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THE DYNAMIC ADJUSTMENT OF CENTRAL BANKS' TARGET INTEREST RATE: THE CASE OF THE ECB

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Abstract

A fundamental aspect of the ECB's monetary policy is that it aims to pursue price stability "over the medium term." However, the ECB has not defined the medium term with reference to a predetermined horizon, retaining some flexibility with regard to the exact time frame. The objective of this paper is to shed some light on how the horizon of price stability is being achieved in practice, in a context where the ECB faces convex and non-convex costs of adjusting the target interest rate. We assume that ECB's monetary policy follows an average flexible inflation target framework, and we analyse the R^2 of an equation where the target interest rate is specified as a function of the *j*-period window over which average inflation rate is measured. Target interest rate inertia is incorporate through a switching interest rate equation based on the play model of hysteresis. We have found that the ECB is targeting the key interest rate over a seven years window, implying that the ECB is following a hybrid approach to price stability in line with average inflation target. We also have found hysteresis effects in the dynamic adjustment of ECB´s target interest rate.

JEL Classification E43; E52

Keywords: inflation target, price-level targeting, key interest rates,

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1. INTRODUCTION

According to Article 127(1) of the Treaty on the Functioning of the European Union, "the primary objective of the Eurosystem shall be to maintain price stability." The ECB has defined price stability as a year-on-year increase in the Harmonised Index of Consumer Prices for the euro area of below 2% over the medium term.[4]

A fundamental aspect of the ECB's monetary policy is that it aims to pursue price stability "over the medium term". This reflects the idea that monetary policy should not attempt to fine-tune developments in inflation over short time horizons. Therefore, some short-term volatility in inflation is acceptable (see ECB, 2011, p. 68).

The ECB monetary policy strategy, as stated above, is in fact rather ambiguous. The ECB has not defined the medium term with reference to a predetermined horizon, retaining some flexibility with regard to the exact time frame. According to ECB (2011) it is not advisable to specify *ex-ante* a precise horizon for the conduct of monetary policy, since the transmission mechanism spans a variable, uncertain period of time.

The ECB's mandate is explicitly formulated in terms of a price stability objective rather than in terms of an inflation target – entailing a quasi-automatic reaction to deviations of forecast inflation from the target over a predetermined time horizon, typically of one or two years (see ECB, 2011). On the contrary, it bases its actions on a more flexible strategy both as regards the economic variables taken into consideration and the relevant time horizon for responding to shocks in the economy. For example, Domingo Solans former member of the Executive Board of the ECB stated early in 2000 that "None of the inflation targeting characteristics […] can be applied to the ECB's monetary policy strategy. A quantitative definition of stability is not an inflation target in conceptual and practical terms. It is rather a specification of the objective established in the Maastricht Treaty. […] The ECB is, certainly, obliged to comply with its objective in a medium term perspective, but its monetary policy decisions do not 'target' it, in the

[4] The definition makes it clear that inflation above 2% is not consistent with price stability. It also implies that very low inflation rates, and especially deflation, are not consistent with price stability either (ECB, 2011, p. 9).

sense that the ECB will not react mechanically if the HICP increase goes beyond the limit of the definition."[5]

The former president of the ECB Jean Claude Trichet also clarified the medium-term orientation of the monetary policy by stating that there is no fixed time horizon over which price stability has to be re-established, which avoid overly activist and ambitious attempts to fine-tune inflation outcomes**.** [6]

Having in mind that the ECB uses the main refinancing open market operations fixed interest rate as the operating mechanism for monetary policy,[7] the ambiguity of the ECB monetary policy strategy raises the question of how the decisions regarding this key interest rate are taken.

The objective of this paper is to shed some light on how the horizon of price stability is being achieved in practice, in a context where the ECB faces convex and non-convex costs of adjusting the target interest rate, and operates in an uncertainty environment.

For that purpose, we assume that ECB's monetary policy follows an average flexible inflation target framework, allowing constrained discretion, and we analyse the R^2 of an equation where the target interest rate is specified as a function of the *j*-period window over which average inflation rate is measured.

Target interest rate inertia is incorporate through a switching interest rate equation based on the play model of hysteresis.

The remainder of the paper is organized as follows. Section 2 deals with the differences and consequences of price-level targeting versus inflation target. Section 3 discusses the fundaments of the target Central Bank interest rate persistence. Section 4 offers preliminary empirical evidence on ECB key interest rates change, describes the details of the empirical strategy, and the data set. Section 5 presents the estimation results, and Section 6 concludes.

[5] "Monetary policy under inflation targeting." Contribution presented by Eugenio Domingo Solans, Member of the Governing Council and the Executive Board of the European Central Bank, at the Fourth Annual Conference of Banco Central de Chile, Santiago de Chile, 1 December 2000.

[6] See the Speech by Jean-Claude Trichet, former President of the European Central Bank, delivered at the Center for Financial Studies' key event, Frankfurt, 20 November 2003.

[7] From January 1999 until June 2000, the ECB targeted the fixed rate of the main refining operations, from July 2000 to July 2007 it switched to the minimum bid rate of the variable rate tenders, and from that date on the ECB is targeting again the fixed rate of the main refining operations.

2. INFLATION VS PRICE-LEVEL TARGETING

The final goal of the monetary policy of the ECB is price stability. Taken literally, price stability implies price level-targeting with the target price level rising over time at below (but close to 2%). However, ECB monetary policy is usually described in macroeconomic models as a flexible inflation target by means of a Taylor rule variant, even with ECB officials stating that the monetary strategy of the ECB is not an inflation targeting.

The essential distinction between the two regimes lies on how the Central Bank reacts to changes in inflation (see, *e.g.*, Ambler, 2009). Under inflation target the Central Bank reacts to bring inflation back to its target rate. A transitory increase of the inflation rate may not imply a reaction of the Central Bank. It originates, however, a permanent increase in the price level. Thus, transitory inflation shocks have a cumulative impact on the price level. Differently, under price-level targeting the Central Bank reacts to deviations of the price level from its target, implying that an inflationary shock in one period should be followed by a deflationary one in the next. In this case, the price level should be stationary around the trend given by the target value chosen for inflation.

At the present no Central Bank follows explicitly a price-level targeting strategy.[8] The main arguments against its adoption are: the idea that price level path stability would induce increased volatility of inflation and output compared with a regime of inflation targeting; and the inability of the Central Bank to avoid a painful monetary policy tightening following supply shocks that drive up inflation (see *e.g.*, Fischer, 1995).

Nonetheless, recent literature have appointed several advantages of the former strategy.[9]

Firstly, the stationarity of the price level around its specified path, limits uncertainty regarding the future price level,[10] facilitates the forecasting of the real value of payments flow involved in long-term contracts, and therefore reduces the risk premiums demanded by lenders (Vestin, 2006).

Secondly, it reduces the redistributive effects of unexpected price-level changes.

[8] The exception was Sweden in the 1930s (see Guender and Oh, 2006, for an historical perspective).
[9] See, *e.g.*, Ambler (2009), Deutsche Bundesbank, Montly Report - January 2010, Giannoni (2014), and Hatcher and Minford (2016) for a survey.
[10] See, *e.g.*, Batini and Yates (2003).

Thirdly, it may reduce the risk of reaching the zero interest rate lower bound, as a drop in the price level to below the target path leads to a rise in inflation expectations (see, *e.g.*, Eggertson and Woodford, 2003, and Wolman, 2003). In this line, Bernanke (2017) recently proposed a modified monetary policy framework that implies the adoption of a temporary flexible price-level targeting that would work only in periods in which interest rates are constrained by the zero lower bound. In this way the need to tighten monetary policy in the face of temporary inflation shocks away from the ZLB would be avoided.

Fourthly, although from one point of view, price-level targeting may lead to higher inflation volatility, and thus to higher product and employment volatility (in the presence of nominal rigidities),[11] from another perspective it may contribute to macroeconomic stability. Indeed, if expectations are forward looking (or if there is substantial endogenous output persistence[12]), price-level targeting cause expectations to move (automatically) in the opposite direction following a deviation of the price-level from the defined path, which requires a weaker monetary policy response (see, *e.g.*, Svensson, 1999, Nessén and Vestin, 2005, Vestin, 2006, Guender and Oh, 2006, Ambler, 2009, and Giannoni, 2014). Also, Svensson and Woodford (2005), Röisland (2006), and Gaspar *et al*. (2007) have assessed the performance price-targeting framework in the baseline New-Keynesian model and conclude that it delivers lower inflation variability for any given level of output gap variability.

The defined 'medium run' horizon for price stability indicates that the ECB is not following a pure price-targeting neither a pure inflation target, but instead an 'average inflation target,' by which the objective is to stabilized average inflation measured over several periods. Indeed, Nessén and Vestin (2005) show that under discretion, targeting average inflation can yield a superior outcome to both former strategies.

Let us assume that the Central Bank aims at stabilizing inflation around the target, π^*, but also put some weight on stabilizing the real economy. Thus, it minimizes a period quadratic loss function defined as:

$$L\left(\bar{\pi}_{j,t}, x_t\right) = \frac{1}{2}\left[\left(\bar{\pi}_{j,t} - \pi^*\right)^2 + \lambda x_t^2\right] \quad (1)$$

[11] See, *e.g.*, Batini and Yates (2003).
[12] This happens because in an inflation-targeting regime inflation responds on the future path of output, whereas under price level targeting inflation depends on the change in output.

Where x_t is the output gap, λ is the relative weight of output stabilization , and $\bar{\pi}_{j,t}$ is the average inflation rate defined as:

$$\bar{\pi}_{j,t} = \frac{1}{j}\sum_{s=0}^{j-1}\pi_{t-s} = \frac{1}{j}\left(p_t - p_{t-j}\right) \quad (2)$$

Where p_t is the logarithm of the price level in period t. This policy lies between price-level targeting and inflation target. If $j = 1$, we have the standard one period inflation target. Letting j become very large $(j \to \infty)$ correspond to having a price-level targeting.[13] Thus, average inflation target shares with the price-level targeting the property that the price level remains anchored to a predetermined path. The longer the period over which inflation is averaged, the more average inflation targeting resemble price-level targeting.[14]

According to Ha (2000), Smets (2000; 2003) and Akram (2010), the optimal monetary policy horizon depends on: *i*) the structure of the economy, including the length of the monetary policy transmission lag; *ii*) the desire of the Central Bank to avoid excessive interest rate and output volatility, and in particular on the weight put on this objectives in the loss function; and *iii*) the nature of the shocks.

In general, the literature shows that the optimal policy horizon is: *a*) about twice as long for price level objective compared with inflation objective (Smets, 2000; 2003, and Akram, 2010); *b*) longer the greater the weight put on secondary objectives like minimising the output gap and interest rate variability (Smets, 2003); and *c*) longer the higher the degree of forward-lookingness in the pricing equations and the greater the slope of the Phillips Curve (Smets, 2003).

An obvious question is what is the width of the window, j, used to calculate average inflation, which is associated to the 'medium term' concept of price stability. This is ultimately an empirical issue, and it is addressed in Section 4.

[13] Note that the equivalence between price level targeting and inflation targeting with an infinite *j* window, holds strictly only when the output gap weight in the Central Bank loss function is equal to zero (Néssen, 2002, p. 326).
[14] See, *e.g.*, Nessén (2002), Batini and Yates (2003), and Nessén and Vestin (2005).

3. INTEREST RATES SMOOTHING

Official Interest rates smoothing is a widely recognizable characteristic of monetary policy in many countries,[15] and refers to the tendency for Central Banks to adjust key interest rates gradually in the same direction, and with relatively few reversals (see, *e.g.*, Lowe and Ellis, 1997, Goodhart 1999, Srour, 2001, and Bernanke, 2004).[16]

This type of key policy interest rate behaviour is typically captured in models by some form of partial adjustment mechanism with the Central Bank adjusting the key policy rate slowly towards the desired level (see, *e.g.*, McCallum, 1995, Clarida and Gertler, 1996, and Clarida *et al.*, 2000). The policy rule usually takes the form:

$$i_t = \rho i_{t-1} + (1-\rho) i_t^* \tag{3}$$

Where the level of the key Central Bank interest rate in period t, i_t, is specified as a weighted average of the current desired level, i_t^*, and last period actual value, i_{t-1}. Based on historical data, estimates of ρ are often in the range 0.8 - 0.9, implying a slow adjustment of the policy rate to its fundamental determinants (see, *e.g.*, Rudebush, 2002; 2005, and Gerlach-Kristen, 2004).).

There are two competing hypothesis to explain interest rates persistence.

On one hand, the literature refers to an extrinsic or exogenous cause to the Central Bank behaviour. According to this hypothesis the persistence of the key interest rates reflects the response of central Banks to slow cyclical fluctuations in macroeconomic driving variables. Thus, inertia in the dynamics key Central Banks interest rate may reflect inertia in the economy itself (see, *e.g.*, Rudebush, 2002; 2005, Cobham 2003, Gerlach-Kristen, 2004, and Carrillo *et al.*, 2007).

On the other hand, authors like Roszbach (1997), Goodhart (1999), Sach (2000) Bernanke (2004), and Coibion and Gorodnichenko (2012) defend an intrinsic view of interest rate smoothing, by showing that the degree of gradualism typical found in the data cannot be fully explained by the dynamic structure of the economy. In fact, evidence

[15] Lowe and Ellis (1997) furnish evidence of official interest rates smoothing for Australia, the United States, the United Kingdom, Japan, and Germany. Goodhart (1998) offers evidence for France, Italy, Canada, Spain, the Netherlands, Belgium, Sweden, and Austria. See also Roszback (1997) for the case of Sweden.

[16] The slow adjustment of key Central Bank interest rates has been also referred in the literature as partial adjustment, monetary policy inertia or gradualism (see Bernanke, 2004).

suggest that Central Banks deliberate desire to smooth the key interest rate, in addition to what would be justified by existence of serial correlation in the fundamental variables.

This observation immediately suggest the presence of adjustment costs of interest rate change.[17] According to this explanation, a Central Bank with quadratic preferences incurs in convex and non-convex costs of changing the target interest rate. In this case, and in line with Roszbach (1997) the loss function may be written as:

$$L(\bar{\pi}_{j,t}, x_t, \Delta i_t) = \frac{1}{2}\left[\left(\bar{\pi}_{j,t} - \pi^*\right)^2 + \lambda x_t^2 + \beta\,(\Delta i_t)^2 + cI_t\right],$$
$$\text{With } I_t = \begin{cases} 1\ if\ \Delta i_t \neq 0 \\ 0\ if\ \Delta i_t = 0 \end{cases} \quad (4)$$

In this setting, Central Banks face a trade-off between quadratic losses arising from deviations of fundamentals from their targets, $\left(\bar{\pi}_{j,t} - \pi^*\right)^2 + \lambda x_t^2$, and losses resulting from changes in target interest rate, with costs having a convex, $\beta\,(\Delta i_t)^2$, and a non-convex component, cI_t (see, Roszbach, 1997, and Eijffinger *et al*., 1999).

This theoretical framework is able to reproduce the stylized facts typical found in the data concerning Central Banks' key interest rate changes.[18]

On one hand, due to the presence of non-convex adjustment costs, Central Banks do not change the target interest rate when the optimal frictionless rate (in the absence of adjustment costs) change is small. Central Banks change the interest rate only when the losses from deviation of the interest rate from the desired level are bigger than the costs of changing the interest rate. Thus, the dynamic path of key interest rate exhibit long periods of inaction and discrete adjustment.

On the other hand, because of the presence convex-adjustment costs, when Central Banks start to change the interest rate toward the desired level, they typically do so in a

[17] Note that a high significant partial adjustment coefficient, ρ, in Equation (3) may reflect serially correlated or persistent fundamental determinants and possibly the omission of other relevant variables (such as assets prices, market volatility, liquidity and credit conditions), and thus compatible with the extrinsic hypothesis, but it is also compatible with the desire of the Central Bank to adjust gradually the key inters rate, because of the presence of adjustment costs, and thus reflecting the intrinsic hypothesis (see Rudebush, 2002; 2005).

[18] An alternative would be to consider a zone quadratic loss function where the Central Bank only change the interest rate when inflation rate is outside a given range, in line with Orphanides and Vieland (2000) and Tachibana (2008). Although this specification is able to produce some of the features of the target interest rate dynamics – notably inertia, it is not fully capable of explain the almost absence of interest rate reversals observed in the data.

succession of small steps in the same direction, exhibiting gradualism and persistence (see Guthrie and Wright, 2004).

In the context of the intrinsic view, the literature mentions at least four sources of target interest rate adjustment costs.

Firstly, by changing key policy rates smoothly, Central Banks reduce excessive reactions in financial markets that might cause financial instability (see, *e.g.*, Goodfriend, 1991, Roszbach, 1997, Mowe and Ellis, 1997, Bernanke, 2004, and Stein and Sunderam, 2015). For example, gradual adjustment of the key policy rate gives time to commercial banks to adjust to changes in the cost of short-term funding, and for that reason it may increase the stability of bank profits. It may also reduce financial stress for households with adjustable-rate mortgages and business dependent of short-term financing (see Bernanke, 2004). In addition, less variable short-term interest rates also reduce the risk the policy rate reachs the zero lower bound, reducing stress in the financial system (Bernanke, 2004). Note that, at least part of these costs are fixed reflecting the fact that even a small target change can unsettle marks (Guthrie and Wright, 2004)

Secondly, by adjusting key interest rates gradually central Banks increase their ability to affect long-term interest rates and consequently influence the economy. In fact, a change in key interest rates induces changes not only in the current short-term market interest rates, but also signals the market that interest rates are likely to continue to change in same direction for some time. Thus, it affects long-term interest rates, and consequently the level of economic activity and inflation, increasing the effectiveness of monetary policy (see, *e.g.*, Goodfriend, 1991, Goodhart, 1999, Woodford, 1999; 2003, Sachs and Wieland, 2000, and Bernanke, 2004).

Thirdly, Central Banks move interest rates slowly in order to avoid frequent key interest rates reversals, as it can be interpreted as reflection of a lack of understanding or control over the economy, and thus affecting its credibility (see, *e.g.*, Lowe and Ellies, 1997, and Goodhart, 1999).

Finally, inertia in the dynamic adjustment of Central Banks' key interest rates may also be associated with the characteristics of Central Bank governance, including institutional rigidities, and sociological and political influences that affects the decision making process (see, *e.g.*, Riboni and Ruge-Murcia, 2010, and Favaretto and Masciandro, 2016).

Adding to these costs of adjusting the interest rate that are incorporated in the Central Banks´ loss function, there is the effect of uncertainty surrounding monetary

policy decisions. The literature distinguishes three types of uncertainty (see, *e.g.*, Cateau, 2010, and Mendes *et al.*, 2017 for a survey).

Firstly, Central Banks face uncertainty about the economic model that is used to inform monetary policy decisions. This concerns to: *a*) general model uncertainty, when monetary authorities ignore the correct specification of the 'true' structural model of the economy and the variables that should be included in the model (see, *e.g.*, Onatski and Stocks, 2002, and Svensson, 2004); *b*) model parameters magnitude uncertainty, when monetary authorities know the structural equations that characterize the economy, but face uncertainty concerning the parameter values that must be estimated using statistical techniques that are subjected to error (see, *e.g.*, Brainard, 1967, and Martin and Salmon 1999); and *c*) the identification of the shocks, including uncertainty about the serial correlation properties of shocks (see, *e.g.*, Onatski and Williams, 2003).

Secondly, there is uncertainty about the state of the economy related to the quality of the data implying that a gradual adjustment of the key interest rate may be the optimal response of monetary policy (see, *e.g.*, Sack, 2000, Rudebush, 2001, Smets, 2002, Orphanides, 2003, and Bernanke, 2004). This result either because some variables, such as the GDP, are only available with some time lag and frequently subjected to revisions, or because some other variables, such as the output gap and the natural interest rate, are unobservable, being the results sensitive to the method of estimation.

Thirdly, uncertainty (of knightian kind) arises due to unforeseen developments, economic and geopolitical shocks, and natural disasters (Mendes *et al.*, 2017).

4. A MODEL OF KEY INTEREST RATES CHANGE FOR THE EURO AREA

4.1 Empirical Evidence on Key Interest Rates Change

The analysis of the dynamics of the ECB official interest rate in the period from January 1999 to December 2017 exposes the following stylised facts.[19]

First, the ECB makes changes in the key interest rate at discrete intervals and in discrete amounts, despite changes in the dynamic behaviour of the economy (see Figure

[19] We use monthly data from the ECB and EUROSTAT. Data covers the period from January 1999 to December 2017.

1). In fact, ECB key interest rate (MRO) changes relatively infrequently – it didn´t change at all in 81% of the periods under analyse (see Table 1).

By simple visual inspection of the histogram of the key interest rate change (Figure 2 *a*.) and the histogram of the changes in the fundamentals (Figure 2 *b.*, *c.*, *and d.*) we can conclude that the shape of the distribution of the key interest rate change differs markedly from the distributions of changes in fundamental variables. In particular, compared with the distribution of monthly key interest rate change, the distributions of changes in fundamentals exhibit a much lower frequency of episodes of zero change and a greater incidence of large variations. Moreover, the frequency of interest rate changes has declined in the post-crisis period. Thus, the preliminary evidence do not favour the extrinsic inertia hypothesis.

Second, the distribution of the key interest rate changes is clustered around a handful of values regardless the sign (see Figure 2 a.). When the key interest rate is changed, the change is generally made in multiples of quarters of a percentage point. The most common change (positive or negative) is a quarter of a percentage point, the maximum positive change is an half of a percentage point, and the maximum negative change three fourths of a percentage point (see also Table 1).

Third, the size of the change does depend on the sign of the change - decreases tend to be bigger on averages than increases (see Table 1).

Fourth, when the ECB changes its key interest rate it tends to adjust incrementally in a series of small steps in the same direction – gradual adjustments characterize periods of key interest rate increases as well as periods of decreases. This leads to a kind of an interest rate cycle. Thus, the key interest series exhibit positive autocorrelation.

Fifth, a change of a given sign is unlikely to be followed by a change of opposite sign. Indeed, for the total sample of the positive key interest rate changes, 83% were directly followed by inaction, and 17% were directly followed by another increase, while 0% were followed by a decrease (see Table 3).[20] Of the negative key interest rate changes, 70% were directly followed by inaction, and 30% were directly followed by another decrease, while 0% were followed by an increase. This smoothing behaviour is also documented by the high ratio of continuations to reversals (see Table 2). Moreover, ECB

[20] To distinguish between these two types of adjustment costs, in each period interest rates changes were classified in three regimes: inaction ($\Delta i_{k_{t-1}} = 0$); positive change ($\Delta i_{k_{t-1}} > 0$); and negative change ($\Delta i_{k_{t-1}} < 0$). This information was then used to compute the probabilities of transition between regimes in two consecutive periods of time (probability transition matrix).

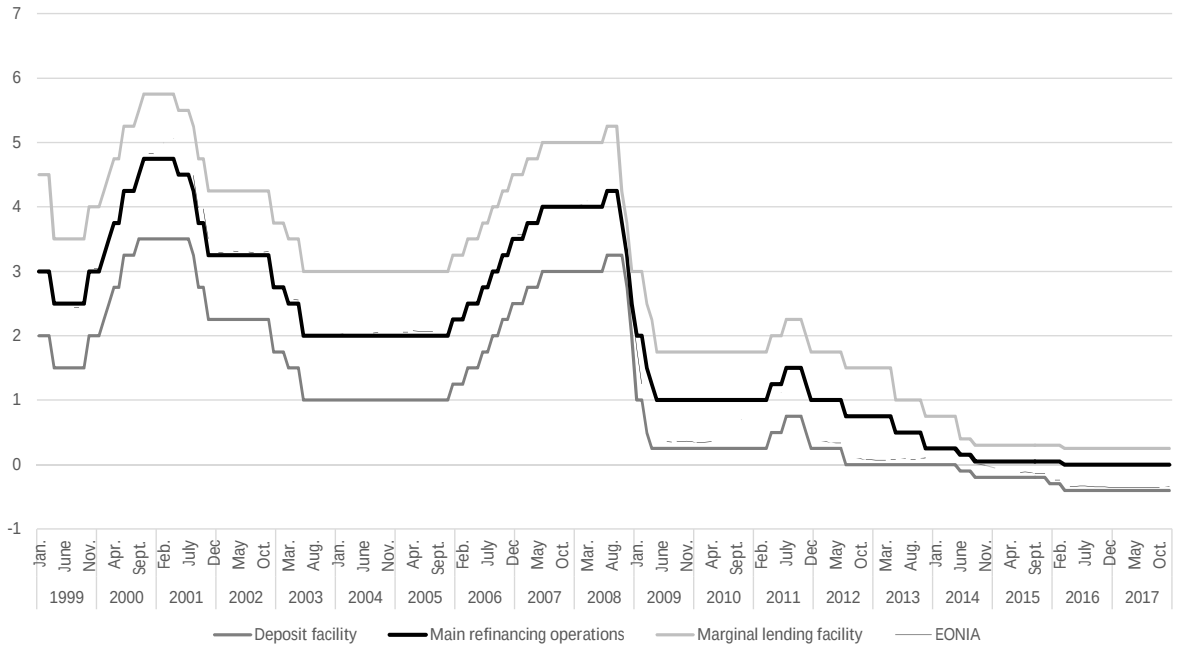
leaves the key interest rate unchanged for a relative long time before moving it in the opposite direction. In fact, the average duration before continuations is lower than the average duration before reversals (see Table 2).

The fact that the ECB does not change the key interest rate in a continuous way in response to new information concerning the fundamentals, acting discontinuously when the accumulation of changes in the fundamentals become sufficiently large, is compatible with the presence of non-convex costs of interest rate adjustment and uncertainty regarding future developments of inflation and economic activity. Moreover, as documented by Sack (2000) continuations seem to constitute adjustments within a single policy movement, while reversals may instead imply a new policy action. This is a sign that convex costs of interest rate adjustment are also present.

The presence of mixed signs of convex and non-convex target interest rate adjustment costs is also documented in Table 3. On the one hand, there is a great percentage of no adjustment (82%) and a high probability that changes should be followed by inaction (see the first column of the probability transition matrix). On the other hand, the main diagonal exhibits large serial correlation between positive and negative adjustments, which indicates that the ECB spread the adjustment over more than one period ahead**.**

Different structures of adjustment costs have different consequences in terms of the serial correlation of interest rate adjustment (see Guthrie and Wright, 2004). Convex adjustment costs imply that one period of small adjustment should be followed by another period of small adjustment, as the Central Bank tries to spread the whole adjustment over several periods. This partial adjustment dynamics can be captured by the introduction in the monetary reaction function of the lagged valued of the key interest rate. On the contrary, non-convex adjustment costs imply that one period of adjustment should be followed by periods of inaction. In this case the dynamics is better described by hysteresis-type models (see, *e.g*., Visitin 1994, and Mayergoyz, 2003).

Figure 1. ECB *Key Interest Rates*



Source: ECB

Figure 2. *Key Interest Rates Changes Histogram*
(Time span:1999:01-2017:12)

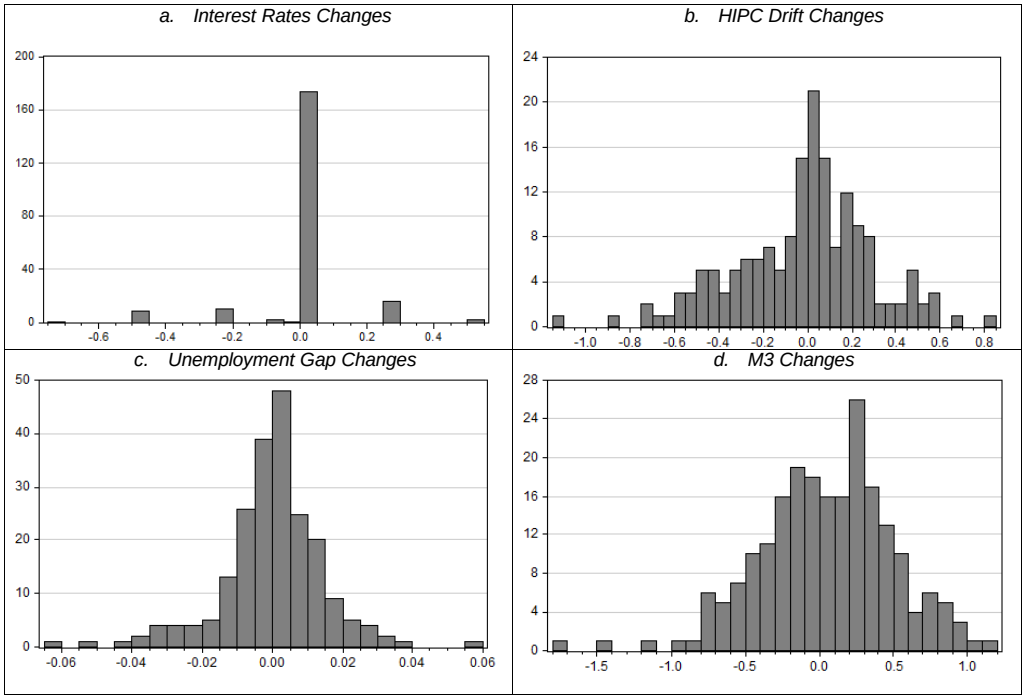


Table 1. *Key Interest Rates (MRO) Changes*
(Time span:1999:01-2017:12)

Period		Months	Changes			Average Change (Mode)			MAX Change		MIN Change	
			Total	$\Delta I_{k_t} > 0$	$\Delta I_{k_t} < 0$	Total	$\Delta I_{k_t} > 0$	$\Delta I_{k_t} < 0$	$\Delta I_{k_t} > 0$	$\Delta I_{k_t} < 0$	$\Delta I_{k_t} > 0$	$\Delta I_{k_t} < 0$
Total Sample	1999:01-2017:12	228	41	18	23	0.32* (0.25*)	0.28 (0.25)	-0.35 (-0.25)	0.5	-0.75	0.25	-0.05
Pre-Crisis	1999:01-2007:07	104	23	15	8	0.33* (0.25)*	0.28 (0.25)	-0.41 (-0.5)	0.5	-0.5	0.25	-0.25
Post-Crisis	2007:08-2017:12	124	18	3	15	0.32* (0.25)	0.28 (0.25)	-0.25 (0.25)	0.5	-0.75	0.25	-0.05

*****in absolute values

Table 2. *Key Interest Rates Average Durations*
(Time span:1999:01-2017:12)

Period			Average Duration Following: (Max Duration Following :)			Duration Before:				Ratio of Continuations to Reversals
						Continuations*		Reversals*		
			$\Delta I_{k_t} \neq 0$	$\Delta I_{k_t} > 0$	$\Delta I_{k_t} < 0$	+ +	− −	+ −	− +	
Total Sample	1999:01-2017:12	Occurrences	41	19	23	12	18	3	3	5.0
		Average	4	2.2	5.7	2.5	3.6	3.7	19	
		Maximum	29	12	29	12	17	6	29	
Pre-Crisis	1999:01-2007:07	Occurrences	23	15	8	10	5	1	2	5.0
		Average	3.6	1.6	6.8	1.6	3.8	6	17.5	
		Maximum	29	6	29	2	12	6	29	
Post-Crisis	2007:08-2017:12	Occurrences	18	3	15	2	13	2	1	5.0
		Average	4.6	4.3	5.1	6.5	3.5	2.5	22	
		Maximum	22	10	22	11	17	3	22	

*Consecutive and Non-Consecutive

Table 3. *Key Interest Rates (MRO) Prob. Transition Matrices*

Total Sample: 1999:01-2017:12

% of the total observations

	$\Delta I_{k_{t-1}} = 0$	$\Delta I_{k_{t-1}} > 0$	$\Delta_{k_{t-1}} < 0$
$\Delta I_{k_{t-1}} = 0$	67%	7%	7%
$\Delta I_{k_{t-1}} > 0$	7%	1%	0%
$\Delta I_{k_{t-1}} < 0$	7%	0%	3%

Prob. Transition Matrix

	$\Delta I_{k_{t-1}} = 0$	$\Delta I_{k_{t-1}} > 0$	$\Delta_{k_{t-1}} < 0$
$\Delta I_{k_{t-1}} = 0$	82%	9%	9%
$\Delta I_{k_{t-1}} > 0$	83%	17%	0%
$\Delta I_{k_{t-1}} < 0$	70%	0%	30%

Pre-Crisis: 1999:01-2007:07

% of the total observations

	$\Delta I_{k_{t-1}} = 0$	$\Delta I_{k_{t-1}} > 0$	$\Delta_{k_{t-1}} < 0$
$\Delta I_{k_{t-1}} = 0$	59%	12%	7%
$\Delta I_{k_{t-1}} > 0$	12%	3%	0%
$\Delta I_{k_{t-1}} < 0$	7%	0%	1%

Prob. Transition Matrix

	$\Delta I_{k_{t-1}} = 0$	$\Delta I_{k_{t-1}} > 0$	$\Delta_{k_{t-1}} < 0$
$\Delta I_{k_{t-1}} = 0$	76%	15%	9%
$\Delta I_{k_{t-1}} > 0$	80%	20%	0%
$\Delta I_{k_{t-1}} < 0$	88%	0%	13%

Post-Crisis: 2007:08-2017:12

% of the total observations

	$\Delta I_{k_{t-1}} = 0$	$\Delta I_{k_{t-1}} > 0$	$\Delta_{k_{t-1}} < 0$
$\Delta I_{k_{t-1}} = 0$	72%	3%	8%
$\Delta I_{k_{t-1}} > 0$	3%	0%	0%
$\Delta I_{k_{t-1}} < 0$	8%	0%	5%

Prob. Transition Matrix

	$\Delta I_{k_{t-1}} = 0$	$\Delta I_{k_{t-1}} > 0$	$\Delta_{k_{t-1}} < 0$
$\Delta I_{k_{t-1}} = 0$	87%	3%	10%
$\Delta I_{k_{t-1}} > 0$	100%	0%	0%
$\Delta I_{k_{t-1}} < 0$	60%	0%	40%

4.2 The Model and the Empirical Strategy

We assume that monetary policy not only aim to stabilize inflation, but also put some weight on stabilizing the real economy.

As considered in the first pillar of the monetary strategy, the ECB looks for a variety of shocks that affect the economy with potential impact on price stability, not all of them resulting from demand side factors. Thus, inflation pressures are not entirely the result of the state of demand. For that reason we add to equation the unemployment gap. Due to the role for money advocated by the second pillar of the ECB strategy, we include also the low-frequency component of M3 growth. Indeed for the ECB (2011, p. 78), the low-frequency component of M3 growth moves closely in line with the low-frequency component of inflation, and developments in trend money growth tend to systematically lead developments in trend inflation (see also Surico, 2003, and Hofmann, 2008). We also include in the model a proxy of financial markets stress, in line with Rudebush (2002; 2005), Gerlach-Kristen (2004), and Coibion and Gorodnichenko (2012). For example, Gerlach-Kristen (2004) defend that Central Bank key interest rates tend to be lowered by more than inflation and output gap in periods of financial stress. To provide a more accurate representation of the time delay with which information becomes available to policymakers, we consider a one-month information lag.

Accordingly, hour baseline specification for the frictionless ECB desired interest rate based on fundamentals, i_t^*, is:

$$i_t^* = \beta_0 + \beta_1\left(P_t - P_{t,j}^*\right)_{-1} + \beta_2 UGAP_{t-1} + \beta_3 M3_{t-1} + \beta_4 SPREAD_{t-1} \qquad (5)$$

$$\text{With } P_{t,j}^* = P_{t-j}\left(1 + \frac{0.02}{12}\right)^j$$

Where P_t is the harmonized consumer price index; $P_{t,j}^*$ is the desired price level path for the window j; $UGAP_t$ is the unemployment gap constructed as the Hodrick-Prescott detrended component of the unemployment rate,[21] $M3_{t-1}$ is the moving average over 6 months of the broad monetary aggregate M3, and $SPREAD_t$ is the average spread between Euro Zone treasury bonds with maturity of 10 years and the correspondent Germany bonds.

[21] We consider the standard smoothness parameter of 14400 for monthly data.

To shed some light about the 'medium run' concept referred by the ECB, we search for the value of j that maximizes the goodness of fit of a model of key interest rates determination by the ECB (Equation 5). We considered a grid of values for j ranging from $j = 1$ month to $j = 150$ months, with increments of six months.

To allow for a possible structural break due to recent financial crisis, we reestimate Equation 5 with an additive and multiplicative dummy variable, D_t, that takes the value of one for all the months after the failure of Lehman Brothers, and zero in the other months.

So far we assumed a linear relationship between the official interest rates and fundamentals. Now we consider, in line with Checchetti (1996), Lowe and Ellis (1997) and Roszbach (1997), and Guthrie and Wright (2004) that there are convex and non-convex costs involved in reversing the direction of the target interest rate. The presence of non-convex target interest rate adjustment costs is sufficient to generate hysteresis.[22]

Thus we estimate a hysteretic version of Equation (5) based on the linear play model of hysteresis.[23]

As we are considering that the ECB maximizes a set of secondary objectives such as output stabilization and financial markets stability subject to the constraint that it achieves a price level at a given horizon in the future, *i.e.* flexible average inflation targeting, as in Smets (2000), we assume that the price level is the only hysteretic variable.

The linear play model is implemented empirically via a linear switching key interest rate equation with an unknown splitting factor - the $PLAY$.[24]

Following Belke and Göcke (2001), we describe the change in current key interest rate i_t, induced by a change in $\left(P_t - P_{t,j}^*\right)$, as divided between a weak reaction along a *play line* when the change in $\left(P_t - P_{t,j}^*\right)$ is small and a strong reaction along a *spurt line*, when $\left(P_t - P_{t,j}^*\right)$ changes sufficiently, and we estimate the following equation:[25]

$$i_t = \beta_0 + \beta_1 \left(P_t - P_{t,j}^*\right)_{-1} + \beta_2 SPURT_{t-1} + \beta_2 GAP_{t-1} + \beta_3 M3_{t-1} + \beta_4 SPREAD_{t-1} \quad (6)$$

[22] Hysteresis is the property of a mathematical system whereby some temporary exogenous shocks can have permanent effects.
[23] See Visitin (1996) for a general description of the model.
[24] The term is used due to its analogy to play in mechanics.
[25] The details of the empirical implementation of the play model (in the case of the dynamics of employment) can be found in Belke and Göcke (2001) and in Mota *et al.* (2015).

Where $SPURT_t$ (the spurt variable) results from the $\left(P_t - P_{t,j}^*\right)$ series with all small changes $\left[\Delta\left(P_t - P_{t,j}^*\right) < PLAY\right]$ filtered out. In this framework, β_1 gives the reaction of key interest rate, i_t, along the *play line*, while β_2 is the difference of the reaction of i_t along the *spurt line* and the *play line* caused by changes in fundamentals.

The test for the presence of hysteresis consists of checking the ability of the hysteretic transformed input variable, $SPURT_t$, to explain the observed key policy rate dynamics. The strategy is to test whether the non-linear model, which includes hysteresis, provides better results than the linear one, by looking to the significance of the transformed $\left(P_t - P_{t,j}^*\right)$ - hysteresis implies $\beta_2 > 0$ in Equation (6).

Following the algorithm described in Belke and Göcke (2001), a MATLAB program to generate the spurt variable, $SPURT_t$ was developed and implemented, which in turn requires the estimation of the $PLAY$ width.

As a new feature, we estimate the model allowing for possible structural changes in the value of the switching parameter due to the different stages of the financial crisis.

5. ESTIMATION RESULTS

We start by applying the Augmented Dickey-Fuller unit root test to find the order of integration of the series. Table 4 shows the augmented Dickey-Fuller test statistic for the levels and for the first difference of the variables. For the majority of the variables in levels the augmented Dickey-Fuller test statistic is larger than the 5% critical value (-2.874)indicating that we do not reject the presence of a unit root. The hypothesis of stationarity of the first difference of the series is rejected fore some vriables meaning that not all the series are integrated of order one, I(1).

Table 4: *Augmented Dickey-Fuller Test Statistics (5% critical value: -2.874)*

Variable		Level	1st Difference
$P_t - P^*_{t,j}$	j = 1	-2.319	-9.242
	j = 6	-2.383	-9.514
	j = 12	-2.293	-12.447
	j = 18	-3.772	-2.430
	j = 24	-1.623	-11.317
	j = 30	-3.237	-2.447
	j = 36	-0.962	-11.304
	j = 42	-2.490	-2.106
	j = 48	0.0477	-12.323
	j = 54	-0.498	-2.682
	j = 60	0.660	-3.852
	j = 66	-0.605	-2.039
	j = 72	0.025	-3.728
	j = 78	0.079	-2.796
	j = 84	-0.446	-3.334
	j = 90	-1.064	-2.324
	j = 96	-0.598	-3.290
	j = 102	-3.075	-1.697
	j = 108	-1.045	-2.722
	j = 114	0.437	-1.395
	j = 120	0.172	-1.760
	j = 126	-0.920	-1.504
	j = 132	-1.089	-2.069
	j = 138	-0.404	-2.100
	j = 144	-0.915	-1.290
	j = 150	-1.171	-1.435
GAP_t		-2.820	-6.315
$M3_t$		-2.669	-3.367
$SPREAD_t$		-1.756	-14.021
$SPURT_t$		-0.690	-3.196

To rule out the possibility of a spurious regression and to verify the existence of a true equilibrium relationship between the variables we test for the existence of cointegration using the Johansen Test Procedure.[26]

By applying the Johansen cointegrating test the hypothesis of a single cointegrating vector relating the variables is not rejected. We report the trace test statistic of the cointegrting equation that includes the series $\left(P_t - P_{t,j}^*\right)$ that maximises the R^2 of the interest rate equation (see Table 5).[27]

However, because the series are non-stationary, to obtain asymptotically unbiased estimates of the parameters, we estimate the cointegrating Equation (5) by Fully Modified Least Squares (FM-OLS), as proposed by Phillips and Hansen (1990), which is an asymptotically efficient direct estimator of long-run economic equilibrium relationships. This method modifies least squares with smiparameyric corrections that account for serial correlation effects and for endogeneity in the regressors that result from the existence of cointegrating relatioinships.

We estimate equation 5 for different values of j ranging from $j = 1$ month to $j = 150$ months, with increments of six months. Figure 3 shows the R^2 of the regression for each value of j. The maximum R^2 is reached for $j = 84$ months, implying that seven years is the length of the medium term concept for the ECB, at least at is being achieved in practice.

The results of the estimation of equation 5 (for $j = 84$) by FM-OLS are in Table 5 (column 2). All the regressors are statistical significant at the normal level of 5%, and the associated coefficients have the expected signal. The ECB´s target interest rate reacts positively to the deviation of the price level from the desired path, negatively to the unemployment gap, and to the average spread between Euro Zone treasury bonds with maturity of 10 years and the correspondent Germany bonds, and positively to the low frequency component of M3.

Table 5 (column 3) displays the results of the estimation when we consider the possibility of a structural break in October 2008. The estimates are relatively stable. The only significant difference is that the proxy of financial distress ($SPREAD_t$) only has an impact on the target interest rate after the failure of Lehman Brothers.

[26] We apply the Trace Test performed with four lags in the VAR representation and with an intercept and time trend in the cointegration equation. We report the results of testing the null hypothesis of no cointegration (r=0) against the existence of at least one cointegrated vector (r).
[27] Note that all the variables in Table 5 are I(1).

Figure 3: *R2 of the ECB Target Interest Equation*

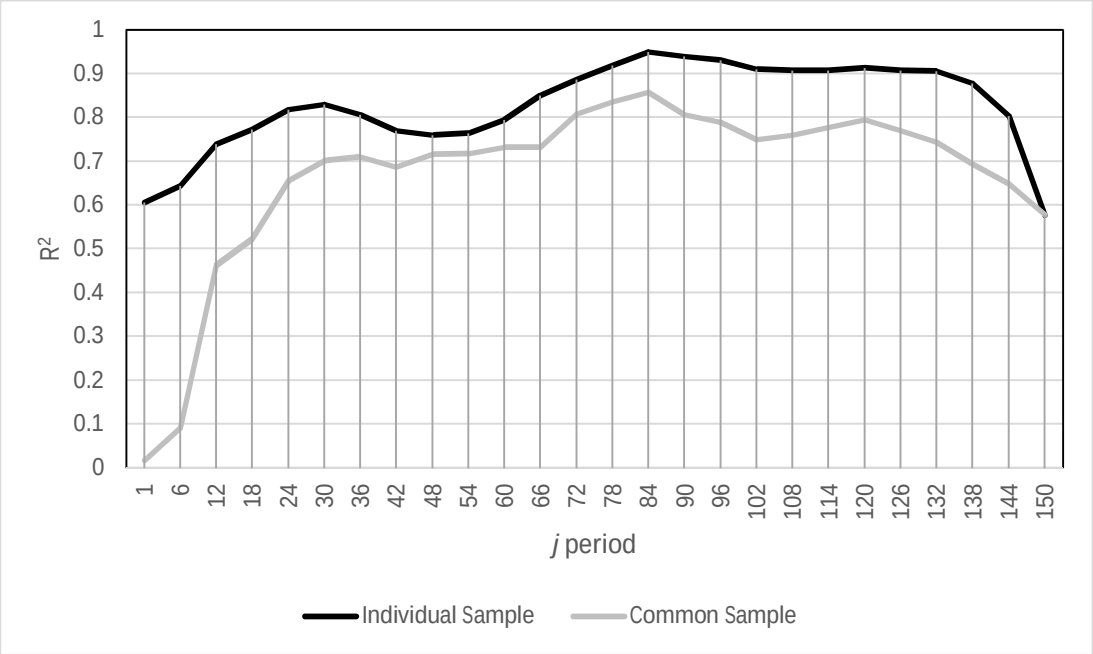


Table 5: *Results of the estimation by FMOLS (Dependent variable: Key ECB interest rate)*

Variable	Model I (baseline)	Model II (structural break: 2008:010)	Model III (hysteresis, structural break of the switching parameter in: 2007:09; 2008:10; and 2011:01)
$const$	**1.693*** ** (8.405)	**1.191*** ** (8.989)	**1.431*** ** **(6.568)**
$\left(P_t - P^*_{t,84}\right)_{-1}$	**0.322*** ** (19.861)	**0.213*** ** (3.078)	**0.098** (1.135)
$H\left(P_{t-1} - P^*_{t-1,84}\right)$	-	-	**0.225**** (2.601)
$UGAP_{t-.1}$	**-0.905*** ** (-6.387)	**-0.997*** ** (-3.955)	**-0.920*** ** (-6.706)
$M3TREND_{t-1}$	**0.121*** ** (5.269)	**0.181*** ** (10.489)	**0.118*** ** (5.335)
$SPREAD_{t-1}$	**-0.705*** ** (-6.253)	**0.0553** (0.015)	**-0.712*** ** (-6.519)
$\left(P_t - P^*_{t,84}\right)_{-1} \times D_t$	-	**0.0592** (0.829)	-
$UGAP_{t-.1} \times D_t$	-	**0.325** (1.195)	-
$M3TREND_{t-1} \times D_t$	-	**-0.104*** ** (-5.229)	-
$SPREAD_{t-1} \times D_t$	-	**-0.234** (-0.065)	-
R^2	0.9498	0.9551	9.954
Trace Test Statistic$^+$	82.232 (critical value 5%: 69.82)		137.77 (critical value 5%: 95.75)

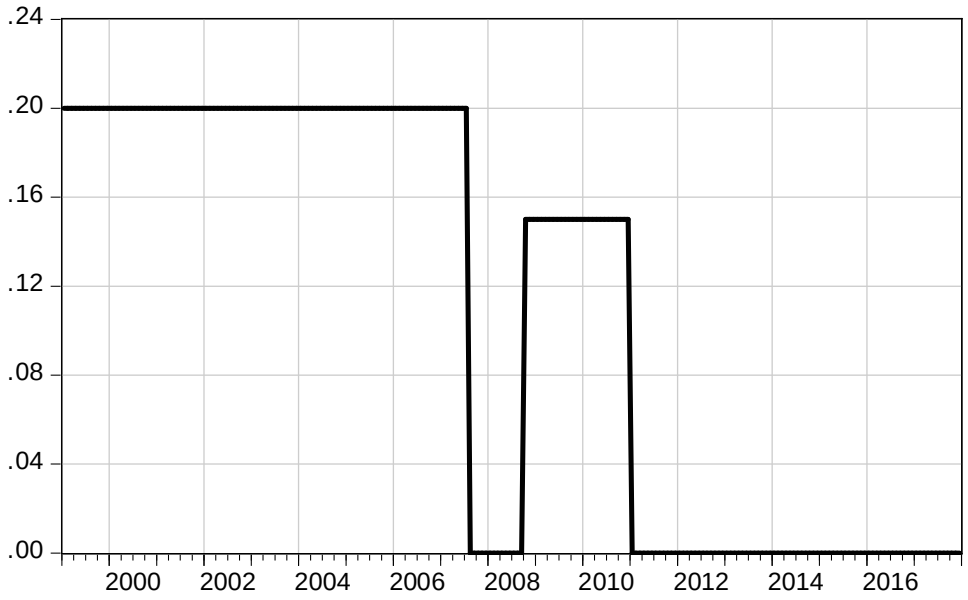
t-statistics are in parentheses.
***, **,* Significant at 1, 5, and 10 per cent respectively.

Finally, we estimate a switching target interest rate equation by applying the play model of hysteresis (equation 7).

Figure 4 exhibits the estimated values of the switching parameter (the play), obtained through the process of grid search over the set of admissible values described in

the previous section. The width of the switching parameter is a proxy of an inaction band associated to the target interest rate.[28] Figure 4 shows that the width of the inaction band decreased after the crisis, and in particular after the beginning of the Eurozone debt crises, implying that the target intrest rate become more responsive to fundamentals.

Figure 4: *Switching Parameter*



The estimates of the employment elasticity along the play lines, β_1, and the increment of this same elasticity along the spurt lines, β_2, are displayed in Table 5 (colunm 4). The employment elasticity along the spurt lines is given by $\beta_1 + \beta_2$.

Applying a fully-modified Wald test, which uses conventional chi-squared criteria for inferential purposes with respect to the coefficients, we find that β_2 is significant, while β_1 is non-significant. The results indicate that the reaction along the play line is non-significant, while the reaction along the spurt line is positive and strongly significant. This implies that interest rate change requires sufficiently large shock in $\left(P_t - P^*_{t,84}\right)_{-1}$.

The coefients associated to the other fundamental variable are relatively stable compared with the estimations of the previous models, and the signs are the expected.

[28] The concept is analogous to the employment band of inaction (see Mota *et al.* 2015).

6. CONCLUSIONS

We have found that the ECB is not following a pure price-targeting neither a pure inflation target, but instead an 'average inflation target,' by which the objective is to stabilize average inflation measured over seven years. This corresponds in practice with the medium run orientation of monetary policy followed by the ECB.

These findings are in line with some theoretical literature. For example Smets (2000) using a forward-looking model of the Euro Zone Economy found that when output gap and inflation have equal weights in the Central Bank's loss function the optimal horizon for price level objective is six years, *i.e.*, it may extends over a full business cycle. Batini and Nelson (2001) reaches an optimal horizon for inflation objective in between eight to 19 quarters. Smets (2003) reports an optimal horizon for price level objective of eight years. Finally, Akran (2010) indicates an optimal horizon of six to eight years for price level objective

In this paper target interest rate inertia is considered by means of the estimation of a switching employment equation based on the play model of hysteresis.

We have found also significant hysteresis effects in the dynamics of the ECB key interest rate, reflecting the presence of non-convex costs of interest rate adjustment and uncertainty.

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