The Taylor rule: can it be supported by the data?

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Abstract

The Taylor equation is a simple monetary policy rule that determines the Central Bank's policy rate as a function of inflation and output. A significant body of literature verifies the consistency of the Taylor rule with the data. However, recently there has been a growing literature regarding the validity of the estimated parameters due to the non-stationarity of the interest rate. In this paper I test the consistency of the Taylor rule with the Greek data for the period 1996-2004. It appears that the data do not support the Taylor rule in the sense that they do not form a cointegration set of variables. Therefore, the estimated parameters should be considered fragile and the forecasting for the interest rate as a function of inflation and output should not be expected to be adequately consistent with the actual data.

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1. Introduction

The determination of interest rate is an important issue in both academic and policy-making fields in modern macroeconomics. From a purely theoretical point of view, knowledge of the determination mechanism helps in the understanding of the interaction between the monetary and the real sector. From a more practical point of view, an operational device that would help the central bank to determine its instruments, say a short run policy interest rate, would be highly welcome. To this end, in the last years, a great amount of studies have dealt with the central bank policy vis-à-vis the macroeconomic developments, especially in an environment of high and volatile inflation (Christiano and Rostagno, 2001). It is generally accepted that in the context of countercyclical policy, monetary policy increases the interest rates when inflation exceeds its target, and decreases interest rates when inflation is below that target. The determination of a policy-controlled interest rate as a function of macroeconomic variables is usually called in the literature as reaction function. A particular specification of the reaction function, known as Taylor rule, was proposed by Taylor (1993) and relates the policy rate with the equilibrium real interest rate, the gap between actual and target inflation and the gap between the actual and potential output. The Taylor rule is a useful policy device, since it determines the central bank's policy rate and forms the basis of evaluation of alternative policy scenarios. Furthermore, it constitutes an indispensable part in the context of structural macroeconometric models, (Gerdesmeier and Roffia, 1993). Although various studies refer to the USA and the European economies, there are very few studies referring to Greece' economy. Additionally, and this is important for the focus of this paper, the vast majority of studies assume stationarity of the involved series (Eleftheriou, 2003) or they do not explicitly refer to the statistical properties of the estimated equations. In the context of stationarity, the estimates may be statistically meaningful and be interpreted in economics terms. However, in a context of non-stationarity, it might be the case that estimates are meaningless if the involved variables are not cointegrated. In such a case, the Taylor rule is perhaps not robust to alternative variable specifications and the parameter estimates may be fragile. In this paper I would like to investigate the statistical adequacy of the Taylor rule in the Greek context, and, if it is statistically possible, to test for a structural break after 2001. The findings of this paper imply that the data for the given period do not show consistency of the Taylor equation with the data, since no sound evidence of cointegration can be supported.

The structure of the paper is as follows: Section 2 reviews briefly the Taylor equation and Section 3 is concerned with the empirical studies of the equation. Section 4 refers to preliminary statistical considerations, while Section 5 refers to the estimates. Section 6 is about the validity of estimates on the basis of cointegration tests and Section 7 concludes the paper.

2. Background

Taylor (1993) has proposed the following equation that captures the dependence of the interest rate from the developments of output and inflation:

$$i^*_t = \overline{r} + \pi_t + \theta_1(\pi_t - \pi^*_t) + \theta_2(y_t - y^*_t)\,. \qquad (1)$$

i^*_t is the target nominal interest rate of the central bank, π_t is the current actual inflation, $\overline{r}$ is the equilibrium real interest rate that corresponds to full employment, π^*_t is the inflation target, y^*_t is the potential output and θ_1 and θ_2 are positive parameters. Given that the nominal equilibrium interest rate $\overline{i_t}$ equals the real equilibrium rate $\overline{r}_t$ plus the inflation target π^*_t, which under rational expectations equals the expected inflation rate, we get $\overline{i}_t = \overline{r}_t + \pi^*_t$, meaning also that $\overline{r}_t = \overline{i}_t - \pi^*_t$. Substituting $\overline{r}_t$ in (1) for $\overline{i}_t - \pi^*_t$, we have:

$$i^*_t = \overline{i}_t - \pi^*_t + \pi_t + \theta_1(\pi_t - \pi^*_t) + \theta_2(y_t - y^*_t),$$

$$i^*_t = \overline{i}_t - \pi^*_t + \pi_t + \theta_1\pi_t - \theta_1\pi^*_t + \theta_2(y_t - y^*_t),$$

$$i^*_t = \overline{i}_t - (1+\theta_1)\pi^*_t + (1+\theta_1)\pi_t + \theta_2(y_t - y^*_t). \tag{2}$$

Defining $a = \overline{i}_t - \beta\pi^*_t$, $\beta = \theta_1 + 1, \gamma = \theta_2, x_t = y_t - y^*_t$, we get:

$$i^*_t = a + \beta\pi_t + \gamma x_t. \tag{3}$$

Equation (3) is a typical Taylor function that can be estimated econometrically from the data, although Taylor did not estimate this function empirically, but he assumed the same importance in both gaps, i.e. $\theta_1 = 0.5, \theta_2 = 0.5$. Further, he assumed that inflation target π^*_t is 2% and that the equilibrium real interest rate $\overline{i}$ is 2%. Therefore, (2) becomes the initial Taylor function:

$$i^*_t = \pi_t + 0.5(\pi_t - 2) + 0.5x_t + 2, \tag{4}$$

$$i^*_t = 1 + 1.5\pi_t + 0.5x_t. \tag{5}$$

If inflation π_t exceeds the target π^*_t, i.e. $\pi_t - \pi^*_t > 0$ and/or the demand for output y_t is greater than the capacity of the economy y^*_t, i.e. $y_t - y^*_t > 0$, implying the beginning of inflationary pressures due to excess demand, then the nominal interest rate i^*_t tends to increase to impair additional overheating of the economy. On the contrary, in recession, i.e. when $\pi_t - \pi^*_t < 0$ and/or $y_t - y^*_t < 0$, the nominal interest rate i^*_t tends to decrease to motivate further investments. The parameters θ_1, θ_2 determine the direction of monetary policy. Higher θ_1 relative to θ_2 implies that monetary policy is inflation-target oriented, whereas higher θ_2 relative to θ_1 implies that monetary policy targets towards smoothing the business cycle.

3. Literature on Taylor Rule

In many empirical studies the Taylor equation has been extended with the inclusion of some expectations scheme of rational agents and/or the inclusion of variables beyond those of output and inflation gaps. For example, Clarida, Gali and Gertler, hereafter CGG, (1996), start from the initial Taylor equation, but they enhance it with a 12-month forward looking scheme to capture rational expectations. Further, in CGG (1998), the model is enriched with additional variables such as the lagged inflation, the gap between M3 and its target, the short run interest rate of the FED when they study USA, Japan and Germany or the short run interest rate of the Bundesbank when they study Italy, France and United Kingdom. They find that the lagged inflation and the gap between M3 and its target, are not statistically significant, while, on the other hand, the real exchange rate of the German mark against the US$ is a statistically significant factor, although with rather weak magnitude. Dornbusch et al. (1998), beyond the output and inflation gaps, include the deviation of the nominal exchange rate from its target level. They comment that their results would have been produced from estimating either a forward-looking model, or from the original Taylor rule, because, for them, the focus of their research lies on the equilibrium parameters, and as such, they are not dependant on expectational errors, (see Eleftheriou, (2003)). Another foreword-looking Taylor function is in Faust et al. (2001). The authors estimate the reaction function of the Bundesbank and compare its behaviour with that of the ECB after 1999. This comparison is justified by the authors on the basis that policies, similar to the Bundesbank's, had been adopted by other national central banks. The comparison shows that in these countries, the interest rate reacts to a lesser degree than in the case of the Bundesbank. The authors conclude that this may be ascribed to a higher importance of the output gap that ECB has given in comparison to the Bundesbank. Furthermore, Peersman and Smets (1998) confirm CGG findings for Germany and compare their empirical reaction function with another reaction function, constructed on the basis of optimality conditions of a loss function. They conclude that the empirical reaction function behaves very well, the only difference being the lower importance of the output gap relative to the optimized reaction function. Gerlach and Schnabel (1998) refer to the explanatory power of the Taylor rule in Europe and observe that the initial Taylor weights, i.e. 0.5 for inflation and 0.5 for the output gap capture the data quite well. Additional information set, such as the lagged inflation and exchange rates, does not significantly alter the estimated parameters.

The above approaches to Taylor rule are extended in another direction, that of the enrichment of the initial Taylor equation with adequate dynamics in order to capture the "gradualism" or "interest rate smoothing" of monetary policy. Gradualism is a measure of inertia in the Taylor equation and can be caused by various factors such as private sector expectations, model, parameter and data uncertainties, learning, measurement errors and financial markets reactions, see Castelnuovo (2002). Modelling of the inertia is done by the inclusion of the lagged interest rate. CGG (1999, 2000) estimate dynamic Taylor equations with the USA data and find a magnitude of the lagged interest rate close to 0.8. Similar is the magnitude of the lagged interest rate in Kozicki (1999), Amato and Laubach (1999), Doménech et al. (2002). However, the introduction of the lagged interest rate has been criticized by several authors, e.g. Rudebusch (2002) and Söderlind et al. (2003). Rudebush (2002) shows that the statistical significance of the lagged interest rate estimated parameter reflects serially correlated shocks to the economy while Sönderlid et al. (2003) assert that the whole Taylor rule suffers from fundamental problems, (cited in Österholm, 2003). A similar critique about the lagged interest rates is also found in Lansing (2002). He shows that efforts to identify the FED's policy rule using final data (instead of real-time data) creates the illusion of interest rate smoothing behaviour when, in fact, none exists. The lagged interest rate just helps the fitting of the model to the data which contain correlated real-time measurement errors, which are not taken into account by the standard estimation procedure, and, therefore, the lagged interest rate has nothing to do with monetary policy inertia.

To my knowledge, studies referring to Greece are rather limited. A relevant article is included in the Euro Area Monthly Bulletin, a publication of the National Bank of Greece (2001). The article concludes that the econometric estimates of the Taylor rule for Greece, with monthly data for the period 1994:1-2001:3, show that the weight of the inflation gap is 60% and the weight of the output gap is 40%. Furthermore, the model includes dynamic adjustment with the introduction of the lagged interest rate which explains 67% of the data whereas the remaining 33% is ascribed to the typical Taylor variables (the two gaps). More recently, Arghyrou (2006) estimated a range of linear and non-linear reaction functions for Greek monetary policy during the period 1991-2000, with quarterly data, and used the estimates to obtain projections for the level of interest rate that would have prevailed in Greece had the country not joined the EMU. He found that, if Greece had not been a member of the EMU, its interest rate would on average be approximately three times higher than the one set by the ECB during 2001-2003. He concludes that the interest rate policy of the ECB is incompatible with Greek macroeconomic fundamentals, and this helps to explain the post-2000 increase in Greek inflation. This conclusion is rather different than that in Eleftheriou (2003) who, after extensive experimentation with several output and inflation gaps and various monetary variables, for several periods ranging from 1990 to 2002 with monthly data, draws the conclusion that for Greece, along with Germany, Portugal, Austria, Italy and the Netherlands, the EMU target interest rate does not deviate significantly from the national interest rates targets and, therefore, it will not probably cause macroeconomic asymmetries.

A vital assumption in the majority of these studies, which is not usually tested however, is that the series involved in the Taylor rule specifications are stationary. The focus of this paper is to search whether this assumption is valid and, if not, what the consequences of non-stationarity are. Although, as it is already known, any linear regression equation is meaningful only in a stationary or cointegrated environment, Taylor rule, in turn, is statistically meaningful either in a stationary world or in a cointegrated set of variables. The reason is that in a non-stationary environment the regression equation is just spurious in the sense that the probability distributions of the estimates are not bounded (Hatanaka, 1994). Hence, neither statistical inference is possible, nor can "accurate" projections be done. As a result of non-bounded probability distributions, parameters' estimates become very fragile across several possible specifications of the model and perform inaccurately outside the sample. A common finding from other monetary policy studies is that the interest rate is usually a $I(1)$ process. On the other hand, the two gaps in (1) should normally be stationary. If this is true, then clearly a regression estimation of the Taylor equation is rather spurious. Despite the importance of the issue, the problem of non-stationarity and spurious estimates in the Taylor equation has not been set in the literature until recently. In this context, Österholm (2003), with US, Australian and Swedish quarterly data and for periods ranging from 1960 – 2002, concludes that the only data set in which cointegration can be supported, is with the US data for the period 1960-1979. In contrast, the remaining data sets do not support evidence of cointegration.

4. Data, Variables and Unit Root Tests

The nature of this exercise includes a variety of sets of variables, gaps and frequencies. An open issue is what variables will be included in the specification, at what frequencies, and how the gaps will be defined. Given the availability of the data, the models I estimate are in both quarterly and monthly frequencies and the production gap is estimated by both GDP (for quarterly data) and Industrial Production (IP). The monthly series are a three-month money market interest rate, obtained in monthly frequency, the CPI and the IP. GDP is the only quarterly series obtained directly form the statistical sources. The rest of the quarterly series, i.e. interest rate, CPI and IP, have been constructed as the three-month average from the monthly data. Inflation rate is constructed on the basis of CPI. The potential output is estimated by both deterministic trends (linear and non-linear functions of time) and the HP filter (Hodrick and Prescott, 1997), and as measure of price levels I have used the CPI. The periods covered are 1996:III – 2004:III for quarterly data and 1996:7 – 2004:9 for monthly data. These periods have been chosen on the basis that for the years 1981 – 1996 the interest rate in Greece was mainly administered and therefore it exhibited no significant variation. Hence, regression with series with low volatility would not be meaningful. The sources of data are the Statistics Service of Greece (www.statistics.gr) for GDP, IP, CPI and the Bank of Greece (www.bankofgreece.gr) for the interest rate. In total, we have six data sets, presented in Table 1. After preliminary testing, I ended up with the following deterministic estimates for the production gap: With quarterly data the semilog linear trend model $\log y_t = \alpha + \beta t + u_t$ for GDP and the quadratic trend model $\log y_t = \alpha + \beta t + \gamma t^2 + u_t$ for the IP. With monthly data, the $\log y_t = \alpha + \beta t + \gamma t^2 + u_t$ for the IP. In all these models y_t is GDP or IP. For the use of these models in the estimation of the gaps, see Clarida et al. (2000), Dornbusch et al. (1998). The estimations of these deterministic models are given in Figure 1.

Now, I examine the stationarity of all series by means of the ADF test (Dickey and Fuller, 1979) and for the determination of optimal lag, I adopt the Schwartz Information Criterion (SIC). The results are presented in Tables 2 and 3 for the quarterly and the monthly series, respectively. From these results, one can draw the conclusion that while interest rate is non-stationary at 5% and 10% significance levels (s.l.) with quarterly data and at all conventional levels with monthly data, all other variables are stationary. This finding is important because it gives a first impression about the validity of estimates of the Taylor rule with these sets of data. It appears that a regression with these statistical properties of the variables might be rather spurious. However, for the time being, I ignore these results and proceed to estimates. The justification for this choice is that the unit root test has low power, and favors the null hypothesis of no-cointegration against the alternative of stationarity. It would be of interest to see weather the unit root test results are different than those of cointegration test. The next section presents the functional form of the models along with their estimates.

5. Estimates

Six equations, corresponding to the data sets of Table 1, are estimated by OLS and are of the form $i_t = \alpha + \beta(\pi_t - \pi^*) + \gamma(y_t - y^*_t) + 3\,\text{dummies} + u_t$, with $\alpha = \overline{r} + \pi^*$, $\overline{r}$ the equilibrium real interest rate, i_t the nominal interest rate, $\pi^*_t = \pi^*$ the inflation target, π_t the actual current inflation, y_t the actual production, y^*_t the potential production and u_t a white noise process. α, β, γ are parameters to be estimated. The parameters β, γ correpospond to parameters θ_1, θ_2 in the Taylor equation. The 3 dummies are referring to the (probable) structural break of the Taylor equation because of the introduction of euro in Greece (1/1/2001). They are as follows: Dummy 1 is for the constant, Dummy 2 is for the inflation gap and Dummy 3 is for the production gap. The numerical assumptions (see Gerlach and Schnabel, 1999) prior to estimation of the Taylor equation are: With quarterly data, the target inflation rate is 2%, the average real interest rate is 7.11% for the first period (1996:III – 2000:IV) and -0.29% for the second period (2001:I-2004:III). With monthly data the average real interest rate is 7.11% for the first period and -0.31% for the second period. The proximity of the estimates at these two frequencies reflects the fact that the quarterly data have been constructed from the monthly data. See Table 4 for the numerical assumptions. The estimates of the six models are presented in Tables 5.a – 5f while the fitting of the models is presented in Figure 2. Summary of the estimated parameters $\hat{\alpha}, \hat{\theta}_1, \hat{\theta}_2$ are given in Tables 6, 7 and 8, respectively. It should be noted that the two parameters of the gaps should be positive, and, according to Taylor, they should be close to 0.5. From Table 6 it can be seen that for quarterly data the parameter a is underestimated for both periods under investigation, especially in the second period (after EMU). With monthly data, the estimated parameter $\hat{a}$ is close to its theoretical value in the first period (before EMU), but it is overestimated in the second period. Similarly, from Table 7 it is observed that the estimates of $\hat{\theta}_1$, the parameter for the inflation gap, and before the EMU, do not approach the theoretical value 0.5 in none of the equations considered. Models (1) and (2) yield estimates that deviate significantly from the 0.5 (0.90 and 0.85, respectively) and the sign is the expected (positive). After the EMU, the estimated values for models (1) and (2) have negative sign. Models (3) and (4) yield the right sign and value and values close to the theoretical ones. With monthly data, i.e. models (5) and (6), for the pre-EMU period, the values are close to the theoretical values, o.76 and 0.77, and have the expected, positive sign. After the EMU, with monthly data, the estimated parameters have negative sign, (-0.65 and -0.71). From Table 8, with quarterly data, the estimates for θ_2 of the models (1) – (4) have negative sign. After EMU, the same models yield positive signs, but low values. With monthly data, i.e. models (5) and (6), estimates are low, close to zero, and the same the picture is true for the period after the EMU.

6. Spurious Estimates? Discussion

The estimates presented above should be taken into consideration with caution. The cointegration test, shown in Table 9, (see Engle & Granger, 1987; Engle and Yoo, 1987, Table 2), shows that in the two cases with monthly data (models 5 and 6), regressions are spurious, due to non-stationarity of the residuals. However, with quarterly data, cointegration test shows that at 5% and 10% s.l. regressions are not spurious. This is at odds with the unit roots tests according to which no cointegration is expected due to non stationarity of the interest rate and the stationarity of the two gaps. Of course, the above estimates for $\beta = \theta_1$ and $\gamma = \theta_2$ can well deviate from the theoretical values of 0.5 of the initial Taylor formulation. However, due to non-stationarity of the variables, the probability distributions of the estimated parameters are not the usual t distributions and, therefore, statistical inference is not valid. Hence, the proximity of estimates to their theoretical values can neither be accepted nor rejected.

It appears that the models discussed above do not verify the consistency of the Taylor equation with the particular data sets. Of the six models, models 1-4 (i.e. those with quarterly data) possess cointegration properties, on the basis of cointegration test, at 5% and 10% significance levels, whereas models 5 and 6 (i.e. with monthly data) do not possess cointegration properties at any of the conventional significance levels. Consequently, only models 1-4 can be initially considered as valid statistical models. From an economics point of view, the evaluation criteria for models 1-4 are the sign, which should be positive, and a reasonable magnitude of the estimated parameters. An interesting finding is that before EMU the inflation gap has a positive sign but it becomes negative after EMU. The opposite picture is observed for the sign of the production gap. In summary, none of the above models 1-4 seems to explain interest rate fluctuations, in a fashion consistent with the Taylor rule, at least on the basis of sound statistical properties, signs and magnitude of the estimated parameters. A final point in the present analysis is, as it turns out from Tables 5a-5f, that the null hypothesis of normality cannot be rejected, according to the JB statistics.

7. Conclusion

This paper attempts to investigate empirically to what extend the data can support a Taylor rule for Greece, for the period 1996-2004. From the unit root and cointegration tests as well as the estimated parameters, the following conclusions can be drawn:

Firstly, models 1-4 (with quarterly data) on the basis of cointegration test appear to be cointegrated at 5% and 10% significance levels but not at 1%. However, on the basis of the individual unit root test, cointegration is not expected due to different order of integration between the interest rate (order of integration 1) and the inflation, and production gaps (order of integration 0) at 5% and 10% significance levels. These findings from the cointegration and the unit root tests are conflicting. Estimated parameters, in general, do not have the expected (positive) sign for the two gaps. *Secondly*, in models 5 and 6 (with monthly data), cointegration cannot be established at all conventional significance levels. And in this case, the estimated parameters do not have the expected sign. *Thirdly*, the estimated parameters do not depend much on the variable used (GDP or IP) to define the production gap, and on the detrending method (deterministic trend or HP filter). *Fourthly*, experimentation with different model specifications (not shown), including time lags for the two gaps, did not alter significantly the consistency of the models with the Taylor equation. However, although the inclusion of the lagged interest rate in these models improved the explanatory power of the models, measured by the adjusted R^2, but, on the other hand, it left no room in the gaps to function as a significant explanatory set of variables. Hence, the estimated parameters for this specification do not support the logic of the Taylor rule, since more than 85% of the explanatory power of the model is ascribed to the lagged interest rate term, and only the remaining 15% to the twp gaps. This numerical finding is in accordance with the literature employing the "interest rate smoothing" approach. Another approach was to estimate an equation in the form of $i^*_t = \alpha + \beta\pi_t + \gamma x_t + u_t$, (as in equation (6)) on the ground that i^*_t and π_t, being both unit root processes, may cointegrate so their stationary combination cointegrates with the stationary part x_t, the production gap. However, and in this experimentation, cointegration test (not shown) clearly implies spurious estimates.

As the above analysis has shown, the Taylor equation, in its initial specification, or in its enhanced form with the inclusion of the lagged interest rate, with the particular set of data, cannot be supported empirically for the period under investigation, in terms of descriptive, explanatory and predictive power and cannot be in accordance with the modern cointegration theory. As Phillips (1986, 1988) has already shown, if the variables are of first order of integration or near integrated and the static equation is miss-specified, then the estimates are spurious. It seems that this is the case here. And, apart from the purely statistical considerations of the issue, no Central Bank has asserted that it follows a Taylor rule; see Österholm (op.cit.). In this context of conflicting results, the hypothesis of a possible structural break due to introduction of the euro in Greece (1/1/2001) can neither be accepted nor rejected. Moreover, the forecasting for the interest rate as a function of inflation and output is not expected to be adequately consistent with the actual data. Overall, the fragility of the estimated parameters, the uncertainty about the structural break and the low forecasting ability of the Taylor rule can be ascribed to the lack of cointegration properties of the particular data set.

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Appendix

Table 1 Data Sets

Data Sets and Models	Variables
DS1 Monthly Data - Model 1	IR, CPI, Inflation Gap=CPI Inflation-Target Inflation, Output Gap = IP – LL Trend (IP).
DS2 Monthly Data – Model 2	IR, CPI, Inflation Gap=CPI Inflation-Target Inflation, Output Gap = IP – HP filter (IP).
DS3 Quarterly Data – Model 3	IR, CPI, Inflation Gap=CPI Inflation-Target Inflation, Output Gap = IP – LL Trend (IP).
DS4 Quarterly Data – Model 4	IR, CPI, Inflation Gap=CPI Inflation-Target Inflation, Output Gap = IP – HP filter (IP).
DS5 Quarterly Data – Model 5	IR, CPI, Inflation Gap=CPI Inflation - Target Inflation, Output Gap = GDP – LL Trend (GDP).
DS6 Quarterly Data – Model 6	IR, CPI, Inflation Gap=CPI Inflation -Target Inflation, Output Gap = GDP – HP filter (GDP).

Note: IR: Interest rate, QD Trend: quadratic trend, IP: Industrial production. LL Trend: Log-linear trend.

Table 2 Unit Root test with quarterly data

Variable	ADF t Statistic	Lags	Unit Root at 1%, 5%, 10% s.l.
Interest Rate	-2.74	7	No, Yes, Yes
Inflation Gap	-3.03	0	Yes, No, No
GDP Gap (with trend)	-3.80	3	No, No, No
GDP Gap (with HP filter)	-3.89	3	No, No, No
IP GAP (with trend)	-3.57	8	Yes, No, No
IP GAP (with HP filter)	-3.33	8	Yes, No, No

Note: Critical McKinnon values (with constant): -3.72, -2.98, -2.63 at 1%, 5%, 10% s.l. Critical McKinnon values (without constant or trend): -2.90, -2.64, -1.61 at 1%, 5%, 10% s.l.

Table 3 Unit Root test with monthly data

Variable	ADF t Statistic	Lags	Unit Root at 1%, 5%, 10% s.l.
Interest Rate	-0.87	2	Yes, Yes, Yes
Inflation Gap	-2.96	0	Yes, No, No
IP GAP (with trend)	-3.17	11	Yes, No, No
IP GAP (with HP filter)	-2.64	11	No, No, No

Note: Critical McKinnon values (with constant): -3.50, -2.89, -2.51 at 1%, 5%, 10% s.l. Critical McKinnon values without constant or trend: -2.59, -1.94, -1.61 at 1%, 5%, 10% s.l.

Table 4 Numerical assumptions

Variable	Quarterly data		Monthly data	
	1996:III – 2000:IV	**2001:I – 2004:III**	**1996:III – 2000:IV**	**2001:I – 2004:III**
Real interest rate $\overline{r}$	7.11%	-0.29%	7.04%	-0.31%
Average annual inflation π	3.67%	3.35%	3.74%	3.37%
Average nominal interest rate	10.78%	3.06%	10.78%	3.06%
Inflation target π^*	2%	2%	2%	2%

Table 5.a Estimates of the Taylor equation: Model 1

Model	Frequency	Production	Potential Production	R^2	DW	JB
1	Quarterly	IP	Quadratic trend	0.89	1.18	0.16

Period 1996:III – 2000:IV $i_t = 8.77 + 0.9(\pi_t - \pi^*) - 0.38(y_t - y^*_t) + u_t$

Period 2001:I – 2004:III $i_t = 2.21 - 0.59(\pi_t - \pi^*) + 0.11(y_t - y^*_t) + u_t$

Note: DW: Durbin-Watson statistic. JB: Jarque-Bera statistic. IP: Industrial production.

Table 5.b Estimates of the Taylor equation: Model 2

Model	Frequency	Production	Potential Production	R^2	DW	JB
2	Quarterly	IP	HP filter	0.89	1.18	0.18

Period 1996:III – 2000:IV $i_t = 9.05 + 0.85(\pi_t - \pi^*) - 0.37(y_t - y^*_t) + u_t$

Period 2001:I – 2004:III $i_t = 2.35 - 0.48(\pi_t - \pi^*) + 0.13(y_t - y^*_t) + u_t$

Note: DW: Durbin-Watson statistic. JB: Jarque-Bera statistic. IP: Industrial production.

Table 5.c Estimates of the Taylor equation: Model 3

Model	Frequency	Production	Potential Production	R^2	DW	JB
3	Quarterly	GDP	Linear trend	0.87	1.00	0.22

Period 1996:III – 2000:IV $i_t = 8.30 + 1.34(\pi_t - \pi^*) - 0.40(y_t - y^*_t) + u_t$

Period 2001:I – 2004:III $i_t = 2.13 + 0.7(\pi_t - \pi^*) - 0.13(y_t - y^*_t) + u_t$

Note: DW: Durbin-Watson statistic. JB: Jarque-Bera statistic.

Table 5.d Estimates of the Taylor equation: Model 4

Model	Frequency	Production	Potential Production	R^2	DW	JB
4	Quarterly	GDP	HP filter	0.87	0.98	0.24

Period 1996:III – 2000:IV $i_t = 8.39 + 1.31(\pi_t - \pi^*) - 0.40(y_t - y^*_t) + u_t$

Period 2001:I – 2004:III $i_t = 2.09 + 0.71(\pi_t - \pi^*) + 0.07(y_t - y^*_t) + u_t$

Note: DW: Durbin-Watson statistic. JB: Jarque-Bera statistic.

Table 5.e Estimates of the Taylor equation: Model 5

Model	Frequency	Production	Potential Production	R^2	DW	JB
5	Monthly	IP	Linear trend	0.76	0.45	13.02

Period 1996:III – 2000:IV $i_t = 10.25 + 0.76(\pi_t - \pi^*) - 0.02(y_t - y^*_t) + u_t$

Period 2001:I – 2004:III $i_t = 4.93 - 0.65(\pi_t - \pi^*) + 0.07(y_t - y^*_t) + u_t$

Note: DW: Durbin-Watson statistic. JB: Jarque-Bera statistic. IP: Industrial production.

Table 5.f Estimates of the Taylor equation: Model 5

Model	Frequency	Production	Potential Production	R^2	DW	JB
6	Monthly	IP	HP filter	0.75	0.43	13.91

Period 1996:III – 2000:IV $i_t = 10.23 + 0.77(\pi_t - \pi^*) - 0.02(y_t - y^*_t) + u_t$

Period 2001:I – 2004:III $i_t = 5.01 - 0.71(\pi_t - \pi^*) + 0.06(y_t - y^*_t) + u_t$

Note: DW: Durbin-Watson statistic. JB: Jarque-Bera statistic. IP: Industrial production.

Table 6 Summary of the estimates $\hat{\alpha}$

	Quarterly data		Monthly data	
	Theoretical value a	Estimate $\hat{a}$	Theoretical value a	Estimate $\hat{a}$
Before EMU (1996-2000)	10.78	8.77 (1)	10.78	10.25 (5)
		9.05 (2)		
		8.30 (3)		10.23 (6)
		8.39 (4)		
After EMU (2001-2004)	3.06	2.21 (1)	3.06	4.93 (5)
		2.35 (2)		
		2.13 (3)		5.01 (6)
		2.09 (4)		

Note: In parentheses is the Model (1…6) from which the estimate has been obtained.

Table 7 Summary of the estimates $\hat{\theta}_1 = \hat{\beta}$ of the inflation gap

	Quarterly data		Monthly data	
	Theoretical value θ_1	Estimate $\hat{\theta}_1$	Theoretical value θ_1	Estimate $\hat{\theta}_1$
Before EMU (1996-2000)	0.5	0.90 (1)	0.5	0.76 (5)
		0.85 (2)		
		1.34 (3)		0.77 (6)
		1.31 (4)		
After EMU (2001-2004)	0.5	-0.59 (1)	0.5	-0.65 (5)
		-0.48 (2)		
		0.70 (3)		-0.71 (6)
		0.71 (4)		

Note: In parentheses is the Model (1…6) from which the estimate has been obtained.

Table 8 Summary of the estimates $\hat{\theta}_2 = \gamma$ of the production gap

	Quarterly data		Monthly data	
	Theoretical value θ_2	Estimate $\hat{\theta}_2$	Theoretical value for θ_2	Estimate $\hat{\theta}_2$
Before EMU (1996-2000)	0.5	-0.38 (1)	0.5	-0.02 (5)
		-0.37(2)		
		-0.40 (3)		-0.02 (6)
		-0.40 (4)		
After EMU (2001-2004)	0.5	0.11 (1)	0.5	0.07 (5)
		0.13 (2)		
		0.13 (3)		0.06 (6)
		0.07 (4)		

Note: In parentheses is the Model (1…6) from which the estimate has been obtained.

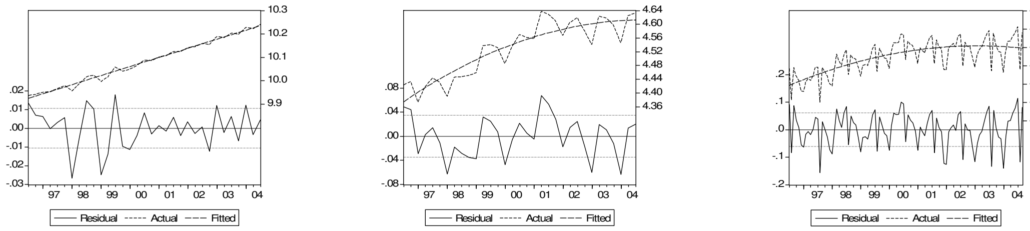
Table 9 Cointegration test

Model	Frequency	t Statistic	Unit Root at 1%, 5%, 10% s.l.
1	Quarterly	-4.222680	Yes, No, No
2	Quarterly	-4.276126	Yes, No, No
3	Quarterly	-4.267513	Yes, No, No
4	Quarterly	-4.247039	Yes, No, No
5	Monthly	-1.564607	Yes, Yes, Yes
6	Monthly	-1.603221	Yes, Yes, Yes

Note: Critical values for cointegration test are: For sample size 100 (monthly data) the critical values at 1%, 5% and 10% s.l. are -4.09, -3.70 and -3.42, respectively. For sample size 25 (quarterly data) the critical values at 1%, 5% and 10% s.l. are -4.45, -4.02 and -3.68, respectively.

Figure 1 Equations for the GDP and IP gaps

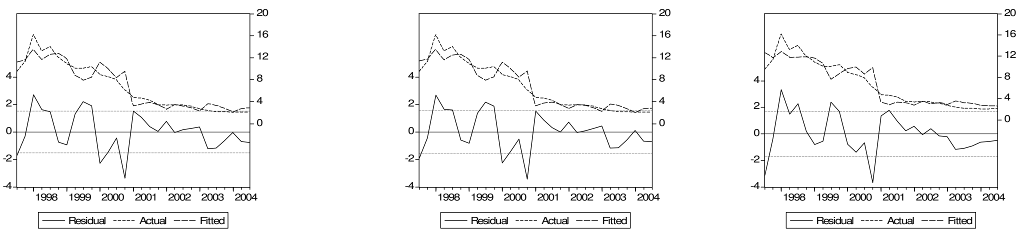
GDP Quarterly	Industrial Production Quarterly	Industrial Production Monthly
$\log y_t = \alpha + \beta t + u_t$	$\log y_t = \alpha + \beta t + \gamma t^2 + u_t$	$\log y_t = \alpha + \beta t + \gamma t^2 + u_t$
$\bar{R}^2 = 0.98$, $DW = 2.21$	$\bar{R}^2 = 0.82$, $DW = 1.42$	$\bar{R}^2 = 0.52$, $DW = 1.82$



Note: y_t is GDP or IP.

Figure 2 Models 1 – 6: actual and fitted values

Model 1 **Model 2** **Model 3**



Model 4 **Model 5** **Model 6**