and the lags on the right side of the formula.

This type of formula and the OLS estimation represent the basic way to estimate a Taylor rule. This approach is very elementary even if it is used in literature, especially in the more dated papers.

In order to expand and deepen the analysis I estimate another formula. The crucial role that the expectations have in the literature induced me to also use a more complex approach. Indeed, I estimate a forward looking rule in order to compare the results of the two methodology. In this case I use both the TSLS and the iterative GMM estimations. The TSLS is used in some studies and it gives the same results of the standard GMM approach under normal conditions. The iterative GMM is not so widespread in literature but I decided to use it in order to have a further comparison and evaluate the different results (Florens, Jondeau and Le Bihan (2001) used two-step GMM and iterative GMM in order to compare the different results and highlight their properties).

The following formula visualizes the second equation I estimate:

$$\Delta i_t = \beta_1 + \beta_2 \mathrm{E}_t(\Delta\Pi_{t+k}^{gap} \mid \Omega_t) + \beta_3 \mathrm{E}_t(x_{t+k}^{gap} \mid \Omega_t) + \beta_4 \mathrm{E}_t(\Delta e_{t+k} \mid \Omega_t) + \beta_5 \Delta i_{t-1} + \varepsilon_t \quad (2)$$

In this case $\mathrm{E}_t(\Delta\Pi_{t+k}^{gap} \mid \Omega_t)$ represents the expectation at time t of the inflation gap t+k periods ahead, $\mathrm{E}_t(\Delta x_{t+k}^{gap} \mid \Omega_t)$ is the expectation of the output gap and $\mathrm{E}_t(\Delta e_{t+k} \mid \Omega_t)$ is the expectation of the exchange rate. Ω_t represents the set of the available information at time t. The other symbols have the same meaning of the previous formula. In this case, it is straightforward to observe that the formula is completely forward looking. I substitute the lagged independent variables of the equation 1 with their respective expectations.

The instruments used for the estimations are the same both for the TSLS and for the iterative GMM. I follow the main literature, even if I introduce some changes. I employ a constant and the lagged independent variables together with other variables as instruments. To be more precise, I use as instruments a constant, lags 1 to 6, lag 9 and lag 12 of the exchange rate and interest rate, lags 2 to 7, lag 9 and lag 12 of the inflation gap, output gap and commodity prices. The use of different lags in comparison with a large part of the literature (see Clarida, Galì and Gertler (1998)) for the inflation gap, the output gap and the commodity prices, is motivated by the fact that these variables are not immediately calculated and so I decided not to use the lag 1 within the set of available information at time t. In other words, I use a slightly different set of instrumental variables in order to make the estimations more realistic. For these three variables I employ lags 2 to 7 instead of lags 1 to 6. It is a very slight change, but I decided to employ it because in this way one can mimic in a more precise mode the way in which the policy makers form their expectations. Moreover, I follow the critique by Orphanides (1997) which underlined the problems related to the use of contemporaneous independent and dependent variables in the original Taylor rule. In his study he focused on the US case during the period 1987-1992 (the same period analysed by Taylor (1993)) and showed the differences that emerged using contemporaneous or real time data. In so doing, he stressed the limits of the original formulation of the Taylor rule and recommended to be more cautious in the choice of the right timing for the variables. As a consequence, following his teaching I try to use this different set of instruments to make the estimations more truthful.

Before showing the results of the three types of estimations, it is useful to deeply analyse the data I used for my study.

As regards the inflation gap, I used the annual rate of change of the HICP published by Eurostat for the Euro area, the core inflation for the US (CPI, all items less food and energy published by the Bureau of Labor Statistics) and the CPI (all items, published by the UK government) for the UK. In all the cases the gap is referred to a 2 per cent threshold. In the case of the US, this ceiling is not explicit but there is a common view about the importance of this threshold for the core inflation. Then, given the lack of stationary, I calculated the monthly variation of the inflation gap and employed this series in the regressions.

For the output gap, I employed the Hodrick-Prescott (HP) filter on the industrial production index time series (data from OECD for the three areas) and then I calculated the difference between the actual data and the trend obtained through the HP filter:

$x_t^{gap} = 100*[\log(IP_t) - \log(IP^*)]$

where IP_t is the actual series of the industrial production and IP* is the time series calculated through the HP filter. The output gap series calculated in this way are stationary.

As regards the exchange rate, I employed different exchange rates to have an ampler inspection. I used the “broad” and the “narrow” nominal effective exchange rates, published by the Bank for International Settlements, and one bilateral exchange rate for each nations: the Euro-US dollar for the Euro area, the Pound Sterling-US Dollar for the UK and the US Dollar-Euro for the US. All these time series are published by Eurostat. In this case I used the monthly percentage variation of the exchange rates in my estimations.

The interest rate, as I said before, is the monthly average of the day-to-day interest rate (data published by Eurostat for the three areas) and in the estimations I used the monthly variation.

For the commodity price, used as instrument, I used an index, in dollars, published by the International Monetary Fund. In this case I used the US dollar-Euro and the US dollar-Pound Sterling exchange rates to transform the time series of the commodity prices for the Euro area and the UK cases. In all the cases I employed the first difference of the log of the series.

4 Results

The analysis I have done tries to compare, as I have pre-announced, three economic areas: the Euro area, the US and the UK. In so doing, it is possible to highlight the particular features of the Euro area.

In the following pages I will firstly show the backward looking estimations and then I will employ the forward looking version of the rule.

Backward looking – OLS

The following tables show the estimation of the equation 1. In this case I employ the OLS estimation.

Tables 1, 2 and 3 respectively show the results using, as regressors, the broad NEER, the narrow NEER and the bilateral exchange rates previously mentioned. In the tables I show the value of the coefficients, their significance, the R^2 statistics, the Durbin Watson test, the results of the White test and the maximum value of the Variance Inflation Factors (VIF).

The first important thing to analyse are the coefficients on the inflation gap. These coefficients are not statistically different from zero in the three areas and with the three different exchange rates used. It seems that the relationship between the interest rate and the inflation gap is not more present using this specification of the formula.

As regards the coefficient on the output gap, β_3, we can observe a significant coefficient, at one percent level, for the Euro area, but a not significant coefficient in the other two nations. We got the same result using the different exchange rates. In this case the ECB seems to be more alert on the information coming out from the real economy in comparison with the other central banks.

Moreover, a more mixed result comes out with the coefficient on the exchange rate: in the Euro area this coefficient is always statistically different from zero and it has the right sign. It is bigger in the first two cases (broad and narrow NEER) than in the case of the Euro-US Dollar exchange rate; in the US this coefficient has always the wrong sign and only the bilateral exchange rate is significant; for the UK, the exchange rate is always highly significant but with the wrong sign. Even in this case, the ECB seems to observe the fluctuations of the exchange rate as an indicator for the pace of the monetary policy.

At the end, the lagged dependent variable is highly significant in the US and the UK in all the three cases, but it is not significant in the Euro area.

The values of the statistics shown in the tables highlight that there are no problems of autocorrelation, heteroskedasticity or collinearity. Indeed, the Durbin Watson tests show values around 2, the White tests show the absence of heteroskedasticity and the VIFs have a very little value.

These results show a different approach of the central banks: the ECB seems to be more alert on information about the economy (output gap) and exchange rates, while in the other cases (the Fed and the BoE) these coefficients are not significant or they have the wrong sign. But the most interesting result is the one linked with the inflation gap coefficients. With this specification of the Taylor rule it seems that the central banks do not observe the fluctuation of the inflation gap before deciding about the variations of the interest rate. Obviously, in these cases all the time series are stationary and so the lack of this linkage is really interesting for a real insight of the central banks behaviours.

This first step has highlighted different results in comparison with the literature. The inflation gap is not significant and this is really strange for central banks that have an explicit or implicit inflation target. The Fed has not significant *policy* coefficients (except for one case, but with the wrong sign). Only the smoothing parameter is significant in the three estimations. The situation for the BoE is not so different from the US case.

These results are surprising but one have to be cautious: this is the backward looking approach and before drawing a definitive conclusion it is wise to also observe the forward looking results.

Table 1: OLS, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: broad NEER			
	EA	US	UK
β_1	0.006	-0.002	-0.014
β_2	-0.064	-0.077	-0.081
β_3	2.648***	-1.349	2.548
β_4	-2.170**	1.443	4.565***
β_5	0.167	0.720***	-0.466***
adj R^2	0.120	0.498	0.210
DW	2.12	2.29	1.99
Test White	9.96 pv: 0.764	16.23 pv: 0.299	15.00 pv: 0.377
V.I.F.	<1.12	<1.04	<1.06
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

Table 2: OLS, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: narrow NEER			
	EA	US	UK
β_1	0.005	-0.002	-0.012
β_2	-0.064	-0.080	-0.080
β_3	2.735***	-1.360	2.502
β_4	-2.160**	0.766	4.546***
β_5	0.165	0.721***	-0.464***
adj R^2	0.117	0.496	0.211
DW	2.11	2.30	2.00
Test White	10.65 pv: 0.712	16.43 pv: 0.287	14.27 pv: 0.429
V.I.F.	<1.14	<1.04	<1.05
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

Table 3: OLS, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: bilateral rate			
	EA	US	UK
β_1	0.006	-0.000	-0.019
β_2	-0.063	-0.087	-0.092
β_3	2.567***	-1.272	2.014
β_4	-1.320**	1.387**	2.757***
β_5	0.169	0.713***	-0.463***
adj R^2	0.119	0.517	0.209
DW	2.07	2.32	1.97
Test White	9.33 p v:0.809	15.63 p v:0.335	15.76 p v: 0.328
V.I.F.	<1.1	<1.04	<1.04
*Significant at ten percent level, **Significant at five percent level, ***Significant at one percent level.			

Forward looking – TSLS

As I have previously said, in order to deepen the analysis I also use a forward looking version of my rule. I estimate the equation 2 through TSLS and iterative GMM. In this section I show the TSLS estimation results. Tables 4, 5, 6 illustrate the estimated coefficients, the R^2 and the Durbin Watson statistics. Even in this case I employ three different exchange rates as regressors (broad and narrow NEER and a bilateral exchange rate).

The results are not so different from that obtained with the OLS-backward looking approach.

Table 4: TSLS, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: broad NEER			
	EA	US	UK
β_1	0.005	-0.001	-0.008
β_2	0.021	0.371*	0.045
β_3	2.152**	-1.829	5.274
β_4	-1.814	1.763	1.931
β_5	0.134**	0.747***	-0.488***
adj R^2	0.031	0.543	0.227
DW	2.20	2.13	1.96
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

Table 5: TSLS, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: narrow NEER			
	EA	US	UK
β_1	0.007	0.000	-0.007
β_2	0.011	0.306	0.044
β_3	2.270**	-1.705	5.073
β_4	-2.469*	1.671	1.605
β_5	0.126	0.751***	-0.488***
adj R^2	0.024	0.540	0.225
DW	2.22	2.15	1.95
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

Table 6: TSLS, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: bilateral rate			
	EA	US	UK
β_1	0.007	0.001	-0.015
β_2	0.003	0.281	0.092
β_3	1.914*	-1.579	5.279
β_4	-1.391**	1.371*	2.408
β_5	0.150	0.739***	-0.484***
adj R^2	0.025	0.526	0.213
DW	2.25	2.19	1.95
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

Indeed, the coefficient on the inflation gap is statistically different from zero in only one case (in the US with broad NEER). In the other cases we find no significant coefficients. So, even using the expectations, the situation does not change. It seems that the central banks I analysed in this study do not observe the course of the inflation gap before deciding on the interest rate variations. Obviously, this result is quite surprising.

As regard the coefficient on the output gap, the situation is similar to the previous one. The coefficient is statistically different from zero and with the right sign in the Euro area, but in the other two areas this coefficient is not significant at all. Again, using the expectations, the ECB seems to be focused on the course of the real economy, that is the industrial production.

The situation is mixed when we analyse the exchange rates. In this case, the broad NEER is not significant in the three regions, and it has the right sign only in the Euro area. The narrow NEER is significant in the Euro area and it has the right sign, but this coefficient is not statistically different from zero in the other two nations. The bilateral exchange rate is highly significant in the Euro area, again with the right sign, and it is slightly significant in the US, but in this case with the wrong sign.

The Durbin Watson statistics are always near 2.

In sum, the situation with the forward looking approach and TSLS estimations is not so different from the one depicted with the backward looking rule. Indeed, even in this case the ECB seems to be the unique central bank that has a focus on the real economy and on the fluctuations of the exchange rates (but I am not affirming that ECB *controls* the exchange rate). The other estimations, for the FED and the BoE, do not show significant coefficients. The last thing to notice is the lack of significance for the coefficient on the inflation rate, as previously mentioned.

Forward looking – iterative GMM

The last estimation is carried out through the iterative GMM. In this case it is useful to give some details in order to fully explain the set-up I used.

Firstly, the *weighting* matrix (*W*) employed in this case is an identity matrix (*I*). Given the nature of the iterative GMM, the matrix *W* is recalculated several times until the convergence is achieved. So, the use of the identity matrix for the first step of the iteration does not create problems for the robustness of the results.

Moreover, I used the kernel of Bartlett and the software by default calculates HAC (heteroskedasticity and autocorrelation consistent) estimations. So, the coefficients do not incorporate these possible problems.

In tables 7, 8 and 9 I show the value of the estimated coefficients together with the J-test. The J-test, or test for over-identifying restrictions, has the correct specification of the model as null hypothesis. The results of the Hansen's J-test are always positive: in all the cases it is not possible to reject the null. As a consequence the models tested in this section are "*valid*".

The values of the coefficients are, in some cases, very surprising.

In the Euro area case, the coefficient on the inflation gap is now significant but it has the wrong sign in the three cases. This result is deeply different in comparison with the TSLS and OLS estimations, in which the coefficient on the inflation gap has never been significant. The output gap is significant in the first and third specifications (with the broad NEER and with the Euro-US dollar exchange rate) and it has the right sign. The smoothing parameter is now significant for the first time in the Euro area case. As regards the exchange rates, the broad and narrow NEER are not significant, while the euro-US dollar exchange rate remains significant and with the right sign.

As regards the US, the exchange rate is significant in two cases (broad NEER and bilateral exchange rate) but with the wrong sign. The smoothing parameter and the constant are significant, but the other coefficients are not statistically different from zero. In this case the estimation is similar to the previous ones. The Taylor rule estimated with US data shows a Federal Reserve that does not care about inflation and real economy.

For the UK the situation is mixed: the constant and the smoothing parameter are always significant; the inflation gap is significant in the last case only and it has the right sign; the other coefficients (output gap and exchange rate) give strange results: the output gap is statistically different from zero in the three cases, but it has the right sign only in the first regression; the exchange rate is significant in the three equations and it has the right sign in the last two regressions (narrow NEER and bilateral exchange rate).

The estimations with the iterative GMM have given mixed results: we find more coefficients with significant value but they often have the wrong sign. The situation is not extremely different from that depicted in the previous tables.

The presence of different values is not so strange. In other works, some of these have been previously cited, the use of different estimation methodologies produced very different values of the coefficients. But, notwithstanding this fact, it is possible to draw some conclusions on the basis of the estimated data.

Table 7: iterative GMM, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: broad NEER			
	EA	US	UK
β_1	0.012**	0.010***	0.016*
β_2	-0.152***	-0.029	-0.005
β_3	1.216***	-0.697	5.950***
β_4	-0.537	1.229*	3.707**
β_5	-0.173***	0.694***	-0.697***
J-test	20.02 pv:0.98	18.86 pv:0.99	20.38 pv:0.98
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

Table 8: iterative GMM, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: narrow NEER			
	EA	US	UK
β_1	0.003	0.007**	0.018*
β_2	-0.109***	-0.019	0.023
β_3	0.509	-0.252	-4.203***
β_4	0.461	0.567	-3.697**
β_5	-0.170***	0.568***	-0.636***
J-test	19.29 pv:0.98	18.35 pv:0.99	19.96 pv:0.98
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

Table 9: iterative GMM, robust standard error, sample January 1999-June 2008.			
Dependent variable: day to day rate. Exchange rate: bilateral rate			
	EA	US	UK
β_1	0.015***	0.007**	0.020**
β_2	-0.120***	-0.020	0.361***
β_3	0.916**	-0.763	-3.279***
β_4	-0.547**	0.585**	-2.133**
β_5	-0.119***	0.573***	-0.474***
J-test	20.45 pv: 0.98	18.58 pv:0.99	21.21 pv:0.97
*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level.			

5 The central banks' behaviour

This complex study sheds a critical light on the role of the monetary policy. Many works have studied the course of the inflation rate during the last decades and, at the same time, it is well known the role of the monetary policy as possible explanation of the Great Moderation (as regards the Great Moderation see, for example, Bernanke (2004), Giannone, Lenza and Reichlin (2008), Melick and Galati (2006) or Rogoff (2003) while for an analysis of the inflation processes see Angeloni, Aucremanne and Ciccarelli (2006), Angeloni, Aucremanne, Ehrmann, Galì, Levin and Smets (2004), Assenmacher-Wesche and Gerlach (2006), Berck (2000), Borio and Filardo (2007), Cecchetti and Debelle (2005), Cogley and Sargent (2001) or Forte (2009a)). The interesting feature is that the result given by the estimations presented in this paper is a little bit surprising, if we remember the key role of the central banking in the theoretical framework of the Great Moderation.

In fact, I have found that the coefficient on the inflation gap is not significant in my regressions. This means that the decisions on the interest rate course are not linked with the fluctuations of the inflation gap. Obviously, this is a very strange picture for central banks that have to anchor the inflation rate around the target, especially for the ECB and the BoE that have an explicit target. I think that this result reduces the role of the central banks in guiding and anchoring the inflation rate during the last lustrums. Furthermore, this result would suggest that these monetary policies might have led to an unstable inflation process. And this is at odds with the mandate of the central banks. For the ECB, we have observed a focus on the real economy and on the fluctuations of the exchange rates, but this result cannot cover the lack of attention on the inflation process.

In other words, the study has highlighted a very low direct attention of the central banks towards their main target and, as a consequence, the conclusion is that it is not possible to ascribe to these authorities a crucial role in dampening and guiding the inflation course.

In sum, it is possible to affirm that, using stationary time series, the result obtained via Taylor rule reduces the presumed key role of the central banks as prominent figures in the context of the low and stable inflation. As a consequence, that result, the low inflation, is probably linked to other global economic features.

6 Conclusions

In this paper I have used a modified Taylor rule to examine the monetary policy of the European Central Bank, the Federal Reserve and the Bank of England during the last years (from January 1999 to June 2008). The purpose of this paper was to find a possible linkage between the monetary policy and the stable course of the inflation, especially in the Euro area. The international comparison was useful in order to highlight the particular features of the central banks I analysed.

The lack of stationary in some time series induced me to use the first difference of the data in order to avoid the presence of spurious regressions. In so doing, I transformed the original Taylor rule and I obtained results that are not directly comparable with the main literature in this field of research. I used three different methodologies for the estimation of the rule: OLS for the backward looking version and TSLS and iterative

GMM for the forward looking specification. I introduced slight changes in the formula and in the instruments used as set of information in the forward looking set-up.

The estimations have showed some interesting, and a little bit surprising, results.

Firstly, the coefficient on the inflation gap has been quite always not significant or with the wrong sign. This means that the variation of the interest rate is not linked with the variation of the inflation gap. This result has been valid both with the backward looking and the forward looking approach. This feature is the most surprising one of this work: the three central banks of the study do not care about the course of the inflation gap.

As regards the output gap, the ECB seems to be alert toward this indicator while the other two central banks do not show, in many cases, significant coefficients. In this case it is possible to assert that the ECB shows a certain degree of attention toward the economic growth as indicator of possible threats for the stability of the inflation.

I obtained a similar result with the exchange rates. In this case the regressions with the Euro area data show that the ECB observes the trend of the exchange rates. In details, I used both a broad and a narrow version of the NEER (by BIS) and the Euro-Us dollar bilateral exchange rate and I found that the coefficients on these exchange rates are often significant both with the backward looking and the forward looking formulas. For the other central banks, the role of the exchange rate is extremely limited.

These results cannot shed more light on the stability of the inflation rate in the Euro area, in the US or in the UK . We have observed a not so direct approach toward the inflation gap. The ECB, even if it shows a more active behaviour in comparison with the Fed and the BoE, does not seem to be really aggressive against the inflation course. This finding can lead to two different ideas: one is that probably the stability of the inflation is linked with other economic factors. I give an idea on this issue in Forte A. (2009b); the second is that the standard Taylor rule has two problems: firstly, the use of time series in level probably produces spurious regressions; secondly, my analysis highlighted that the central banks probably examine other macroeconomic-indicators. That is, a pure forward looking approach induces the central banks to focus on leading indicators instead of observing the realized or expected inflation. This can open a new strand of research: a Taylor rule without the inflation gap as regressor.

Table 10 unit root tests.
Phillips Perron: H0: unit root. KPSS: H0: stationary

	Phillips Perron	KPSS
Δ dtd US	-4.811***	0.1066
Δ dtd UK	-15.364***	0.1940
Δ dtd EA	-9.852***	0.1315
Δ infl. gap US	-10.720***	0.0786
Δ infl. gap UK	-10.117***	0.2855
Δ infl. gap EA	-9.539***	0.1383
Output gap US	-2.912**	0.1332
Output gap UK	-5.463***	0.1557
Output gap EA	-3.663***	0.1960
Δ Broad NEER US	-8.246***	0.5045**
Δ Broad NEER UK	-10.025***	0.2519
Δ Broad NEER EA	-7.625***	0.2292
Δ Narrow NEER US	-8.121***	0.3045
Δ Narrow NEER UK	-10.032***	0.2082
Δ Narrow NEER EA	-7.592***	0.3977*
Δ Euro/US dollar exch. rate	-7.781***	0.3830*
Δ Pound St./US dollar exch. rate	-9.371***	0.2193
Δ Commodity US	-9.541***	0.2396
Δ Commodity UK	-9.663***	0.1609
Δ Commodity EA	-8.790***	0.1277

*Significant at ten percent level, ** Significant at five percent level, ***Significant at one percent level. KPSS test without trend. PP and KPSS: lags 12

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