Some empirical evidence of the euro area monetary policy

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SOME EMPIRICAL EVIDENCE OF THE EURO AREA MONETARY POLICY

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Abstract:
In this paper I try to find some empirical evidence of the European Central Bank's behaviour from its outset, January 1999, to the mid 2007, using a Taylor-type rule. I test a new and simple method for estimating the output gap in order to avoid problems linked with the estimate of the potential output. Moreover, I analyse the significance of some explanatory variables in order to understand what the basis of the E.C.B. monetary policy decisions are. Finally, I find an important evidence of the role of the Euro-Dollar nominal exchange rate in the conduct of the Euro Area monetary policy.

Keywords: Taylor Rule, European Central Bank, Euro-Dollar exchange rate.

JEL Classification: E43, E52, E58.

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Introduction

The Taylor Rule, Taylor (1993), has been widely used in the literature in order to reproduce the monetary policy of Central Banks. This rule has been used in different ways in the literature: with different regressors, in levels or in first difference, with lagged or contemporaneous data, with expectations, and the estimations have been carried out with different techniques. This paper uses the basic version of the formula and OLS and NLS estimations in order to study the significance of many regressors, some of that completely new in literature. I introduce a new way to calculate the output gap. This new methodology seems to be, in this first attempt, quite convincing. Moreover, I tried to find what types of independent variables one should use to improve the fitting of the data and I also present a section focused on the role of inflation expectations. The rest of the paper is divided into eight sections: firstly, I introduce some works on the Taylor rule; then I explain the way in which I calculate the output gap; in the third section I present the initial findings; in the fourth paragraph I focus my attention on monetary variables; the fifth section analyses the importance of the Euro-Dollar exchange rate; the following two sections deal with the role of the inflation expectations and the interest rate smoothing; the last section concludes.

1. Taylor rules

The dispute about the best type of Taylor Rule is still unsolved. Both the backward looking and the forward looking approaches provide good results. During the last years, given the growing importance of the expectations in the theoretical framework of the economic science, it seems that the forward looking rule acquired the supremacy. Notwithstanding this, there are so many works on this issue that it is really impossible to determine what the right formula is.

At the same time, it is likely that, citing this literature, one disregards a relevant part of the works in consequence of their considerable number. Indeed, the Taylor rule can be estimated in different ways, see Carare and Tchaidze (2005) for a short excursus. In my work, I follow both the backward and the forward looking Taylor Rule strands and try to find some empirical evidence on the European Central Bank's (ECB) behaviour from the onset of its operations, January 1999. As regards the forward looking approach, I don't strictly use the expectations, for example using GMM or other types of methodologies applied in the literature, but I simply use time series for the inflation expectations obtained through consumers and experts surveys.

Given the just recalled amplitude of the literature on the Taylor rule, in this paragraph I only cite some works on the issue that I face in this paper.

In 1996, Clarida and Gertler published a work in which they study the monetary policy of the Bundesbank through a Taylor rule. This study has been one of the first for the European countries and the rule showed its usefulness also in this case. Two years later, in 1998, Clarida, Galì and Gertler presented a paper on the

monetary policy in the US, Japan, Germany, Italy, France and the UK. They used GMM estimations and their work started to be a fundamental reference point in this field.

Gerlach and Schnabel (1999) analysed the EMU area. In their study they highlighted the role of the inflation expectations in the Taylor rule. They also studied the significance of other regressors, such as the Euro-Us Dollar exchange rate, but in their analysis these regressors showed a very limited role.

A work by Fourçans and Vranceanu (2002) is really interesting. They estimated many policy rules, analysing the first four years of the ECB activity. They demonstrated, using OLS and GMM, that the ECB is a conservative central bank and that the ECB is also focused on the real economy. Moreover, in line with the result of my paper, they also showed that the monetary policy disregarded the fluctuations of the M3.

Ullrich (2003) compared the Fed and the ECB from 1995 to 2002. She found that the ECB adopted an easier monetary policy in comparison with the former national central banks. This result is supported by the value of the coefficient on inflation that was above unity before the monetary union, while it decreased below unity with the ECB monetary policy.

Another work that employs the Taylor rule is the one by Sauer and Sturm (2003). They studied the first years of the Euro area using OLS and NLS. Their results leave no doubts: with the use of expectations, the coefficient on inflation is above unity. While, on the contrary, using contemporaneous data, the ECB seems to accommodate the course of the inflation rate.

In 2006 Carstensen published a work in which he tried to analyse whether the revision of the Euro area monetary policy strategy in 2002 had a real impact on the ECB behaviour. He found that this revision did not have a concrete effect on the value of the coefficients. Another important finding of this study is the very marginal role of the monetary aggregates.

Rotondi and Vaciago (2007) used a Taylor-type rule to compare the ECB with the Bundesbank. They showed that the coefficient on the inflation gap using the backward looking version of the formula is lower than the one obtained with the forward looking approach.

A paper by Parsley and Popper (2009), focused on Korea, uses GMM to estimate a policy reaction function similar to a Taylor rule, from January 1999 to April 2008. They used the exchange rate in the formula and they often find a significant relationship between this regressor and the interest rate. The exchange rate is not often used in the monetary policy rules, but some of the works I cited use the exchange rate as regressor and, recently, even Engle (2009) demonstrated the usefulness of introducing the exchange rate in an open-economy two-country model.

Starting from this literature, I present an analysis focused on the Euro area monetary policy. As I have previously said, I followed both the backward and the forward looking strands and I tried to find some empirical evidence on the ECB's behaviour from the onset of its operations, January 1999, to August 2007.

2. Output gap: a simple estimate

It is possible to rewrite the original Taylor Rule in the following way:

$$i_t = \beta_0 + \beta_1(\pi_t - \pi^*) + \beta_2 x_t \qquad (1)$$

Where "*i*" is the nominal interest rate, the monetary policy tool; the coefficient β_0 is the long run nominal interest rate, the rate that emerges when both output and inflation hit their target; β_1 is the coefficient on inflation gap, it expresses what the change in the nominal interest rate is if the inflation rate deviates from its target; π_t is the time t inflation rate and π^* is the inflation rate objective: their difference is the inflation gap; β_2 is the output gap coefficient and it expresses how a Central Bank reacts to change in the economic growth speed, and the last coefficient, x_t, represents the output gap, that is, the difference between the actual output and the potential output that an economy can reach.

In more detail, the output gap (x) is defined as the difference between the actual output and the potential output. The potential, or natural, output level is the output level that an economy can get if perfect flexibility of prices and wages exists. This is the most generic and theoretical definition of output gap (see for example Clarida, Galì and Gertler, 1999). But it is very difficult to calculate it. First, as it is straightforward to understand, it is impossible to know the value of the true natural output level. It is necessary to use an estimate for this value. And so, before carrying out studies about a Taylor Rule it is necessary to derive the level of the potential output in order to obtain the value of the output gap. The natural level of the output is often estimated applying a filter on the output time series.

For this reason, the estimate gained with the Taylor Rule can be influenced by the initial estimate of the output gap. The use of different time series to obtain the output gap, or a different method for calculating the natural level of output, can affect the final results. It could be possible that an economist starts a work with an *original error*.

Moreover, it is common to substitute the gross domestic product with the industrial production as a proxy of the output. And so, many economists estimate a natural level of the industrial production and an industrial production gap through the use of the Hodrick Prescott filter on this type of time series and they use this type of gap in the Taylor Rule.

In this paper, in order to eliminate this initial problem, I have used a different and simpler way to estimate the output gap: I do not substitute the gross domestic product time series with other time series and I do not make use of any type of filter.

Analyzing the attitude of the ECB towards the economic framework, I have supposed that a quarterly GDP growth between 0.5 and 0.6% could be considered as an inflation-neutral speed growth. We can see at this range as a natural and non-inflationary economic growth. I suppose that the ECB moves the nominal interest rate if the quarterly GDP growth is above or below this specific range only. It is clear that this type of method is

really simple: for example, a quarterly GDP growth above 0.6% could represent a threat for price stability and so the ECB is induced to move nominal interest rate adopting a tighter monetary policy. Using this simple method it is possible not to use preliminary estimates (i.e. estimates on GDP trend or other type of calculation in order to obtain an output gap) before testing the Taylor Rule. Furthermore, this method has given very good results, as one can see in the next sections. In next sections I refer to this indicator as the GDP gap.

3. Initial findings

As I have said before, in this first section I use a backward looking Taylor Rule and the estimates are obtained with OLS regressions. I use the day-to-day rate as dependent variable. The sample examined in the paper starts in January 1999 and ends in August 2007. I decided to disregard the first period of the crisis. I got data on GDP, inflation and Euro-Dollar exchange rate from Eurostat's website and those on monetary aggregate M3 from the ECB's website.

Inflation data are monthly. I have transformed the GDP data from quarterly to monthly with a simple method. I have applied the GDP quarterly growth to each month of that quarterly. The quarterly GDP growth indicates the increase of the GDP over a period of three months in comparison with the previous three months. It means that, on average, the monthly amount of GDP is increased with the same pace. For example, if we recognize a 0,5% quarterly GDP growth in the second quarter of a year, we can assume that in each month of that quarter (April, May, June) there has respectively been a 0,5% GDP growth in comparison with the first, second and third month of the previous quarter (January, February, March). Through this simple approach I have transformed my GDP gap quarterly data in GDP gap monthly data. Then, if we consider the gap between actual value of GDP growth (gdp%) and the natural range of growth (0,5%÷0,6%= gdp%*, see the previous section) we can obtain the GDP gap for a single month. In the rest of the paper I will call this gap GDP gap (= gdp% - gdp%*) and I will use this value in the estimates of the Taylor Rule.

As regards the lags, the ECB Council decides the path of the MRO rate during the meetings held the first Thursday of each month. So, it is really impossible that the ECB has contemporaneous values of output gap and inflation gap at disposal (this is the original prevision made by Taylor, 1993). For this reason I decided to use two lags for the inflation rate and 4 lags for the GDP gap. Indeed, it seems plausible that at the beginning of a month the ECB *knows* the value of the inflation gap of two month before. For the GDP I have considered the great difficulty to calculate this indicator and the delay of its release.

The resulting formula is:

$$i_t = \beta_0 + \beta_1(\pi_{t-2} - \pi^*) + \beta_2 x_{t-4} \qquad (2)$$

The results of the first estimation are shown in table 1.

Coefficients on inflation gap and on GDP gap are significant, but the values of these coefficients and the value of the R^2 statistic indicate that this initial estimate does not have a great economic significance. Coefficient on

inflation gap (inflgap_2) has a value slightly below 0,60. This is a little value compared to the major empirical work or to the optimal value suggested by the dominant economic theory (see, for example, Clarida, Gertler and Galì, 1998), even if this value, according to the work of Ball (1999), is fully acceptable. This value implies that the ECB is not very reactive towards inflation fluctuations. Coefficient on GDP gap is quite big. This value, above the unity, means that the ECB is really careful about deviations of GDP around its trend.

Table 1. Taylor Rule, basic version

OLS, 100 obs., sample 1999:05-2007:08, robust standard errors, dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	3,00640	0,153089	19,6382	<0,00001	***
inflgap_2	0,603602	0,307136	1,9653	0,05224	*
gdpgap_4	1,07067	0,373052	2,8700	0,00504	***

Mean of dependent variable = 3,0453
Standard deviation of dependent variable = 0,91656
R.S.S. = 72,0106
Standard Error of residuals = 0,861613
R^2 = 0,134156
Adj. R^2 = 0,116304
F-test statistic (2, 97) = 4,39156 (p-value = 0,0149)

These results could be caused by the long sample that I have considered and by the different events occurred during this last seven years. We can remember, for example, the end of the positive economic cycle due to the internet bubble in the first part of 2001, or we can consider the global economic shock due to terrorist attacks of 11th September 2001, or we can just mention the change in the conduct of the ECB's monetary policy in 2002-2003. All these phenomena, together with many others not mentioned here, have probably induced some changes in the managing of the Euro Area monetary policy. All these facts reduce the model suitability in reproducing the actual data and, as a consequence, it is not possible to represent in the right way the ECB's monetary policy. So, we can assert that this basic Taylor Rule seems not to work well over this long sample.

It can be useful to deepen this work in search of a more accurate rule. In the next pages I will add other explanatory variables in the right hand side of my Taylor Rule in order to improve the correspondence of the estimated data to the actual values.

4. Does the first pillar have an active role?

The ECB's monetary policy is based, as the official documents say, on two pillars. On the one hand the first pillar is focused on Euro area monetary situation. On the other hand the second pillar consists of the study of the entire economic system situation.

There has been a great debate on the role and importance of the first pillar (see for example Gerlach, 2004, and Jaeger, 2003), mostly because it has been the ECB that officially and explicitly communicates, at the onset of its activity, a target value for the growth of the monetary aggregate M3. The ECB specified a precise

objective for the M3 growth: a 4.5 percent annual growth for the moving three-month averages of the M3. This growth, according to the European Central Bankers, was neutral for the price level of the area. For these reasons I included M3 in my basic Taylor Rule formula to test how the ECB has reacted to fluctuations of this aggregate.

There is an ample debate on the role of this pillar given the fact that the 3-months moving average of M3, since the first months of 1999, has grown more than its established target. As a consequence, one could question if the monetary pillar really exists.

Table 2 shows results obtained with the M3 gap as an explanatory variable in the Taylor Rule. The formula estimated in this case is:

$$i_t = \beta_0 + \beta_1(\pi_{t-2} - \pi^*) + \beta_2 x_{t-4} + \beta_3(M3gap_{t-2}) \tag{3}$$

Table 2. Taylor Rule with M3

OLS, 100 obs., sample 1999:05-2007:08, robust standard errors, dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	3,21785	0,391119	8,2273	<0,00001	***
inflgap_2	0,607302	0,288817	2,1027	0,03811	**
gdpgap_4	1,01752	0,35411	2,8735	0,00500	***
M3gap_2	-0,0857523	0,137823	-0,6222	0,53529	

Mean of dependent variable = 3,0453
Standard deviation of dependent variable = 0,91656
R.S.S. = 70,549
Standard Error of residuals = 0,857255
R^2 = 0,15173
Adj. R^2 = 0,125221
F-test statistic (3, 96) = 3,56476 (p-value = 0,017)

We can immediately note that coefficients on GDP gap and inflation gap have the right sign and are statistically different from zero. The reaction coefficient on M3 gap is not statistically significant and it is negative. If this value was right, we should have a Central Bank that performs an expansionary policy when M3 increases more than its optimal target (a similar result, i.e. a negative coefficient on the M3, is showed in Ullrich, 2003).

The emerging of this type of relation between the day-to-day rate and M3 raises many doubts over the role of the monetary aggregate in the conduct of the monetary policy by the ECB. It seems that the ECB does not pay so much attention to the fluctuations of this monetary aggregate. This result is in line with the findings of the papers by Fourçans and Vranceanu (2002) and Carstensen (2006).

Moreover, the global results are quite disappointed. As we have noted for the basic model, it seems that a very simple rule, as the one used here, does not succeed to acceptably explain the course of the monetary policy over a long sample, even with the use of the M3 gap.

We could have two alternative problems: the Taylor rule is not useful in this context or the regressors I have chosen are not completely correct.

In sum, over this sample the Taylor Rule continues to provide useless information on the conduct of monetary policy in the Euro area. We can't use this formula as a benchmark to examine the monetary policy and to make some assumptions on the future path of the interest rate.

5. The weight of the Dollar

An ample political debate and many economic works have concerned the role of the exchange rates in the conduct of monetary policy, especially in the new framework of the European Monetary Union (see for example Carstensen, 2006, Clarida and Gertler, 1996, Clarida, Galì and Gertler, 1998, Parsley and Popper, 2009, Engle, 2009). It is well known that the fundamental task of the ECB is to keep inflation low and so the mandate of the ECB does not explicitly include a supervision of the exchange rate fluctuations. As a consequence, the ECB should not directly care about the fluctuations of the exchange rates, when it decides the course of the interest rates (see art. 105 of the Treaty). That is, the aim of the ECB is not to control the course of the exchange rate. However, the path of the exchange rate can obviously be part of the analysis of the second pillar of the ECB's monetary policy.

The just cited works have tried to find empirical evidences on the importance of the exchange rates in a Taylor-type rule. It is unquestionable that the exchange rates cover a crucial role in determining the speeding up and the slowing down of the economic cycle, mainly for the opened economies. But they also have an impact on the price level (through the pass-through effect). Even if these effects seem to be more mitigate than they were in the previous decades, we cannot disregard their existence and their possible impact on inflation.

Moreover, with the onset of the monetary union the role of the exchange rates for the nations inside the EMU has strongly changed. Before the adoption of the Euro every EMU nations should care about many bilateral exchange rates within the European boundaries. From January 1999 the attention has been mainly directed to the US Dollar – Euro bilateral exchange rate. Indeed, this exchange rate has now a central importance for the development of the European economic cycle.

Let us consider, for example, that all the raw material (not only the energetic raw material but also the unprocessed agricultural products) are quoted in US Dollars. The nominal value of these goods changes if the Euro-Dollar exchange rate is fluctuating and this could have an impact on the domestic inflation. Furthermore, the United States are one of the most important market for the European exports.

Besides, the importance of the Euro-Dollar exchange rate is increased by the strong linkage among Dollar and other national currencies all around the World. Indeed, there are many pegged exchange rates that have the USA Dollar as an anchor (for example the Chinese yuan or the currencies of the O.P.E.C.). In this way an appreciation or a depreciation of the Euro towards the Dollar has a strong impact on the value of other import-export flows and on other import prices.

Given these facts, I decided to add the Euro-Dollar exchange rate in the basic formulation of the Taylor Rule. An important difference in comparison with the usual procedure is the direct use of the nominal exchange rate in the formula. I have chosen to use the nominal exchange rate without adopting any type of transformation. I add the time series of the nominal Euro-Dollar exchange rate in levels for three main reasons. First, the nominal exchange rate is an indicator easy and ready to use. Second, there is a psychological cause: the value of the nominal exchange rate has a great impact on the political behaviour, on the economic decisions and on the feelings of the people. Third, I think that the Taylor Rule should be an useful and simple instrument to inspect the course of the monetary policy and so I have avoided the use of transformations of the time series that should have made the rule too complex for unskilled people.

So, in my work I suppose that the Council of the ECB simply watches at this nominal exchange rate when it examines the entire economic framework of the Euro area.

I added the monthly average of the Euro-Dollar nominal exchange rate (symbol: €/$) with one lag:

$$i_t = \beta_0 + \beta_1(\pi_{t-2} - \pi^*) + \beta_2 x_{t-4} + \beta_3 €/\$_{t-1} \qquad (4)$$

Table 3.7 shows the results obtained with this regression. I obtained a good result with the estimation: all the estimated coefficients have the right sign and they are different from zero at the usual levels of significance.

At a first sight even the graph of the actual and estimated values of the day-to-day rate (figure 3.5) shows a certain degree of likeness between the two series. And this is obviously a very good goal if we consider the fact that we are testing the rule over our complete sample. But it is useful to carefully examine all the data.

First, it seems that the value of the constant is too high. This value (6.65) is higher than the values obtained in the previous regressions or in other comparable works.

But this value is strongly influenced by the coefficient on the bilateral Euro-Dollar nominal exchange rate. We must subtract the negative coefficient on the exchange rate to the value of the constant. As it is possible to understand watching the data in table 3, the coefficient on Euro-Dollar nominal exchange rate is negative and it is multiplied by a value between 0.87 and 1.37 (respectively the minimum and the maximum value of the monthly average exchange rate in my sample). So it has a deep impact on the value of β_0. In this way the real value of the constant is reduced to a more normal value (around 3.3).

The coefficient on exchange rate has two functions. On the one hand, it impacts on the constant and so we have to jointly consider these values. On the other hand, it obviously indicates the marginal effect produced by a variation of the exchange rate on the nominal interest rate. We can infer an important information analysing this coefficient: an appreciation of about 30 cents of the exchange rate (that is, the Euro has strengthened against the dollar) induces the ECB to cut the interest rate of about 100 basis points.

Given this analysis, it is evident the importance of the nominal Euro-Dollar exchange rate in determining the decisions of the ECB's monetary policy.

Table 3. Taylor Rule with exchange rate

OLS, 100 obs., sample 1999:05-2007:08, robust standard errors, dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	6,65496	0,970459	6,8575	<0,00001	***
inflgap_2	0,471199	0,218169	2,1598	0,03328	**
gdpgap_4	1,04028	0,239931	4,3357	0,0004	***
€/$_1	-3,29523	0,921761	-3,5749	0,00055	***

Mean of dependent variable = 3,0453
Standard deviation of dependent variable = 0,91656
R.S.S. = 44,6884
Standard Error of residuals = 0,682279
R^2 = 0,462674
Adj. R^2 = 0,445883
F-test statistic (3, 96) = 10,5077 (p-value < 0,00001)

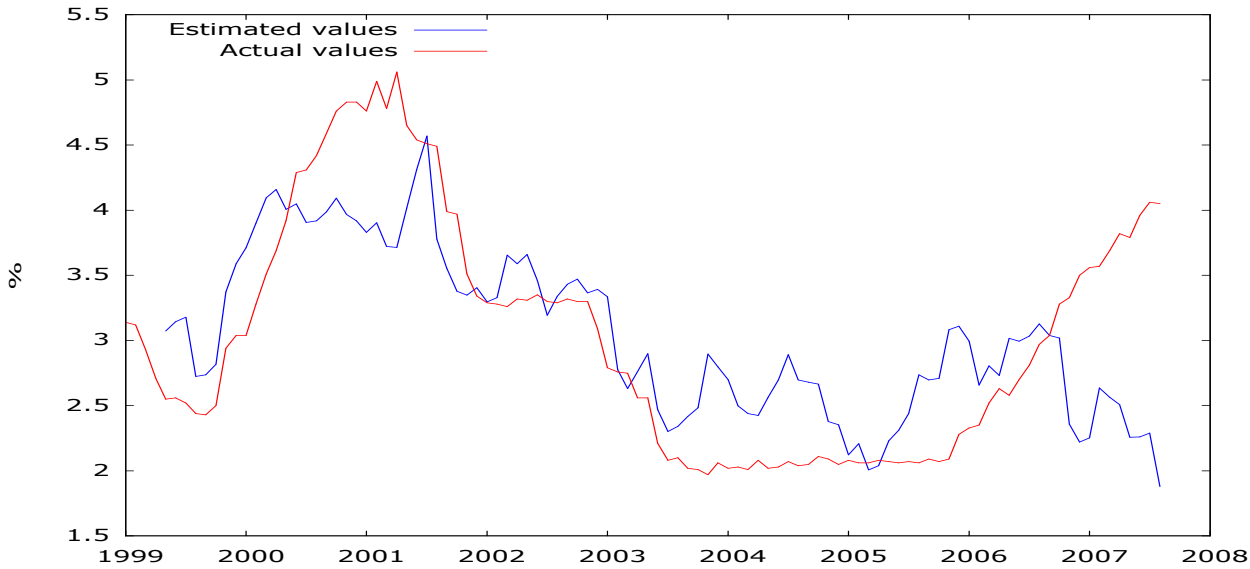

Figure 1. day-to-day rate (actual and estimated values)

This prominent attention towards this exchange rate can also explain the reduction of the coefficient on inflation gap that has a lower value than the ones estimated in the previous models.

Figure 1, as I have said before, shows the estimated and the actual values obtained with this last model. The two series diverge in a considerable way during the second half of 2006. Starting from that period, the model does not manage to well reproduce the path of the day-to-day interest rate.

Given this result, it seems that during the last period of the sample there has been a change in the managing of the Euro area monetary policy. If it was true, this fact should have caused interference on the estimated series.

So, I have thought to repeat the regression with the same model but over a shorter sample. I have eliminated the last period, in which the two series diverge, and so the sample now starts in January 1999 and ends in June 2006.

Table 4 shows the results of this last regression and Figure 2 illustrates the path of the estimated and actual values of the Euro area day to day interest rate.

Coefficients are always highly significant and they have the right sign, but the value of the coefficients has changed in comparison with the previous regression. The constant and the coefficient on the exchange rate have changed most of all. But if we remember the analysis suggested in the previous pages, we can only see a change in the marginal impact of the explanatory variables on the dependent variable. Indeed, the constant and the coefficient on the exchange rate have to be jointly evaluated. Even in this case, if we compute in the right way this linkage, we will find a constant around 2.5.

At a first sight, we could consider too small a value of 0.60 for the coefficient on inflation gap, but we should remember that in this model the ECB reacts in a very sharp way to fluctuations of the Euro-Dollar exchange rate. Following my results, the ECB should cut the interest rate by 1 per cent point if the Euro-Dollar nominal exchange rate grows by 20 basis points. If we consider these two effects at the same time, the impact of the coefficient on inflation gap and on exchange rate, and if we bear in mind the impact of this exchange rate on inflation, a value of 0.60 on inflation gap is acceptable. In addition a low value of the coefficient on the inflation gap is showed in other works too, see Ullrich (2003).

Table 4. Taylor Rule with exchange rate, short sample

OLS, 86 obs., sample 1999:05-2006:06, robust standard errors, dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	8,59879	0,639332	13,4496	<0,00001	***
inflgap_2	0,595707	0,116116	5,1303	<0,00001	***
gdpgap_4	0,83068	0,198511	4,1845	0,00007	***
€/$_1	-5,27647	0,569766	-9,2608	<0,00001	***

Mean of dependent variable = 2,96628
Standard deviation of dependent variable = 0,953266
R.S.S. = 13,1562
Standard Error of residuals = 0,400551
R^2 = 0,829673
Adj. R^2 = 0,823442
F-test statistic (3, 82) = 36,0183 (p-value < 0,00001)

Furthermore, we can suppose that, as some economists have stressed (see Blinder, 1997), in real world the central bankers are more cautious in comparison with what the empirical works suggest. And this happens because Central Banks do not have a perfect knowledge of the economic system. Prudence is fundamental in order to avoid an excessive or incorrect intervention that could undermine the stability of the financial system. This reasoning is especially worth for the ECB that has had to operate (and still operates) in a new economic framework. It is much more difficult for the ECB to forecast the reactions of the economic system to its monetary policy operations: this fact fully supports the choice of a high degree of prudence in opposing the fluctuations of the inflation.

The coefficient on output gap has the right sign and it has a plausible value.

It is also important to stress that the value of the R^2 statistic is the highest one among all the regressions of this paper. Indeed, both the R^2 statistic and figure 2 demonstrate that this last model mimics very well the course of the dependent variable.

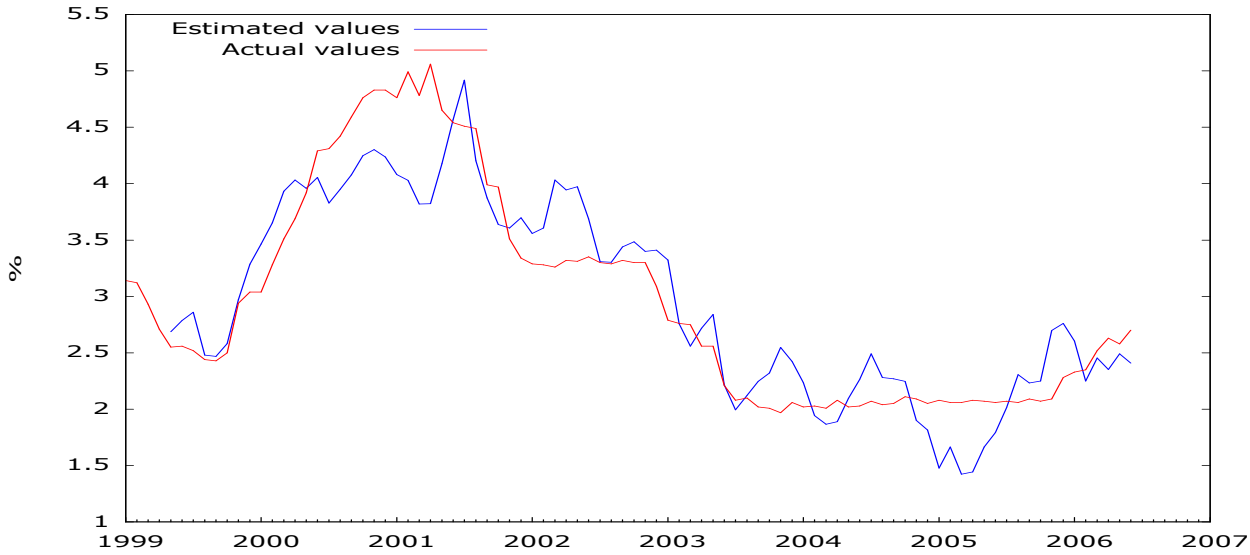

Figure 2. day-to-day rate (actual and estimated values), short sample

This version of the Taylor Rule makes it possible to draw another important conclusion. I have previously explained the interaction between the value of the constant and the value of the coefficient on exchange rate. From this linkage a relevant result derives: the ECB can define a different value for the interest rate even in the presence of the same value of inflation gap and output gap. For example, in the basic structure of the Taylor Rule, without the Euro-Dollar nominal exchange rate, when output and inflation match their target values, central bank always sets the same interest rate. On the contrary, with the last model the value of the interest rate can be different even if inflation gap and output gap have the same value in different times. This happens because the value of the interest rate varies with the change of the exchange rate.

The example in table 5 makes this result more evident. We suppose that inflation gap and output gap are zero (i.e. inflation and output are at the target level). In this situation the interest rate will not always be the same, but it will be higher if the Euro-Dollar exchange rate has a low value and it will be lower if the exchange rate is appreciated. In this way we can grasp the role of the exchange rate in dampening or heating the inflation rate even if output and inflation match their respective target. All these findings make it possible to say that this last model is the best, among the ones I tested till now, in reproducing the path of the day-to-day rate in the Euro area over a very long period of time.

Table 5. The role of the exchange rate in the Taylor Rule

$$i_t = \beta_0 + \beta_1(\pi_{t-2} - \pi^*) + \beta_2 x_{t-4} + \beta_3 €/\$_{t-1} \quad (5)$$

using the data of the table 4, equation (4) becomes:

$$i_t = 8.59879 + 0.595707(\pi_{t-2} - \pi^*) + 0.83068 x_{t-4} - 5.27647 €/\$_{t-1} \quad (6)$$

If $(\pi_{t-2} - \pi^*)$ =0 and x_{t-4} =0 the value of i_t will not be always the same,

but i_t will change with the fluctuations of €/$\$_{t-1}$:

a) If $€/\$_{t-1}$ = 0.90 => i_t = 3.85

b) If $€/\$_{t-1}$ = 1.20 => i_t = 2.27

From the graphical analysis we get some further interesting features. We note that the line of the estimated values is much more unstable then the line of the actual values. Remembering the Taylor's words (1998), this difference between estimated and actual data could be a measure of the ECB's discretion. We should not forget that, even if a Central Bank uses a monetary rule, there is always a certain degree of freedom in the conduct of the monetary policy. As a consequence, it is impossible to perfectly mimic the actual data.

A last note regards figure 1. During the second half of 2006 the line of the estimated values and the line of the actual data of the day-to-day rate diverge. It seems that the ECB's monetary policy becomes tighter in contrast with the estimated policy that shows a reduction of the interest rate. If we study the course of the lines of the three explanatory variables used in the formula, we find that probably the ECB, starting from the mid 2006, does not put any more attention on the path of the exchange rate. It seems that the ECB started to follow a different strategy in comparison with the past: a monetary policy with a smaller weight on the fluctuations of the Euro-Dollar exchange rate. Indeed, it is just before that period that the Euro-Dollar nominal exchange rate started to grow.

This result could strengthen the idea, sustained by some European politicians, that the rise of the interest rate since the end of 2006 had been inappropriate.

6. The inflation expectations

The analysis of the previous pages has highlighted two main features: first, the basic version of the Taylor Rule has not been able to reproduce in a suitable way the monetary policy of the ECB over a long period; second, the use of the Euro-Dollar exchange rate has improved the fitting of the rule.

In this paragraph I try to change the rule eliminating the inflation gap as a regressor and substituting it with a measure of the inflation expectations. It is well known the relevance of the inflation expectations in the studies on monetary policy (see, for example, Berck, 2000, Bernanke, 2004 and Cecchetti and Debelle, 2005). The role of the expectations is essential from different points of view: first, the anchoring of the inflation expectations is one of the basic tasks of the Central Banks; second, the stability of the expectations could be seen as an index of the Central Banks credibility; third, a solid stabilization of the expectations reduces the

effects of negative shocks on the prices trend; and fourth, stable inflation expectations are essential to reduce the sacrifice that a Central Bank should impose on the economy in order to absorb a price shock. These four points, but there are obviously others not cited here, underline the importance of the inflation expectations in managing the monetary policy.

There are different way for using the inflation expectations in the Taylor Rule, and there are different studies that employ them (among the others see Gerlach and Schnabel, 1999, Sauer and Sturm, 2003 and Rotondi and Vaciago, 2007). In this paper I use two different indicators. A monthly qualitative indicator of the inflation expectations published by the European Commission and a quarterly quantitative value of the inflation expectations calculated by the ECB.

In the first attempts I employ the inflation expectations published by the European Commission. A systematic business and consumer survey is done each month and this survey provides "essential information for economic surveillance, short-term forecasting and economic research"[2]. In this survey there are two questions that are useful to my purpose. A question deals with the perception of the prices trend and another one is focused on the prices expectations. So, in the Taylor Rule I use the time series extrapolated from these questions. The questions are qualitative rather than quantitative. As a consequence, the consumers do not explicitly specify a value for the future inflation, but they only indicate what their opinion on the future speed of the prices is. A final indicator is created using these answers. This indicator is completely different from an inflation point estimate. As a consequence, in this case the coefficient on the inflation expectation has no more the significance given in the previous sections and we cannot say if the Taylor principle has been enforced or not in the Euro area. But, we can also draw important conclusions.

The Taylor Rule used in this attempt is the following one:

$$i_t = \beta_0 + \beta_1 \pi^e_{t-2} + \beta_2 x_{t-4} + \beta_3 €/\$_{t-1} \qquad (7)$$

π^e_{t-2} is the inflation expectation, that has the same lag of the inflation gap of the previous paragraphs, and x_{t-4} is, as usual, the output gap with four lags. We also have a lagged value of the bilateral Euro-US Dollar exchange rate.

The results of this regression, with inflation expectations, GDP gap and exchange rate as regressors are shown in table 6 and in figure 3. The coefficients have the expected sign and the coefficients on inflation expectations and exchange rate are significant. Only in the last period the two lines diverge but this is a problem of all the regressions that I have tested.

It seems that during this long period the ECB has focused the attention on these macro-indicators in order to develop the right monetary policy. The attention on the inflation expectations highlights the medium to long term vision of the ECB, in line with its mandate. Moreover, the results have underlined the key role of this

[2] The Joint Harmonised EU Programme of Business and Consumer Surveys, User Guide, 2007, p. 2

inflation expectations time series in order to have a good performance of the Taylor rule over a long period. It is difficult to give an economic meaning to the value of the coefficient on the inflation expectations because it is a qualitative expectation and not a quantitative one but it is possible to affirm that the ECB is very vigilant in observing the course of this indicator. The value of the coefficient on the inflation expectations indicates that the ECB moves the interest rate by 0.059% if that value varies by 1. From this result one can wisely assert that the inflation expectations are crucial to the study of the Euro area monetary policy.

Then, the Euro-Dollar exchange rate has an important role too. In this case the ECB reduces (increases) the interest rate by 0.15% if the Euro appreciates (depreciates) by 10 cents against the Dollar.

Table 6. Taylor Rule with qualitative inflation expectations

OLS, 100 obs., sample 1999:05-2007:08, robust standard errors, dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	3,75679	1,04534	3,5939	0,00052	***
Inflexpect_2	0,0597757	0,0127212	4,6989	<0,00001	***
gdpgap_4	0,459608	0,298362	1,5404	0,12674	
€/$_1	-1,57295	0,850314	-1,8499	0,06741	*

Mean of dependent variable = 3,0453
Standard deviation of dependent variable = 0,91656
R.S.S. = 29,2958
Standard Error of residuals = 0,552417
R^2 = 0,647752
Adj. R^2 = 0,636745
F-test statistic (3, 96) = 26,4634 (p-value < 0,00001)

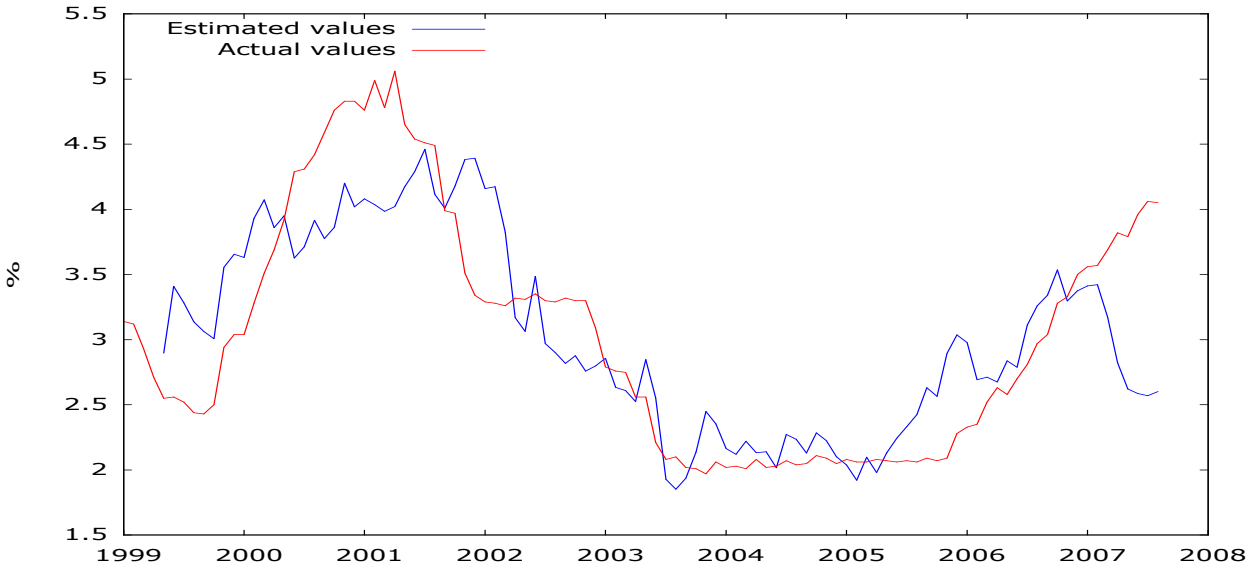

Figure 3. day-to-day rate (actual and estimated values), T.R. with expectations

But there is a clear limit in this study: the use of this type of inflation expectations makes it impossible to directly compare these results neither with the ones obtained using the inflation gap nor with the other studies

that employed a quantitative measure of the inflation expectations. I eliminate this limit at the end of this paragraph using another type of inflation expectations time series.

Before changing the inflation expectations time series, I show the results of a regression with the use of the inflation perception instead of the inflation expectations. This attempt can highlight two main aspects: firstly, it can show if the high significance level of the inflation expectations is only a fortunate case; secondly, it can also highlight if the ECB analyses the course of the inflation perception too. I used the time series of the inflation perception published by the European Commission. The methodology is the same of the inflation expectations but, in this case, the question is focused on the perception of the consumers about the course of the prices during the preceding 12 months[3].

In this case the estimated equation is:

$$i_t = \beta_0 + \beta_1 \pi^p_{t-2} + \beta_2 x_{t-4} + \beta_3 \text{€}/\$_{t-1} \tag{8}$$

π^p_{t-2} is the inflation perception. The other regressors are the same of the preceding estimations.

The results are shown in table 7. The coefficient on the inflation perception is not significant and the value of the p-value (0.81003) leaves no doubts. So, one can rightly affirm that the ECB is more concerned about the inflation expectations than the perception of past inflation. In theory, given the mandate of the ECB, this result is plain. But it was important to obtain an empirical result that is in line with what the theory and the ECB always affirm.

Besides, this result makes even more credible the one showed in table 6.

Table 7. Taylor Rule with qualitative inflation perception

OLS, 100 obs., sample 1999:05-2007:08, robust standard errors, dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	6,78254	0,496488	6,507	<0,00001	***
Inflpercept_2	0,00239066	0,00660928	0,241	0,81003	
gdpgap_4	0,890843	0,291248	2,897	0,00467	***
€/$_1	-3,45871	0,471812	-3,527	0,00065	***

Mean of dependent variable = 3,0453
Standard deviation of dependent variable = 0,91656
R.S.S. = 47,6965
Standard Error of residuals = 0,704868
R^2 = 0,426505
Adj. R^2 = 0,408583
F-test statistic (3, 96) = 23,7982 (p-value < 0,00001)

Till now, one can only underline that the use of the inflation expectations increased the correspondence between the estimated and the actual values and that the expectations are statistically significant, differently from the perception. But we have not a *numerical idea* of the weight of the inflation expectations.

[3] The exact question is: "How do you think the consumer prices have developed over the last 12 months?" and the possible choices are: "+ + risen a lot", "+ risen moderately", "= risen slightly", "- stayed about the same", "- - fallen", "N don't know".

In order to overcome these limits, linked with the use of a qualitative inflation expectations time series, I change this time series with a quantitative one, published by the ECB[4]. This time series provides quarterly data on the inflation expectations. So, in order to harmonize the data, in the following regressions, I use quarterly data for all the macroindicators. The aim of these regressions is to estimate a coefficient that could show the quantitative attention of the ECB towards the fluctuations of this indicator.

The use of quarterly data obviously reduces the number of the observations. As a consequence, I have decided to expand the sample till the first quarter of 2008, even if this implies the use of data over the period of the subprime crisis.

Even in this case the equation that I regress is:

$$i_t = \beta_0 + \beta_1(\pi^e_{t-1} - \pi^*) + \beta_2 x_{t-2} + \beta_3 €/\$_{t-1} \qquad (9)$$

$(\pi^e_{t-1} - \pi^*)$ is the inflation gap calculated using the "one year ahead" inflation expectations of the period t-1. The other symbols have the usual meaning.

The results are shown in table 8. All the coefficients have the expected sign and are highly significant.

Figure 4 shows the estimated and the actual values. The lines show the usual divergence at the end of the sample.

The results of this last regression show a very different situation in comparison with the results of the backward looking Taylor Rule used in the previous paragraphs. But, in order to directly compare the results I also estimate this last equation using real time quarterly data over the whole sample. The results of this case, shown in table 9, are in line with the ones obtained in the previous paragraphs using monthly data.

Table 8. Taylor Rule with quantitative inflation expectations

OLS, 35 obs., sample 1999:III – 2008:I, robust standard errors, Dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	7,85957	1,01441	7,7479	<0,00001	***
InflexpecOYA_1	3,14009	0,724922	4,3316	0,00014	***
gdpgap_2	1,36625	0,247747	5,5147	<0,00001	***
€/$_1	-3,61714	0,912405	-3,9644	0,00040	***

Mean of dependent variable = 3,11857
Standard deviation of dependent variable = 0,925079
R.S.S. = 10,5444
Standard Error of residuals = 0,583218
R^2 = 0,637601
Adj. R^2 = 0,60253
F-test statistic (3, 31) = 17,24 (p-value < 0,00001)

[4] I used the "One Year Ahead" inflation expectations time series of the ECB survey of professional forecasters.

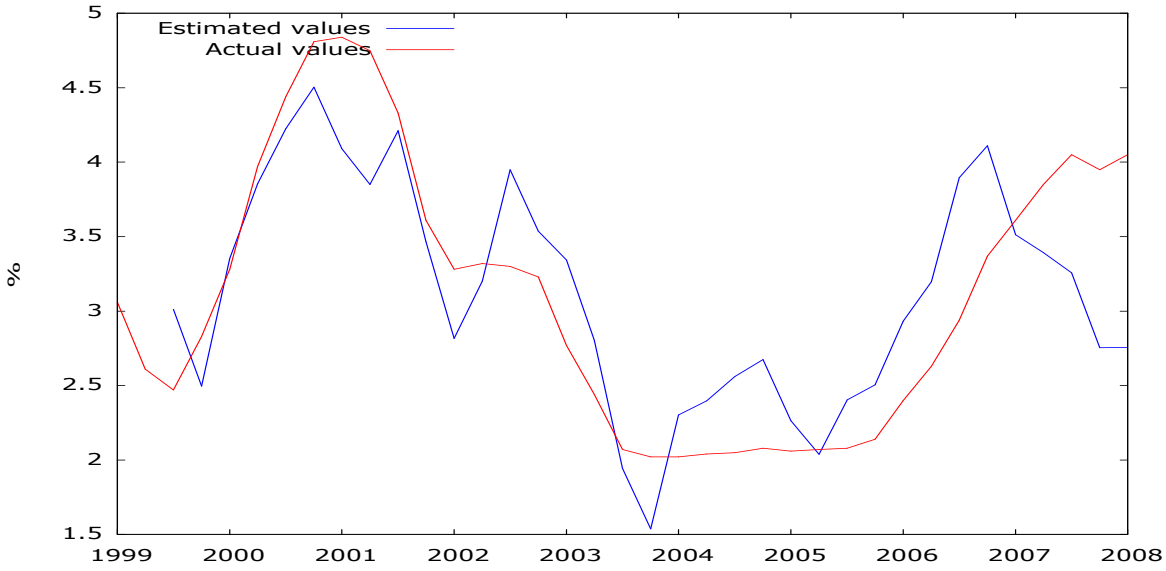

Figure 4. day-to-day rate (actual and estimated values), T.R. with expectations, quarterly data

The replacement of the real time data with the inflation expectations has radically increased the coefficient on the inflation gap (from 0.70 to 3.14). This change is in line with some other works (see for example Sauer and Sturm, 2003 or Rotondi and Vaciago, 2007). Using expectations, it seems that the ECB follows the Taylor principle. That is, the ECB increases the real interest rate when the inflation expectations go up. Moreover, the coefficient on the inflation expectations is very high. This highlights a very great attention of the ECB in defeating all the possible divergences of the inflation expectations from the target. The anchoring of the inflation expectations seems more important than a direct contrast of the actual inflation. Indeed, the coefficient calculated with real time data both with monthly and quarterly series has always been below the unity.

Table 8. Taylor Rule, basic version and quarterly data

OLS, 35 obs., sample 1999:III – 2008:I, robust standard errors, dependent variable: day to day rate

Explanatory Variable	Coefficient	Std. Err.	t-test	p-value	
Const	5,49463	1,24749	4,4046	0,00012	***
Inflation gap_1	0,702295	0,280743	2,5016	0,01786	**
gdpgap_2	1,7495	0,315123	5,5518	<0,00001	***
€/$_1	-2,19142	1,20241	-1,8225	<0,07803	*

Mean of dependent variable = 3,11857
Standard deviation of dependent variable = 0,925079
R.S.S. = 16,2623
Standard Error of residuals = 0,724286
R^2 = 0,441085
Adj. R^2 = 0,386996
F-test statistic (3, 31) = 11,5731 (p-value = 2,97e-005)

Furthermore, in the regressions with the quarterly inflation expectations the coefficient on the GDP gap is highly significant and its value is slightly above the previous ones. The Euro-Dollar exchange rate coefficient

remains negative and significant as in the preceding regressions. The R^2 statistic has the highest value of all the regressions. It seems that the Taylor Rule can provide a very good fit of the data using inflation expectations.

In this section I tested whether the inflation expectations have or not a concrete role in the conduct of the monetary policy in the Euro area. I present two types of analysis. Firstly, the regressions with the monthly data of the Business and Consumers Survey highlighted the difference between the expectations and the perceptions: the ECB only reacts against negative fluctuations of the inflation expectations, while it disregards the course of the inflation perception. Secondly, I used the *One Year Ahead* inflation expectations time series of the ECB survey of professional forecasters in order to have a quantitative value of this *attention* towards the inflation expectations, since the Business and Consumers Survey does not supply a point estimate of the future inflation. This attempt gave a good result: it provided the evidence of the ECB great attention towards the inflation expectations. The elevated value of the coefficient on the inflation expectations means that the ECB is very alert in the surveillance of the fluctuations of the inflation expectations in order to stabilize them around the 2 per cent threshold.

7. Interest rate smoothing

A large part of the dominant theory suggests the use of a dependent lagged variable in the Taylor Rule (see for theoretical and empirical examples Clarida, Galì and Gertler, 1999, Taylor, 2000, Rotondi and Vaciago, 2007 or Sauer and Strum, 2003). This is due to the so called "interest rate smoothing". The smoothing can be seen has an evidence of the central bank activity or prudence. An high degree of interest smoothing means that the central bank is not so active in suddenly contrasting the signals that come out from the economy, but it prefers to act gradually towards its optimal rate.

Many studies have been undertaken in this field but their results are not always unanimous (for a short review of this literature see Sauer and Sturm, 2003). In my attempt I use a simple model to catch the interest rate smoothing.

The model used is the following:

$$i_t^* = \beta_0 + \beta_1(\pi_{t-1}^e - \pi^*) + \beta_2 x_{t-2} + \beta_3 €/\$_{t-1} \tag{10}$$

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} \tag{11}$$

i_t^* is the optimal or target interest rate that the Central Bank should set every month. But this rate is not stable (as one can see watching the preceding figures) and so the Central Bank should change the nominal interest rate every month, often reversing its direction quickly. As a consequence, in order to eliminate this *problem*, the actual interest rate i_t gradually adjusts towards the optimal value, i_t^*, following the equation (10), in which

ρ is the smoothing parameter. In this way one can gauge the role of the lagged variable (that is, the role of the smoothing).

In this paragraph I use again quarterly data and the inflation expectations published by the ECB, since this specification has provided the best results. The symbols have the same meanings as in the preceding regressions. In the regression showed below, I drop out the exchange rate because I tested it and find that it does not radically improve the results. So, I decided to show only the basic rule with the smoothing parameter:

$$i_t = (1-\rho)\cdot[\beta_0 + \beta_1(\pi^e_{t-1} - \pi^*) + \beta_2 x_{t-2}] + \rho i_{t-1} \tag{12}$$

or equivalently

$$i_t = \widetilde{\beta}_0 + \widetilde{\beta}_1(\pi^e_{t-1} - \pi^*) + \widetilde{\beta}_2 x_{t-2} + \rho i_{t-1} \tag{13}$$

where $\widetilde{\beta}_i$ are the short run coefficients.

After estimating this equation, it is possible to calculate two different types of coefficient: a short run coefficient, the product of (1-ρ) with the β_i, that is the $\widetilde{\beta}_i$ coefficients, or the long run coefficients, the β_i. I show both the results. Table 9 shows the short run coefficients and the relevant statistics while figure 3.14 shows the estimated values. I used the NLS estimator with robust standard errors.

Given these results, the resulting modified Taylor Rule is:

$$i_t = 0.438452 + 0.271160(\pi^e_{t-1} - \pi^*) + 0.793710 x_{t-2} + 0.889058 i_{t-1} \tag{14}$$

The coefficient of the lagged variable is highly significant and the value is in line with the relevant literature. The coefficient on the inflation gap is no more significant while the coefficient on the output gap remains highly significant.

Starting from this equation it is straightforward to calculate the long run coefficients (see below). The values of both the long run and the short run coefficients are very high in comparison with the usual values gauged in other works. Indeed, the Taylor Rule should be:

$$i_t = 3.9521 + 2.44417(\pi^e_{t-1} - \pi^*) + 7.15431 x_{t-2} \tag{15}$$

(8,090) (1,232) (3,069)

(the *t*-statistics are in the parentheses).

The coefficient on the output gap is highly significant and it is quite high while the coefficient on the inflation gap is not significant. The results of this regression underline a high importance of the lagged dependent variable and of the output gap while the inflation gap is now no more significant. A similar result is shown in Sauer and Sturm, 2003. But the peculiarity of this regression lays on the high value of the coefficients. A very impressive value: it implies that the ECB changes the interest rate with a very high reactivity.

At the end, the high degree of the interest rate smoothing is what we can draw from this paragraph together with the role of the output gap. It seems that the ECB has been very careful in changing the leading interest

rate. It has preferred to smooth the variations of the interest rate towards the optimal interest: in this way the ECB does not transmit a wrong signal to the market or exceed in its monetary policy action.

Table 9. Taylor Rule, interest rate smoothing

NLS, 35 obs., sample 1999:III-2008:I, robust standard errors, dependent variable: day to day rate

Parameter	Estimate	Std. Err.	t-test	p-value	
$\tilde{\beta}_0$	0,438452	0,112024	3,914	0,00046	***
$\tilde{\beta}_1$	0,271160	0,203680	1,331	0,19280	
$\tilde{\beta}_2$	0,793710	0,144632	5,488	<0,00001	***
P	0,889058	0,0384405	23,128	<0,00001	***

Mean of dependent variable = 3,11857
Standard deviation of dependent variable = 0,925079
R.S.S. = 1,14261
Standard Error of residuals = 0,191986
R^2 = 0,96073

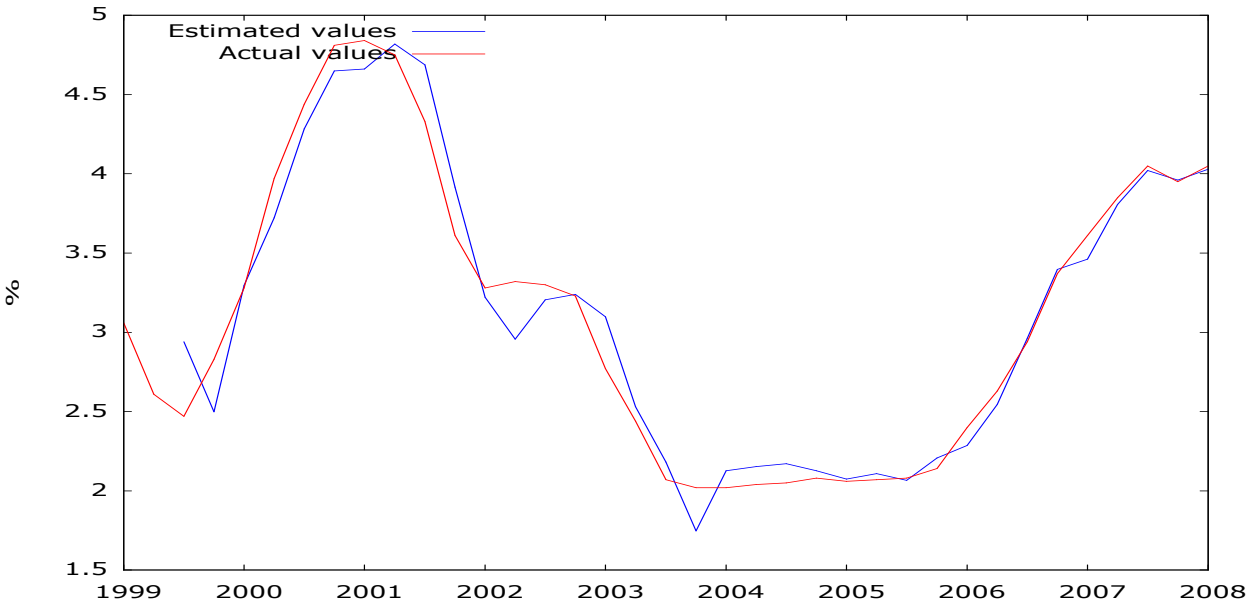

Figure 4. day-to-day rate (actual and estimated values), T.R. with interest rate smoothing

8. Conclusions

In this paper I tried to formulate the simplest and more effective Taylor Rule that is able to reproduce the behaviour of the ECB during the first years of its activity. It is obviously arduous to summarize in one simple rule with few explanatory variables the job of a Central Bank, nevertheless I obtained some relevant findings.

I used different types of rule. The basic formula (with only two explanatory variables: the output gap and the inflation gap) has given bad results over a long period. The coefficients are highly significant but the R^2 of the regression is very low. Then, I tested the importance of the monetary aggregate M3. I showed that the role of

M3 is irrelevant in deriving the right behaviour of the ECB. And this finding, as stressed in other works, is in contrast with the official general strategy announced by the same ECB. It seems that the “first pillar” does not have importance for the general strategy of the central bank.

In the subsequent attempt, I examined a Taylor Rule with three explanatory variables: inflation gap, output gap and Euro-Dollar nominal exchange rate, and I found that thanks to this rule the results have radically improved. This type of formula reproduces very well the path of the day-to-day interest rate over a long period of time. It depicts in a good way the behaviour of the European Central Bank. The interpretation of the estimated values presents some caveats, but this rule seems to work very well.

I also underlined that my gdp gap, that is, the methodology used in the paper to calculate the output gap, has been a valid tool for the analysis. It has been significant in almost all the model.

After these first findings, I expanded the analysis checking the relevance of the inflation expectations. I used two very different inflation expectations time series and, in both cases, the use of the inflation expectations improved in a very considerable way the fitting of the data. Moreover, the ECB seems to be more aggressive against the excessive fluctuations of the inflation expectations above the target than it is against the path of the actual inflation rate.

At the end I added a lagged dependent variable to test the importance of the interest rate smoothing and it seems that the interest rate smoothing is also fundamental in order to explain the monetary policy behaviour of the ECB.

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